Contributing Paper

Operation, Monitoring and Decommissioning of Large Dams in India

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Operation, Monitoring and Decommissioning of Dams

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Content

Acronyms

AIBP	-	Accelerated Irrigation Benefit Programme
BOL	-	Build-Own-Lease
BOO	-	Build-Own-Operate
BOOT	-	Build-Own-Operate-Transfer
CADP	-	Command Area Development Project
CBI&P	-	Central Board of Irrigation & Power
CWC	-	Centre Water Commission, New Delhi
DSARP	-	Dam Safety Assurance and Rehabilitation Project
DSO	-	Dam Safety Organisation, New Delhi
GNP	-	Gross National Product
GSI	-	Geological Survey of India
IMD	-	Indian Metrological Department
MF&E	-	Ministry of Forest & Environment, Govt. of India, New Delhi
MOWR	-	Ministry of Water Resources, Govt. of India, New Delhi.
NCBM	-	National Council for Cement and Building Material, New Delhi
NCDS	-	National Commission on Dam Safety
NGRI	-	National Geophysical Research Institute, Hyderabad, India.
NSP	-	Nagarjun Sagar Project
NSRC	-	Nagarjun Sagar Right Canal
NWP	-	National Water Policy
O&M	-	Operation & Maintenance
PCB	-	Pollution Control Board
PIM	-	Participatory Irrigation Management
PMF	-	Probable Maximum Flood
RBO	-	River Basin Organisation
RIS	-	Reservoir Induced Seismicity
SPF	-	Standard Project Flood
WUA	-	Water Users Association

1. INTRODUCTION

1.1 Irrigation Strategy

Agricultural growth is a prerequisite for the economic and social development of India. It contributes 28% of GNP, about 60% of employment and is the primary source of livelihood in rural areas, which account for 75% of India's population and 80% of its poor. The irrigated and agriculture, contributes nearly 56% of agriculture output. The increase in irrigation intensity has contributed to the growth in the overall cropping intensity (including rainfed crops) which increased from 111.07% in 1950-51 to 131.19% in 1993-94. The nature of irrigation expansion of tubewells and availability of surface water from storage type irrigation projects has enabled the production of Rabi and summer crops. Supplemental irrigation is available via run-of-the-river irrigation schemes as the snow melt. In the 1950s and 1960s, extension in cultivated area contributed substantially to increase in our foodgrain production. Mid Sixties onwards, expansion of irrigation as well as introduction of high yielding varieties of rice, wheat and other crops brought the country's foodgrain production to a satisfactory level. Further step up in foodgrain production, to the extent of its doubling in next 10 years, would mainly depend on the availability and performance efficiency of irrigation. The Ninth Plan is making a thrust in this direction through a "Special Action Plan". The overall strategy of irrigation development and management during the Ninth Plan has the following core ingredients:

a) Improvement of water use efficiency by progressive reduction in conveyance and application losses,
b) Bridging the gap between the potential created and its utilisation by strengthening the Command Area Development Programme (CADP), institutional reforms and promoting farmers' involvement in irrigation management.
c) Completing all the ongoing projects, particularly those, which were started during pre-Fifth and Fifth Plan period as a time bound programme to yield benefits from the investments already made.
d) Restoring and modernise the old irrigation systems which were executed during the pre-Independence period and 25 years ago.
e) Introducing rational pricing of irrigation water, based initially on O&M cost and then to encourage higher level of water use efficiency.
f) Taking concrete steps towards comprehensive and integrated development of natural water resources, taking into account the possibility of inter-river-basin transfer of surplus water and,
g) Promoting adaptive research and development to ensure more cost-effective and efficient execution and management of irrigation systems.
h) Promoting Participatory Irrigation Management (PIM) with full involvement of the water user community, which will be at the centre stage of the implementation of above strategies of the Ninth Plan.
i) Encouraging and implementing the conjunctive use of ground and surface waters towards optimal utilisation of water resources and to have its development environmentally sustainable as well.
j) Accelerating the development and utilisation of ground water, particularly in the eastern region on sound technical, environmental and economic considerations along with proper regulatory mechanisms.

1.2 Irrigation Development through the Plan periods - Overview

Irrigation is a vital input to increase agricultural output to keep pace with the food requirements of the ever-increasing population. As recently reassessed by the Ministry of Water Resources, the country's ultimate irrigation potential is tentatively estimated at 139.89 m.ha. comprising of 58.46 m.ha. through major & medium irrigation and 81.43 m.ha. from minor irrigation as against pre-revised ultimate irrigation potential of 113.50 m.ha. In the post-Independence period a sum of about Rs.91943.40 crore (including about Rs.13469 crore of institutional investment) at the current price level (Rs.231,386.59

crore at 1996-97 constant price), has been made in major, medium and minor irrigation projects including ground water and as a result, the creation of irrigation potential increased from 22.6 million hectares(m.ha.) in the pre-Independence period, to about 89.56 m.ha. at the end of the Eighth Plan. With this, India has the largest irrigated area among all the countries in the world. This has greatly contributed to the increase in foodgrains production from 51 million tonnes (mt.) in 1950-51 to 198 mt. in 1996-97 at a compound annual growth rate of around 3 per cent. Broadly speaking, about 60% of the foodgrains production has come from the irrigated area which constitutes about one-third of <total cultivated area and the remaining production has come from the rainfed areas.

Table-1.1 shows the magnitude and the composition of investment in irrigation and flood control projects through successive Plan periods.

Table – 1.1: Magnitude & Composition of Investment through Plan periods in Irrigation and Flood Control Sectors

(Rs. in crore at current price level)

Plans	Major & Medium Irrgn.	Minor Irrigation			C.A.D.	Flood control prices	Total at current
		Public Sector	Institu-tional Finance	Total			
First (1951-56)	376.24 (7803.42)	65.62 (1360.99)	Neg.	65.62 (1360.99)	-	13.21 (273.98)	455.07 (9438.39)
Second (1956-61)	380 (6013.98)	142.23 (2250.97)	19.35 (306.24)	161.58 (2557.21)	-	48.06 (760.61)	589.64 (9331.80)
Third (1961-66)	576 (6674.84)	327.73 (3797.82)	115.37 (1336.94)	443.10 (5134.76)	-	82.09 (551.28)	1101.19 (12760.88)
Annual (1966-69)	429.81 (3943.90)	326.19 (2993.10)	234.74 (2153.96)	560.93 (5147.06)	-	41.96 (585.02)	1032.70 (9475.98)
Fourth (1969-74)	1242.30 (7976.41)	512.28 (3289.18)	661.06 (4243.45)	1173.34 (7532.63)	-	162.04 (1040.40)	2577.48 (16549.18)
Fifth (1974-78)	2516.18 (12519.42)	630.83 (3138.74)	778.76 (3874.67)	1409.58 (7013.41)	-	298.61 (1485.75)	4224.36 (21018.59)
Annual (1978-80)	2078.58 (7949.67)	501.50 (1918.02)	480.40 (1837.32)	981.90 (3755.34)	362.06* (1388.16)	329.96 (1261.95)	3753.40 (14355.15)
Sixth (1980-85)	7368.83 (19625.50)	1979.26 (5271.39)	1437.56 (3826.67)	3416.82 (5100.06)	743.05 (1978.97)	786.85 (2095.63)	12315.55 (32800.16)
Seventh (1985-90)	11107.29 (21207.15)	3118.35 (5953.87)	3060.95 (5844.27)	6179.30 (11798.14)	1447.50 (2762.85)	941.58 (1797.76)	19675.67 (37566.77)
Annual (1990-92)	5459.15 (8125.60)	1680.48 (2501.29)	1349.59 (2008.78)	3030.07 (4510.07)	619.45 (922.01)	460.64 (685.63)	9569.31 (14243.32)
Eighth (1992-97)	21071.87 (31057.63)	6408.36 (9445.22)	5331.00 (7857.31)	11739.36 (17302.52)	2145.92 (3162.85)	1691.68 (2493.35)	36648.83 (54016.36)
Total	**52606.25 (132389.93)**	**15692.83 (39492.89)**	**13468.77 (33895.77)**	**29161.60 (73388.66)**	**5418.88 (13385.66)**	**4856.67 (12222.39)**	**91943.40 (231386.59)**

Source: Reports of the Working Groups of Ninth Five Year Plan .
Upto 3/80.
Note : Figures within brackets above indicate the expenditure at constant prices at 1996-97)

1.3 National Water Policy

The National Water Policy (NWP) was adopted by the National Water Resources Council, headed by the Prime Minister in its meeting held on 09.09.1987. The NWP recognises water to be prime natural resource, a basic human need and a precious national asset. Therefore, planning and development of water resources need to be governed by a national perspective. The intention of the NWP was to mark the territory in broad terms, so as to establish the need for a. National Water Policy, and to give a broad outline of what the policy document needs to cover. The formulation of NWP is not a one-time exercise but is to be kept constantly under review, thereby including within its purview more and more issues and areas of concern as they emerge. For a more effective operationalisation of the NWP stress would have to be placed on the following:

(i) Watershed management, rain water harvesting and water saving practices should be an integral part of development and management of water resources at the basin level and while formulating water resources development projects. Also, Micro irrigation systems need to be promoted particularly in arid regions where water is scarce and the topographic and soil conditions do not permit efficient irrigation by conventional methods;

(ii) Drainage is to be an integral part of the irrigation system, particularly. when perennial irrigation is contemplated;

(iii) The Management of irrigation systems by farmers should also cover water rights and the need for establishing and regulating them.

(iv) Since water markets are expanding, there is a need to develop and enforce guidelines for their operation.

(v) During the Ninth Plan period, the pricing of water for various uses including agriculture should be rationalised in a phased manner so as to at least fishy recover the Operation and Maintenance Cost.

(vi) Policy framework or guidelines on the criteria for inter-State river water allocation among the basin states should be evolved.

(vii) Both demand and supply for water resources should be assessed on the basis of agro-ecological-irrigation zones, cropping systems and other uses within a dynamic ***time***- frame;

(viii) Conjunctive use of surface and ground water should be encouraged by making adequate energy available to farmers;

(ix) The role and responsibility of various agencies and organisations involved in water resources development and utilisation should be clear]y defined Appropriate infrastructure should be developed to promote proper linkages among them;

(x) Involvement of farmers organisations, such as. Water Users Associations should be increased in respect of decisions on cropping systems, planning and implementation of water release schedules, collection of water rates, maintenance of irrigation systems, etc Assistance of voluntary agencies/NGOs should be enlisted in this task. A gender dimension should be integrated in all decisions relating to water use. The new paradigm of water use management should include important parameters such as, efficiency, ecology, equity and employment in addition to economics of energy-use efficiency;

(xi) in view of increasing demand for water, there is a need to augment the resource through inter-basin transfers, artificial recharge of aquifers, use of marginal quality water, conjunctive use of surface and ground water, rain water harvesting in rainfed areas, watershed development, adoption of water saving practices etc.

(xii) In order to ensure sustained availability of pound water, average annual withdrawal should not exceed average annual recharge. Ground water of marginal quality could be used advantageously in combination with good quality of water or for alternate irrigations.

(xiii) The existing law on water quality needs to be effectively implemented for prevention of pollution of surface and ground water. Ground water pollution being more serious and hazardous, as compared to surface water pollution would require special institutions for preventing and abating pollution.

(xiv) The Indian Prime Minister while addressing the Nation on 22nd March 1998 indicated that the Government would go all out to achieve five goals which include “unveiling a National Water Policy” so that no water goes waste and our water resources are cleaned up. Appropriate action in this regard has already been initiated.

2. Dam Building Activity in India since 1900

2.1 Completion of Pending Works vs Starting New One's – Private Sector Participation

India is among the foremost countries in the world in developing its water resources. The Grand Anicut in Tamil Nadu across river Kaveri dates back to second century during the Chola dynasty. Even today this anicut in its remodelled state serves as one of the most important irrigation facility to the State of Tamil Nadu.

Due to favourable agro-climate, by and large the Indian economy has been traditionally based on agriculture since centuries. Agriculture contributes about one-third of GNP, and remains a key sector in the national economy. It engages two-thirds of labour force and accounts for about 18% of India's merchandise exports.

In spite of the fact that this country is endowed with vast land and water resources, it is a water short country in relation to agriculture, municipal and industrial needs. About 80% of the annual rainfall and run-off are concentrated in the monsoon months. During this period maximum utilization of water can be made from the run of the river with small regulation requiring very little storage. Less than 15% of the hydropower potential has been achieved. Also only 25% of culturable area is irrigated. About 70% of river flows are discharged into the sea without utilization. The rainfall is not evenly distributed in space and time resulting in flooding in certain areas and drought conditions in certain parts of the country as seen in earlier paras. Therefore, it became necessary to store water by building large storage capacity reservoirs and storage tanks so that supplies for multiple purposes like domestic, irrigation, industries and power generation can be assured during the dry season, in addition to effecting flood control in certain rivers.

Modern dam construction began during the second half of 19th century, even though they had been built since ancient times. At the turn of twentieth century (1900) there were 42 dams in India. During 1901 to 1950 about 250 dams were added. That is, at the time of the beginning of plan period (1950-51), after India obtained Independence in 1947, there were a total of about 300 dams. During the next twenty years, there has been a spurt in the dam construction activity in which 695 dams were added bringing the total number of dams to nearly 1000 up to the year 1970. The dam building activity intensified during the next two decades and at the end of 1990 the total number of Indian dams stood at 3244 without accounting for 236 number of dams for which the year of construction is not available. Due to dwindling economy only 115 dams could be added after 1990 and today about 695 dams are at various stages of construction. As per the National Register of Large dams, India has as on today 4291 large dams including the 695 dams under construction. Distribution of large dams in India according to the age *is* given in Table 2.1.

Table – 2.1 Distribution of large dams according to age.

Year of Completion	No. of dams
Up to 1900	42
1901-1950	251
1951-1960	234
1961-1970	461
1971-1980	1190
1981-1990	1066
1991 & above	116
Year of constr. Not available	236
-do-	-do-

Under construction	695
Total :	**4,291**

Source: CBI&P

Table 2.2 gives the Statewise distribution of dams, according to different types and Table 2.3 shows distribution of dams in different States of India, according to the purpose of reservoir.

A close examination of the data presented in the Tables indicate the following:

- Darn building activities have been in practice in India since many centuries, mainly for the purpose of irrigation and domestic use.

- Due to non-availability of systematic records, details regarding a number of ancient dams could not be known.

- Fillip for dam building activity was given when the Five-Year Plans started in 1950-51 and about 700 dams were added in the next two decades. This activity got intensified further and more than 2000 dams were completed during 1971-1990, after which the dam building activity moved with slow space mainly due to global economic crunch. Today about 700 dams which were commenced many years back are in various stages of construction.

- The total existing large dams comprises of more than 89% of earth dams, concrete / masonry gravity dams little less than 5% and composite dams little over 5%. The States of Maharashtra and Madhya Pradesh have taken a leap followed by the States of Gujarat**,** Karnataka, Andhra Pradesh, Orissa, Uttar Pradesh, Tamil Nadu and Bihar in that order.

Table – 2.2 Statewise Distribution of Dams under Different Categories

Sl. No.	State	Total	TE (Earth)	ER (Rockfill) (Masonry)	PG TE/PG	Composite	Remarks
1.	Andhra Pradesh	184	147	-	13	24	
2.	Arunachal	1	-	-	-	1	
3.	Assam	3	-	-	3	-	
4.	Bihar	94	82	2	4	6	
5.	Goa	7	3	-	2	2	
6.	Gujarat	537	453	-	8	74	TNK=2
7.	Himachal Pradesh	5	1	2 TYPE	2	-	
8.	Jammu & Kashmir	9	7	1	1	-	
9.	Karnataka	216	175	2	14	22	TNK=3
10.	Kerala	54	8	-	36+1 ARCH	9	
11.	Madhya Pradesh	5	1	2 TYPE	2	-	
12.	Maharashtra	1529	1465	1	29	34	
13.	Manipur	5	4	-	-	1	
14.	Meghalaya	7	1	-	5	1	
15.	Orissa	149	132	1	6	10	
16.	Punjab	2	-	1	1	-	
17.	Rajasthan	126	91	-	10	20	TNK=5
18.	Tamil Nadu	97	39	-	40	18	
19.	Tripura	1	1-	-	-		
20.	Uttar Pradesh	145	122	-	15	8	TNK=Type
21.	West Bengal	27	26	-	1	-	not known
	Total :	**4291**	**3839**	**11**	**200**	**231**	**10**

Source:CBI&P

Table – 2.3: Statewise Distribution of Dams by Function

Sl. No.	State	Type of Dam						
		I	**I/S**	**I/H**	**S**	**H**	**S/H**	**TNK***
1.	Andhra Pradesh	155	4	5	7	5	-	8
2.	Arunachal	-	-	-	-	1	-	-
3.	Assam	-	-	-	-	2	-	1
4.	Bihar	84	2	6	1	-	-	1
5.	Goa	5	2	-	-	-	-	-
6.	Gujarat	505	21	2	9	-	-	-
7.	Himachal Pradesh	-	-	3	-	2	-	-
8.	Jammu & Kashmir	2	-	-	-	2	-	5
9.	Karnataka	193	3	3	5	9	-	3
10.	Kerala	21	-	-	2	25	-	6
11.	Madhya Pradesh	1088	2	3	-	-	-	-
12.	Maharashtra	1469	16	22	8	10	-	4
13.	Manipur	4	-	-	-	1	-	-
14.	Meghalaya	-	-	-	1	6	-	-
15.	Orissa	136	4	7	-	1	-	1
16.	Punjab	-	-	2	-	-	-	-
17.	Rajasthan	120	1	2	-	1	-	2
18.	Tamil Nadu	47	2	22	1	24	-	1
19.	Tripura	-	-	-	-	1	-	-
20.	Uttar Pradesh	129	-	11	-	4	1	-
21.	West Bengal	25	-	1	-	-	-	1
	Total :	**3983**	**57**	**89**	**34**	**94**	**1**	**33**

Source: CBI&P
* Type not known.

The analysis further reveals that more than 92% of the dams built in India serve solely the purpose of irrigation, 2.2% hydroelectric power generation, less than 1% water supply and less than 35% serve a combination of multi-purpose of irrigation, water supply and hydropower generation.

Table 2.4 gives the details of dams of height 100 m and above. Idukki dam is the only concrete arch dam in India, having a height of 169m standing across Periyar River in the State of Kerala. These dams have created a total live storage capacity of 177 km^3 by 1995 as against 15.60 km^3 in the pre-plan period. Besides, dams to create an additional live storage capacity of 75 km^3 are under various stages of construction. Also dams under formulation/consideration will create an additional live storage of 132 km^3. When all the dams under construction and those under consideration are completed, India would have created a total live storage of 384 km^3, which is less than 56% of assessed utilisable surface water resources of 690 km^3. By the year 2025, the country's water requirement has been projected as 1050 km^3, the share of surface water being 700 km^3, which would necessitate construction of large capacity reservoirs in addition to those presently under construction and formulation. If such a programme is to be accomplished, solutions to the administrative and environmental problems which, have dampened the spirit and slowed down further development, are also required to be found urgently in the right earnest.

2.2 CONCLUSION

An examination of available statistics reveals that increase in production has closely followed the creation of surface storages which clearly indicates the necessity for not-only sustaining the potential created so far but the need for creating additional storages. Available statistics also indicates that the vast hydroelectric power potential available needs to be developed if industrial and domestic energy requirement have to be met with. All out efforts are required to develop all the resources available to meet the demand due to increasing population and consequent requirement for increased food and fibre as well as electricity. The presently existing hydro thermal-ratio of 25 : 75 has to be brought to the accepted norm of 40 : 60. Hydropower cannot be developed without creating storages by building high dams/large capacity reservoirs. Creation of storages and development of surface irrigation and hydropower development are also beset with associated problems like environmental degradation water logging, loss of capacity due to siltation etc. but they have to be attended to pari pasu the development progrannnes instead of advocating total stoppage of the development works.

During the last five decades since independence, India has achieved a spectacular development of water resources, in respect of irrigation and hydropower. Drought-famine syndrome is eliminated to a large extent and the “rain-floods” syndrome is reduced considerably. Over one-third of flood prone area has been protected. Irrigated area and food grain production has gone up by four times. Safe drinking water is assured most part of Country except in problem villages.

Over a tenth of irrigation potential created is unutilised. Problems of water logging and low productivity need to be tackled. Ground water development needs to be given due attention. Water resources development is facing a serious crisis and uncertain future. Plan investment has also come down drastically. Continuance of sustainable water resources development at a fast pace is imperative for the very survival of the Nation. The political and bureaucratic set-up need to ponder and give fresh impetus and may be a course correction to accelerate about 700 on-going projects which have been held up for want of funds. This is very essential in view of the rapidly growing population and rising demand for water from various competing Sectors. This reality has also to realise the growing public resistance against such activity (Appendix-I).

Table – 2.4: Dams above 100 metre height

Sl. No.	Name of Dam	Year of comple-tion	State in which located	Type	Height above found	Length of dam M	Volume content 10^3 m^3	Gross capacity 10^3 m^3	Effective capacity 10^3 m^3	Design purpose
1.	Idamalayar	1985	Kerala	PG	100	375	860	115300		
2.	Karjan (Lower)	U/C	Gujarat	TE/PG	100	903	1440	630000	581,000	
3.	Kulamavu*	1977	Kerala	TE	100	385	453	0		
4.	Supa	1987	Karnataka	TE	101	322	1020	4178000	3758,000	
5.	Koyna	1964	Maharastra	TE/PG	103	805	1555	2797400	2640,000	H
6.	Sholayar	1971	Tamil Nadu	PG	105	1244	2533	152700	143,070	
7.	Salal (Concrete Dam)		J&K	PG	113		8000	285000		I/H
8.	Kakki*	1966	Kerala	PG	114	336	725	455020	447.4	H
9.	Salal (Rockfill Dam)	1986	J&K	TE/ER	118	630	1500	285000		H
10.	Nagarjuna Sagar	1960	Andhra Pradesh	TE/PG	125	4865	7725	11561000	5444,000	I/H
11.	Ramganga	1974	Uttar Pradesh	TE	128	715	10000	244960	218,770	I/H
12.	Pong Dam	1974	Himachal Pradesh	TE	133	1956	35500	8570000	729,000	I/H
13.	Cheruthoni	1976	Kerala	PG	138	650	1700	1996000	1459,430	H
14.	Jamrani	1990	Uttar Pradesh	TE	140	765	0	206600	206,600	I/H
15.	Chamera	1994	Himachal Pradesh	TE	141	240	1342	3913000	109,650	H
16.	Srisailam	1984	Andhra Pradesh	PG	145	512	1953	8722000	4250,000	H
17.	Idukk18	1974	Kerala	TE	169	366	460	1996000	1459,430	H
18.	Lakhwar	U/C	Uttar Pradesh	TE	204	452	2800	580000	330,000	I

19.	Bhakkra Dam	1963	Himachal Pradesh	TE	226	518	4130	9621000	7191,000	I/H
20.	Kishau	U/C	Uttar Pradesh	PG	236	680	9500	1810060	1330,000	I/H
21.	Tehri	U/C	Uttar Pradesh	TE	261	610	27032	3540000	2615,000	I/H

Source:CBI&P

2.3 Completion of Pending Works Vs Starting New

In view of foregoing starting new dams in place of ongoing projects would not arise due to following reasons:

- Growing local public resistance.
- Sagging fund flow from financial institutions.

As rightly reported in Economist of November 20 – 26th 1999 the flow of aid money is drying up. Since big dams are so controversial, even the World Bank, once the biggest force behind big dams, has grown skittish. Achim Steiner, the secretary-general of the WCD, which was created by governments, development agencies and non-governmental organisations, notes that even Asia's zealous builders of big dams "are being pulled into global principles by market forces." This is because they face a squeeze from both private and public investors.

The decline in aid money raises the costs of financing. And the inevitable protests and legal wrangles facing such projects add financial risk, which translates into higher costs. Another blow is the continuing deregulation of the global power industry, which shifts financing to the private sector and so to low-risk projects with quick returns. That means away from big dams and towards gas-fired plants.

And the locals are growing in importance. In India, for example, pressure from grassroots organisations is forcing the government to scale back its plans for the Narmada valley. The number of dams is sure to be cut and the heights of those remaining reduced; many will also be redesigned to reduce their social and environmental impact feels Smitu Kothari of Lokayan, a social think tank at Delhi.

Private sector participation involves not only the private corporate sector but also groups like farmers' organisations, voluntary bodies and the general public. About 90-95% of ground water development is by private efforts either through own financing or institutional financing or both. However in the case of surface water, especially major and medium projects, all the irrigation projects are not equally endowed with the potential for privatisation and, as such, identification of projects as a whole or partially (i.e. planning and investigation, construction, operation and management financing and maintenance etc.) may have to be undertaken in the light of its viability vis-à-vis various privatisation options as available with hydel power generation and recreation, etc. along with irrigation, the viability for privatisation of a project improves.

2.4 Private Sector Participation

Some states like Maharashtra, Madhya Pradesh and Andhra Pradesh have initiated the action for privatisation of irrigation projects. These projects are envisaged for privatisation on Build-Own-Operate (BOO), or Build-Own-Operate-Transfer (BOOT) or Build-Own-Lease (BOL) basis. In the case projects on BOO basis, the Irrigation Department may buy water in bulk from the agency at mutually agreed price for distribution to the farmers. Apart from this, Maharashtra Krishna Valley development Corporation (MKVDC) for Krishna Valley Projects, Sardar Sarovar Narmada Nigam Ltd. (SSNNL) for Sardar Sarovar Project in Gujarat and Jal Bhagya Nigam for Upper Krishna Project, Karnataka have mobilised financial resources through issue of Public Bonds from the private market.

Some States like Maharashtra, Madhya Pradesh and Andhra Pradesh have initiated the action/process for privatisation of irrigation projects. These projects are envisaged for privatisation on Build-Own-Operate (BOO), or Build-Own-Operate-Transfer (BOOT) or Build-Own-Lease (BOL) basis. In the case projects on BOO basis, the Irrigation Department may buy water in bulk from the agency at mutually agreed price for distribution to the farmers. Apart from this, Maharashtra Krishna Valley development Corporation (MKVDC) for Krishna Valley Projects, Sardar Sarovar Narmada Nigam Ltd. (SSNNL) for Sardar Sarovar Project in Gujarat and Jal Bhagya Nigam for Upper Krishna Project, Karnataka have issue bonds for mopping up funds from the private market. On the basis of views expressed by the various States, in general, the following conclusions have emerged in the regard.

1. The deliberations in the Workshop indicate that private sector participation in irrigation & multipurpose projects is feasible but selectively. Some procedural and legal changes are required to be undertaken in respect of clearances of projects and involvement of private sector investors in this regard. More specifically, some suggestions as indicated below in brief have been offered by the participants.
2. Private sector participation could be thought of on BOL or BOOT basis for a specified period of say 10-30 years.
3. While it may be more suitable for medium and minor projects, it could pose some problems in the case of major projects.
4. Clearances such as forests, environment, resettlement and rehabilitation, acquisition of land etc., should be carried out by the Government departments.
5. Concessions should be offered to private sector investors to augment their revenue. These may include tourism, water sports, navigation, moratorium on loans, tax concessions, etc.
6. Distribution of water after bulk supply to water Users” Association should not be handled by private sector. The WUAs should be encouraged to be formed and they should manage distribution.
7. Safety and sociological aspects should be looked into by the Government departments.
8. There should be a guarantee on the return of investment of the private sector.
9. In difficult terrains, there should be investment from the Government side.
10. While broad national policy guidelines on private sector participation may be framed by the Centre, details may be worked out by the States as suited to their conditions within the framework of such policy and guidelines.
11. The obligations of the Government departments and the private sector should be clearly spelt out in the agreement for such participation. It should also include penalty clauses applicable to both the parties so that slippages do not occur in implementation.

The ongoing six hundred and odd need to be completed for which the IXth plan document has made a categorical statement with particular emphasis on those started in pre-fifth and Fifth Plan period. In fact there is already Accelerated Irrigation Benefit Programme (AIBP) running. This programme was launched in 1996-97 by the Government of India with an outlay of Rs.900 crore, subsequently revised to Rs.500 crore to accelerate the completion of selected ongoing irrigation projects in order that the envisaged benefits from locked investments in these projects are accrued. Initially, this programme had two components. The first component was designed to include major/multipurpose projects, each with the project cost exceeding of Rs.1,000 crore and the project being beyond the resource capability of the States. The other component was for irrigation projects where, with just a little additional resource, the project could be completed and farmers could get the assured water supply to the extent of one lakh ha. in the following 4 agricultural seasons or two agriculture years. Upon the revision of this cost criteria, now an irrigation project with its cost exceeding Rs.500 crore is eligible. The funding for AIBP is in the form of loan to the States on 50% matching basis. During the Annual Plan 1996-97, a sum of Rs.500 crore was released to various States and, as reported by the Ministry of Water Resources about 16180 ha. of additional irrigation potential has been created so far. During A.P. 1997-

98 and A.P. 1998-99, the approved outlays under AIBP are Rs.1,300 crore and Rs.1,500 crore respectively.

The cost of creation of irrigation potential per ha. through the successive Five Year Plans at current as well as at 1980-81 constant prices has been steeply escalating as show in Table –2.5.

Table – 2.5: Cost of creation of Irrigation Potential (per ha.)

(in Rupees)

Plan Period	**Cost of creation**	
	(at current prices)	(at constant prices of 1980-81)
First Plan (1951-56)	1200	8620
Second Plan (1956-61)	1810	9289
Third Plan (1961-66)	2526	10289
Annual Plans (1966-69)	2893	8313
Fourth Plans (1969-74)	4758	11060
Fifth Plan (1974-78)	6075	9074
Annual Plans (1978-80)	10940	14111
Sixth Plan (1980-85)	21610	18771
Seventh Plan (1985-90)	50000	31475
Annual Plans (1990-92)	66570	29587

Source : Report of the Working Group on Major & Medium Irrigation Programme for the 9^{th} Plan (para 1.3)

The above would show that a substantial increase in cost has taken place from the Sixth Plan onwards which is mainly due to introduction of the extension and distribution system upto 5-8a block, the cost of rehabilitation and resettlement, environmental & forest aspects, inclusion of the cost of the catchment area treatment and drainage system in the command of the irrigation projects and increase in establishment costs, etc. However, studies indicate that by clubbing some of the above activities together, the costs overrun, primarily due to change in the scope of the project (35 to 43% of total increase in cost due to this factor alone in some selected projects), rise in the lump-sum provisions, which include, besides others, the R&R activities (40 to 47% of total increase in the revised estimate of some selected projects), increase due to price rise/inflation which varied from 8% to 63% of the total increase in a period of 2 to 20 years in the sample of 11 projects and increase due to change in design (about 38% of the total increase in a selected project was due to this factor), etc.

2.5 Increase in cost of creation of irrigation potential

The available data indicate that a substantial increase has taken place in the Cost of creation of irrigation potential per hectare from the Sixth Plan onwards which is mainly due to introduction of the extension and distribution system upto 5-8 ha. block, the cost of rehabilitation and resettlement, environmental & forests aspects, inclusion of the cost of catchment area treatment and inclusion of drainage system in the command of irrigation projects and increase in establishment costs etc.

During Seventh and Eighth Plans, as a strategy, only a few new major and medium projects were taken up and greater emphasis was laid on the completion of ongoing projects as a first charge on the available resources, almost 80% of the budget was earmarked for completion of ongoing projects.

As per the IXth Plan document for completing about 300 projects, it would cost about Rs.41,300 crores involving an additional irrigation potential of about 7.2 Mha. If CWC data of 1999 about 600 ongoing projects is taken into consideration, the cost is approximately double. As the targets of even VIIIth Plan have not been met by may states, there are likely high time and cost overruns. The availability of funds also are going to be problem. No authentic figures are available, but one can guess that the completion will spillover to even XIth Plan. This is considering Eighth Plan expenditure of Rs.31,000 crores. It is to be noted that dams under consideration for water potential of 132 Km^3 would require huge sum which is difficult to come (Pie-diagram page No.19)

The Government of India constituted a Higher Power Commission in September 1996 for Integrated Water Resources Development Plan to take a holistic view of the overall water resources in the country and maximise the availability and its utilisation including consideration of inter-basin transfers. Presently, the Member Secretary, Planning Commission is the Chairman of the Commission. The terms of reference of the above Commission are as follows:-

a) To prepare an integrated water plan for the development of water resources for drinking, industrial, flood control and other uses;
b) To suggest the modalities for transfer of surplus water to water-deficit basins by inter-linking of rivers for achieving the above objectives;
c) To identify important ongoing projects, as well as new projects, which should be completed on priority basis, together with phasing;
d) To identify a technological and inter-disciplinary research plan for the water sector with a view to maximise the benefits;
e) To suggest physical and financial resource generation strategies for the water sector; and
f) Any other related issue.

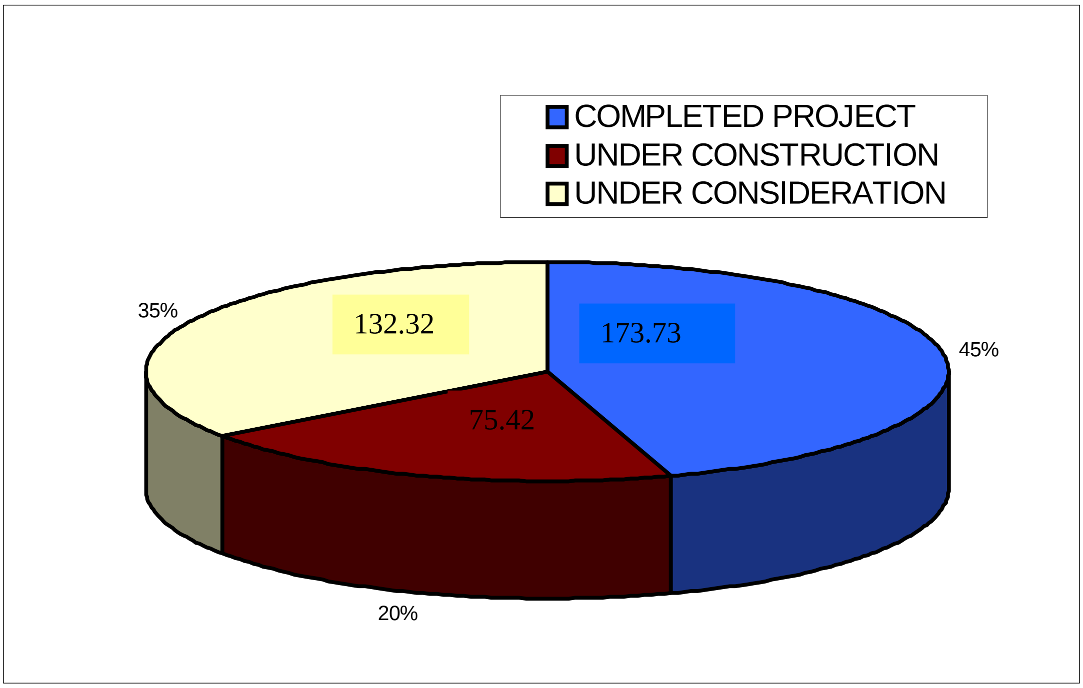
The report of the Commission is in advance stage of preparation.

High Power Commission for Integrated Water Resources Development Plan

The Government of India constituted a Higher Power Commission in September 1996 for Integrated Water Resources Development Plan to take a holistic view of the overall water resources in the country and maximise the availability and its utilisation including consideration of inter-basin transfers. Presently, the Member Secretary, Planning Commission is the Chairman of the Commission. The report of the Commission is in advance stage of preparation

The 695 ongoing projects have already spread social cost in terms of displacement of an overall 40,000 per large dam and full settlement process will take larger time for completion. The environmental costs have already come in terms of deforestation but other costs would start accruing after these projects are completed. Therefore, it is clear that scope for shelving ongoing projects over and above new under consideration does not arise. There is specific effort to complete them on priority basis. No doubt some under consideration will be taken up due to their importance and political consideration. One thing is certain that funds are going to be big constraints. There are bound to be cost and time over run which may spill over to several future five year plans.

LIVE STORAGE CAPACITY OF RESERVOIRS IN INDIA (CUBIC KM)



Source : National Water Policy, MOWR, 1987

3. DAM SAFETY & FUNCTIONING – ROLE OF DIFFERENT VARIABLES

According to ICOLD data, around 2.2% of all dams built before 1950 have failed and 0.5% of dams built since then. The average Worldwide risk of any dam failing in a given year is calculated to be in the order of 1 in 10,000[i]. The dam failure incidents are given in Table-3.1 below. According to this the number of such incidents are very few in India.

Table – 3.1: Recorded dam failures since 1860 which have killed more than 10 people

Dam	Country	Type	Height (m)	Year completed	Year failed	Cause of failure	People killed	Cost of damage
Dale Dyke (Bradfield)	England	E	29	1858	1864	Social Forestry	250[1]	£0.5 m
Iruhaike	Japan	E	28	1633	1868	OT	>1000[2]	
Mill River	MA, USA	E	13	1865	1874	SF	143	>$1m
El Habra†	Algeria	R	36		1881	OT	209	
Valparaíso	Chile	E	17		1888	SF	>100	
South Fork (Johnstown)	PA, USA	E	22	1853	1889	OT	2,209	
Walnut Grove	AZ, USA	R	34	1888	1890	OT	150	
Bouzey	France	G	15	1881	1895	SF	150[1]	
Austin	PA, USA	G	15	1909	1911	SF	80	
Lower Otay	CA, USA	R	40	1897	1916	OT	30	
Bila Desna	Czechoslovakia	E	17	1915	1916	SF	65	
Tigra	India	G	24	1917	1917	OT	>1,000[2]	
Gleno	Italy	M, G	44	1923	1923	SF	600	
Eigiau/Coedty §	Wales	G/E	11	1908/19	1925	PI/OT	16	
St.Francis	CA, USA	A	62	1926	1928	SF	450	
Alla Sella Zerbino	Italy	G	12	1923	1935	OT	> 100	
Vega de Terra (Ribadelago)	Spain	B	34	1957	1959	SF	145	
Malpasset (Fréjus)	France	A	61	1954	1959	F	421	
Orós	Brazil	E	54	const	1960	OT	c.1,000	
Babii Yar	Ukraine	E			1961	OT	145	
Panshet/ Khadakwasla§	India	E/R	54/42	const/1879	1961	SF, OT/OT	> 1,000[2]	
Hyokiri	S.Korea							
Kuala Lumpur	Malaysia							
Vaiont	Italy	A	261	1960	1963	OT	2,600	
Quebrada la Chappa	Colombia							
Swift	MT, USA							
Zgorigrad (Vratza)	Bulgaria	Ta	12			OT	> 96	
Nanaksagar	India	E	16	1962	1967	SF/OT	c.100	
Sempor	Indonesia	R	54	const	1967	SF/OT	c.200	
Frías	Argentina	R	15	1940	1970	OT	> 42	
Buffalo Creek	WV, USA	Ta	32	const	1972	OT	125	$30-50m[15]
Canyon Lake	SD, USA	E	6	1938	1972	OT	237*	$60m
Baniqao, Shimantan, 60 others	China	E		late 1950s	1975	OT	≤ 230,000[4]	
Teton	ID, USA	E	90	1976	1976	SF	11-14	$0.4-1bn
Laurel Run	PA, USA				1977		39[3]	$20-45m[2]
Kelly Barnes (Toccoa Falls)	GA, USA	E	13	1899	1977	SF	39[3]	
Machhu II	India	E	26	1972	1979	OT	> 2000	$15m

								crops
Gopinatham	India			1980	1981	OT	47[5]	
Taus	Sapin	R	77	1980	1982	OT	> 20[6]	
Stava	Italy	Ta		1960s	1985		269[7]	
Kantalai	Sri Lanka	R	15	1952	1986	PI	82[8]	
Sargazon	Tadjikistan		23	1980	1987		> 19[9]	
Belci	Romania	E	18	1962	1991	OT	c.48[10]	
Gouhou	China	R	71	1987	1993	PI	342[11]	$18m
Tirlyan	Russia	E	10	<1987	1994	OT	19-37[12]	Rs40bn
Virginia No.15	S.Africa	Ta	47		1994		39[13]	$15m
Lake Blackshear Project/Flint River Dam	GA, USA	E	< 15		1994	OT	15[14]	
N/A	Philippines	N/A	N/A	N/A	1995	N/A	c.30[15]	

Notes and Sources :

Dam types: E=Earthfill; R=Rockfill; G=Gravity; M=Multi-arch; B=Buttress; A=Arch; Ta=Tailings
Cause of failure : OT=overtopping; PI=piping; SF=structural failure; F=geological/foundation weakness.
* unable to distinguish dam break fatalities with those caused by `natural' flood.
† EI Habra first failed in 1872 without loss of life. It was then rebuilt, failed again in 1881, rebuilt again, then failed again in 1927 (without fatalities) and was then abandoned.
§ The flood from the collapse of the first dam breached the second dam downstreams.

Source:

1. N. Smith, *A History of Dams,* Peter Davies, London 1971.
2. F. Lemperiere, `Dams That Have Failed by Flooding. An Analysis of 70 Failures', *Water Power and Dam Construction, October 1993.*
3. J.E. Costa, `Floods from Dam Failures', in V.R. Baker et al. (eds.), *Flood Geomorphology,* Wiley, New York 1998.
4. Human Rights Watch/Asia. *The Three Gorges Dam in China: Forced Resettlement, Suppression of Dissent and Labour Rights Concerns.* New York, February, 1995.
5. Centre of Science and Environment, *The State of India's Environment-1982: A Citizen's Report,* CSE, New Delhi 1982.
6. `Overtopped Spanish Dam Collapses as Spillway Gates Stay Shut', *World Water*, November 1982.
7. `South African Dam Breach Followed Warnings', *Construction Today*, March, 1994.
8. `Kantalai Failure Leaves 18,000 Homeless', *Water Power & Dame Construction*, May 1986.
9. `Burst Raises Doubts about Sovient Hydroelectricity Dam', *Nature,* 26 March 1987.
10. `Flooding and Landslides Cause Three Major Failures in Romania', *Water Power & Dam Construction,* October 1991.
11. `China Disciplines 15 for Dam Break', *Tibetan Environment & Development News,* Issue 16, 1994.
12. `The Tirlyan Breakthrough', *Moscow News,* 19 August, 1994.
13. `When the Bough Breaks….', *Higher values* (Minewatch Bulletin), April 1994.
14. `Georgia Flood Deaths', *International Water Power & Dam Construction,* August 1994.
15. R. Tangbawan, `Angela's Toll in Philippines Nearing 500', *San Francisco Chronicle,* 5 November 1995.
16. B. Ellingwood et al. `Assessing Costs of Dam Failure', *Journal of Water Resources Planning and Management,* Vol. 119, No.1, January/February 1993.

All others : R.B.Jansen, *Dams and Public Safety,* US Department of the Interior, Washington DC, 1990.

There are about 4300 major dams in India. More than 2342 of them are 15 metres or more in height. Safety of such a large number of dams, therefore, is very important. For monitoring Dam safety activities in the entire country, a Dam Safety Organisation (DSO) was established in Central Water Commission (CWC) in 1979. Subsequently, with a view to build up appropriate expertise at State Level to cater to their requirements, Dam Safety Units started functioning in 12 States of Andhra Pradesh, Bihar, Gujarat, Karnataka, Kerala, Madhya Pradesh, Maharashtra, Orissa, Rajasthan, Tamil Nadu, Uttar Pradesh and West Bengal who have significant number of large dams.

Apart from monitoring the dam safety activities, the DSO in CWC, on special requests from State Governments, assists them to locate causes of potential distress in dams and recommends measures for their redress. The National Committee on Dam Safety (NCDS) constituted by Government of India meets twice in a year and deliberates on various issues relating to Dam Safety. It guides and pursues the implementation of action points recommended in the reports on Dam Safety procedures approved by Ministry of Water Resources, Government of India.

A large number of things can go wrong with a dam. The two main reasons for dam failure are `overtopping – responsible for around 40% of failures and foundation problems – around 30%'.

Embankments dams, which make up about four-fifths of the world's dams, are most vulnerable to being washed away when water flows over their crest. There are, however, usually a number of interrelated reasons why any particular dam collapses. A dam may be overtopped, for example, because of the inadequate capacity of its spillways to discharge floodwaters, because of a spillway blockage with flood-borne debris, or due to mechanical or electrical problems which prevent the spillway gates being opened in time. The spillway gates may also be opened late because of poor operator judgement or incorrect predictions of the size of flood entering the reservoir. Internal erosion (known as `piping') caused by leaks through the core of a dam can also cause it to slump and be overtopped.

There will always, therefore, be pressure for dam builders to cut corners of safety, just as they cut corners on hydrological or sedimentation studies. A confidential 1991 World Bank report notes that because of `financial factors and local pressure to take shortcuts or ignore poor quality work', construction quality in India is `deficient for a number of dams, posing serious potential risk to downstream populations'. The report explains how during construction `large illicit profits can be made by using substandard materials'.

3.1 Factors Affecting the Dam Safety:

3.1.1 Geology and Hydrogeology

Every dam site has unique geological characteristics. Gaining the details is expensive and time consuming. Therefore, dams are located and designed mostly based on partial knowledge of local site conditions. As McCully says, the builders must have to hope that they will not fund an unstable formation which will fail to support their foundation or cause the roofs of their tunnels to come crashing down.

Inadequate hydrological data can also cause dam failures. In World of McCully "Just as dam builders often skimp on geological surveys, so they have shown themselves willing to build on the basis of seriously inadequate hydrological data. When there is not enough water to turn a dam's turbines or fill its canals, or so much water that the dam is threatened with breaching, an `Act of God' – drought or flood – will invariably be blamed for the ensuing electricity shortage or inundation. However, an act of dam builder – construction without sufficient data to predict how much water is likely to be available or deliberate disregard of unfavourable data – is more likely to be where the blame should be laid.

No hydrologist can accurately predict the exact quantity of inflow of water in a planned reservoir. Usually data of 50 to 100 years (if available) is taken to predict for future but its reliability is not guaranteed taking into account annual cycles of variations in rainfall particularly due to global warming. Data on seasonal, monthly and daily peak is also necessary to datawise the maximum flood level. Due to this reason hydrologist extrapolate streamflow based on rainfall pattern which is not proper because variable like rainfall intensity, evaporation and ground cover etc. are not accurately assessed, Dam builders often build based on overestimating annual flows and underestimating peak floods".

BuRec's (US Bureau of reclamation) inability to accept inconvenient stream-flow data is paralleled by the refusal of the authorities building Sardar Sarovar to accept the overwhelming evidence that much less water is likely to be available than was assumed when the project was planned. SSP was designed in the 1970s on the assumption that over 27 million acre-feet of water flowed down the Narmada in three out of every four years. Yet in 1990 the 42 years of flow data then available gave a three out of four years' discharge past the dam site of just 22.7 million acre-feet. More recent figures indicate the flow may be even lower.

The Central Water Commission (CWC) admits that its measurements now show there is less water in the Narmada than was previously assumed. Yet it continues to support building SSP to a height which would displace many tens of thousands more people than a smaller dam designed to take account of the actual flow data. The CWC's justification for its seemingly untenable positions is that:

> Since water resource development activity cannot be delayed for want of data of adequate quality and quantity, best judgement assessment has to be resorted to. In the field of hydrology one has to devise methods to suit the data available and come out with solutions. Accepting a solution in turn needs judgement with due consideration to sociological, economic and political situations.

In words of McCully, political pressure to build the higher dam makes it necessary for the Indian authorities to support the fact that more water flows down the Narmada than their measurements show.

3.3.2 Reservoir Induced Seismicity (RIS):

Large dams can trigger earthquakes. The first observation of possible RIS was noted for Algeria's Quedd Fodda Dam in 1932; the first extensive study of the correlation between increased earthquake activity and variations in reservoir depth was made in the 1940s for Hoover Dam. Today there is evidence linking earth tremors and reservoir operation for more than 70 dams. Reservoirs are believed to have induced five out of the nine earthquakes on the Indian peninsula in the 1980s which were strong enough to cause damage. The table-3.2 below gives details of RIS.

3.2 Table – 3.2

3.3 Reported cases of Reservoir-induced seismicity greater than magnitude 4.0

(Richter Scale)

Dam	Country	Dam height (m)	Reservoir volume (m^3x10^6)	Impounding began	Largest earthquake	Size
Koyna	India	103	2,780	1962	1967	6.3
Kariba	Zambia/ Zimbabwe	128	175,000	1958	1963	6.2
Kremasta	Greece	160	4,750	1965	1966	6.2
Xinfengjiang	China	105	14,000	1959	1962	6.1

Srinakharin	Thailand	140	17,745	1977	1983	5.9
Marathon	Greece	67	41	1929	1938	5.7
Oroville	USA	236	4,400	1967	1975	5.7
Aswan	Egypt	111	164,000	1964	1981	5.6
Benmore	New Zealand	110	2,040	1964	1966	5.0
Eucumbene	Australia	116	4,761	1957	1959	5.0
Hoover	USA	221	36,703	1935	1939	5.0
Banjina-Basta	Yugoslavia	90	340	1966	1967	4.5-5.0
Bhatsa	India	88	947	1981	1983	4.9
Kerr	USA	60	1,505	1958	1971	4.9
Kurobe	Japan	186	149	1960	1961	4.9
Monteynard	France	155	275	1962	1963	4.9
Shenwo	China	50	540	1972	1974	4.8
Akosombo[2]	Ghana	134	148,000	1964	1964	4.7
Canelles	Spain	150	678	1960	1962	4.7
Danjiangkou	China	97	16,000	1967	1973	4.7
Grandval[2]	France	88	292	1959	1963	4.7
Kastraki	Greece	96	1,000	1968	1969	4.6
Lake Pukaki	New Zealand	106	9,000	1976	1978	4.6
Nurek	Tadjikistan	317	10,500	1972	1972	4.6
Fuziling	China	74	470	1954	1973	4.5
Khao Laem[3]	Thailand	130	8,860	1984	1985	4.5
Piastra	Italy	93	13	1965	1966	4.4
Vouglans	France	130	605	1968	1971	4.4
Clark Hill	USA	60	3,517	1952	1974	4.3
P.Colombia/ Volta Grade*	Spain	49	37	1960	1964	4.1
Manicouagan[3]	Canada	108	10,423	1975	1975	4.1

* Epicentre near Porto Colombia and Volta Grande dams.

Source :
1. S.Klaipongpan, `Geological and Seismicity Evaluation of Srinagarind Dam', in S. Prakash (ed.), *Proceedings of Second International Conference on Recent Advances in Geotechnical Earthquake Engineering and Soil Dynamics*, University of Missouri-Rolla 1991.
2. T.Valdut, `Environmental Aspects of Reservoir Induced Seismicity', *Water Power & Dam Construciton*, May 1993.

The actual scientific explanation for RIS is still not well understood and therefore not possible to predict RIS. Most of the strongest RIS are observed for dams over 100 mts. Reservoirs can increase the frequency of earthquakes in areas not known for this. This most widely accepted explanation of how dams cause earthquakes is related to the extra water pressure created in the microcracks and fissures in the ground under and near a reservoir. When the pressure of the water in the rocks increases, it acts to lubricate faults which are already under tectonic strain, but are prevented from slipping by the friction of the rock surfaces.

Koyana Case Study:

Among the earthquake associated with the impounding of the artificial lakes and the injection of fluid through deep disposal wells, the Koyna earthquake of December 10, 1967, is the most significant, having claimed about 200 lives, injured over 1,500, and rendered thousands homeless. The Koyna Nagar township was in a shambles, and more than 80% of the houses were either completely destroyed, or became uninhabitable. The city of Bombay and its suburbs, 230 km away from the epicenter, were rocked. People were driven by panic to the road for safety, and the non-availability of the hydroelectric power from the Koyna Hydroelectric Project paralyzed industry throughout the area.

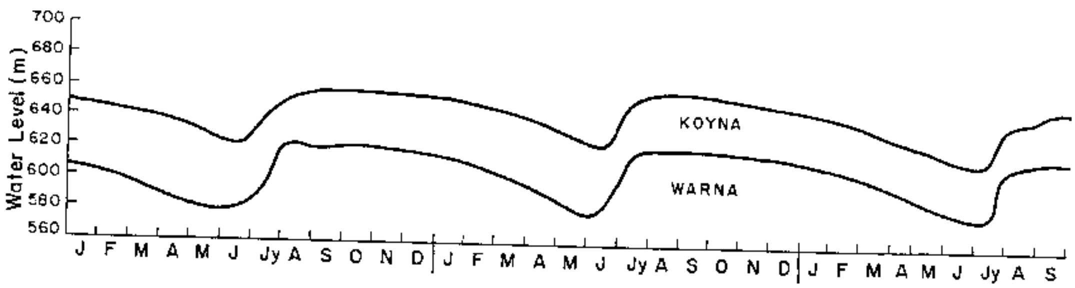
The Koyna Dam and the Shivaji Sagar Lake are situated in the Peninsular Shield of India, which had been considered free from any significant seismic activity. The seismic zoning map of India, prepared by the Indian Standards Institution in 1962 and later revised in 1966, showed this region to be aseismic. However, after the Koyna earthquake, some earthquakes have been cited in nearby areas in the historical past, suggesting that, although the Peninsular Shield has been geologically stable, it was wrong to rule out the occurrence of such an earthquake entirely.

Soon after the impounding of the Koyna reservoir in 1962, reports of earth tremors near the dam site began to be prevalent. The frequency of these tremors increased considerably from the middle of 1963 onwards. These tremors were invariably accompanied by sounds similar to those of blasting (Mane, 1967). The strongest of these tremors would rattle windowns, disturb utensils, etc. To monitor these earthquakes, a close network of four seismological observatories was established, when reports of felt earthquakes began to be prevalent in the region during 1963. The hypocenters were found to cluster near the lake, at a very shallow depth. Before the December 10, 1967 earthquake, five other earthquakes occurred during 1967 which were strong enough to be recorded by many Indian seismological observatories. The September 13, 1967, earthquake was of magnitude 5.5 and it caused minor damage locally.

Reservoir induced earthquakes began to occur in the vicinity of Shivajisagar Lake formed by Koyna Dam in Maharashtra state, western India, soon after its filling started in 1962. Induced earthquakes have continued to occur for the past 34 years in the vicinity of this reservoir, and so far a total of 10 earthquakes of $M \geqq 5.0$, over 100 of $M \geqq 4$ and about 100,000 of $M \geqq 0.0$ have occurred. Every year, following the rainy season, the water level in the reservoir rises and induced earthquakes occur. Seismic activity during 1967-68 was most intense when globally, the largest reservoir induced earthquake occurred on 10 December,

1967. Other years of intense seismic activity are 1973 and 1980. During 1986 another reservoir, Warna, some 20 km south of Koyna, began to be filled. The recent burst of seismic activity in Koyna-Warna region began in August, 1993, and was monitored by Scientists from NGRI with a close network of digital and analog seismographs. During August, 1993-December, 1995, 1,272 shocks of magnitude ≧ 2 were located, including two earthquakes of *M* 5.0 and *M* 5.4 on 8 December, 1993 and 1 February, 1994, respectively. Two parallel epicentral trends in NEE-SSW direction, one passing through Koyna and the other through Warna reservoir are delineated. The 1993 increase in seismicity has followed a loading of 44.15 m in Warna reservoir during 11 June, 1993 through August 4, 1993, with a maximum rate of filling being 16 m/week. The larger shocks have been found to be preceded by a precursory nucleation process.

Earthquakes and water level fluctuation:



Until now, the Koyna earthquake of December 10, 1967, is the largest known reservoir-induced earthquake. There is no physical reason to assume that a large induced earthquake will not occur. However, in view of the uniqueness of the Koyna earthquake and the fact that thousands of dams have not experienced similar earthquakes, Allen (1982) concluded that a magnitude and any dam that will impound a deep reservoir (depth exceeding 80-100 m) should be designed with the assumption that a 6.5 magnitude earthquake could occur nearby. It is further observed that shaking associated with a local 6.5 magnitude earthquake does not pose a very severe design problem for the engineers.

(a) Significant variations is rock properties at shallow depths are revealed by a close scrutiny of geological maps, magnetic anomaly maps, gravity anomaly maps and radiometric anomaly maps. These variations are associated with the upper portion of the pluton which intruded in the older metamorphic rocks. Induced earthquake hypocenters cluster around the boundaries of these plutonic bodies.

(b) Induced seismicity is limited temporally and spatially to the immediate vicinity of the reservoir with focal depths < 3 km and the largest induced earthquake is of magnitude $M_L = 2.8$.

(c) Prevailing stress distribution, lateral heterogeneities is rock properties permit only small faults (~ 1 km) to break at a time for a given earthquake. This limitation puts an upper bond of $M_L \simeq 4.0$ on the earthquake magnitude.

(d) Stress regime, as inferred from in situ measurements, favours thrust faulting at shallow depths. Inferred stress barriers of varying depths limit the vertical extent of reservoir-induced earthquake sources.

(e) Extrapolation of earthquake magnitude-frequency curve to estimate the recurrence period of larger magnitude earthquakes is not justified. A maximum cut-off magnitude likely for the Monticello region is estimated to be $M_L \simeq 4.0$.

Dhamani Dam Case Study:

Dhamani Dam (height 59 m, capacity 285 Mm^3) was constructed about 100 km north of Mumbai (Bombay), India over the Deccan flood basalt and across the Surya River. The filling of the reservoir started in 1983. Construction of the dam was completed in 1990. However for want of environmental clearance, the maximum water column height in the reservoir since 1988 has been 45 m (8 m short of the maximum possible, 53 m) with the volume of water in the reservoir being 175 Mm^3. The first phase of seismicity started in August 1984, soon after the reservoir reached a 22.5 m depth over the river bed level, and the increased level of seismicity continued for two years, when 605 shocks of $M \geqq$ - 1.7 to 2.5 were recorded. During 1987-93, there were only a few shocks. Seismicity rejuvenated in 1994 when over 2000 shocks of $M \geqq$ - 1.7 to 3.8 occurred, including 20 shocks of $M \geqq 3.0$ which occurred during the months of January – February and August – September. Seismicity has continued at a low level during 1995 and 1996. The hypocenters are located in a volume of 10 x 10 x 10 km^3 situated just south of the reservoir along the NW trending Kalu-Surya fault. Correlation of a space-time pattern of seismicity with reservoir filling and the seismic characteristics like *b* value, foreshock-aftershock pattern and decay rate of aftershocks indicate that the seismicity is reservoir induced.

3.3.3 Sedimentation / Siltation:

All rivers contain sediment. This sediment settles in the bottom of the reservoir. The proportion of a river's total load captured by a dam otherwise called trap efficiency approaches 100% for many projects, especially those with large reservoir. In such a situation the dam slowly looses its capacity to store water & defeating the basic purpose for which it was built. The rate of sedimentation varies from reservoir to reservoir.

A World Bank study of 1987 states that around 50 cubic kilometers of sediment – nearly 1% of global reservoir storage capacity – is trapped behind the World's Dams every year and by 1986 around $1/5^{th}$ of the storage capacity has been consumed. Apart from rapidly filling their reservoirs, sediment – filled rivers also cause abrasion of turbines and other dam components thereby reducing the generating efficiency of the power.

In India, government statistics on 11 of the country's reservoirs with capacities greater than 1 cubic kilometer show that all are filling with sediment faster than expected, with increases over assumed rates ranging from 130 per cent (Bhakra) to 1,650 per cent (Nizamsagar in Andhra Pradesh). A 1990 World Bank paper on watershed development concluded that in India, `erosion and [reservoir] sedimentation are not only severe and costly, but accelerating. It is now obvious that the original project estimates of expected sedimentation rates were faulty, based on too few reliable data over too short a period (see Table – 3.3 & 3.4).

The most effective method of controlling siltation rates of reservoirs is by treating the catchment areas. The construction of dams invariably degrades the catchment areas as pressures supported by the land and forests that are submerged by the project, get transferred partly or wholly to the remaining land and forest in the catchment area. In its turn this degradation negatively affects the dam and the reservoir.

3.4 Table – 3.3

3.5 Name of reservoir	3.6 Annual rate of siltation (ha m/1000 sq.km.)		Percentage of assumed life actually available*
	Assumed	3.7 Observed	
Bhakra	4.29	5.95	72.2
Tungabhadra	4.29	5.98	78.77
Matatila	1.33	4.33	30.25
Panchet	6.67	10.48	63.88
Maithon	9.05	12.39	72.85
Mayurakshi	3.75	16.48	22.70
Shivaji Sagar	6.67	15.24	44
Hirakud	2.52	6.6	38.087
Gandhi Sagar	3.61	9.64	37.41

Source : Adapted from PAC 1982-83 : 103

* Life of reservoir refers to physical life based on the rates of siltation assumed at the design stage and presently observed.

4. Table – 3.4

4.1 Name of reservoir	4.2 Annual rate of siltation (ha m/1000 sq.km.)		Percentage of assumed life actually available*
	Assumed	4.3 Observed	
Bhakra	23,000	33,745	146.7
Maithon (DVC)	684	5,980	874.2
Panchet (DVC)	1,982	9,533	480.9
Ramganga	1,089	4,366	400.9
Tungabhadra	9,796	41,058	419.1
Mayurakshi	538	2,000	371.7
Nizam Sagar	530	8,725	1,646.2
Ukai	7,448	21,758	292.1

Source : ICR 1972, Vol.1 : 326, Table 14.1

Sedimentation and its Impact on Life of Reservoir – Illustration of Tehri & other Dams:

Sedimentation studies and its impact on the life of Tehri reservoir have been carried out using the observations of the Central Water Commission (CWC) for the sediment load of river Bhagirathi since 1972. The sediment distribution studies confirm the designed life of reservoir as 100 years. These studies also reveal that this reservoir may serve its intended purpose with reduced benefits even for 160 years against the designed life of 100 years. The rough estimates given the benefit cost ratio and the cost of unit power generation after 160 years of operation as 2.12 and 51 paisa respectively. This shows that the reservoir is economically viable even after 160 years of operation. The elaborate action plans for soil conservation measures and watershed management which are being implemented under catchment area treatment plan would reduce the rates of siltation. This reduction in siltation rate would increase the economic life of the reservoir even beyond 160 years.

Siltation or sedimentation in reservoirs is a very serious problem, for it considerably reduces the life of the man-made lakes various streams flowing into the reservoirs inevitably bringing a high load of sediments from the catchment areas which of late been exposed to accelerated erosion. The life of a reservoir depends on the rate of silt inflow and its dead storage capacity the Tehri reservoir was initially designed for an expected sediment rate of 8.2 ha m/100 km/year giving a total sediment load of 608 Mm over a period of 100 years. But provision of dead storage capacity of 925 M m has been made to be on the safe side.

Silt load studies were started in 1973 at Tehri town below the confluence of Bhagirathi and Bhilangana. Data is available for a period of 17 years upto 1990. The project authorities have calculated average suspended silt load as 12.6 ha m/100 km/year to which has been added a bed load of 15% (1.90 ha m). Assuming a flap efficiency of 96 per cent the total silt load has been calculated as 14.00 ha m/100 km/year. Further to be on the safer side, it has adopted a silt load of 14.5 ha m/100 km/year.

4.1.3.1.1 The storage of Tehri reservoir was calculated by the project authorities, that

(i) Dead storage at EL 740 m is	925 M m
(ii) Dead storage at EL 720 m is	600 M m
(iii) Total sediment load after	1090 M m
100 years is (@ 14.5 ha m)	[596.23 M m in dead storage and 493.77 M in line storage]

The calculation clearly portray that the dead storage used upto the elevation 720 m in one hundred years. This level also coincides with the invest level of the Head Race Tunnel.

It is, however, much more probable that the actual silt load in the reservoir may be much higher than assumed on the basis of limited data as is evident from other reservoirs of the country, and further catchrnent also throw light on the nature and characteristics of terrain. Reservoir sedimentation committee in its report of July, 1985 reports that, some reservoirs in the world have silted up so fast that they have become useless. Many of the reservoirs in India are losing capacity at the rate of 0.5 to 1.5 per cent annually. A glaring example of the brisk decline of lakes is the premature silting -up of the reservoir behind the Ichari Dam on the Tons River. With in a very short span of a little over two years (1975-77) the reservoir was filled with sediments upto the level of the rest of the spillway, 160 m high. The total sediment transported into the lake was of the order of 29 million m in (1978-79).

To quote some more examples, in the Govind Sagar behind the Bhakra Dam there was heavy sedimentation in the reach 24 to 26 m above the dam, forming a hemp and resulting in maximum capacity loss between the elevation of 427 and 457 in above mean sea level. The average sediment deposition during the period 1959-64 was 36.86 million and between 1959-69 about 39.3, 65 per cent being in the dead storage and 35 per cent in the live storage zones. As a result of this unhecked sedimentation the lifespan of the reservoir would be 103 years instead of expacted 250 years. The rate of sedimentation behind the 12 m high Kalagarh Dam in the Rain Ganga is 1.90 ha m/km/year of the catchment area so that within the stipulated lifespan of 100 years, about 5900 ha m of sediments would accumulate in the lake, reducing its life to 76 years. According to another estimate, its life span has been reduced from 185 to 48 years.

In case of Tehri, the empirical formulae for sediment calculation, is evidently of little value and its use in predicting silt load as is clear that the adoption of a silt load factor of 8.2 ha m/100 year, so derived, would have been totally inadequate, and misleading because, the catchrnent area critical assessment indicates that, the entire area is highly seismic and landslide prone area. The remote sensing data showed that there are more than 25 landslide areas, which raised the huge of amount of sediment movement. The Tehri Dam catchment area is quite geodynamically sensitive and vulnerable.

5. Table – 3.5

6. Depicting Sedimentation Rates in some Indian Reservoirs

6.1 Name of Dam	Silt deposited in cu. m. per 100 sq.km., of catchment per year	6.2 Type of catchment
Bhakra Dam (Punjab)	58, 700	Hilly catchment, shiwalik rocks glacier fed.
Panchet Dam (Bihar)	1,03,400	Denuded of forest and vegetal cover, badly corroded land, cultivated land 50 per cent.
Maithon Dam (Bihar)	1,29,200	Same as per Panchet dam.
Tungbhadra (Karnataka)	64,600	About 25% catchment is thick and thin forest.
Matatila (Uttar Pradesh)	43,200	Mostly rocky covered with shrub jungle.
Nizamsagar (Andhra Pradesh)	68,100	Partly hilly, partly plain, Contour & Partly forest.
Tehri Dam	1,42,800 (assumed in design for checking dead storage level)	Hilly catchment, partly snow bound.

Source : CWC

With regard to silting phenomenon in reservoirs, it may be mentioned that after a few years of construction of the dam, the rate of silt trapped in the reservoir shows a decreasing trend. This is partly due to changes in the river regime and partly due to the fact that catchment areas treatment (if done property) begins to bear fruit. It is pertinent to mention that in Bhakra reservoir (a major dam in the Himalayan region), the rate of silting has decreased after an initial period of high silting as indicated in the following Table – 3.6:

6.3 Table – 3.6

6.4 Period	Rate of silt deposition in cu. mts./Per year
6.5 Year 1959-1965	39208700
6.6 Year 1965-1973	29483000

Source : CBI & P

It is also of interest to note that the project, at the time of design had assumed an average figure of 33517500 cu.m. against the actual inflow of silt of 2948300 cu.m. during the period 1965-1973. It is also to be noted that the silt inflow rate beign now assumed for checking dead storage level of Tehri (142800 cu.m./100 sq.km./year) is 2.4 times that of average rate of silt inflow into Bhakra from 1959 to 1973 (59500 cu.m./100 sq.km./year). Given the similarity in the nature of the catchment areas of Bhakra and Tehri, it is reasonable to except a reduction in silt rate in Tehri also. The above data, provides further support to the assumption of the life of the reservoir beyond 100 years.

Accordingly to McCully, there are three categories of methods to prolong the life of a reservoir: reduce the amount of sediment flowing into it; flush through the dam the sediment and has already accumulated; or dredge the sediment. All have severe limitations, either because they simply do not work, they are prohibitively expensive, or because they conflict with the dam's ability to supply water and power.

`Watershed management' – including afforestation and the promotion of farming practices which reduce soil erosion – is frequently advocated at the best way of cutting sediment deposition in reservoirs. While these shcemes may be recommended in project plans, they are rarely implemented: dam-building agencies are usually more interested in putting their funds towards building dams than planting trees and digging field terraces. When attempts are made to implement soil conservation schemes in the large tropical and sub-tropical watersheds which are most prone to erosion they are usually underfunded and opposed by local farmers who after already losing valuable riverside land to a reservoir resist having more of their land taken over for tree plantations.

It is difficult to find any examples of the successful implementation of watershed anti-erosion measures in the tropics and sub-tropics. K.Mohmood believes that in any case, for most large river basins,

> … over period of engineering or economic interest, the sediment yields are largely unaffected by watershed management. The sediment sources within the basin, including the hillslopes, valley floors and river channels will amply make up for whatever reduction of erosion can be affected by watershed control.

Overall, building a dam in a valley is much more likely to increase erosion than reduce it: dams open up remote areas to road builders, developers, loggers, farmers and miners, accelerating deforestation and soil loss. When insufficient resettlement land is made available, oustee farming families may have no choice but to clear land further up the valley or hillside. In any case, deforestation and soil erosion are both increasing rapidly around the world, and it should be assumed when dams are built that soil erosion in their watershed will increase over the projected economic life of the reservoir.

Sediment Sluicing, Flushing etc. :

Sediment sluicing is the name given to a type of reservoir operation which draws the reservoir down at the start of the flood season and then allows as much sediment-heavy flood water as possible to pass through the dam before it has a chance to settle. This method can drastically slow down the rate of reservoir sedimentation but has only been successfully used in a few projects, most notably the Low Aswan Dam. It is also the method which finally stabilized the sediment build-up at Sanmenxia. Sluicing is only effective for reservoirs which are small and narrow relative to river flow and it seriously reduces or eliminates the dam's ability to generate electricity and supply water during the prolonged period when the reservoir is lowered. It also conflicts with the aim of many projects to store flood waters.

Sediment flushing is a method of washing out deposits which have already accumulated in a reservoir. Again it depends on the reservoir being drawn down, with the aim that fast-flowing water will erode the sediments on the reservoir bed and flush them through the dam. Flushing a long reservoir will require several months of drawdown to a level where the flow of water through the reservoir is close to that of the original river. While flushing can be effective at removing fine, silty deposits near the outlets, it usually has little impact upon the coarser deposits further upstream or cohesive sediments such as compacted clays. In general, flushing has little impact on a seriously sedimented reservoir.

An obvious way of restoring reservoir capacity is dredging. However, this is extremely expensive and is normally only viable for small, urban water supply reservoirs where water consumers can afford the cost, and landfill sites are available to take the dredged sediment. Mahmood cites the cost of dredging at $2-$3 per cubic metre in 1987, around 20 times more than the cost of providing additional storage in a new dam. Restoring the original capacity of major reservoir would require the removal (and transport and dumping) of billions of cubic metres of sediment. Based on Mahmood's cost estimate, dredging the annual volume of sediments deposited in Tarbela Reservoir each year would cost some $400-$600 million; dredging the sediments accumulating in reservoirs worldwide every year would cost $100-$150 billion.

3.3.4 Waterlogging and Salinisation:

Waterlogging and salinity are two global environmental problems facing the developing countries. Every year 200,000 to 300,000 hectares of fertile land World over are added to the agricultural land affected by waterlogging. In India about 10 million hectares of cultivated land is affected by waterlogging and 25 million hectares by salinity problems. The problem eludes easy solution since it is a complex environmental management problems linked to land development policy, cropping patterns, water and soil management practices, farmers attitude and perception towards water use, irrigation systems, topography and drainage systems.

Table – 3.7 gives the area affected by waterlogging in various states of India. It has been reported that waterlogging is not a severe problem in Andhra Pradesh, Tamil Nadu, Orissa, (National Commission on Agriculture, 1976). But because of increase of irrigation more and more area has been affected by waterlogging. This is evident from study carriedout by P.K.Joshi and B.L.Gajja of Central Soil salinity research institute and Jai Singh of Haryana Agricultural University. Table – 3.8 gives the extent of waterlogging and salinity in selected Command Areas.

Table – 3.7

Extent of Waterlogged Areas Estimated by Various Agencies

(In lakh hect.)

	N.C.	Sehgal & Ratan-Singh (1972)	Others	Summary and estimate of available data
Punjab	10.9		--	10.90
Haryana	6.2	14.27	--	6.20

Uttar Pradesh	8.10	6.8	--	8.10
Bihar	NR	NR	1.17	1.17
Rajasthan	3.48	NR	--	3.48
Gujarat	NR	4.84	0.60	4.84
Madhya Pradesh	0.57	NR	0.33	0.57

	N.C.	Sehgal & Ratan-Singh (1972)	Others	Summary and estimate of available data
Karnataka	0.07	NR	3.39	3.39
Maharashtra	0.28	1.11	--	1.11
West Bengal	18.50	3.09	--	18.5
Orissa	--	--	0.60	0.60
Tamil Nadu	--	--	0.18	0.18
Kerala	--	--	0.61	0.61
Delhi	--	0.01	--	0.81
Jammu & Kashmir	--	0.10	--	0.10

Source : National Commission on Agriculture, 1976, Vol.5, Resource Development.

Table – 3.8

Extent of Soil Salinity and Waterlogging in Selected Irrigation Command Area ('000 ha.)

Irrigation Project	Extent of the problem	
	Soil salinity	Waterlogging
Sharda Sahayak	303 (28.34)	50.00 (4.68)
Indira Gandhi Canal	43.10 (7.98)	29.11 (5.39)
Western Jamuna Canal	251.00* (20.9)	--
Bhakra	102.00* (8.8)	--
Kakarpar bank	16.2 (4.3)	8.3 (2.2)

Note: Figures in parentheses are percent of the gross irrigated area.
* Includes soil salinity and water logging.

Source: Adverse effects of land degradation on the agricultural economy : Source evidence from saline and waterlogged areas – P.K.Joshi, B.L.Gijja & Jai Singh.

The study done by Administrative Staff College of India has estimated the magnitude of the problem of waterlogging in three major irrigation projects in areas which not have serious waterlogging prior to the initiation of these irrigation projects the three projects studied were:

i) Tungabhadra Project where there is salinity and waterlogging.
ii) Sriramsagar Project where waterlogging is a serious problem.
iii) Nagarjunasagar Project where waterlogging is due to seepages from the tributaries, field channels and canals.

These three projects were selected to highlight the environmental management problems involved in waterlogging and salinity. Here we shall discuss only Nagarjunasagar case.

3.3.5 Waterlogging and Adverse Environmental Impact

The soil, water and plants are delicately balanced since plants mainly act as an interface between soil and water. The introduction of irrigation disturbs this balance causing a rise in ground water table and disturbing the natural salt distribution in the soil thereby affecting vegetation. Waterlogging is thus the problem of rising water table and the consequent increase in salinity of the soil. Waterlogging affect adversely the agricultural yield in a number of ways. The seriousness of the problem lies in the fact that the land affected by waterlogging are comparatively superior. Further, water is a scarce resource in most of the developing countries and loosing fertile and irrigated land out of production is a major environmental risk. The marginal cost of increasing irrigation to new areas are much higher than the cost of efficiently using water in the irrigated areas.

Waterlogging, soil quality, soil salinity and agricultural productivity are closely inter-related. The salts in the soil do not evaporate with the soil moisture. Therefore, as moisture in the soil evaporates and transpires the salt content in the remaining water increases. Irrigation water unused by plants may percolate down to the water-table, which in turn becomes increasingly salty (Eckholm 1976). When the saline water reaches root zones it prohibits the crop growth. Even when the water is not salty it damages the crop by choking the roots, cutting off the oxygen supply (Eckholm 1976). When the watertable reaches three meters from the surface, water begins to move upward by capillary action. As the water reaches the surface and evaporates, a thin deposit of salt will be left behind. As a result the soil becomes saline. Rise of watertable causes in most cases secondary soil salinization, either due to high salinity of the groundwater or due to dissolution of solid phase salts by rising fresh ground water (Worthington 1977). Under waterlogged conditions biological activity will be curtailed and the organic matter will accumulate as raw humus (Trugill 1981). The soil quality thus gets deteriorated severely. Waterlogging is an environmental management problem because it is caused by the interaction of a large number of factors such as ground water recharge, drainage, surface irrigation, cropping patterns, ground water pumping for irrigation, soil characteristics, seepage from channels and distributories. Once the problem becomes acute, changing one or two factors alone cannot immediately reverse waterlogging. Agricultural productivity is a sensitive function of soil salinity. The sensitivity of various plants differ considerably with respect to reduction in agricultural productivity. Increase in salinity measured in terms of increasing electrical conductance reduces the agricultural productivity (Cox and Atkins, 1979) have reported the effect of salinity in terms of reduction in agricultural yields for various plant species.

The increase of soil salinity or rise in watertable are slow processes which cannot be observed directly. But once the problem becomes acute it will take several years for the reclamation of the soil. In otherwords waterlogging reduces the soil quality severely but there are no short term solutions to the problem once it becomes severe. The main reason for irreversible degradation of soil quality comes about because of the precipitation of clay and also due to the removal of calcium. Secondly, reclamation of soils affected by waterlogging is a costly proposition involving a large number of drainage operations. In areas where drainage cannot be provided water withdrawal by pumping can cause temporary reduction in waterlogging.

Waterlogging in economic sense means opportunity cost in terms production lost and ineffective use of irrigation facilities. One of the major reasons for waterlogging is inefficient use of water or overuse of water and this results in tailenders getting smaller quantities of water for irrigation. hence, waterlogging lowers production in otherwise fertile soils and reduces the possibility extending irrigation to the tail enders. Opportunities forgone in terms of loss of fertile land and in terms of non-availability of water to the tail enders results in lower output per unit of investment in agriculture. The main cause for concern is not in short term economic losses but in terms of loss of production over long period.

In conclusion waterlogging and salinization of the soil are two environmental problems that are generated by the extension of irrigation in soils which do not allow easy drainage due to either the soil structure or slope of the area.

3.3.6 Causative Factors

As per study carried out by Joshi, Gijja & Jai Singh following are the causative factors for water logging:

a) Higher seepage losses;
b) Poor operation and maintenance of canal networks;
c) Introduction of canal irrigation in marginal lands;
d) Mismanagement of canal irrigation;
e) High subsidy on canal irrigation;
f) Higher acreage allocation in favour of rice and sugarcane; and,
g) Poor groundwater quality.

Some other location-specific reasons observed are poor drainage porosity of soil, lack of drainage, outlet, presence of shallow hard pan below soil surface, saline groundwater, etc.

The statistics, though diverse, clearly indicate that the problem is of serious enough dimensions to threaten the growth of the agricultural economy. The consequences of degrading land resources due to salts and waterlogging are witnessed at farm, regional and national levels. We shall briefly discuss important negative effects at each level.

At the farm level, the negative effects are a threat to the sustainability of land resources; and, decreased farm production by abandoned crop production, decline in resource productivity, and cut-back in resource use. According to farmers' perceptions, in selected irrigation projects, yields of important crops declined substantially due to irrigation-induced salinity and waterlogging (see Table – 3.9). High salt and water stress affected the net returns of all crops and in affected areas yield came down drastically (see Table – 3.10). In some cases, the net returns over variable cost were negative.

7. Table – 3.9

Yield of Important Crops in Different Types of Soils (ka/ha.)

Crop	Normal soils	Salt-affected soils	Waterlogged area
SHARDA SAHAYAK IRRIGATION PROJECT			
Paddy (HYV)	2773	1349	1630
Paddy (Local)	1958	1067	1450
Wheat	2596	1139	580
WESTERN YAMUNA CANAL AND BHAKRA			
Paddy	5979	4047	4837
Wheat	3281	2418	2838
Cotton	1022	592	412
Sugarcane	38730	22849	16333
INDIRA GANDHI CANAL PROJECT**			
Wheat	1920	1136	445*
Cotton	2240	630	330*
Sugarcane	88630	43200	33160*

Notes: * Indicate severely affected saline soils; ** Agrihotri, Joshi and Singh (1985)

7.1 Table – 3.10

Net Income from Important Crops in Different Types of Soils (Rs./ha.)

Crop	Normal soils	Salt-affected soils	Waterlogged area
SHARDA SAHAYAK IRRIGATION PROJECT			
Paddy (HYV)	1844	245	853
Paddy (Local)	920	-104	416
Wheat	2061	162	-397
WESTERN YAMUNA CANAL AND BHAKRA			
Paddy	5246	3117	4619
Wheat	5468	4030	5138
Cotton	4946	1867	1231
Sugarcane	4083	3436	2097
KAKARPAR RIGHT BANK CANAL			
Cotton	7756	-146	-1276*
Sugarcane	16260	2844	57*

Notes: * Indicate severely affected saline soils.

The results at farm level are giving clear signals that important high value crops would gradually disappear from the affected areas since it was not economically viable to cultivate on saline and waterlogged areas without their reclamation to achieve the acceptable yield levels. Failing to take any measures, irrigation benefits will be negated by the emergence of the problem of soil salinity and the rise in water-table.

Regional-level Effects:

At the regional-level, the consequences are:

a) Displacement of labour from agriculture;

b) Widening income disparities; and

c) Declining sustainability of secondary and tertiary sectors.

To be more specific about on-farm employment, it was observed that labour employment was restricted due to the lower productivity in moderately degraded areas and abandoned crop production activities in severely affected areas. It was observed that the labour demand was cut-back from a low of about 5 percent to produce wheat in the Sharda Sahayak Command area to a high of about 62 percent for sugarcane in parts of the Western Yamuna canal and Bhakra command area (Table – 3.11).

Interestingly, rice, cotton and sugarcane are high labour requirement crops and many agro-based industries are dependent upon their output. Any decline in production of these crops will definitely affect sustainability of such a phenomenon and will lead to unemployment and underemployment in the potential labour absorbing areas.

Table – 3.11

Total change in Output and Pure Soil Degradation Effect (percent)

Crop	Salt-affected vs. normal soil		Waterlogging vs. normal soils	
	Total change	Salinity effect	Total change	Waterlogging effect
SHARDA SAHAYAK IRRIGATION PROJECT				
All crops	84.4	63.4	83.9	64.4
Paddy (HYV)	83.7	74.1	--	--
Paddy (Local)	54.3	36.0	--	--
Wheat	93.1	62.6	--	--
WESTERN YAMUNA CANAL AND BHAKRA				
Paddy	29.9	48.8	21.2	19.4
Wheat	31.8	22.9	12.9	0.2
Cotton	62.0	39.0	--	--
Sugarcane	37.8	2.9	77.5	9.8

Crop	Salt-affected vs. normal soil		Waterlogging vs. normal soils	
	Total change	Salinity effect	Total change	Waterlogging effect
INDIRA GHANDHI CANAL PROJECT				
Wheat	22.6	7.6	--	--
Groundnut	17.3	5.4	--	--
KAKARPAR RIGHT BANK CANAL				
Paddy	49.1	43.0	--	--
Cotton	31.6	19.0	--	--
Sugarcane	20.6	11.2	--	--

Source : Joshi, Singh etc.

3.3.7 Results of Study of Nagarjuna Sagar Project:

The monitoring of water table fluctuations in the command area of the left bank was started in 1975 by State Groundwater Department through a net work of 115 observation wells covering an area of about 1.17 lakh hectares.

After release of water in NSP in 1967, draft from the existing 6,000 wells is considerably reduced and there is an indication that, in some places, the water table rose to 1 to 3 meters from ground level. Table 3.12 and 3.13 give the status of watertable in observation wells. The average water table level was 4.2 meters in 1975 and it rose to 2.9 meters by 1979. The number of wells showing waterlogging conditions rose from 35 percent in 1975 to 68 in 1978. Figure 3.1 shows the location of the wells with waterlogging conditions in 1975-76 and Figure 3.2 shows the status in 1978. The average water table level in waterlogged areas is found to be 2.22 meters in 1975 and 1.4 in 1978. Table – 3.15 gives the extent of waterlogged and saline area in three projects including NSP which indicates an area of about 25,000 ha.

Salinity of ground water has been observed in some areas. In 1980 these areas have gone out of production due to salinity. Table 3.14 gives the changes in Electric Conductance of ground water over years, indicating that salinity has been increasing as electrical conductance of more than 2500 micro siemens was noticed. In 1975 only 3 percent of the water samples have shown high EC of more than 2500 micromhos indicating. This has risen to 14 percent by 1979.

Table – 3.12

Average depth to Water Table in Nagarjunasagar Command Area

Year	1975	1976	1977	1978	1979	1980	1981	1982
Command Area (whole)	4.20	3.90	-NA-	2.90	4.80	4.30	5.25	5.6
Waterlogged Area	2.2	2.2	-NA-	1.4	2.2	1.9	2.7	3.2

Table – 3.13

Frequency distribution of water level in observation wells in Nagarjunasagar Command Area

(Percentage Distribution)

Depth to water table (in Mtrs.)	1975	1976	1977	1978	1979	1980	1981	1982
0 - 3 (Waterlogged)	35	38	-NA-	68	33	38	14	10
3 - 6 (Prone to waterlogging)	50	50	-NA-	25	53	51	56	52
Below 6 (Free from Waterlogging)	15	12	-NA-	7	14	11	30	38

Table – 3.14

8. Electric conductance of ground water samples at Nagarjunasagar Command Area

Electrical Conductance in microsiemense	Year (Percentage of wells in the given Electrical conductance range)		
	1975	1979	1982
Below - 500	2	--	3
500 - 1000	51	35	44
1000 - 1500	24	28	30
1500 - 2000	16	12	8
2000 - 2500	4	10	4
Above - 2500	3	14	11

Source : 8.1 **Tables 3.12 to 3.14**
Waterlogging from Irrigation Project : An Environmental Management problem – Department of Environment, GOI, 1984.

However during 1981 the canal water was stopped for some time as the canal lining work has begun. As a result of this the average water table level came down to 5.6 meters in 1982 (from 4.6 meters in 1980) and only 11 percent showed high EC. The number of wells showing waterlogging conditions came down from 60 to 10 during this period. Fig.6.3 shows the location of wells with waterlogging conditions.

A study was carried out by National Remote Sensing Agency, Hyderabad in 1996 on assessment of waterlogging and soil salinity/alkalinity in NSRC. A total of 1710 ha. land along the Coast in the 22nd block was found experiencing waterlogging problem. Salt - affected soils cover an area of 42,800 ha. Of this, the saline-sodic soils with an estimated area of 28,480 ha. comprise the major salt-affected soil category. The study covered the periods 1985-86 and 1990-91.

<u>ANALYSIS OF WATERLOGGING IN NSP</u>

3.3.8 Irrigation and Cropping pattern:

This is one of the major reasons for waterlogging in NSP. Before the introduction of irrigation farmers used to depend on rain and ground water. After the introduction of irrigation water farmers tended to overuse this waters as they do not have any prior experience in water management. The problem got compounded as Govt. permitted violation of localisation pattern approved by them. As a result, areas reserved for ID crops also got converted into Paddy fields.

Farmers consider that usage of higher quantity of water will result in increased yields and always there is a tendency to overuse water. It has been shown that perception plays a major role in identification of environmental risks (Bowonder 1980, Miller 1982, Bennett and Chorley 1977, Rapoport 1977). Problems of misperception are aggravated by the fact that once beliefs are formed an individual will tend to structure and distort the interpretation of new evidence thereby creating high resistance to information that confirms an opposing view or discredits one's own beliefs (Covello and Menkes, 1982). This irregular and over irrigation in the absence of proper drainage facilitates waterlogging. The agricultural extension services were ineffective in educating the farmers on these aspect.

3.3.9 Drainage and Seepages:

Soil characteristic is one of the major parameters that determines the waterlogging. The command of NSP has freely drained sandy loams. Drainage is a critical problem in the command area. Lack of drainages coupled with poor water management have caused waterlogging and salinity. This is especially so in the case of low-lying areas and areas which have poor natural drainage. The provision for drainages was omitted from the initial project plan to reduce the capital cost in all the project. The farmers do not appreciate the benefits of drainages. As a result only a few fields are drained.

Another major reasons for severe waterlogging is seepages from water courses. In the command area only the main canal is lined. The NSP Left Canal was lined in 1981. The analysis of water table fluctuations however show that the non-lining of the canal has a bearing on water table build up in NSP command area (Figure 3.3). Adjacent to areas where there is good water availability, if seepages are severe and slopes do not favour easy drainage there will be waterlogging from over irrigation.

3.3.10 Utilisation of ground water:

Before the introduction of irrigation, the agriculture was based on rains, supplemented with ground water. In NSP there were 6,000 wells used for irrigation purposes. At the advent of irrigation draft from these wells is completely stopped. With seepages, over irrigation and lack of drainage facilities, this lead to a fast build up of ground water table. As study reveals, this trend got accelerated by the water pricing system. Water pricing is based on the area irrigated and not based on quantity of water withdrawn. Whereas, if well water has to be used for irrigation running expenses as well as electricity charges are to be paid under these conditions study observes, farmers do not have any economic incentive for conjunctive use of ground water along with canal water. In the Aswan Dam area also the problem of waterlogging is aggravated by the irrational or improper pricing system (Wittington and Guariso, 1983).

Increased irrigation facilities without scientific land use practices lead to increased erosion of soil and consequently most of the natural drains have silted up in the command area. No efforts have been initiated either to desilt the natural drains or to have new drainages.

3.3.11 Conclusions:

Waterlogging and salinity are present in NSP Command giving some fluctuating trend, but the risk of its increase can not be ruled out.

One of the major barriers that come in the way of reduction of waterlogging is that farmers do not consider waterlogging as a severe problem till the effects are manifestly serious in nature. Agricultural Department and Command Area authorities do not consider waterlogging as a serious problem since they see the problem only in terms of total agricultural production. Though Command Area Development Authority is the agency for coordinating the education, planning and agricultural extension, it has not prescribed and visualised in real sense waterlogging as major environmental management problems.

In case of Nagarjunasagar Project, limitted groundwater monitoring has been initiated. One of the major problems in conducting research on effect of waterlogging is the lack of data. An efficient system of monitoring all the parameters related to water, and soil quality and agricultural yield are essential for any major command area to take up development plans in command areas.

At the project initiation stage itself, provision has to be made for drainages and lining of distributories. Project reports for major irrigation projects should contain environmental safeguards necessary for containing waterlogging.

Lastly, senior governmental decision makers are unaware of the seriousness of waterlogging and salinity increase. There should be a public awareness programmes and training programmes for imparting environmental concerns to the senior level decision makers.

The major policy action recommended are:

1. In all irrigation projects there should be a system for monitoring groundwater levels, quality and initiating corrective action to reduce waterlogging and salinity. Though in the case of Sriramsagar Project there is a monitoring system no corrective action has been taken up. In the case of TBP there is no monitoring system and detailed information on waterlogging and salinity are not available. Provision for monitoring and corrective action should be integral parts of irrigation project reports.

2. Along with project feasibility studies environmental impact assessments have to be prepared for irrigation projects. This will also help in collecting the base line data on

various technical parameters which will have bearing on waterlogging, salinity and soil degradation.

3. In Command areas enough investments have to be made for providing drainages. In the case of Maharashtra State 80 percent of the waterlogged area has no drainages. One of the preparatory activity for providing irrigation can be the simultaneous planning for drainages. Farmers can be asked to take up construction of drainages as one of the conditions for providing irrigation in newer areas.

4. Agricultural extension education should be modernised to include aspects of efficient use of irrigation water, conjunctive use of ground and canal water. School education also should impart the need for efficient use of water and the need for conserving water. Farmers should be educated about water practices through demonstration programmes.

5. Water Echnology Demonstration Centres have to be started in all major command areas. Instead of starting one large centre in one command area, smaller centers should be started in large number in every command area. Provision for Water Technology Demonstration should be made in all irrigation projects. Coordination between irrigation and agricultural departments should be envisaged so that the Water Technology Demonstration Centres are part of agricultural extension programme.

6. Financial credits and loans should be provided for land development and for providing drainage. Land Development Banks should earmark a proportion of expenditure for environmental conservation activities such as land reclamation and soil conservation.

7. Waterlogging and salinity can be technically handled in the form of improved irrigation practices, improved drainage systems, developing newer strains of plants less susceptible to waterlogging and salinity problems. Research on waterlogging and salinity problems have to be taken up.

8. Taking up complementary development strategies such as afforestation, cultivation of green fodder bearing plants, farmer education and demonstration programmes.

9. Pricing of irrigation water will go a long way in improving efficiency of water use. Policy for pricing of water has to be properly implemented which can help the long term development of potential of the Command area.

10. A system of incentive or disincentive to be introduced for efficient use or overuse of water respectively.

11. Public participation in water use decision is necessary.

12. A co-ordinated system for managing watershed under one agency for agriculture, irrigation, education etc.

13. Soil conservation and land development are perceived as activities of long term benefits with no short term benefits. This can be changed only through intensive training and education. Irrigation Engineers and Senior Governmental Officials should be given orientation on the possible consequences of soil degradation and water logging.

14. Instead of electric pumps, windmill based pumps can be installed in areas where watertable level is high. Providing a windmill pump and a drain channel for water can bring down the watertable without much problem. Different models of windmills can be tested and then an appropriate model suitable to that area can be selected. Since windmill pumps do not need any energy from external sources, only the initial cost has to be subsidized, or has to be given as a refundable loan.

Table – 3.15

Waterlogging in Three Projects : Summary Information

Parameter	Sriramsagar	Nagarjunasagar
Age of the Project as on 1983	10 years	14 years
Cost of the Project (Rs.million)*	401	1649
Area irrigated (Million Hectares)	0.23	0.14
Soil type	Red soils, sandy loams	Sandy loams
Number of wells in the Command area	900	6000
Crops Grown	Rice, Sugarcane, Maize, Bajra, Jowar	Rice, Sugarcane, Maize
Depth to Water table (Average) in meters in 1983	4.3	5.6
Percentage of Water Samples with more than 2500 microsiemens electrical conductance	2	11
Area affected by waterlogging/ salinity (Hectares)	30,000	25,000
Impact on agricultural yield	30 percent reduction	--

* (IUS S = 10 Rs.)

Source : Waterlogging from Irrigation Project : An Environmental Management problem – Department of Environment, GOI, 1984.

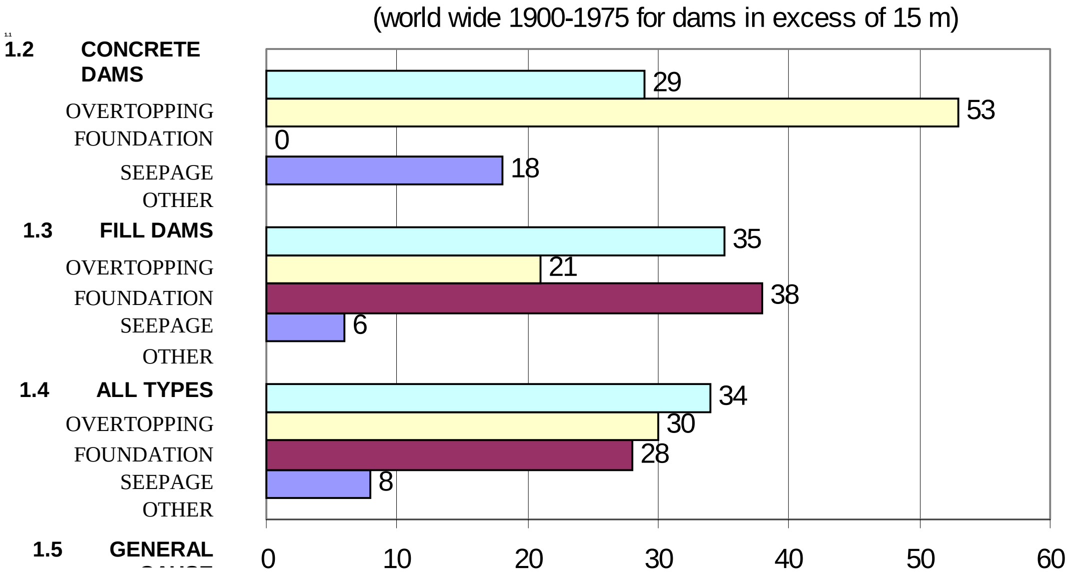
Parameter	Sriramsagar	Nagarjunasagar
Reasons for waterlogging/salinity	i. Seepages from distributories; ii. Over irrigation; iii. Non-withdrawal of ground water. iv. Lack of drains.	i. Seepages from distributories; ii. Over irrigation; iii. Non-withdrawal of ground water. iv. Lack of drains.
Monitoring system for ground-water fluctuations	Through 270 observation wells covered over 0.23 million hectares	Through 115 observation wells covering 0.117 million hectares.
Monitoring agency	Groundwater Department, Government of Andhra Pradesh.	Groundwater Department, Government of Andhra Pradesh.

Source : Waterlogging from Irrigation Project : An Environmental Management problem – Department of Environment, GOI, 1984.

3.3.12 Design Aspects:

Design plays a vital role in safety of dams. The table below gives the details of causes of dam failure.

9. Figure – 3.4


(world wide 1900-1975 for dams in excess of 15 m)
1.2 CONCRETE DAMS
OVERTOPPING
FOUNDATION
SEEPAGE
OTHER
1.3 FILL DAMS
OVERTOPPING
FOUNDATION
SEEPAGE
OTHER
1.4 ALL TYPES
OVERTOPPING
FOUNDATION
SEEPAGE
OTHER
1.5 GENERAL
29
53
0
18
35
21
38
6
34
30
28
8
0
10
20
30
40
50
60

10. Causes of Dam Failures

About 30% of these are due to foundation failure.

Defensive Design Measures : Case of Tehri Dam:

To make the design of Tehri Dam earthquake proof, various defensive design measures have been incorporated. These are:-

(i) The dam section adopted for Tehri dam has upstream slope of 2.5:1 and downstream slope of 2:1. As against this some recent dams built/planned in regions of higher seismicity that that of Tehri have steeper slopes. For example Puebla Viejo dam in Gautemala (height 130 m) and Honda dam in Venezuela (height 130 m) have upstream slopes of 2:1 lan PERCENT OF FAILURES :1 respectively. World renowned seismic dam design expert-Prof seed has recommended slopes of 2.25:1 (upstream) and 1.9:1 (downstream) for 180 metres high Karnali dam in Nepal, to be built in the Himalayan region similar to Tehri.

(ii) During the occurrence of an earthquake, there is magnification of earthquake acceleration, as the seismic wave travels from base of the dam to its top. The dam top which is of thinner section is subjected to greater acceleration. To prevent to possibility of its cracking/deformation in such an event, a very wide crest width of 20 metres has been provided, though it was not needed otherwise. The width of the crest has been further increased to 25 metres as its contact with abutments.

(iii) A very liberal free board 9height of dam above maximum reservoir level) of 9.5 m. has been provided, which can take care of any settlements or slumping of crest due to earthquake.

(iv) In order to prevent the failure of dam in event of cracking of core, either because of earthquake or otherwise, the filter zone provided immediately downstream of core, has been designed on most stringent criteria. The filter is capable of preventing migration of finest particles of core material in the event of its cracking, thereby not permitting the erosion of the core when water flows through the cracks.

(v) A fine sand layer has been provided on upstream face of the core, so that in the event of cracking of core, it would get washed into cracks and seal them by choking the water passages.

(vi) As a prime defensive measure for ensuring stability during an earthquake, the fill materials to be placed in the dam are to be compacted to very high, concrete like densities.

(vii) To improve the resistance to sliding of dam material in the upper part of the dam, during an earthquake, rocks in this portion would be blasted-stones with angular edges, rather than rounded gravel materials used for placement in the lower portion of the dam. The blasted-stones, because of better interlocked and better frictional grip, would resist sliding movement along slopes during the earthquake.

The design of the dam, as evolved by Indian experts was thoroughly appraised by experts of Hydro Project Institute, USSR. Although the design of the dame was checked by Soviet experts for earthquake of intensity one point higher than assumed in the Indian design, yet they did not suggest any change in the dame sloes, its base width, type of dam, free-broad, core geometry and core thickness. The only change suggested by them was to increase the width of blasted rockfill zone in the near-crest portion of the dam, substitution it for gravel fill zone. The adopted design is thus independently confirmed by a consultant of international repute.

Designing aspects and its research need are discussed separately in the paper.

Design also includes the designing of canal network its impact on drainage and water-logging. In view of large area getting waterlogged and saline there is every need to improve the design system otherwise the effectiveness or function of the dam is effected.

The system of canals superimposes an arbitrary concrete grid on the existing pattern of natural drainage in the command area. It's a little like re-organising the pattern of reticulate veins on the surface of a leaf. When a canal cuts across the path of a natural drain, it blocks the natural flow of the seasonal water and leads to water-logging. The engineering solution to this is to map the pattern of natural drainage in the area and replace it with an alternate, artificial drainage system that is built in conjunction with the canals. The problem, as one can imagine, is that doing this is enormously expensive. The cost of drainage is not included as part of the Sardar Sarovar Projects. It usually isn't, in most irrigation projects.

David Hopper, the World Bank's vice-president for South Asia, has admitted that the Bank does not usually include the cost of drainage in its irrigation projects in South Asia because irrigation projects *with* adequate drainage are not economically viable. *It costs five times as much to provide adequate drainage as it does to irrigate the same amount of land.*

There is a difference between the planners of the Sardar Sarovar irrigation scheme and the planners of previous projects. At least they acknowledge that water-logging and salinization are real problems and need to be addressed.

S.S. authorities plan to have a series of electronic groundwater sensors placed in every 100 square kilometres of the command area. (That works out to about 1,800 ground sensors). These will be linked to a central computer which will analyse the data and send out commands to the canal heads to stop water flowing into areas that shows signs of water-logging. A network of `Only-irrigation', `Only-drainage' and `Irrigation-cum-drainage' tube-wells will be sunk, and electronically synchronised by the central computer. The saline water will be pumped out, mixed with mathematically computed quantities of freshwater and re-circulated into a network of surface and sub-surface drains (for which more land will be acquired). To achieve the irrigation efficiency that they claim they'll achieve, according to a study done by Dr. Rahul Ram for Kalpavriksh, 82 per cent of the water that goes into the Wonder Canal network will have to be pumped out again!

They have never implemented an electronic irrigation scheme before, not even as a pilot project. It has not occurred to them to experiment with some already degraded land, just to see if it works. Instead, they will use borrowed money to install it over the whole of the two million hectares and then see if it works. In words of Ms.Arundhati Roy, "What if it doesn't? If it doesn't, it won't matter to the planners. They will still draw the same salaries. The will still get their pension and their gratuity and whatever else you get when your retire from a career of inflicting mayhem on a people.

How can it possibly work? It's like sending in a rocket scientist to milk a troublesome cow. How can they manage a gigantic electronic irrigation system when they can't even line the walls of the canals without having them collapse and cause untold damage to crops and people?"

3.4 RESEARCH NEED OF DAM SAFETY:

3.4.1 Introduction:

Safety of dams is dependent on various factors which require to be analysed constantly and measures evolved for ensuring their safety. There are number of different causes for failure of dams. Natural causes like floods, rock slides, earthquakes etc. and other factors such as seepage, foundation failure, structural failure etc. can cause dam failures. Study of actual failure of dams will lead to better understanding of causes of failure to evolve suitable modification in dam engineering.

The dam engineering concept relating to dam safety is not limited to construction alone. The concept covers investigation, design, construction and continues during operation also. With the advancement of technology in recent years, especially the progress in numerical modelling, analytical capabilities offered by the finite element method and advances in solution techniques and material models; the science of dam engineering has developed to a considerable extent resulting in better and sound designs, use of new construction materials as well as modern methods of construction.

More and more new dams are coming up and the demand for these dams especially the higher ones subjected to greater design loads and earthquakes are also increasing. Further, there are some aging dams, built more than 50 years ago which require strengthening measures. According to ICOLD World Register of Dams, some 5000 and odd dams now in operation were built before 1950. The safety of these old dams are to be evaluated and strengthening carried out wherever needed. Continuous research activities are essential in order to solve the more complex problems likely to arise in assuring continued safety of the dams.

As per CWC, following aspects need improvement / research.

3.4.2 Investigation:

3.4.2.1 Foundation Investigation:

It is not generally possible to take up any exhaustive drilling programme in a dam in distress. Improvised drilling techniques are to be used aiming at higher percentage of core recovery with minimal disturbance to the dam or foundation.

Some of the other disciplines where there is plenty of scope for improvement and research are:

- New Innovation in geological investigation methods.
- Special drilling from foundation of dam already constructed.
- Improvements in technology of TV bore-holes and geologers to operate under difficult conditions such as bore holes containing dirty water.
- Techniques for drilling in Karstic strata.
- Collection of undisturbed samples from weak seams/materials.
- Refinement in drilling to collect rock and soil samples as much “Undisturbed” as possible.
- Geophysical method such as ultrasonic methods, use of geo-radars, acoustic emission techniques etc. to identify and locate cavities or voids.
- Development of software for plotting on stereographic nets, information like orientation and attitude of various weak planes.

3.4.2.2 Material Investigation:

The areas where there is ample scope for refinement and research are:

- Improved and accurate techniques for evaluation of density of the in-situ material.
- Stress and strain characteristics of rock masses under confining pressures, dilation and change of volumes as the rock yields.
- Quantification of correction factors by borehole jaks, elastometer and pressuremeter.
- Effect of saturation, consolidation, rate of loading on shear strength.

- Improvements in determination of permeability like development of air pressure, free oscillation test and radio active methods.
- Technique for evaluation of permeability in heterogeneous flow.
- Study of alkali-aggregate reactivity with respect to durability of concrete.
- Suitability of new materials like asphalt in treatment of leakage.

3.4.2.3 Sealing System:

The design and construction methodology for new materials for impervious blankets and for vertical cut-off walls and diaphragm are to be developed.

Research needs are felt in studying the following aspects in grouting:

- To define rock-type specific groutability.
- To develop new grout materials, admixtures.
- To develop relationship between penetration radius, grouting pressure, thickness of joints and viscosity of mix.
- Establish long term stability of grout materials.
- New techniques to develop for evaluating the effectiveness of grouting.
- To develop proper grout mix to achieve effective grouting in karstic strata.

3.4.2.4 Concrete Properties:

Concrete has been widely used for construction of dams both as lean concrete in hearting zone and as rich concrete in different grades in selected areas such as facing, erosion resistant layers on spillways and energy dissipation systems, piers, guidewalls etc. The performance of concrete made with aggregates containing certain active materials and exposed to aggressive waters and with aging effects are the main concerns. The strength of mass concrete is increased approximately 40% in 5 years to that of 28 days strength. Improved quality of concrete with age has been established in few cases. In the case of Idukki dam in Kerala, constructed during 1969 to 1974, the over cored samples collected in 1995 gives average modulus of elasticity of about 0.400 x 10^6 Kg/cm^2, against an initial value of 0.150 x 10^6 Kg/cm^2.

However, the deterioration effects with the aging of concrete in majority concrete especially under unfavourable environments is a reality. Factors contributing to such deterioration needs to be investigated and established. Correlated field and laboratory level performance studies including aging/durability aspects and use of marginal grade aggregates are needed. The influence of deleterious materials is another field where there is considerable scope for research.

3.4.3 Hydrology:

The hydrological aspects call for repeated review of dam safety when more and more hydrometeorological and climatological data of severe magnitudes become available, surpassing the earlier events on which the hydrological studies for the projects were based. The two greatest difficulties in the field of dam safety are:

- ❖ Computing the probability of occurrence of a feared event.
- ❖ Defining the limits of acceptability of this risk.

Though hydromet approach and modelling gives a complete definition of the inflow flood hydrographs, there had been apprehensions in the minds of dam engineers and others on various inherent judgements exercised by hydrometeorological and hydrologists in the storm estimation and flood modelling. Hence, it is essential the agreed procedures are evolved among these professionals and reasonable convergence is reflected in the recommended design flood.

3.4.4 Design Concepts:

3.4.4.1 Concrete and Masonry Dams:

Important developments have taken place in terms of adoption of design to site conditions, improving performance of structures, rationalising design considerations and optimisation. Some of the areas where research and development efforts are required include the following:

- ❖ Developing data base on material properties used at various dams and its comparison with design values.
- ❖ Defining and reviewing considerations of various parameters including of factors of safety and allowable stress for analysis with reference to methods of analysis and design.
- ❖ Improvised methods for successful grouting of masonry dam to arrest seepage, improve strength and replace washed cement.

- Grouting of cooling pipes buried in concrete.
- Study of corrosion of reinforcement and methods for protection.
- Collection of data on performance of various elements in dams and working out probabilities and risk factors for the same.
- Development of models, software, methods and analysis for dams taking into consideration the aging factor.
- Developing models and methodology for optimisation of designs and comparison of performance predicted by the models with behaviour of prototypes.
- Developing guidelines and systems for more efficient hydraulic design of various structures like spillways, sluices, conduits etc.
- New techniques for predicting inception and propagation of cracking and damage to hydraulic structures.

3.4.4.2 Fill Dams:

At present fill dams constitute about 80 percent of the total dams of different types in the world. According to Jatana B.L.,(3) damage caused by internal erosion by the action of seeping water through the cracks in the dam body is one of important cause of failure for earth dams and three fold research is needed to safeguard the dam against failure because of internal erosion.

- Understanding the causes of cracking and defining appropriate measures to remove/reduce such causes.
- Defining core material which is less prone to cracking and more resistant to erosion.
- Defining criteria for design of filters which can prevent migration of core particles once erosion starts.

Cracking develops through out the height of the dam, though these cracks close as the fill is built up. The remedial measures that has been arrived at based on centrifugal model studies, is to leave the surface of the fill near the abutments about 15 m below the general level of the fill in the middle at the end of each working season, and then to fill up this level next year. In similar ways, much more research is needed using various combinations of abutment geometry and soil properties.

Some of the other aspects where considerable need for research exists are:

- Different measures to be adopted for reducing stress transfer from core to shell.
- Studying the phenomenon of hydraulic fracturing and standardising analytical procedures for determining the possibility of the same.
- Studies of find whether sand from the fine sand filter gets washed into cracks and if so to define its appropriate gradation.
- Improvement in design near exist of pipes in the body of the dam so as to break the fuse plug even with small head.
- Development in diaphragm installation in rockfill dam.

3.4.5 Construction Aspects:

The main construction aspect of concrete dam is controlling the cracks in mass concrete by inhibiting damaging potential from heat of hydration. Various measures have been undertaken to control the cracking in mass concrete. Considerable work has been done towards increasing the rate of raising of concrete dams to bring concrete dams construction more competitive with fill dams. The main area of concern in these dams is control of leakage/seepage and cracking at the joints.

Some of the aspects where research is needed are :

- New techniques for economical and more rapid raising of concrete dams.
- Improvement of existing practices.
- Assessment of performance of dams constructed using newer techniques.
- Evolving efficient and economical lining for diversion tunnels to resist erosion damage due to high velocity flow with rolling boulders.

3.4.6 INPSECTION AND MONITORING ASPECTS:

Periodic and systematic inspection of dam structure, and maintenance of the records is an important aspect in dam safety. The Dam Safety Organisation of Central Water

Commission has issued `Guidelines of Safety Inspection of Dam' in June, 1987. It consist of a two-phase inspection to assess the general condition of a dam and to determine the need for any traditional engineering investigation and analysis including hydrological aspects. It consists of a visual examination of the dam and a review of available engineering data including operating records, costly and extensive exploration or analysis are not intended.

Considering the developments made in this field and experience gained, some of the research efforts required are listed below:

- ❖ Improvement of underwater inspection of structures by underwater TV cameras for remote inspection of dams and energy dissipating systems.
- ❖ New techniques for core observation such as BTV picture survey.
- ❖ Review of present guidelines and evolve a quantified rating system for preliminary inspections.
- ❖ Development of diagnostic flow chart based inspection models and analysis of data.
- ❖ Development of simplex techniques for inspection of drains and cleanup.
- ❖ Method of restoration of tilted abutment.
- ❖ Comparison of the actual behaviour of the piles with the design considerations.

3.4.7 EARTHQUAKE ASPECTS:

There has been a great progress in the last twenty years in the study of strong earthquake ground motion and its engineering applications. Considerable scope exists in the research efforts on earthquake aspects and some of them are as follows:

- ❖ Installation of more and more seismographs, collection of data to delineate faults and seismic zoning.
- ❖ Prediction of earthquake and global warming system.
- ❖ Improving the guidelines to evaluate seismic parameters for analysis and design.
- ❖ Refinement of analytical methods for computing the response of all types of dams to earthquakes and development of computer programmes needed for their implementation.
- ❖ Improvement in the analysis of arch dams and the interaction between the dam and supporting foundation rock.

- ❖ Significant part of the vibratory earthquake response energy of dam may be transmitted by reservoir pressure wave into the bottom silt layer, but the amount of such energy loss depends directly on the absorption coefficient of the reservoir bottom. A field measurement programme to obtain this information is needed.
- ❖ Technique to determine damping properties of the dam and the foundation in a more realistic manner.
- ❖ Study of reservoir induced seismicity to ascertain whether the reservoir increase the size of the earthquake or only act as a trigger to initiate a natural earthquake that would have occurred otherwise.
- ❖ Development of analysis procedure to determine the dynamic sliding and rocking response of gravity dam monoliths.
- ❖ Interpretation techniques of the dynamic analysis.
- ❖ Development in dynamic testing to determine material properties suitable for use in non-linear seismic safety evaluations.
- ❖ Improved shaking-table tests to verify the effectiveness of the safety evaluation procedures.
- ❖ Adequate seismic instrumentation to provide information on the characteristics and spatial variation of the ground motion at the site, the response of the dam and the hydrodynamic pressures exerted on the dam.
- ❖ Conducting forced-vibration tests at different water levels and analysing the results.
- ❖ Development of appropriate equipment to test multiaxially loaded mass concrete specimens under the cyclic deformations of the type induced by earthquake.
- ❖ To undertake comprehensive experimental studies to define the stress-strain characteristics and strength of mass concrete better.
- ❖ Selection of proper shape and profile of dam section, providing fillets and stress concentrators at vulnerable locations.
- ❖ Improvement in the solutions to cope with the high tensile stresses in the critical dam zone like provision of a seismic belts.
- ❖ Study of ductility of concrete to analyse the post-cracking behaviour which covers the range between the full development of cracks and the limits of dynamic stability of detached concrete blocks.
- ❖ Study on location of appurtenant structures and proper analysis of hydrodynamic pressure on the gates.

- Development in the strengthening of the existing dams.
- Improvements in assessing the pore pressure developed in the earthen dam during earthquake.

3.4.8 INSTRUMENTATION:

The safety of dams would be improved and their life span increased by a carefully planned and implemented surveillance programme. A key part of such a programme is dam instrumentation which would provide necessary information to assess the structural behaviour during different stages of construction, initial filling of reservoir and subsequent operations. Adequate care is required to select the appropriate instruments, their installation, transmission of data and interpretation. The main objectives of instrumentation can be classified into three categories, namely (1) Diagnostic, (2) Predictive and (3) Research and Development.

One of the most important factor in instrumentation is the reliability of the instruments. In the Idukki high arch dam in Kerala completed in 1974, a number of embedded instruments have become either unreliable or defective. Eleven different types of instruments were installed in the dam to monitor the horizontal deformation of the dam, the foundation and the principal and normal stresses of the dam. Initially, 82 rosettes of vibrating wire strain meters were embedded into the body of the dam. By 1993, approximately 20% of the instruments were not functional, 11 were malfunctioning and 9 were giving unreasonably high readings. Table 1 summarises instrument reliability upto December 1983

Instrumentation & Monitoring of some existing Dams:

Seepage measurements are being carried out regularly in almost all dams where the quantity of seepage water is considerable, e.g. Koyna dam, Bargi dam, Shibsagar dam (Lonavala, Maharashtra), Mettur dam, Idukki dam etc. Piezometers have been installed by drilling in the embankment and foundation between chainages 90 to 91 of Panchet Hill embankment dam where seepage problem was encountered during 1984, along with the remedial measure to the seepage affected zone. The peizometer readings indicated the effectiveness of the remedial measure and also the pore pressure development in the foundation and embankment. Cracks developed at Konar and Rihand dams due to thermal and Alkali-Aggregate Reaction effects respectively which are being monitored by dial gauges. Pore pressure and uplift pressures are being monitored in the case of Barna Dam.

Bhandardara Dam:

The dam is 82.32 m(270') high rubble masonry gravity dam built in hydraulic lime mortar using crushed sand across of river Pravara, a tributary of river Godavari during 1910 – 1926. No uplift forces and earthquakes were accounted for in the design. No instrument was provided initially in the dam.

Since completion of dam in 1926 till 1969 the dam has not shown any sign of distress. On 10.9.69 the following signs of distress were observed:

(i) A strong jet of water throwing water 6.10 m(20') away from d/s face of dam issued through a drain pipe connected to the bottom of plumb bob shaft was found filled with water nearly upto 12.20 m(40') below lake level.

(ii) A heavy sheet of flow of water was gushing out from the contact plane between masonry and foundation rock from R.D. 182.93 m(600') to R.D. 195.12 m(640'). The discharge was 0.62 m3/sec(22 cusecs).

(iii) Inclined cracks were seen in masonry side walls of structures supporting the canopies over the d/s valves of the outlet near toe of dam qt. R.D. 262.20 m(860') and R.D. 278.96 m(915').

(iv) Seven numbers fine vertical cracks were noticed on d/s face of dam between R.D. 189.63 m(622') to R.D. 221.04 m(725').

> After a thorough investigation, such as geological drill holes, tracer studies, photo-elastic studies, visual examination, etc., it was concluded that `a crack was developed in the body of dam in entire central portion at a depth 42.68 m(140') to 44.21 m(145') from the top. This crack after following a horizontal course upto some length from U/s face dipped towards the D/s and strike at the foundation rock at a distance of 6.10 m(20') to 9.15 m(30') U/s from D/s toe. The crack provided a clear passage for reservoir water through body of dam to D/s giving rise to boils and sheet of flow. The distress was thus due to progressive tensile failure of the dam masonry'.

Based on inspection of the dam and conclusions of the investigations, the committee appointed by Government of Maharashtra recommended in addition to immediate and Permanent Remedial Measures. Instrumentation of Bhandardara Dam for monitoring the behaviour of structure during the after remedial measures. Accordingly the following instruments were installed:

1. Uplift measurement		
i) through piezometers	13 nos.	8 nos. ch. 583 to 1013 (1970) 5 nos. ch. 540 to ch. 950 (1982)
ii) through drainage holes	2 nos.	1 no. ch. 875 (1970) 1 no. ch. 900
2. Displacement Measurement		
i) Inverted plumb bob	1 no.	ch.860 (1971)
ii) Tiltmeter (Wood Anderson Type Torsion Tiltmeter)	1 no.	ch.711 (1971) (not functioning)
iii) Crack monitoring by DEME Strain gauge extensometers	2 nos.	(One installed out of two recommended – not working)
3. Other instruments		
i) Water level recorder	1 no.	For measurement of Lake Level (1971)
ii) V-Notches		For measurement of Leakages through drainage holes, dam body and plumb bob shaft

4. Special Instruments

i) Seismitron	1 no.	**To monitor Mircro Seismic activity (1971) – not working.**
ii) Seismometers	1 no.	Local tremors (1971) – functioning
iii) Thermographs	1 no.	**Temperature variation (1971) – not functioning.**

5. Drainage holes	32 nos.	**Between ch.425 to 885 – functioning (1971)**

Based on the instrumentation data available from 1970 to 1987, the analysis indicated improvement in behaviour of dam after repair. The major improvements are listed below:

(i) There is a gradual increase in drop of piezometeric head.

(ii) There was no arrangement to release the uplift pressure in foundation before distress. Functioning of drainage holes indicates the release of uplift.

(iii) Total quantity of seepage reduced from 600 lts./sec. (22 cusecs) in 1970 to about 5 lts./sec. in 1986.

(iv) Deflection of dam (Inverted plumb bob) was reduced from 10.30 mm in 1971 to 4.50 mm in 1986 which was due to effectiveness of strengthening by buttresses.

(v) Tiltmeter indicated reduction in tilt from 72 seconds in 1970 to 28 seconds in 1973.

(vi) There was no widening of crack on downstream face of dam after repair works.

Periyar Dam:

Periyar Dam of Tamilnadu has completed a century of its existence. The dam was strengthened by providing RCC backing and the following instruments were installed in 1986.

1. GROUP Strain	Block 8 & 9	36 nos.
2. Stress Meter	-do-	4 nos.
3. Joint Meter	-do-	4 nos.
4. RTD Thermometer	-do-	8 nos.
5. Uplift Pressure Cells	-do-	4 nos.
6. No-stress strain meters	-do-	6 nos.

After a year of observation all the instruments became defective.

Koyna Dam:

Koyna Rubble Concrete Dam with a Maximum height of 103.62 m(338') above the deepest foundation and length of 807.72 m(2880') at road level is constructed across the river Koyna, a tributary of Krishna River. The dam was completed in 1963. The dam consists of 43 monoliths each generally of 50' width. Central spillway extends from monoliths No.18 to 24 and accommodates 6 Nos. radial gates of size 41' x 25'. The non-overflow monolith No.25 and overflow monolith No.22 are instrumented. In addition, instrumentation has also been provided in the concrete backing of monolith No.17. The details of instrumentation at Koyna Dam is given in Table below:

Sl. No.	10.1 Location	10.2 Type	Total No.	Working / Not working
1.	Mon. 22/23	Coordimeter	2	All working
2.	Mon. 22	Thermometer	52	49/3
3.	Mon. 22	Spillway Therm.	9	5/4
4.	Mon. 22	Stress meters	17	8/9
5.	Mon. 22	Strain meter	39	29/10
6.	Mon. 22, 24, 25, I.G., Stilling Basin	Uplift cells	66	52/14
7.	Conc. Backing Mon.17	Thermometer	58	51/7
8.	Conc. Backing Mon.17	Stressmeters	10	8/2
9.	Conc. Backing Mon.17	Strainmeter	30	26/4
10.	Conc. Backing Mon.17	Joint meter	8	6/2
11.	Conc. Backing Mon.17	Uplift press	4	None working

Uplift Pressure :

In 1991, 22 holes were drilled to investigate uplift pressures at the dam foundation contact. The maximum uplift pressure observed for full reservoir level was only 18% of the static head.

Deflections:

The Dam Review Panel has recommended that a precision survey (Triangulation Survey) of the crest be made at least once in 3 or 5 years when the reservoir is at its maximum and minimum levels to confirm that deflections are consistent with those of Blocks 22 and 25 which contain plumb lines.

Srisailam Dam:

Srisailam Dam is a component of Srisailam Multipurpose Project constructed across Krishna River near Srisailam Town of Kurnool District in Andhra Prdesh. The project is located at about 113 Km u/s of Nagarjuna Sagar Dam. It is a gravity dam in stone masonry and concrete having a height of 145.10 m above the deepest foundation level and total length at top is 512.07 m. it consists of 22 blocks (10 NOF & 12 OF sections). This project is in operation since 1984. The following instrumentation have been provided in two blocks, one block each in overflow and non-overflow sections respectively.

Instrument installed	10.3 Block 9 – OF		10.4 Block 18 - NOF	
	Total installed	10.5 Working	Total installed	10.6 Working
1. Group of 5 strainmeters & 1 non-stress strainmeter and 1 strainmeter	7	7	5	5
2. Group of 5 strainmeters and 1 no-stress strainmenter	--	--	2	2
3. Thermometer	47	31	22	19
4. Pore pressure cells	7	4	4	3
5. Long-gauge strainmeter	4	1	4	1
6. No-stress strainmeter (Isolated)	2	2	2	2
7. Uplift pressure pipes	8	--	6	--
8. Rock compression disp. Meter	11	1	3	1
9. Stress meter	6	1	1	1
10. Plumb line	1	1	1	1

Source : CWC

The details additional instrumentation as suggested by Central Water Commission are as follows:

10.7 Instruments	10.8	10.9 Number
1. Inverted plumb line	3 nos.	Each in block 9, 12 and 18
2. Bore hole extensometer		One number in block 18
3. Inclinometers		One number in block 12
4. Joint meters		4 nos. between block 8&9, 9&10, 17&18 and 18&19.

Practical experiences show that some instruments become out of order immediately after installation, some after few years of satisfactory working. There is urgent need for improved design and manufacturing of instruments to last longer and giver reliable measurements. Similarly new techniques are to be developed for proper installation of the instruments and their protection.

3.4.9 Emergency Action Plan:

The most important question facing the dam engineer is that of the risk of its failure. The cost of the failure of a major dam is high and their occurrence has to be minimised. The acceptable flood risk relevant to human and economic consequences of failure, has to be translated into an appropriate annual exceedence probability for the design flood. Records show that large number of partial or total failure of dams are due to unprecedented floods. Therefore, there is exist needs for emergency action plan to lessen or mitigate its impact upon human beings and property. Dam break analysis helps in preparation of inundation map, risk of subsequent dam failure and preparation of emergency action plan etc.

Sophisticated computer programmes have been developed in the recent few years that can simulate the dam break flood hydrographs and route the flood waves. However, these programmes are dependent on certain inputs regarding the geometric and temporal characteristics of the dam breach.

10.9.1 Table – 3.13
10.9.2 Instrument Reliability

10.10 Instrument	Original Total	Functioning at Dec.83	Defective instrument	Cable damaged	Total not functioning
10.10.1.1 Reservoir					
- Reservoir level	1	1	-	-	-
- Water Thermometer	8	5	2	1	3
10.10.1.2 Horizontal Deformation					
- Pendulum	6	6	-	-	-
- Crest Collimation	3	3	-	-	-
- Electric Joint Meter	12	8	3	1	4
10.10.1.3 Foundation					
- Base Meter	4	2	2	-	2
- Rock Target	30	30	-	-	-
- Clinometer	1	1	-	-	-
10.10.1.4 Stresses					
- Vibrating Wire Thermometer	62	54	U/S 5 D/S -	- 3	8
- Carlson Type stress meter	52	39	U/S 7 D/S4	- 2	13
- Strain meter groups	82	68	U/S 5 D/S 4	2 3	14

Source : CWC

3.4.10 Top Ten Actions Required for Effective Dam Safety Programme:

1. **Pass firm dam safety laws with provisions to facilitate enforcement and to hold owner accountable.**

2. Establish well trained, full staffed and adequately funded Government Dam Safety Organization (GDSO) which is independent of design, construction or operating entities.

3. Require a dam review panel whose members have renown experience in various critical aspects of dams similar to the dam being designed and constructed.

4. Assure that lead designers, geologists and materials specialists are available and involved on site during key decision periods under the construction phase.

5. Assure that the GDSO has an active and independent role starting from establishment of rules and regulations to the long term monitoring of the dam’s performance.

6. Establish procedures where checks are made by the design and construction supervision personnel to minimize the possibility of technical error.

7. Provide an atmosphere for technical training, technology transfer and advancement of personnel capabilities in design, construction supervision and operation and maintenance of dams on a country-wide basis.

8. Assure that construction quality is given extremely high priority and attention and that an adequate O&M plan is developed early and followed.

9. Assure that complete records are assembled and maintained by the owner to include site investigation data, design documentation, construction records, test results, as-built drawings, contract specifications, change orders, instrumentation measurements and O&M records. Selected records should be furnished to and maintained by the GDSO. Selected records should also be kept on file at the dam.

3.4.11 Tehri Dam Environment & Safety Aspects – A Case Study:

The CWC in 1986 with help of experts from various agencies arrived at the following conclusions:-

(a) Even though Tehri Dam was located in seismic zone, adequate data and studies have been made to arrive at a safe and economic engineering structure and all relevant facts that needed to be taken have been taken into account in the project design as well as in the estimates;

(b) The seismic status of the project area does not pose any additional problem of siltation.

(c) The formation of a reservoir does not pose any problem of Reservoir Induced Seismicity (RIS).

(d) Enough technical expertise is available in the country to tackle the design and construction of the Tehri Dam.

(e) It was stressed that proper attention should be given to treatment of the catchment area to reduce the rate of siltation and to improve the general environment.

(f) Existing seismological net work should be strengthened for continuing the seismic monitoring of the project area. Arrangements to be made for aerial photography at 5 years intervals.

10.10.1.5 In view of the high seismicity of Tehri Dam area, detailed studies have been carried out for ensuring its safety in the even of an earthquake. These relate to seismicity of the project area, liquefaction of the fill materials, dynamic properties of the fill materials and dynamic stability analysis. Seismicity of the area has been established after thorough examination of the seismotectonics of the region and review of the historical records of the occurrence the earthquakes and both deterministic and probabilistic approaches have been used in deciding seismic design parameters. A detailed account of the studies and adoption of design parameters on that basis has been given in the Environmental Action Plans submitted to ME&E in November, 1989.

Besides, rigorous analysis, adequate defensive design features, based on the engineering judgement have been incorporated in the dam design to ensure the integrity of the dam under a most severe seismic event. The Soviet consultants have already preliminarily checked the dam section proposed by the Indian side for one point higher intensity earthquake and found it to be safe even in this case and no changes on its outer slopes or base width have been suggested except replacement of gravel shells by rockfill in the near crest portion of the dam. However, to be doubly sure, the seismicity of the area is being reassessed using satellite imagery which has been procured and more rigorous stability analysis using an elastoplastic model and sequential construction is planned. The dam is also being tested on centrifuge mode facility. These are going to be the confirmatory studies but the result already available fully justify for going ahead with the Tehri Dam Project; this view has also been supported by the Soviet Experts.

In or to have long range data base about accurate assessment of seismicity of the area around Tehri Dam and in the adjoining region and also to study the impact of the reservoir induced seismicity, a network of 32 seismological stations costing Rs.1.80 crores is being established by the project with the help of Department of Earthquake Engineering, University of Roorkee. The network is already operations for eight stations in the adjoining regions. The remaining network is expected to became operational from June, 1991. This would enable us to continuously monitor seismic activity of the area and take corrective measures, wherever called for.

Possibility of Reservoir Induced Seismicity (RIS) from the construction of Tehri reservoir and its effect on the civilian structures has also been investigated. Factors influencing the reservoir induced seismicity are the geo-tectonic environment of the reservoir (type of faults, mechanical competency of shallow surface rocks, permeability of rocks) and the background seismicity. It has been generally observed in other parts of the world that in regions of high backgrounds seismicity, R.I.S. is generally absent. Behaviour of the reservoirs already created in Himalayas in similar geotectonic environment like Bhakra Dam, Pong Dam, Ramganga Dam in India and Mangla and Tarbela Dam in Pakistan shows to trace of induced seismicity. In fact, in the case of Mangla Dam and Tarbela Dam, there has been a reduction in local seismicity due to construction of these reservoirs. It is concluded that construction of Tehri Dam would not lead to reservoir induced seismicity and hence there is no danger to civilian structures due to construciton of Tehri reservoir. All this information in detail has been furnished to Ministry of Forest & Environment with Environmental Action Plans in November, 1989.

There is a positive correlation between the height of the water column in the reservoirs and the seismicity induced – 6 out of 20 (30%) – reservoirs with water height between 150-250m have experienced Reservoir Induced Seismicity (RIS). And where the height of the water column is between 90 and 120, the RIS was felt in only 6 per cent cases. It was thus noticed that as the water level rose, the degree of seismicity also increased and the strongest shock was registered when the level attained the highest point, particularly higher than 100m.

As regards statistical seismicity of the Tehri region he says, that “A significant observation worthy of note is the gap in seismicity immediately east of the rupture zone of the 1905 Kangra earthquake that extends for over 700 kms to that of the 1984 Bihar earthquake. This is long enough to require ruptures by at least 3 major earthquakes (M8.0) from West to East to release strain that may have accumulated at the edges. The Tehri region where no major earthquake has occurred since 1828 (M=7.6) may thus have large residual strains which have accumulated during this period.” And, “since, earthquakes of a magnitude less than 8.0 do not relax sufficient strain, the probability of a major earthquake whose rupture zone may traverse the dam site is high...”.

He had, therefore, initially suggested that "The dam should be designed for a horizontal acceleration of about 2 g considering the probable magnitude to be more like 8.0; and for an equal vertical acceleration." However, since then he has modified his position, as is evident from his personal communications with the Department of Environment. Government of India, and he now feels that the dam should be designed for a horizontal acceleration of 0.56 g.

Professor L.S. Srivastava of the Department of Earthquake Engineering University of Roorke, in his comments on the note submitted by the NGRI, has made an equally elaborate analysis of these problem and has suggested that "The peak horizontal ground acceleration of 0.25 g evaluated for maximum credible earthquake and recommended for adoption in DEQE report for evaluation of acceleration response spectra and compatible time history of ground motion for design analysis of Tehri Darn will provide adequate safeguards for the probable maximum earthquake strong ground motion at the Tehrl Dam Project Site.'

It must be pointed out that the Tehri dam project authorities have not accepted the recommendation of either the National Geophysical Research Institute, or the recommendations of Professor LS. Srivastava, and have presently stated in their Project Report (1986) Vol. Ip. 128, that "the Seismic factor for the design, of rockflll structure has been provisionally adopted as 0.15 g."

We do not claim any expertise in Geotectonics, but the direct quotations given above reveal the facts that the present design of the dam, as given in project reports of the Tehri dam authorities till end 1986, is not good enough for the `risk-factor' as calculated either by the NGRI or by Professor L.S. Srivastava of Roorke University, who had been commissioned by the Government to look into the earthquake risk to the Tehri darn (Paranjpye, 1988).

The conclusion reached by us after going through the mass of documents arising from the controversy related to the risk factor has been confirmed by a recent assessment made by the Russian experts who have now been commissioned to "render technical assistance in the erection of the high dam, the constituent hydro-electric and storage plants and a transmission line on a contract or turnkey basis."

Earthquake Resistant Dam Design:

10.1.10.1.5 Seismicity

Environmentalists and scientists have commented on the design parameters adopted for Tehri Dam, as the project lies in a high seismic area. Inadequate understanding of the different seismological terms used in seismic design of the dam, has led to certain misconceptions leading to inaccurate conclusions. One of the misconceptions about the dam has been that it is under designed against seismic forces and that its revision might result in cost escalation. Given below is a clarification on this point :

(i) The value of 0.15 g approved by Central Water Commission is not the safety factor of dam as has been assumed by some persons, but it is the value of seismic coefficient. In seismic coefficient method, an equivalent static force is applied to the dam whose effect is assumed to be same as the actual earthquake. Seismic coefficient for river valley projects is recommended by a Standing Committee for recommendations of design seismic parameters in river valley schemes, consisting of members from premier National Organisations in the country viz. Central Water Commission (CWC), Geological Survey of India (GSI), Indian Meterological Deptt. (IMD), National geophysical Research Institute (NGRI) and Deptt. of Earthquake, University of Roorkee etc. Thus, in choosing this design parameter, best technical advice from premier national organisations was obtained.

(ii) Peak ground acceleration and seismic coefficient are in fact two different terms rather than the same as assumed by some people. While the later represents the equivalent static force on the dam, the former is the peak value of acceleration imparted to the ground surface. This parameter is used in the modern method for dynamic design of dam and has been selected, after due deliberations with the national and international experts. For design of dam, elaborate assessment has been made with regard to magnitude of earthquake that could occur in the area. For this, the Department of Earthquake Engineering, University of Roorkee, was entrusted with the responsibility to carry out micro-seismic survey of Tehri area. They assessed which tectonic features in the area could generate earthquakes and upto what degree of severity. Based on their expert advice, design parameters, effective peak ground motion and response spectra for the earthquake motion has been fixed in detailed design of dam.

Defensive Design Measures:

This has been dealt earlier in this Chapter and therefore not repeated here.

CHAPTER – 4

DEFICIENCES IN DAMS COMMISSIONED AND REHABILITATION MEASURES

4.1 The safety of dam can be threatened by natural phenomenon such as floods, rook slides, earth quakes, alkali aggregate reaction, deterioration of dam body and foundation, ageing higher internal pressures and paths of seepage: Some of the natural processes are slow and require continuous monitoring of the dam for identifying any inadequacy either in the design or any problem brewing inside the dam.

Inadequate Spillway Capacity:

The most significant and common is the inadequacy of spillway capacity. In the case of gravity dams, the inadequate spillway capacity causes abnormal rise in upstream flood level leading to overtopping of NOF Sections, Gate tops etc. The inadequacy of the spillway capacity therefore, calls for a critical review on the basis latest hydrometeorological data.

Deterioration of Concrete & Masonry:

Deterioration is caused by weathering forces, seepage etc. and compounded if proper construction procedures are not followed. Vide range of' temperature fluctuations cause micro-cracking, expansion joints opening and possibility of rupture of grout curtain. Such cracking is the source of ingress of water leading to deterioration of concrete and masonry.

Clogging of drainage systems is another common problem, large volumes of calcium deposits in the drainage conduits due to excessive free lime in the cement and its chemical reaction with water. Cracking at external faces have been reported at several Dams either due to solar heat absorption, alkali silica reaction, gradual warming of the interior mass from the low initial placing temperatures. The maximum displacement of the crack was about 6-5mm. Such Cracking was treated by post-tensioning and grouting. Certain stray cases like -the 60m

Casteloau Dam observed to be undergoing an irreversible crest displacement in an upstream direction. (Inverted pendulums indicated that the underlying rock formation was not a contributing factor.).Indicated unsatisfactory quality of the concrete was considered to be the reason of the displacement. Alternating thermal and hydrostatic forces caused cracking in the unusually thin arch Gage Dam which had to be put out of service as a result of the cracking.

Excessive leakage in or Across the body/Foundation:

The incidence of seepage and uplift pressures within a dam due to possible penetration/percolation of water through the body/foundation of the masonry/concrete dam along the mortar joints, lift joints, contraction joints, construction joints, cracks and foundation contact etc. is an important phenomenon and one of the important governing factors for a stable and safe design of the dam. Control and monitoring of this seepage are essential to evaluate the safety factor of assurance. The seepage/leakage water causes uplift forces, erosive forces, leaching of lime from the mortar/concrete, deterioration of the structure due to weathering etc. and would lead to distress/failure of the dam.

Foundation Problems:

Foundation problems are a major contributing cause for dam failure. Unlike other aspects, foundation conditions are not evident. Gravity dams are normally founded on unyielding rocks. These foundations may, however, contain deformable pockets, discontinuities like faults, shear zones, seams fissures etc. along which the strength might be considerably low which may further reduce with the seeping water. If these have not been treated properly, failures may take place due to sliding, settlement, excessive uplift, erosion of the material in weak features etc.

Alkali-aggregate reaction:

Reaction between the alkali components in Portland cement and certain active minerals in some rocks is well recognized as a very potential cause of concrete deterioration, detrimental to durability of structures. Essentially, the alkali-silicate gel formed on ambient moisture swells and develops pressure leading to distress of concrete. Such classical alkali-silica reaction is more pronounced with high alkali cement and potentially reactivesilliceous aggregates containing minerals such as opal, chalcedony, chert etc.

Excessive scour downstream of spillway:

When a high velocity jet or sheet of water flows d/s from the spillway, it may erode the bed material and carry it either in suspension or as bed load farther d/s. Serious scour immediately below the spillway may endanger its foundation. Several Dams with flip buckets, founded on stratified rocks are experiencing scour d/s. Ukai Dam in Gujarat, Srisailam Dam are such examples.

4.2 CASE STUDY:

Distress in Bandara Dam: (Maharashtra)

Completed in 1926, the Bandara Dam is one of the oldest and highest stone masonry Dams in Maharashtra. Bandara Dam Dam is a gravity structure built in rubble masonry 82 m high, 507 m long. No drainage gallery or other drainage arrangements have been provided.

The full reservoir level was reached every year. It had an ungated side channel spillway. The annual fluctuations in the reservoir level were of the order of 34m. From the first filling of the reservoir the dam showed extensive seepage and wetness over the entire length of the d/s face.

The first signs of visible distress were noticed in the dam on 10th Sept.1969. A 15mm drain outlet emerging from a plumb bob shaft which was till then discharging a trickle, suddenly started issuing a fall jet of water projecting about 6m d/s. The large springs or boils from which water was gushing, were noticed in the backfill at the d/s toe of the dam with a total discharge of the order of the 0.87 m ½. Inclined cracks were seen in the canopy structure over an outlet, close to the d/s face of the dam. These cracks extended about 0.6 m to 7.0 m above the foundation. Removal of the backfill at the toe near the boils showed a sheet of water gushing through the contact of masonry and the foundation which were both, apparently in good condition. Investigations immediately initiated to determine the source and propagation of the crack both on model and field studies. The crack initiated at the u/s had thrown increasing load on the d/s face. The series of the photo elastic tests showed that once the crack had reached the base of the dam, the mortar at the would tend to crush and would be washed away by the high hydrostatic pressure of water behind it, resulting in the development of vertical crack on the d/s face wherever such loss of support had occurred. The height of these cracks would depend on the width at the base along which the contact is affected.

The temporary remedial measures included grouting near the u/s face, providing drainage holes from d/s face, anchoring the dam by prestressing cables and providing dowel bars across the main crack, in addition to control of reservoir filling. The permanent remedial measures included strengthening of the dam by providing massive masonry buttresses on the d/s and sealing the U/s crack by apoxy and gunniting over a steel mesh.

Kadana Dam:

Kadana dam across the river Mahi in Gujarat State is a composite dam with the maximum height of the masonry dam about 66m. Considerable leakage of water through the block joints in the drainage foundation gallery from 26 l/min to 50 l/min in the blocks was noticed.

Seepage water observed from the bottom of the gallery joint indicated the possibility of choking of the foundation drainage holes. As a remedial measures to redrill the drainage holes adjacent to the joint was considered and the treatment was carried out. The leakage was considerably reduced.

Hirakud Dam (Orissa):

The Hirakud Dam is a composite structure of earth, concrete and masonry, built across the river Mahanadi (Orissa). The main dam is 4800 m long of which I 148.5m is of concrete and masonry. Coarse aggregate (crushed rocks) obtained from local quarries as well as river Shingle from the right wing of the Mahanadi river were used in concrete.

The following manifestations of distress were observed:

i) Horizontal cracks on the vertical faces of the operation gallery, gateshaft, sluice barrel and to a small extent on the right foundation gallery, in all the right spillway blocks. The width of cracks varying from hair cracks to a max. of 6 to 9mm at the surface .

Some of the cracks were found to extend to a maximum depth of about 2m. Extensive horizontal cracking on the U/s face of the dam with width of cracks upto 12mm. As a result of cracking several other features viz rails,gate grooves etc. went out of alignment.

ii) Findings of the National Council for Cement and Building Materials:

i) The concrete was properly compacted.
ii) Examination of hardened concrete revealed the concrete to have adequate cement content and not attacked by sulphate, acid waters etc.
iii) Concrete core samples from right spillway have undergone alkali silica reaction. Occurrence of such alkali-silica reaction was detected on the concrete obtained from such locations where common external manifestations of alkali-silica reactions were noticed. River shingles containing quartzite in crushed rock aggregate were identified as reactive.

Remedial Measures:

The following remedial measures were contemplated for tackling the problem.

- Grouting the body of the dam by suitable chemicals.
- Sealing the cracks on the upstream face.
- Drilling fresh drainage holes in foundation from the gallery and redrilling of porous drains in the body of the dam.

Rihand Dam Project (UP):

Rihand Dam, which is a concrete gravity dam is located on river Riband in District Mirzapur of Uttar Pradesh. It is 91.46 metres high, 934Am long and was constructed during the period 1954-1962.

Distress Noticed:

Longitudinal cracks on U/s face observed from 1972 above RL 830 mostly along the lift joints and minor cracks between lift joints. The width of cracks varied from 1mm to

25mm and approximate depths of cracks at various locations were found to vary from 7 to 45 cm by ultrasonic pulse velocity test. Horizontal cracks were also observed in the walls of the foundation gallery, the sluice operating gallery and the hoist operating gallery.

Tilting and deformation of draft tube structure and cracking of generator supports.

Findings of the National Council for Cement and Building Materials (NCBM):

Extensive investigations conducted by the NCBM indicated that the concrete had adequate cement content and not attacked by sulphates, acid waters etc. Non-destructive evaluation of concrete indicated overall quality of concrete to be generally good.

Aggregates obtained from the body of the Dam and also from the quarry contained strained quartz and alkali feldspar. Investigations carried out on concrete cores by electron microscopy revealed the presence of alkali aggregate reaction. Concrete core samples in both the main dam as well as power house structure were found to have undergone alkali-silica reaction, the unmistakable presence of such deleterious reactions being manifest by the occurrence of geltype reaction products inside concrete, dark and white reaction rims and alteration of borders of aggregate and presence of micro-cracks in the mortar phase as examined visually, petrographically and in a scanning electron microscope. The usual treatment of removing bulges, cracks etc. were attended to.

Ukai Dam (Guiarat):

Ukai dam with 22 gates for catering to an outflow of 39,330 m^3/sec was operated as an ungated structure in the year 1969.

The floods were released over the crest during 1969-70 without gates and later gates were erected in 1973. A deep scour hole was noticed 100 m d/s indicating a 29m deep scour in dolorite dyke. In 1978 the spillway discharged 12,750 m^3/sec only through 11 gates. The trajectory of the skijump had caused scour below the foundation level of the dam. As a measure of rehabilitation among other item anchoring of rock foundations by steel grip rods embedded in M20 concrete undertaken.

Tigara Dam:

A hand placed masonry gravity dam was constructed on river Shank in ME. Height of dam above river bed was 24.70 m.

The dam was founded on a stratified sand stone. The foundation of the dam was excavated to a depth of O.61m into the rock and the exposed seams in the width of the foundation were excavated and backfilled with concrete. The pushed out blocks of masonry manifest a uniform good quality of materials and workmanship, thus ruling out defective construction

Water was allowed to spillover through ungated spillway. On 4.8.1917 the dam breached, when whole dam was over-topped by a flood lift of 0.80m. A flood discharge of 8500 m^3/sec was computed to have passed over and in a length of 400 m and the dam was bodily pushed away in a length of about 14m. Two major blocks of masonry of the breached Dam are standing erect even today d/s of the existing dam.

The dam was reconstructed after few years with certain modifications and gates were also provided. The section of dam is kept nearly same as before, but an u/s clay blanket @ 37m long and a cut off trench back filled with concrete at heel up to l/6 max. Height were introduced during reconstruction. The dam has been in service since then.

Machhu Dam (Gujarat):

Machhu River in Saurashtra region has two dams Machhu I & II situated 40 Kms apart Machhu I, all masonry gravity Dam experienced heavy unprecedented floods in August, 1979. The coastal Saurashtra region as well as inland parts experienced heavy storm In June1983. The 1979 flood was estimated as 8,013 M^3/-per second as against the design flood of 3313. The Machhu basin experienced major thrust of storm on 11th and 12th August, 1979 and Machhu II Dam breached on 11th August, 1979. The flood hydrographs derived from

Upper and lower catchments super imposed with lag of time works out flood peaks 20,900 cumecs for Machhu Dam II and 10,600 cumecs for Machhu Dam I. The 2 day design Storm (1983) adjusted for other parameter gives PMP as 986 and 944 mm for upper and lower catchments as compared to the PMP values of512 & 587 determined from 1979 storm. With the review of design flood for Machhu I the spillway capacity required is 13224 cumecs, which is nearly 5 times the original design discharge.

Passing of such large flood over existing structure would increase M.W.L enormously. Various alternatives considered were the existing flat crested weir to be convened as ogee spillway.

i) Provision of a breaching section in the saddle.

ii) Lowering the existing crest level by 1.2 mtrs. and installing the same height Godbole gates. Finally Ogee crest spillway in the place of the original flat crested weir and bed level additional spillway have been considered and adopted at the site. The conversion of existing flat crested weir to Ogee shape involved demolition of a part of the masonry and redoing to the new shape. It also resulted in modification of the original energy dissipation arrangement down stream of the dam.

iii) The Machhu II Dam comprised of a centre spillway in the main river channel and earthen dam of the either flank. Heavy rain of 525 MM in 24 hours created a huge discharge of 13,400 M per second nearly 2 times the spillway capacity. This resulted in continuous rise of water level and over topping of the earth dam by about half a metre. This caused the breaching of the earth dam on either flank enveloping the masonry dam. The design flood of the dam was revised to about 26,000 m^3 per second based on June, 1983 storm and additional spillway accordingly planned for construction.

Koyana Dam: (Maharashtra)

Upto the end of 1965, ICOLD has not received any report on incidents to large Dams reported to have been caused by Earthquakes. Only one severe accident has occurred to large dams namely Koyana in 1967. No other incident involving any large Dam directly from earthquakes was reported. However, Earthquakes close to reservoirs (i.e) Kremaste(Greece), Kariba(Zambia), Koyana(India) made geophysicists to view a link between reservoirs and seismicity called Reservoir Induced Seismicity (RIS).

Deccan plateau is considered stable and most of the Dams constructed do not conform to aseismic designs. In l967, (September & December) earthquakes measuring over 5 & 6 on Richard's scale, have considerably damaged Koyananagar, underground power house, and Dam. The dam was later strengthened by buttresses, cabling, grouting etc.

Nagarjunasagar:

Leakage through Block 44.

Increase in the discharge in porous drainage hole in the foundation gallery since 1988 particularly when the reservoir level was above El.540 if, the maximum discharge being 80 lit/min at FRL (590 ft) to a minimum of 1.5 lit/m at E1510, was noticed. Tracer studies were conducted to identify the paths of leakages in this block, as there are no visual cracks on upstream face of the Dam. The tracer studies indicated the possible location of water ingress are through contraction joint between blocks 44 & 45, and at centre of block between El.540 & 550.

Action is initiated to declogging the porous blocks, and upstream treatment for stopping water ingress.

4.3 CONCEPTUALIZATION AND FORMULATION OF REHABITATION OF THE PROJECT (DSARP, WORLD BANK):

11. The institutional development in States to assure the safety of dams, vis-à-vis the role of World Bank was first discussed in a special meeting held at Nasik (Maharashtra) on 25.5.1989 which was attended by Members of the National Committee on Dam Safety (NCDS) and Mr. G.W. Fauss of World Bank. During the discussions, the States were told about the need for assured funding for rehabilitation of projects where deficiencies have been identified, without which the periodic inspections through the upgraded dam safety programme may not be of arty use.

The matter was further discussed with the World Bank identification Mission led by Mr. J.P.Baudelaire in July 19S9 and questionnaires were sent to the identified States in August 1989.

Based on the information received and the response from the States for the proposal and discussions in the NCDS, it was decided that the States of Madhya Pradesh, Orissa, Tamil Nadu could be considered for institutional strengthening and rehabilitation of dams as a first stage of the proposed Darn Safety Assurance and Rehabilitation Project, which would also include adequate strengthening of the DSO in CWC.

A World Bank Mission comprising Mr. Perry, MrDuscha and Mr. Fauss held extensive discussions with CWC in January-February 1990. They also visited Bhopal (Madhya Pradesh), Madras (Tamil Nadu), Hirakud dam and Bhubaneswar (Orissa) and held discussions with the officers of the Irrigation Departments of these States.

As a result of deliberations during several meetings with the World Bank, CWC and the States of Madhya Pradesh, Orissa, Rajasthan and Tanmil Nadu, a Project report at an estimated cost of Rs.3372.66 million was prepared and submitted to Ministry of Water Resources (MOWR) on 13.8.1990. The scheme was further forwarded to Planning Commission by MOWR for approval/investment clearance on 4.10.1990, indicating that the Project is proposed to be implemented as a scheme in the Central/State sectors. The Project proposal was accepted by the World Bank in December 1990 for external assistance. The

Project was discussed in detail by the then Secretary (MOWR) with Member (Agriculture), Planning Commission during January 1991. The meeting was also attended by senior officers of MOWR and CWC. Negotiations were held in Washington D.C. from 842 April 1991 between the delegation from India and the IDA & IDBR. The World Bank and it was agreed to fund the DSAR Project with a credit of SDR 96.2 million (US $130 million equivalent) and loan US $23 million equivalent.

Subsequently a Development Credit Agreement between the Government of India and the International Development Association was signed on 10 June 1991

11.1 Implementation of the Project:

Dam Safety Assurance and Rehabilitation Project (DSARP) was taken up for implementation with the World Bank assistance in the year 1991. The total estimated base cost of the Project was US $172 million out of which the States' share was US $160 million and that of Centre US $12 million. The total Project cost including contingencies was US$197 million. The contribution of Government of India was kept as US $5.5 million and the contribution of 4 State Governments was US $38.5 million towards the cost of the Project. Funding by the World Bank was through IBRD loan of US $23 million equivalent for 20 years including 5 years grace period and IDA credit of SDR 962 million (US $130 million equivalent) standard with 35 years maturity. Subsequently the Government of India decided not to avail the IBRD loan of US $231 million thereby reducing the total cost of the Project to US $174.0 million. The disbursements were projected over a period of 6 years commencing from 1991-92 and the credit was to close by September 1997.

The main objectives of the Project, as detailed out in Staff Appraisal Report (SAR) of the World Bank are:

* Strengthening of the dam safety institution in CWC and in the four participating States including modernization of flood forecasting system in Mahanadi and Chambal basins by CWC.
* Providing basic dam safety facilities at 98 selected dams [Madhya Pradesh 46, Orissa 15, Rajasthan 21 (initial 13 + additional 8) and Tamil Nadu 16]

* Remedial works for 33 initially and 22 subsequently identified dams (Madhya Pradesh 18, Orissa 11, Rajasthan 11 and Tamil Nadu 15)

Components of the Project:

At the national level, the Project envisages institutional strengthening of Dam Safety Organization and Hydrology Studies Organization of CWC through assignment of 117 incremental staff, purchase of equipments and vehicles, preparation of PMI' Atlases, acquiring technical know-how or attending training on specialized topic abroad by CWC/State engineers on dam safety/hydrology, flood forecasting activities, imparting training to State engineers by CWC engineers and modernization & expansion of flood forecasting network in two inter-State river basins of Mahanadi & Chambal. The total cost of Central components as per Staff Appraisal Report (SAR) of the World Bank including contingencies for institutional strengthening of CWC and the expansion and modernization of flood forecasting activities in Mahanadi and Chambal basins is Rs.3 1841 million.

Under the States' component, the Project envisages strengthening dam safety organizations under Department of Irrigation/Water Resources with 312 incremental staff; upgrading basic dam safety-related facilities (back-up power system, communications, all-weather access roads, monitoring instrumentation, etc.); investigations and rehabilitation works at 33 dams where potential related deficiencies had already been identified (Category I) and at other dams which were to be identified and prioritized (Category II) during the execution of this darn safety programme. The total number of dams identified so far for this purpose are 55 (33 Category I and 22 Category II).

The total cost of the Project (including contingencies) under the States' component is Rs.4241.4 million having a break up of Rs.205 .8 million for institutional strengthening, Rs.604.5 million for basic safety related facilities and balance of Rs.3431.1 million for rehabilitation and strengthening of dams.

Responsibilities of participants:

11.2 Centre - CWC

* Coordination of project activities, monitoring and reporting.

* formulating and disseminating national standards and guidelines on dam safety related aspects.
* ensuring that proposal for remedial works are processed by the States in accordance with procedures agreed.
* review/vetting of hydrology for additional dams, if any, submitted by the State Governments.
* preparation of PMP Atlases for river basins of peninsular India and preparation of guidelines for use of PMP Atlases.
* acquiring technical training abroad in special subjects like Risk Analysis, Design of Dams and formulation of Remedial Measures, Hazard Classification and Application, etc., and Imparting Training to State engineers on varied dam safety aspects.
* preparation of guidelines in use of PMP Atlases, PMF/SPF estimations, etc.
* modernization and expansion of flood forecasting system in Mahanadi and Chambal basins for optimum regulation of reservoir systems including procurement of necessary equipments and vehicles.
* procurement of office equipment and vehicles for enhancing the efficiency of Dam Safety and Hydrology activities at the Centre.

Risk analysis (risk assessment) has recently received much attention as an approach for use in evaluating the safety of dam. Risk is the likelihood of adverse consequences. As applied to dam safety, risk analysis is the process of identifying the likelihood and consequences of dam failure to provide a basis for informed decisions on a course of action. Risk analysis aids the decision-maker in weighing alternatives that have uncertain consequence.

To cover all this aspect and to develop suitable guidelines a package programme on risk analysis comprising of holding workshop/seminar and training by engaging foreign consultants has been proposed to be implemented under ongoing World Bank aided Dam Safety Assurance and Rehabilitation Project. The entire package including CWC and States of Madhya Pradesh, Rajasthan, Orissa and Tamil Nadu is estimated to cost almost 1.75 crores of Rupees.

Participating States: (4)

* to carry out the executive orders issued by the Government in respect of dam safety.
* evaluation of the pre- and post-monsoon. inspection reports received from the field units and to communicate the remedial action to the defects observed in the dams to the field officers for rectification and for ensuring safety of dams.
* to conduct Phase I inspection of large dams of the State and to recommend follow up action on the basis of findings of the Phase I inspections.
* to arrange for Phase II investigations of the dams according to the priorities decided by the State Dam Safety Committee and Dam Safety Review Panel.
* to inspect and prepare reports in the event of failure/accident of a dam.
* to prepare annual reports on the condition of all the large dams for submission to the CWC.
* to ensure preparation of effective and proper designs of the remedial works on the dams under Dam Safety Rehabilitation Programme and ensure quality control of the remedial works and conduct reviews of the implementation of the project.
* to arrange workshops for training in-service officers.
* to constitute a panel of experts to assist the project officers, in the event of occurrence of major distress to a dam.

Restructured Project – 1 *(1st Restructuring October 97 to September 98)*

By the end of September 1997 the objectives of the Project in respect of institutional strengthening and providing basic dam safety facilities were achieved almost to the requirements. The dam safety institutions in CWC and in the four participating States have been strengthened with staff of 81, 45, 67, 77 and 55 respectively (total 325 against the agreed strength of 415). The State DSOs acquired new buildings and equipments like computers, photocopiers, fax, office furniture and telecommunication system, etc. The first cycle of Phase I inspections were almost completed. Review of hydrology for 62 darns were completed by CWC and intimated to the States. PMP Atlas for Mahanadi, Subarnarekha, Brahmani and Baitarni were published and furnished to the beneficiary States. Draft reports for Cauvery, Godavari, Sone, Chambal and Mahi were prepared.

Basic dam safety facilities, viz. approach roads, back-up power systems, communicating systems, instrumentation, stockpiling of emergency materials, etc., were completed for most of the originally identified dams in Orissa and Rajasthan and 50% in the other two States, viz. Madhya Pradesh and Tamil Nadu.

Initially, 33 dams were identified for remedial works and 22 dams were additionally included by the participating States based on the priorities assessed after Phase I inspections and Phase II investigations and recommendations of State Dam Safety Committees and DSR Panels in the four States. Remedial works on 12 dams were almost completed by 30 September 1997.

As the progress of rehabilitation and civil works on 43 dams under the project was already in advanced stage, Government of 1nd~a and the four participating States requested the World Bank for granting extension of two years to the Project, i.e. upto September 1999 so that the works which have been taken up could be completed and the objectives of the project were achieved fully. The World Bank Mission reviewed the progress of implementation of the Project during June 1997 and recommended inclusion of 28 dams (Madhya Pradesh 12, Orissa 9, Rajasthan 3 and Tamil Nadu 4) in addition to the 12 dams on which civil works were likely to be completed by September 1997 in the restructured project and exclusion of 15 dams (Madhya Pradesh 1, Orissa 1, Rajasthan 3 and Tamil Nadu 10). Also 48 dams in Madhya Pradesh and 39 dams in Rajasthan were included additionally for providing basic dam safety facilities.

The World Bank, while agreeing to extend the project, initially for one year, i.e. from 1 October 1997 upto 30 September 1998 and suitably restructuring it had stipulated that the States have to make an expenditure of 75% of the cost of remedial works for the period October 1997 to September 1998 by June 1998 and the progress of implementation was to be reviewed by another Bank Mission in July 1998 for considering further extension, if any.

Restructured Project - 2 ***(2nd restructuring October 1998 to September 1999)***

As stipulated by the World Bank while according extension for one year for the period October 1997 to September 1998, the World Bank Review Mission visited all the participating States from June 12 to June 26, 1998 and held meetings with the State officials and reviewed the progress of implementation of the Project during the first nine months of the first year extension. As a result of discussions and critical reviews, the World Bank finally agreed to extend the Project period selectively and finally upto September 1999 by deleting the Tamil Nadu State component as a whole and telemetry component of Hirakud dam of Orissa State from the DSAR Project.

The World Bank Mission had recommended inclusion of 28 dams in the restructured project during the first year in four participating States, fluting the 2nd year extension of the project, further restructuring was done by the World Bank by agreeing to include only 24 dams in 3 participating States of Madhya Pradesh, Orissa & Rajasthan where remedial measures are being executed.

Status of the Project upto September 30, 1998:

The objectives of the project in respect of institutional strengthening and providing basic dam safety facilities have been achieved almost to the requirements. The darn safety institutions in CWC and in the four participating States have been strengthened with staff of 117, 69, 67, 7? and 53 respectively (total 383 against the agreed strength of 415). The State DSOs have acquired new buildings and have procured equipments like computers, photocopiers, fax, office furniture and telecommunication system, etc.

Significant achievement of the institutional strengthening are:

* Conducting Phase I inspections of all the existing large dams in the States of Orissa (137), Rajasthan (124) and Tamil Nadu (93) and 85% of the dams in Madhya Pradesh (851 out of 1093).
* Hydrology review for 62 dams has been completed against 33 dams initially identified and the same has also been reviewed/vetted by CWC.
* PMP (Probable Maximum Precipitation) Atlases for peninsular India river basins, viz. Godavari, Cauvery, Mahanadi, Subarnarekha, Brahmani & Baitarani Sone,

Chambal & Mahi have been published. Training for the use of the Atlas for State engineers has also been conducted.

* Preparation and issue of guidelines on dam safety aspects, imparting training to the States' engineers in dam safety, hydrology and dam break analysis, etc., by CWC.
* Coordination, monitoring, assisting Dam Safety Review Panels, preparation of Project reports, etc., has been a regular activity of CWC for this project.

Basic dam safety facilities, viz. approach roads, back-up power systems, communicating systems, instrumentation, stockpiling of emergency material, etc., have been completed at most of the initially identified dams (98 Dams) in Madhya Pradesh, Orissa, Rajasthan and Tamil Nadu . 50% of the works have been completed in respect of additionally identified dams (87 dams) in the States of M.P and Rajasthan.

As on 30 September 1998, out of the 55 dams identified for remedial works, rehabilitation works have been completed at 19 dams, works are in progress at 19 dams and 17 dams have been delinked from the ongoing project for which the remedial measures are being undertaken by the States from their own funds.

Dams for which remedial measures were completed and are in progress under the ongoing DSAR Project are shown in the following table.

11.2.1 Status of remedial works

(as on 30 September 1998)

11.2.1.1 Dams Rehabilitated	*11.2.1.2 Dams for which Rehabilitation is in progress*
11.2.2 Madhya Pradesh	**11.2.3 Madhya Pradesh**
11.2.4 1. Gandhi Sagar	1. Pagara
11.2.5 2. Barna	2. Pillowa
11.2.6 3. Dudhawa	3. Kotwal
11.2.7 4. Muramsilli	4. Aoda
11.2.8 5. Barchar	5. Tigra
11.2.9 6. Maniyari	6. Sukta
11.2.10 7. Ravishankar Sagar	7. Chandora
11.2.11 8. Sondur	8. Sampna
11.2.12 9. Tawa	

11.2.13 Orissa	**11.2.14 Orissa**
11.2.15 10. Kangsa Bahal	9. Hirakud
11.2.16 11. Kuanria	10. Derjang
11.2.17	11. Bhanjanagar
11.2.18	12. Soroda
11.2.19	13. Ghodahada
11.2.20	14. Alikuan
11.2.21	15. Behera
11.2.22	16. Jharnai
11.2.23 Rajasthan	**11.2.24 Rajasthan**
11.2.25 12. Ranapratap Sagar	17. Kota Barrage
11.2.26 13. Jawahar Sagar	18. Parbati
11.2.27 14. Matrikundia	19. Galwa
11.2.28 15. Jawai	
11.2.29 16. Sei Diversion	
11.2.30 Tamil Nadu	
11.2.31 17. Kodaganar	
11.2.32 18. Manimuthar	
11.2.33 19. Pechiparai	

The financial summary in respect of CWC at the Centre and 4 participating States upto September 1998 and the targeted expenditure upto September '1999 is as under.

(Rs.in million)

11.1.2.33.1 Total project cost as per *Staff Appraisal Report (SAR)*	*4559.80*
Restructured project cost (September 1997)	4398.30
Restructured project cost (September 1998)	4231.83
Actual expenditure upto September 1998	2888.50
Anticipated expenditure (Oct.[98] to Sept.[99])	1336.46

4.4 DAM SAFETY ASSURANCE AND REHABLILITATION PROJECTS (DSARP) : (ANDHRA PRADESH)

World Bark is extending loan for DSARP through MOWR. The following Projects are indicated under DSARP in Andhra Pradesh.

Kinnerasani Project: Kothagudem (Khammam District)

A composite Earth masonry Dam with a live storage capacity of 6.95 TMcft was completed by 1972 for supplying water to KTPS.

The surplus course got eroded deflecting towards toe of left earth dam, posing a threat to the safety of the earth dam. Realignment of surplus course, regarding of the energy dissipation arrangements, form part of rehabilitation programme.

Gotta Barrage: (Srikakulam District)

Gotta Barrage constructed across Vamsadhara River during 1971 with 22 bays of 18.29m x 4.57m designed with a discharge capacity of 11,328 cumecs (4,00,000 cusecs) experienced higher floods of 16,992 cumecs (6,00,000 cusecs) during 1980, and the flood banks were breached.

Rehabilitation programme consists of providing additional spillway and guide bunds.

P.A.B.R: Penna Ahobilam Reservoir:

PABR consists of a masonry Dam in the main george, rock fill dams on either flank constructed during the period 1978-94.

The main problems afflicting the dam, is leakages in masonry from d/s face and heavy seepage from the foundation gallery.

Rehabilitation programme contemplates drilling and grouting of foundation gallery, upstream face treatment of masonry dam, and grouting through the body of the dam.

Singur Project:

A composite concrete - earth dam was constructed across Manjira River during 1977-88. The free board provided for the earth dam has to be increased by providing a deflector wall on earth dam, the rehabilitation programme contemplates provision for improving the freeboard for earth dam by providing deflector wall, strengthening upstream revetment, raising the earth bund by 0.5m.

Upgrading of Downstream works of Nizam Sagar, Providing additional spillway for Musi Project, improvements Bhairavani Tippa Project in Anantapur, raising the TBL standards of Yeleru Project are also included under Preliminary proposals to DSARP.

Seepage delays Srisailam project's Commissioning:

Excess seepage from unidentified sources into the head race tunnel of the Srisailam Left Bank underground hydro-electric station has delayed the commissioning of the project (This is after the whole hydro station was flooded last year).

The seepage has not only been preventing the A.P.Genco officials from carrying out further excavation of the tunnel but also delaying the erection of machinery which otherwise would have been completed by now.

While the first unit of the 6 x 150 MW power station was scheduled to be commissioned by December, A.P.Genco Chairman and Managing Director, J.Parthasarathy on Sunday extended the deadline up to June 2000. However, with the source of seepage into the tunnel yet to be established, the officials are doubtful about the new deadline too.

Though other works relating to power house cavern, transform cavern, surge cavern and tail race tunnel are nearing completion, the Genco has been facing difficulties in completing the excavation of the 347 metre long head race tunnel. According to sources, the problem lies with the last 30 metre portion close to the intake structure, which could not be excavated due to presence of water up to 70 metre high.

The Genco, which noticed the presence of water three months ago, has been continuously pumping out water using 1000 HP motors. "Much to our surprise, the water level is still maintained at previous level despite our efforts to dewater the 30 metre stretch," a senior Genco official told *Deccan Chronicle.* The underwater video-graphy to find out source of leakage yielded results to some extent with officials detecting leakage from one of the three gates of the intake structure. "Even after plugging the leakage from doors, water is still entering into the tunnel," the official said adding that unless water is entirely drained out, the excavation of the 30 metre stretch cannot be taken up.

Earlier, the officials had a tough time excavating the tail race tunnel too which contained several faulty zones and a major faulty zone. "Unlike other places, rocks between the Srisailam reservoir and Nagarjunasagar reservoir are fragmented and highly jointed which allows water to seep in through gaps," the Genco official said. The Officials had faced many problems while excavating the faulty zone of 120 metre portion of the tail race tunnel which was collapsed at the several places. However, the officials succeeded in filling the gaps through pressure grouting of concrete.

(Figure)

4.6 LESSONS LEARNT FROM DURING THE IMPLEMENTATION OF THE PROJECT:

(i) Adequate institutional support In all fields of specialisation is a must for successful implementation of the project. Specialised training of project implementation officials in technical as well as procurement procedure is necessary for speedy implementation of the project.

(ii) Proper and realistic Hydrology Studies on dams should be completed well in advance.

(iii) Advance funding is an important requirement.

(iv) Adequate and timely flow of funds for early completion of works. Flow of funds to be streamlined round the year specially during the beginning of the financial year.

(v) Delegation/enhancement of financial and administrative powers of officers dealing with the implementation of the projects for quick award and execution of works. Finance officers should also be made accountable for any delay in award of contracts.

(vi) Estimation of quantities for major works for execution are required to be as accurate as possible and should be approved by panel of experts.

(vii) Strict implementation of procurement schedules should be ensured at the highest level.

(viii) Mechanism should be evolved for regular review of construction schedule by project Chief Engineers.

(ix) Officers and staff responsible for implementing the project should be educated and trained about the components and the time schedule for completion of the project. Transfer of project staff and monitoring agencies should be avoided.

(x) PERT, CPM charts and implementation schedules to be prepared and reviewed at the highest level at regular intervals to make up the slippages, if any, during the implementation of the project.

4.7 POLICY & INSTITUTIONAL FRAMEWORK FOR DECISIONS ON REHABILITATION, MODERNISATION ETC.:

Government of India (Ministry of Water Resources) has constituted a Standing Committee to review the existing practices for evolving unified procedures of Dam Safety for all dams in India under the Chairmanship of Chairman, Central Water Commission. The Committee reviewed the existing procedures of Dam Safety in various States and found that they are functioning at varying levels in different States. Central Water Commission has evolved a pre-monsoon and post-monsoon checklist for inspection of dams to be carried out and distress if any for informing to the Government. Each State is expected to submit a annual report on inspections conducted for all the large dams to the Dam Safety Directorate of Central Water Commission.

The Dam Safety Cell has to inspect all the large dams in the States and prepare status report on the health of the dams. The Dam Safety Review Panel visits the project sites and suggest remedial measures. Respective Chief Engineers of the projects will take up follow-up action by way of project reports, its funding and implementation.

National Committee for Dam Safety once in an year meets under the Chairmanship of Chairman, Central Water Commission and the State of Andhra Pradesh is represented by the Engineer-in-Chief/Chief Engineers, Central Designs Organisation. So far major policy outcome have come from the lessons learnt through DSPAR of the World Bank which are detailed as part of recommendations in Chapter 6 of this paper. This covers in detail the deficiencies in institutional and policy matters.

(Three Figures

Figures

Rehabilitation of Spillway at Tigara Dam – Madhya Pradesh

Rehabilitation of spillway and non-over flow section Parbati Dam – Rajasthan

Figure:

Construction of new Kotwal concrete dam – Madhya Pradesh
(old ungated dam in the background)

CHAPTER – 5

INSTITUTIONAL, FINANCIAL AND ECONOMIC ASPECTS OF OPERATION / RE-OPERATION, MONITORING AND RE-PLANNING

5.1 INSTITUTIONAL ASPECTS:

5.1.1 The institutional framework in which the decision making for water resources development takes place is a critical component in a project's success. The institutional aspects worthy of consideration include : regulatory, technical, monitoring and controlling, financial, social administrative and some other such as public participation, education, training and research, and conservation of environment. The evolution of suitable institutional framework results in a harmonised development action, which is beneficial from both social and ecological angles. Every country, society and basin have its own institutional arrangement best suited to its needs.

5.1.2 Regulatory institutions involved in water development have functions which include enactment of legislation, formulation of standards, issuing guidelines, and suggesting policies and procedures. Among the technical functions are planning and implementation, designs, operating procedures and documentation. Remote sensing, creation of data banks and development of management information systems are other useful technical aids. Agencies and institutions are also needed for monitoring and control of project implementation and its post implementation operation.

Financial and banking institutions have an important role to play in the sustainable development of water resources, and international institutions like the World Bank and regional banks, as well as certain UN agencies have rendered significant assistance in the development of this sector.

In India the Central Ministries that are directly involved in the water sector are : Ministry of Water Resources, Ministry of Agriculture, Ministry of Health and Family Planning, and Ministry of Environment and Forests. There are counterpart ministries in most states but the set-up varies from state to state. The Planning Commission at the Centre and similar agencies in the States play a pivotal role in water sector planning in the country.

Central Water Commission is mainly responsible for regulation of surface waters in the country. The Commission has set up an Environmental Management Directorate to deal exclusively with environmental aspects of water resources development projects. Central Water Commission also has set-up Dam Safety Organisation apart from Reservoir Sedimentation Directorate.

The Ministry of Water Resources has constituted an Environmental Monitoring Committee to oversee the implementation of environmental safeguards of irrigation, multi-purpose and flood control projects. There also exist a National Dam Safety Commission. The Central Ground Water Board has the responsibility of safeguarding the ground water resource and of its proper utilisation. Institutions like the Central Pollution Control Board and its counterpart Boards in the states have been created to assist in environmental protection. At the Centre and as well as in the States, there are departments/boards to deal with various issues related to water. Among these agencies those dealing with irrigation, pollution control, forestry fisheries, rehabilitation and ground water are especially important. A database for environmental parameters is available with above organisations. However, there is an urgent need for a centralised data bank. According to CWC, National Informatic Centre (NIC) could form a nucleus for such a bank so that this data could be retrieved for use as and when required. The Government agencies involved in water sector are shown in Figure-5.1.

This Figure does not show the interfacing or dovetailing of the organisations as this would depend upon the administrative convenience of the ministries and does not have clearly defined status of all time.

5.1.3 Standards, Policies and Procedures:

Planning Commission, Central Water Commission and state level planning bodies as well as the departments of irrigation and agriculture contribute in formulating policies and procedures. CPCB, SPCB's and BIS are engaged in setting standards.

11.2.2.33.1 Figure 5.1

Figure –

5.1.4 Financial Institutions:

12. Monitoring of the financial aspects during the implementation and post-implementation stage needs adequate institutional arrangement. The Ministry of Finance, the Auditor & Comptroller General, the Planning Commission and public bodies like Public Accounts Committee of the Parliament perform the functions of financial assessment and control. International organisations like the World Bank the Asian Development Bank have an interest in the technical and financial appraisal of projects funded by them.

5.1.5 Associated Institutions:

Increased availability of water improves food and nutritional availability for the population resulting in better health standards. Other social objectives include employment, income, education, tourism and recreation.

Local bodies, district health officers, health department of the State and, in general, the Central Ministry of Health and Family Welfare have the responsibility of assessing health impacts.

5.1.6 Public Participation:

In India this is not yet visible for projects at the stage of their conception or approval. There is some move, as stated in earlier chapters, to involve water users (in the context of irrigation projects) by forming their associations and delegating some of the powers which is otherwise exercised by the irrigation department.

5.1.7 Role of Voluntary Organisations:

Voluntary Organisations (VOs) have a great role to play in the promotion of sustainable water resources development. Such (VOs) institutions have helped built public and governmental awareness on crucial aspects related to environment-vs-water. In many parts of the world VOs have helped to create awareness, amongst in people and it is suggested that authorities responsible for promoting sustainable water project should avail of the services of these organisation in this respective regions in order to initiate public participation.

5.1.8 Education Training and Research:

In the context of sustainable water resources development certain general aspects and other specialised aspects of education and training are significant. General environmental training is aimed at building awareness of environment as a whole and to develop an understanding of environmental issues. The target group comprise policy makers and decision makers, administrators and planners, engineers, agriculturists, trade unionists, etc. The programmes include a short term in-service training, in-depth training and workshops on selected environmental problems, post graduate programmes and inclusion of environmental component with already existing courses. Specialised training programmes seek to develop the problem-solving capabilities of professionals to work on specific environmental issues. This training is intended for people whose activities and influence have an important bearing on environmental aspects of water resources, such as the ecologists, biologists, hydrologists, engineers, agronomists, foresters, meteorologists, etc. This may be achieved through short-term programmes, conferences, seminars, workshops, etc.

It is imperative that the participants selected are those who could improve environmental decision making. The training programmes should be devised to cater to specific needs and educational levels of participants. Specialised institutions for imparting such training are already in existence in the country. A special aspect of education and training is the training of trainers which would have the much desired multiplier effect.

Besides the mid-and top-level personnel, training facilities are necessary also for the lower cadres, such as technicians, skilled workers and craftsmen. The technicians play a decisive role in the operation and maintenance of plants and equipments, specially in view of the sophistication achieved in measuring and controlling devices and techniques.

Training to enhance capabilities of personnel is basic to development, though it is a sizeable investment and the results become evident after a long period. For this reason, it is imperative that awareness of this need is developed among politicians, and technical, financial and administrative executives. Autonomy of training institutions responsible for human resources development in the area of sustainable water resources development, is much needed for success.

To achieve environmentally sound management of water resources, it is necessary to develop and operate comprehensive inter-disciplinary research and training programmes. Approaches have also to be developed to encourage adequate transfer of technology to users. An important aspect is the assessment of the benefits of a training programme and the follow-up with participants after the training to help them discharge duties effectively.

Research institutions will have to enlarge their activities to solve problems of conservation and use of water with the minimum of adverse environmental impacts and with as much of beneficial environmental impacts as possible. Encouragement should be provided to scientific and technical personnel to undertake specific research for providing answers to known and anticipated problems associated with water management.

Unfortunately none of the above is happening in India in a scientific and organised fashion. Some training and education dues take place but it is sporadic and piecemeal. The training institutions lake budget, manpower and priority they deserve.

5.1.9 Coordination:

A proliferation of independent and splinter agencies without clearly defined objectives leads to problems of coordination and cooperation. Coordination of activities is possible only if the policies of the various agencies are mutually consistent. This is the most difficult area in which problem still continues in India.

5.2 FINANCIAL ASPECTS & ECONOMIC ASPECTS:

Traditionally, to establish the financial and economic viability of a project, a financial and economic cost benefit analysis is carried out. But this method is being questioned in India and elsewhere on the following three grounds:

1. Costs & benefits which are easily quantifiable have often been wrongly estimated. The Public Accounts Committee (PAC) in India stated that, a scrutiny of 32 major projects in post independent India have shown cost overruns of 500 percent and more. Not only have the cost overruns been under estimated, benefits have also been exaggerated.
2. The social and environmental costs have not been taken into consideration in the cost-benefit analysis. It is accepted universally that it is difficult to measure these in purely financial or economic terms.
3. Although no retrospective cost-benefit analysis has been made of the major dams in India, a comparison of their actual and anticipated cost-benefit from available studies of some projects (quoted later) suggest that most of these projects have had higher costs than benefits, and certainly a cost benefit ratio inferior to what was anticipated or required. This has resulted in the conviction that dams must be evaluated in a wider and more realistic perspective.

5.3 POTENTIAL APPROACHES FOR INCORPORATION OF RE-PLANNING AND CONSEQUENT ACTIONS INTO PLANNING, DESIGN AND APPRAISAL OF DAMS:

This can be divided into two parts. One which applies to future projects and other to existing one. So far as the existing projects are concerned, one need to evolve approaches to re-planning based on the experience of the operational projects. This requires a realistic and scientific evaluation of such projects which is rarely done in India. The evaluation should clearly bring-out the actual cost-benefit as compared to anticipated duly taking into consideration social and environmental costs. In most cases it would not be favourable. Therefore, there exists only the possibility of improvement in terms of :

- Maximum utilisation of potential created

- Establishing proper cropping pattern for optimal utilisation of water
- Mechanisms of avoiding waterlogging and proper drainage as planned in Sardar Sarovar Project (yet to be implemented)
- Institutional strengthening of CAD authorities
- Controlled flooding mechanisms and consequential design modifications in spill ways.
- Instrumentation & training for monitoring of siltation, hydro-logical flows, foundational strength, seismicity
- Rotational water supply system
- Timely availability of credit and agricultural inputs to farmers
- Proper catchment treatment
- Proper implementation of rehabilitation of displaced people

The above activities can certainly improve the benefits and reduce cost of social and environmental effects and make the project sustainable. Each one of the above activity will require an action plan and research, apart from the political will of the govt. Unfortunately all of them do not happen together to give the maximum impact of the project. Each of above activities have been covered in more details in Chapter 6 by way of recommendations.

In case of future projects potential approaches may be to look for various alternatives itself. The various alternatives can be:

- Satisfying primary needs of an area considering socio-economic reality of the area. This could be agriculture, artisanal or rural industry
- If best option is agriculture, then alternatives in terms of irrigated agriculture use or rainfed dry land farming or mixture of two may be considered.
- If irrigated agriculture is the best option then best alternative among the minor irrigation, drip irrigation, large dams etc. may be considered.
- If major dam is considered a best option than financial, economic and social cost-benefit analysis need to be carried out on realistic terms.

Whatever be the alternative, objective should be to ensure benefits become available as soon as possible and there are no cost overruns and damage to environment.

Not only could there be alternative designs to a project which could minimise the cost (as has been suggested in the case of Narmada Sagar and Sardar Sarovar), there could also be alternatives to major dams themselves.

One of the alternatives that has not been adequately promoted is minor irrigation. The PAC report of 1982-83, quoting from the *Economic Survey* of the Planning Commission, says 'Minor irrigation projects cost much less and Time-lag between investment decision and the flow of benefits is comparatively small' (PAC 1982-83: 29, para 2.29).

Apart from the minor irrigation, many other types of alternatives exist which include use of ground water and sprinklers, drip irrigation, lift irrigation, etc. In the context of arid and semi-arid areas like Gujarat and Rajasthan, it is interesting to note that the PAC, in its report of 1986-87 syas, "The drip method of irrigation has been foud to be very useful in reclaiming and developing the Arrava desert area in Israel. We have large areas in our country which are arid or semi-arid, with problems similar to those in Israel" (PAC 1986-87: 57-58, para 6.42).

Indian Experience:

1. Certain costs are ignored:

As mentioned earlier, environmental costs are not adequately computed or considered in the cost-benefit analysis. Though this is partly due to the difficulty in computing some of these costs in financial and economic terms, a more important reason is the hesitation on the part of project authorities to acknowledge these costs.

Another cost that is usually underestimated is social cost, cost due to waterlogging, salinity, drainage problems etc. The CAG, in his report for 1979-80 for Madhya Pradesh, made the following observations regarding Tawa dam, the first major dam to be built in the Narmada Valley:

The table – 5.1 given below shows the comparative position of the yields per acre under various crops after irrigation during 1977-78 and 1978-79 and the yields prior to introduction of irrigation (1971-72) in Hoshangabad district, as per the Agricultural Statistics compiled by the commissioner, Land Records.

Table – 5.1

Crop	Before irrigation	Average yields per acre after irrigation	
		1977-78	1978-79
		(in quintals)	
1. Paddy	4.00	2.98	3.83
2. Jowar	2.82	3.64	2.74
3. Maize	4.81	4.07	4.01
4. Wheat	3.14	3.30	3.06
5. Gram	2.43	1.96	2.08

It will be noticed that the yields per acre after irrigation had actually declined.

Thus, it would appear that the project was ill-conceived and the benefits that were presumed would be available could not have been realised.

2. Higher estimation of benefits:

Shortfall in Utilising Irrigation Potential: An analysis of some of the major dams reveals interesting figures concerning the short-fall in the utilisation of irrigation potential.

The computer and Auditor General of India, in the supplementary report for 1975-76, studied 12 major projects and came to conclusion that the area actually irrigated was on average only 64.4 percent of the area planned to be irrigated. Even this average is misleading as there were five among these 12, where the irrigated area was less than 40 percent and one with less than 20 percent of that anticipated. But CAD has made progresses now the average workout to 80% (according to govt. figures).

According to World Bank figures for India, an area equivalent to between 5 and 13 percent of newly irrigated land is typically lost due to reservoirs and canal and drainage infrastructure. However, as the area which actually received adequate irrigation water is usually far less than estimated, and because large amounts of land often have to be taken out of production due to soil degradation, these figures are certain to be underestimated. One of the biggest irrigation fiascos in India is Bargi

Dam on the Narmada, which submerged nearly 81,000 hectares of farmland and forest to irrigate a projected area of 440,000 hectares. Although the dam was completed in 1986, seven years later only 12,000 hectares were receiving irrigation water (3% of the planned area)[1].

Irrigation efficiency (measured as the percentage of water actually used for crop growth relative to the total amount of water delivered by the irrigation system) averages only around 40% worldwide. In India, the World Bank notes, irrigation efficiency is often assumed in project documents at 60%, whereas in real life most Indian schemes probably have an efficiency of 20 or 35%.

Transmission Loss of Water: Another parameter crucial in evaluating the benefits of dams is the transmission loss of water, sometimes causing waterlogging. Again, no detailed figures are available but the Public Accounts Committee, quoting the Comptroller and Auditor General's supplementary report 1975-76, has stated that the difference between projected and observed loses has been around 150 to 300%, in one case going up to nearly 500% (PAC 1982-83). However, situation has since changed linning of canals is being taken up in an large projects and this losses are being reduced. No detailed information is available on actual achievement so far.

Siltation: The benefits of a project depend a great deal on the life of the project. Siltation of reservoirs significantly reduces their life and sometimes even their safety. Many estimates shows that the rate of siltation in most of our reservoirs is much higher than that anticipated, in many cases over 400% more than anticipated. In one case, Nizamsagar, the rate of siltation is 1,642% higher than anticipated.

[1] S.Raman, *'Bargi Oustees Plough Lonely Furrow'*, Economic Times, Ahmedabad.

Recovery of Water Rates: The PAC has following to say:

In 1945-46, i.e., just before Independence, the return from irrigation schemes was Rs.7.92 crores on an investment of Rs.149 crores, i.e., 5.3%. This came down to Rs.1 crore in the following year and thereafter the irrigation and multi-purpose projects have been consistantly showing loses. These have mounted from nearly Rs.154.6 crores in 1975-76 to Rs.424.75 crores in 1981-82 (budget estimates), both in respect of irrigation (commercial) and multi-purpose river valley projects (PAC 1982-83: 135, PARA 4.39).

> The Fifth Five Year Plan document had pointed out that in certain states, receipts from irrigation were not sufficient even to cover the working expenses and this in fact amounted to subsidising of farmers, rather the relatively better-off farmers. The Committee find that the cumulative losses were of the order of Rs.2,053 crores between 1975-76 and 1981-82. Obviously, this situation cannot and should not be allowed to continue (PAC 1982-83: 135-136, para 4.40)

3. Retrospective Cost-Benefit Analysis:

It seems incredible that despite the huge investment made on major dams in Indian there has been little effort at evaluating the actual returns from these projects and comparing these to the projected returns. The Planning Commission admits that ‘there is no regular system of assessing actual economic returns of irrigation projects’ (PAC 1982-83: 114).

4. Class-Benefit Analysis:

In virtually every project it is seen that the primary costs are being paid by the very poor and the tribals, while the benefits are flowing to big farmers and the urban elite. Those who are displaced by such projects are usually too poor and politically weak to safe guard their own interests. The government has little difficulty in imposing its will on such people. However, when it comes to finding suitable alternative land for the displaced, the government seems to lack the political will required to ensure that good cultivable lands are made available. To resettle families to be dislocated by the Sardar Sarvor project, the Maharashtra government is now insisting that forest land be made available. In most projects, current and past, the authorities have been unwilling to make the rich farmers who would benefit from the project, share some of these benefits with those who would be uprooted.

5. Planning – Physics & Chemistry:

Recorded below are some of the relevant observations made by the CAG and the PAC about the planning process in India.

1. For no major irrigation project in India has a study been conducted to establish, step by step, that such a project is the best choice for the region and its problems.
2. Though there have been repeated demands, to date no state has prepared the required Master Plans for water management.
3. Lack of comprehensive planning, and the absence of an adequate National Water Utilisation Plan, built on the basis of state management plans, has led to the proliferation of projects and the subsequent shortage of funds and other inputs. The PAC observes : "The committee, therefore, consider it to be a negation of planning for the Planning Commission to sanction a large number of major schemes without making sure of the availability of funds, the technical personnel and essential inputs like cement, steel, coal etc. to enable completion of the projects within the time schedule laid down and within the approved estimates (PAC 1982-83: 171).
4. Another distortion in the planning process occurs when projects are begun before clearance is given by the Planning Commission and other relevant authorities. This not only subverts the process of project appraisal, aimed at selecting only beneficial projects, but also puts pressure on the various authorities to grant *post-facto* clearance for such projects. Even for those projects, which can be shown to be economically non-viable, considering the huge amounts of money already spent prior to the clearance, it becomes uneconomical and politically difficult to abandon them. Table – 5.2 shows the record of certain past projects.

12.1 Table – 5.2

	Name of scheme	Date of approval by Planning Commission Ministry of Irrigation	Date of commencement of work
1.	Nagarjunasagar (Andhra Pradesh)	22-9-60	1955
2.	Rajasthan Canal Project (Rajasthan)		
	Stage I	4-7-57	1958
	Stage II	17-5-72	1972
3.	Gandak (Bihar)	13-7-61	1961
4.	Kosi (Bihar)	25-4-58	1955

5.	Malaprabha (Karnataka)	5-8-63	***12.1.1.1 Oct. 1960***
6.	Kallda (Kerala)	4/7-2-66	1966
7.	Tawa (MP)	5-8-60	1956
8.	Kangasabati (West Bengal)	28-11-61	1956

In view of the foregoing, conclusions arrived by Sekhar Singh etl. in their paper "Evaluating Major Dams" are the following:

1. Carryout a retrospective cost-benefit analysis to determine, at least for a sample of our major projects, how beneficial they have been to the country.
2. Examine the reasons why the costs were higher and the benefits lower than anticipated, if the analysis establishes this.
3. Ensure that the new projects are so planned and implemented that this does not recur.
4. Ensure that all the costs and benefits are realistically considered before a project is approved.
5. Ensure that all the alternatives are also properly evaluated so that the country has the benefit of the best of these.
6. Ensure that the projects are socially just.

CHAPTER – 6

RECOMMENDATIONS

1. A river basin has a defined watershed boundary and within it there is an inter-relationship between the surface water, ground water and the supporting natural environment. The basin plans for allocation of available water and land resources and for verifying the compatibility of long-term development programmes and projects on sustainable basis, should become the main decision making tool to ensure continuing welfare of people. National Water Policy of Govt. of India adopted in 1987 has also recommended water resource planning on basin or sub-basin basis. The policy has recommended setting up multidisciplinary units in each state for the purpose not only to meet irrigation needs but to harmonise various other uses of water. The basin approach stands as Govt. suggestion, as all the projects in a river basin have direct or indirect linkages in terms of sustainability. Ministry of Water Resources

in Govt. of India have suggested in 1992 for setting up of River Basin Organisations (RBO's). Unfortunately no such action has been initiated by the State Govt. Suggested Krishna Co-ordination Committee has also not come into being. Perhaps this needs a serious consideration by the State Government.

2. Many of the reservoirs in India are losing capacity at the rate of 0.5 to 1.5 percent annually. A glaring example is Ichari Dam on Ton river. In little over two years the reservoir was filled with sediments upto the levels of the rest of the spillway, 160 M high. There are many more examples including NSP discussed earlier. Therefore, this problem need to be tackled seriously. Naturally, a scientific monitoring of siltation of the reservoir should be made on continuous basis. Based on the trends a co-ordinated inter-state action plan for catchment treatment through afforestation and soil conservation measures be taken up. Often such co-ordinations are hard to achieve but it is hoped that once RBO's are set up, some success would be visible on this front. However, pending this to happen, sub-basin catchment treatment by each State Govt. can be taken up by ensuring a proper co-ordination between departments. of forest and soil conservation. It is a pity there does not exist such a comprehensive approach to save the life of the reservoirs apart from maintaining the productivity of land in the catchment area. It is hoped that the Watershed Development Programme of Govt. of India will make some contribution in this direction.

3. It will be difficult to contain waterlogging by merely technical approaches, since waterlogging is an environmental problem caused by under development, lack of education and stress on immediate economic benefits. Intensive farmer education is the only long term solution, but this action is slow and costly. For inexperienced farmers not well versed with irrigated agriculture, waterlogging is a problem that is difficult to perceive and understand concepts like efficient use of water, conjunctive use of water and optimal use of water should be taught to children in schools.

Restricting water supply to waterlogged and conjunctive use of canal and ground water can be effective in reducing waterlogging. But this action is prone to conflicts. Since waterlogging is a common pool resource management problem, corrective action taken by Governmental agencies alone may not be effective. Public participation and involvement of voluntary agencies in remedial action has to be sought for. Farmers participation should be promoted and incentives should be provided for farmers applying remedial measures. In

Nagarjunasagar Project limited monitoring for ground water quality has been initiated. This also started only recently. One of the major problems in conducting research on effect of waterlogging is the lack of data. An efficient system on monitoring all the parameters related to water, and soil quality and agricultural yield are essential for any major command area to take up development plans in command areas.

The major action necessary are:

a) There should be a system for monitoring groundwater levels, quality and initiating corrective action to reduce waterlogging and salinity. Provision for monitoring and corrective action should be integral parts of irrigation project reports. No such action is visible on ground from any projects.

b) In Command area enough investments have to be made for providing drainages. In the case of Maharashtra State 80 percent of the waterlogged area has no drainages. One of the preparatory activity for providing irrigation can be the simultaneous planning for drainages. Farmers can be asked to take up construction of drainages as one of the conditions for providing irrigation in newer areas.

c) Agricultural extension education should be modernised to include aspects of efficient use of irrigation water, conjunctive use of ground and canal water. School education also should impart the need for efficient use of water and the need for conserving water. Farmers should be educated about water practices through demonstration programmes.

d) Water Ecology Demonstration Centres should be started in command areas. Instead of starting one large centre smaller centre should be started in large numbers in the command area. Provision for Water Technology Demonstration should be made in the projects. Co-ordination between irrigation and agricultural departments should be envisaged so that the Water Technology Demonstration Centres are part of agricultural extension programmes.

e) Financial credits and loans should be provided for land development and for providing drainage. Land Development Banks should earmark a proportion of expenditure for environmental conservation activities such as land reclamation and soil conservation.

f) Waterlogging and salinity can be technically handled in the form of improved irrigation practices, improved drainage systems, developing newer strains of plants less susceptible to waterlogging and salinity problems. Research on waterlogging and salinity problems have to be taken up.

g) Taking up complementary development strategies such as afforestation, cultivation of green fodder bearing plants, farmer education and demonstration programmes should be encouraged.

h) Soil conservation and land development are perceived as activities of long term benefits with no short term benefits. This can be changed only through intensive training and education. Irrigation Engineers and Senior Governmental Officials should be given orientation on the possible consequences of soil degradation and waterlogging.

i) Instead of electric pumps, windmill based pumps can be installed in areas where watertable level is high. Providing a windmill pump and a drain channel for water can bring down the watertable without much problem. Different models of windmills can be tested and then an appropriate model suitable to that area can be selected. Since windmill pumps do not need any energy from external sources, only the initial cost has to be subsidised, or has to be given as a refundable loan.

4. Remediation of social cost due to such projects is an important component, though forgotten by the Government. Any development can not be successful, if it is at the cost of any other sections of the society. The involuntary settlement of millions of people need to be guided and helped till at least 2nd generation when things are expected to get stabilized. It is therefore, necessary for CADA or Social Welfare Department to carryout evaluation of socio-economic status of these people and then prepare a comprehensive action plan in a phased manner aiming to mitigate the psychological, social and cultural hardship of these people and

to strengthen their economic position to be better than what it was before their eviction. Funding of the schemes under the action plan can be organised through existing schemes under various Government Departments under overall supervision of collectors concerned. A monthly review meetings to be organised to monitor the progress of the implementation of the action plan. The action plan should aim to cover other project affected people and people in downstream of the project.

Because involuntary resettlement dismantles a previous production system and way of life, all resettlement programmes must be development programmes as well.

5. Detailed long-term evaluation of the project has never been done for also for most of the such projects in India. This corrective mechanism is essential to provide necessary direction to make remedial changes. Such evaluations would involve problems which may relate not just to changes that would have occurred among affected people without a project, but also, in regard to longer term cumulative impacts, to factoring out the relevance of other post project influences. But such problems should not be allowed to come in the way of detailed evaluation as project induced environmental and social impacts have been seriously under estimated. The results of evaluation should be made public to bring in more transparency.

6. The dam may change the river flows downstream. It is therefore recommended that:

-- minimum flow in the river should not be less than the average 10-days minimum flow of the river in its natural state;
-- priorities and requirements downstream should be taken care of as outlined in national Water Policy drinking water, irrigation, hydro-power, navigation, industrial and other uses such as tourism;
-- reservoir operation should be such that 2 or 3 spills of reasonable discharge are allowed in the river on a regular basis;
-- regenerated flows below the dams/barrages/weirs may be quantified at different times of the year to determine quantity of releases; and
-- minimum flows are maintained to meet the demand of aquatic life downstream and also the carrying capacity of the aquatic system.

Downstream river water flows should be monitored regularly. Based on this data, the stream flow downstream should be fixed so that river water quality is maintained within the permissible limits.

7. For water to be used for any specific purpose, its quality in reservoirs, rivers, canals and drainage ditches should receive priority attention. Water quality can be maintained or enhanced by:

-- catchment area treatment to reduce sediment load;

-- adequate treatment of effluents to attain the standards prescribed in appropriate IS, and consideration of assimilative capacities of receiving bodies;

-- proper control of discharges from non-point sources;

-- efficient application of pesticides, fertilizers and other agro-chemicals to reduce their losses due to leaching;

-- minimising the quantity of effluents that may be discharged to water bodies through extensive recycling and reuse so that the load do not exceed carrying capacity;

-- removal and discharge of sediments from reservoir, to reduce oxygen demand;

-- providing reaeration facilities, whenever economically feasible;

-- low flow augmentation; and

-- avoiding discharges of wastes in canals.

8. Demands on fresh water can be reduced through water pricing, as well as recycling and reuse. Treated waste water, both domestic and industrial can be effectively used for irrigation. Seepage water could also be tapped to supplement the most desired use of water.

Demand for irrigation water can be reduced by adopting more efficient irrigation techniques such as sprinkler, drip irrigation, etc., as compared to canal irrigation. Further reduction is possible by practicing optimal scheduling and initiating other conservation measures, such as lining of canals and water courses.

In terms of sanitation, care should be taken to ensure adequate facilities such as proper treatment and disposal of wastes are available and are properly maintained to ensure groundwater and surface water are not contaminated. Similarly landfill sites for disposal of solid wastes should be carefully selected so that leaching does not contaminate groundwater.

9. Prevention of eutrophication can be achieved by:

-- proper treatment of domestic and industrial wastes to reduce the concentration of nutrients reaching water bodies, especially quiescent ones;

-- efficient application of fertilizers to the crops so that the amount leached is kept to a minimum;

-- soil conservation measures.

10. Reservoirs, irrigation canals and drainage ditches may become infested with time with aquatic weeds which may be submerged and floating. Weeds increase water losses by higher evapotranspiration, and by reducing flow velocity in canals, it reduces their carrying capacity. Weeds also improve the habitats of vectors of water-borne diseases, and may affect DO levels due to their decay. Aquatic weeds can be controlled by three methods: mechanical, chemical and biological. Normally more than one technique is used concurrently for effective control. Chemical control means application of herbicides. When applied, the chemicals are translocated throughout the plant, and thus they are destroyed.

There are certain environmental problems which can arise due to the application of chemical herbicides. The herbicides could prove to be toxic to the fish directly, or indirectly by having adverse effect on the organisms on which fish feed. It is also possible that the aquatic organisms may absorb these chemicals and bio-concentration may result which could and prove harmful at higher toxic levels. Other adverse impacts should also be noted. They are:

i) water could be made temporarily unsuitable for domestic and livestock consumption;

ii) chemicals may have adverse impacts on non-targeted species, and

iii) continued use of herbicides could make the weeds increasingly more resistant.

11. ENVIRONMENTAL MONITORING

Though some of the monitoring aspects have been discussed in certain recommendations earlier, but comprehensive recommendation on environmental monitoring is felt necessary. These are discussed here. Any water development introduces complex new inter-relationships in the project area between people, various natural resources, biota and many development forces. Due to lack of adequate knowledge base in the area, environmental monitoring and evaluation has to be carried out regularly to ensure that whatever environmental impacts that might surface are found at the earliest possible opportunity. This will ensure that CADA managers can take appropriate measures to maximise positive environmental impacts and minimise the negative ones.

It should, however, be noted that if monitoring is carried out regularly, it will not automatically improve the environmental management of the projects since monitoring by itself is not enough. Results of environmental monitoring must be forwarded to planners and decision-makers in a timely fashion in order that rational decisions can be taken and then implemented promptly. Equally there must be an integrated environmental monitoring and management plan, within an overall framework of sustainable water resources development of the project, so that the project management authority is not only fully aware of its role in that process but also can initiate responsively and sensitively. Such a process, if functional and transparent, would ensure that the general public would develop faith in Government hydro projects.

In the past' as mentioned in earlier chapters, not only in India but also in all other developing countries, ex-post monitoring and evaluation of water projects have received virtually no attention. For sustainable water resources development, this situation has to be remedied on an urgent basis.

Preparation of monitoring and environmental plans has some basic requirements. These are the following:

i) timeliness;
ii) cost-effectiveness;
iii) maximum coverage;
iv) absence of bias, and
v) identification of users of information.

Following variables that need to be monitored are listed as per the guidelines prepared by CWC.

(a) WATER RESOURCES, INCLUDING QUALITY

Monitoring measures are required for the following:

-- changes in the quality of surface and groundwater;
-- sediment deposition rates and patterns;
-- changes in groundwater levels;
-- water losses from reservoirs and canals due to seepage, leakages and other reasons;
-- reuse of waste water;
-- efficient use of water in various sectors for better water conservation, and
-- status of eutrophication of the reservoir and the river.

The water quality of surface and groundwater should be monitored once in a month for the certain. The ground water levels should be monitored in the wells of the command area. the data collected by Central Ground Water Board can also be utilised. The project authorities on the basis of this data can prepare ground water table contours and specify the area under the risk of waterlogging.

In addition to above quality of waste water discharged into surface water should be monitored at all points. The minimum number of points recommended are:

i) upstream site where water is clean;
ii) stream just below source of pollution or dilution;

iii) the location where stream is at worst condition due to a specific source i.e. bottom of oxygen sag curve; and

iv) stream at a appoint midway between bottom of oxygen sag curve and recovery of oxygen level.

From time to time the measurement for seepage and evaporation must be done as per IS : 8414 and 6939 respectively.

(b) WATER SUPPLY AND SANITATION

-- quality of available drinking water, and reliability of the supply at appropriate locations during each season;

-- quality and extent of waste water treatment and its disposal, and

-- percentage of population having sanitary facilities, and their potential impacts on ground water quality.

(c) WATERLOGGING AND DRAINAGE

-- water table fluctuations in command area;

-- areas under the risk of waterlogging;

-- status of implementation of drainage system as planned;

-- effectiveness of drainage system installed;

-- salinity of drainage water;

-- other water quality aspects of drainage water; and

-- rational reuse of drainage water.

All these should be carried our for each check. The drained water should be analysed for SAR, EC, Residual Sodium Carbonate, Nitrogen, Phosphorus and Pesticides.

(d) SOIL AND APPRAISAL OF SOIL SALINITY

The nutrient content of soils namely Nitrogen (as N), Phosphorus as P_2O_5) and Potassium (as K_2O) as well as micronutrients namely Zinc (Zn), Copper (Cu), Iron (Fe), Manganese (Mn) should be monitored at the beginning of each cropping season and the general dose of application of fertilizers; both chemical as well as organic shall be calculated depending on the nutritional status of the soil and the type of crop grown. This will facilitate to:

-- maintenance and/or enhancement of soil fertility in the project area;
-- efficiency of structural and agronomic measures taken for soil conservation and erosion control, and
-- monitoring of pH, ESP, EC of soil before and after the cropping season.

(e) LAND USE

-- changes in land use from one category to another should be monitored once in five year through satellite imageries;
-- impacts on soil and water due to changes in land use practices, and
-- changes in land-holding patterns by usual observations followed if necessary, by perusal of records.

(f) IMPACTS OF AGRO-CHEMICALS

In addition to the data collected in 9.2 and 9.5 the following items should be monitored:

-- quantity of agro-chemicals being used in the project area;
-- changes in water quality due to extensive use of agro-chemicals in the irrigated areas, and
-- health of workers who apply agrochemical.

(g) ECOLOGY

The ecological parameters should be monitored on regulations after the completion of the project and implementation of ecological management plans and should cover the following:

-- changes in forest cover of the area, and implementation of afforestation programme for optimal watershed management;
-- changes in Biodiversity of the area;
-- changes in migration of aquatic and terrestrial species, and
-- growth of aquatic weeds.

(h) FISHERIES

The items to be mentioned are:

-- total fish catch and their composition;
-- changes in species composition, if any;
-- water quality in the reservoir and river in terms of their potential impact on fish life;
-- fish kill, if any, and the period of occurrence (season), cause and extent of such fish kills;
-- impacts of hydraulic structures on fish migration spewing;
-- changes in employment opportunities due to fishing related activities like recreation, and
-- adequacy of facilities for storing, transporting and marketing facilities.

(i) SPREAD OF AQUATIC WEEDS

-- identification of weed species and their type;
-- identification of problems areas, and
-- effectiveness of weed control measures.

(j) PUBLIC HEALTH

-- status of public health due to increased food production and income;
-- changes in incidence of water related diseases, including vector borne diseases;
-- control of breeding places of vectors especially in resettlement sites;
-- changes in incidence of water-borne disease;
-- effectiveness of all control measures for better public health, and
-- adequancy of medical facilities.

(k) OTHER SOCIO-ECONOMIC FACTORS

-- changes in population in the project area;
-- changes in income levels and employment opportunities;
-- changes in income distribution;
-- changes in types of energy used, and
-- status of landless labourers.

12. Safety of dams is an important aspect. Therefore, CWC has evolved dam safety inspection guidelines in 1987 which will ensure that any distress to any dam is noticed well in time and remedial measures are taken. The Dam Safety Organisations in CWC and states have to continuously keep working and monitoring the safety of dams. The capacity building & instrumentation for dams is a critical aspect for ensuring the dam safety.

13. Research needs as identified need to be studied and solution found for their effective utilisation.

14. The sedimentation and Hydrological flows in different rivers and reservoirs on them should be a continuous study. Mathematical models need to be developed to predict possible impact on Dam Safety or its function. This requires a better network of monitoring stations.

15. RIS is to be taken seriously. Continuous monitoring through a speacialised agency is always helpful to avoid major disasters.

16. There should be continuous consultation process with local population & farmers on all aspects of operation and monitoring of dam. All the information should be made public

from time to time. All good suggestions need to be incorporated in operation and monitoring aspects.

17. Personnels involved with operation should be trained to react to the emergency situations such as passage of extreme floods, malfunctioning of the project spillway, fire in the project control room, power station or access tunnel, abnormal seepage or settlement of the dam or spillway, or damage to any of the major project structures due to land slides. Onsite and off-site contingency plan with regular drills should be in place. The guidelines issued by CWC in 1979 are not exhaustive and never practiced.

18. Review of safety aspects by DSO's could lead to design changes e.g., additional spillway capacity, installation of additional instrumentation, installation of warning system etc.

19. In virtually every project it is seen that the primary costs are being paid by the very poor and the tribals, while the benefits are flowing to big farmers and the urban elite. Those who are displaced by such projects are usually too poor and politically weak to safe guard their own interests. However, when it comes to finding suitable alternative land for the displaced, the government seems to lack the political will required to ensure that good cultivable lands are made available. To resettle families to be dislocated by the Sardar Sarovar Project, the Maharashtra government is now insisting that forest land be made available. In most projects, current and past, the authorities have been unwilling to make the rich farmers who would benefit from the project, share some of these benefits with those who would be unrooted.

20. Epideomological studies to be carried out in command area of the irrigation projects to identify health impacts such as vector born diseases, pesticide poisoning and other water related ailments . This is an area which has been totally neglected in India. Therefore, this requires integration of irrigation and health sector.

21. Numerous cases have been recorded of floods which have been made worse because dam operators held back water while the reservoir was filling, and then, when the rains kept on coming, had to open their spillways to maximum capacity to prevent their dam from being

overtopped. India's Hirakud Dam was first justified in the name of flood control, yet extreme floods in the Mahanadi Delta between 1960 were three times more frequent than before Hirakud was built. In September 1980, hundreds of people were killed after releases from Hirakud breached downstream embankments. Orissa's Chief Minister admitted that panic releases of water from Hirakud were responsible for much of the devastation but argued that if the water had not been discharged as quickly as possible the dam could have failed.

Many other deadly floods have been blamed on emergency releases from Indian dams. In 1978 nearly 65,000 people in the Punjab were made homeless by floods exacerbated by forced discharges from Bhakra Dam. A member of a committee set up to investigate the floods admitted that Bhakra had been close to being overtopped and stated that `If something had happened to the dam, then half of Punjab would have been inundated'. Eleven years later a similar flood occurred. This time an official from the agency in charge of managing Bhakra argued that if the water had not been discharged 'one of the worst catastrophes in living memory' would have occurred. The art of controlled flood need to be incorporated in operation of dams in very effective manner.

22. Conjunctive use of the ground water has to be planned to reduce shortage of water in tail end and tackle waterlogging problem. These exists a great potential for such an exercise.

23. Cost recovery to support O&M is an important instrument. Only Government of A.P. have taken a major step in this direction by introducing threefold increase in water charges for the year 1996/97. This has resulted in water charges/ha. being about 76% of estimated O&M requirement. However, revenue collection efficiency remaining low at about 64%, meaning that actual revenue collection amounted to about 49% of required O&M needs. Therefore, revenue collection need to be stepped up. WUA'S could be fully utilised for this purpose. The many so collected should directly be given to O&M agency.

Investment cost sharing should be introduced for investments in irrigation. This could be contributed by WUA'S. Its importance goes beyond fiscal objectives as such cost-sharing is important to a demand - led programme, a sense of ownership and sustainability of infrastructure.

Additional measures to improve collection would involve computerised billing, transferring collection responsibilities to private agencies or WUA'S and possible contracting out of billing and collections.

Other users like municipalities, industries, power plants, fisheries should be billed by CADA. Assessment modalities and collection should commence as soon as possible. This would certainly pose problems to Government as most of the Municipalities and electricity board is in financial mess. The recovery from them would mean that either Government subsidises this or Municipalities enhance the water tariff and house taxes. All this will require a great political will on part of the Government as subsidisation would not be possible for Government in view of poor financial situation of the States due to populist measures adopted by the Governments. Increasingly political parties are resorting to such populist schemes to retain themselves in power. Their short sighted approach is leading State Governments into almost financial bankruptcy. Its a crime on society by the leaders resorting to such measures and amounts to misuse of Government resources for their personal vested interests. All such actions of such parties their leaders required Judicial intervention and enactment of legislation banning such decisions.

24. As funds availability is a serious problem, expenditure prioritization becomes essential. The approach to prioritisation should be as follows:

The priorities should be as follows:

- First and foremost, the expenditure requirements for <u>maintenance</u> must be assured to halt the decline of infrastructure, and the procedures to achieve this, involving both budgetary allocation and social changes to transfer responsibility to the users have been described above.
- Nearly similar emphasis must be given to the massive needs for <u>rehabilitation</u> of infrastructure.
- Smaller requirements are required to underpin a drive to raise the quality of sector management through <u>investment in human capital and technology;</u> training, computerisation, communications equipment, study tours consultancies.

- Modernization of irrigation and drainage is also needed on massive scale. Existing infrastructure, even after the first round of minimum rehabilitation, must then be brought to higher levels of productivity. Techniques to achieve this should be piloted, and then brought to a state-wide campaign for progressive WUA managed schemes, phasing in as the first-round rehabilitation program is completed.
- Construction activities must be sharply focused, based on rigorous cost-benefit analysis and realistic estimation of public resources and social development objectives. Instead of spreading investment over a large array of projects, with investment levels on each insufficient to bring them to completion, investment should be concentrated on a few viable investments with near - term completion as an objective.
- Selection of viable scheme completions as first priority within available public funds.

25. A capacity building exercise for CADA set up is necessary through training in unfamiliar skills, improving performance and meet new challenges. The approach could be as follows:

- A major training programme for officials and farmers to support the irrigation management transfer, O&M and rehabilitation programmes.

- Creation of linkages and partnership approach between key Government agencies (e.g. CADA, Agriculture and the District Administrations) and between Government farmers.

- Selected capacity creation in key areas: human resources development and training capacity, monitoring and evaluation, MIS, Communications equipment and computerisation.

26. There is need to develop a comprehensive CAD policy covering all aspects of irrigation, such as technical, agricultural and co-operation, environmental and sociological. Central Government should frame only broad parameters and delegate the powers to the State Government for further elaboration. The policies of Localisation, cropping pattern etc. also need to be integrated in comprehensive policy. Instead of co-ercive approach in Localisation, approach of incentives and disincentives be developed by the Government by alternative

policies like support prices for the farm produce, pricing for irrigation water, allocation of water per unit area etc.

27. The systems performance in terms of making water reach in terms of planned distribution has to be improved. This would require seepage losses to be reduced, desilting of distributories to be carriedout periodically and mechanical control devices to be fully operational.

28. Localisation and OFD (On Field Development) need to be monitored seriously in order to ensure higher productivity and optimum use of the water. This would also ensure the better supply to tail end farmers. This would require political will at the Government level and implementation of statutory provisions of CAD Act of 1984.

29. Back up support for agricultural operations in Command Area is very essential for any irrigation scheme to be successful. Arrangements of timely institutional credit, good quality seed, right kind and doses of pesticides and fertilizers and availability of sufficient water at specified times are all essential factors for better production. In modernised agricultural farming systems, absence of any of the above factors can spell doom to farmers. Agricultural extension services are predominantly responsible for these activities, but most of the time are found wanting in their task.

30. An operational plan need to be developed for each project on a three tier basis. The first one for the main canal, determining the water flow along its length and discharges into each distributory level. The second time of plan has to be at each distributory level. The third at the minor level along each distributory or sub-distributory. The details of operational plan need to be well published.

31. Farmers participation is an effective tool to drive maximum benefit of the project. It is now well recognised that farmers can play an active role in water management from much higher level than outlet. WUA’^{S} are felt essential at each level viz. minor distributory and project level, WUA’^{S} formed so far have not become active. Therefore, social scientists, in

the initial years need to utilised for this purpose for guiding and helping the WUA'S in making their role more effective.

32. Re-Organisation of the CADA institutional set up becomes necessary in view of the findings in earlier chapter. There is need to activate state level councils and make their functions statutory and also define the frequency of their meetings. No-doubt this will require a great amount of political will on part of the Government. The CADA be made an autonomous statutory body with complete back-up in terms of technical, scientific and field manpower as well as finances to discharge their duties effectively. The O&M and agriculture unit with field staff also should be part of CADA under unified command of the administrator, who normally should be senior Government functionary with necessary exposure to project management and District Administration. The decisions of the council should be final and all departments should be bound to implement them within seven days. Farmers representation on to the Council & CADA also need to be considered. CADA in turn should decentralise and delegate its authorities to its designated agencies within the Command Area. This will ensure smoother functioning and better co-ordination. An MIS should be developed to monitor the progress of implementation of the decisions and to ensure corrective action on time.

33. Continuous monitoring of factors such as waterlogging, salinisation, water quality, ground water, pesticide poisoning, agricultural yields, incidence of diseases siltation of reservoir etc. should form an integral part of CADA. This certainly would require development of mechanisms to undertake them and also find resources to finance. It is certain that regular budgets of the respective departments, combined with appropriate water tariff and pollution tax on to industries and municipal bodies, can generate enough resources to undertake such an exercise. This would also require Computerisation of CADA Organisation with system of data archiving and retrieving.

34. Conventional water treatment processes of the kind used in India, based on chemical co-ogulation and filtration or biological slow sand filtration, have little capacity to remove water soluble pesticides. Processes involving the use of Ozone, advanced oxidation, and activated Carbon, provide means of upgrading conventional treatment plants to remove

pesticides. These processes are extremely expensive and energy intensive and not appropriate to Indian situation.

According to Sri S.D.Badrinath, a water treatment expert in India, “flocculation may remove 5-10 percent of the pesticide traces in raw water. But chlorination may oxidise the various pesticide traces and eventually aggravate the situation”. He suggests some cheaper options for Indian situation. There are:

- Capping the existing sand filter with bituminous charcoal or coconut shells. The filters would have to be extended by nearly 40%. The advantage of this method is that the pesticide traces would get absorbed for an additional cost of only 10%.

- Increasing by adding Powdered Activated Carbon (PAC) or bentonite clay with doses varying from 25-30 mg/l. The costs would go up by 20%. The use of granular activated Carbon, on the other hand, would double the present cost of water treatment.

- Raw water tanks can be protected by claybeds. But this system would be difficult to operate in monsoons when claybeds may get washed away.

Many experts in west believe that protecting the catchment from chemical contamination is possibly the best and cheapest way to get rid of pesticides and industrial toxins in drinking water. May be organic pesticide’s use and scientific land and water management practices are more effective. This requires a massive awareness and training programme to the farmers by CADA agencies.

35. State Governments need to evolve a formal policy on environmental protection. There should be a statutory requirement for all the development departments to follow it. This will also help in avoiding political pressures for wrong projects. The enforcement agencies like Pollution Control Boards need to be strengthened and allowed a free hand to discharge their duties fearlessly and impartially. The statutory status of Pollution Control Boards (PCB) should be respected by the Government or a sitting judge of High Court should be made the Chairman of the PCB. This would eliminate any Control or influence of the Government on the functioning of PCB’s. An approach of this kind will help in eliminating environmental costs in such projects.

36. Senior Government decision makers are unaware of the seriousness of environmental implications of large dams. There should be a public awareness programme and training programme for sensitisation of the bureaucracy.

37. Enhancement of water resources can be achieved through harvesting of rainfall and runoff, increased ground water recharge, conjunctive use of surface and ground water and recycling and reuse of water.

38. With reference on DSPAR project of World Bank following recommendations are worth considering as per the evaluation mission of the bank

- Inadequate definition of the time frame and sequencing of analysis and design of remedial works to ensure hydrological safety caused delays to accumulate, leading to inaction in some important cases. Hydrological work to collate data for rainstorms, to define Probable Maximum Precipitation (PMP) and unit hydrographs and to agree revised design floods takes a long time, two to four years. Therefore it would be important for any such future possible project that either (a) the project be well prepared by completing hydrological estimates and have agreed designs for remedial works to be carried out in the first two years of the project approved by the financial and administrative authorities in the state before appraisal or (b) a design phase of at least two years should be incorporated in the project from the outset. Highly technical components, such as flood forecasting using telemetry, risk analysis and some other specialised areas must be thoroughly prepared before appraisal, using international consultants where necessary.
- It is important to prioritise investments according to appropriate risk analysis and not on limited parameters such as dam height and reservoir volume. In those countries where they exist at all, guidelines relating to risk analysis are still at an early stage and even ICOLD has yet to finalise such guidelines. In India, draft guidelines, prepared under the project with the help of a consultant, are being finalised by CWC through the National Committee on Dam Safety. When finalised these guidelines should enable prioritisation of dams needing remedial measures, albeit initially with limited risk analysis.
- Resettlement, rehabilitation and environmental issues, resulting from changes to reservoir water levels due to modified designs associated with DSP works, should be addressed at the design stage.
- The engineering of dams is a specialised subject. Training in dam safety should be institutionalised so that all engineers in WRD/ID receive dam safety training routinely or a separate cadre of dam engineers should be established.
- The flood-forecasting component would have been improved had it included the determination and evaluation of reservoir operating strategy during floods and the impact of this strategy of dam safety. This should also be linked to economic analysis of costs and benefits of alternative operating rules. The lack of quantification of potential benefits (such as the reduction of damages and losses downstream of the dam) has resulted in the importance of dam safety not being fully appreciated by those who prioritise the allocation of funds.
- There is a need to define rule curves for reservoir gate operation during floods to ensure more effective control of flood attenuation to optimise downstream benefits and to deliver benefits from flood forecasting. Such rules should be prominently displayed in the operating room.
- There is a need for much more review and analysis of historical events to understand why floods in excess of previous designs were passed without undue damage or difficulty and as an aid to formation of future operational strategies.
- The hydrology of dams on the same river should be considered as a whole in flood analysis, and in operational analysis.
- The use of new instrumentation requires training of the personnel concerned. Where practicable, the supply and installation contract should include a component for on-the-job training.

- Interstate dams having water disputes should be excluded from the project unless both parties are participating states.
- Revisions to O&M manuals should take account of dam safety plans (including operation, maintenance, instrumentation and emergency preparedness), which should be drafted early in the rehabilitation process and progressively updated during implementation. Problems identified with the remedial works should be reflected in revision to O&M manuals. Operation instructions should incorporate design assumptions, particularly concerning expected erosion downstream of spillway energy dissipaters. Results of periodical readings of monitoring instruments installed in the dams should be analysed and the findings should be incorporated in the annual O&M programme, if necessary.

Appendix – 1

MAJOR PEOPLE'S PROTESTS AGAINST DAMS AND HYDROELECTRIC PROJECTS IN INDIA AND THEIR IMPACTS

Year since struggle become active	**13. Year when struggl e ended**	Name of dam/hydel project, the river on which it is proposed	Major issues of protest	Details of displacement	De
1973		Koel Kara on the rivers Koel and Kara, Bihar	1. Displacement of tribals 2. Loss of invaluable forest and farmland, which not only has economic utility, but also historical, spiritual, sentimen-tal importance.	1,256 villages will be affected, displacing 16,350 families most of them being tribals.	Sub whi the
1978		Tehri on the Bhagirathi river Uttar Pradesh.	1. Environmental damage to the fragile Himalayan ecosystem. 2. Arbitrary ousting and disloca-tion of local people. 3. Corruption charges against officials looking into rehabili-tation. 4. Safety of the dam in earth-quake-prone.	1. Submergence of the culturally important Tehri town and nearby satellite villages (23 completely and 72 partially along the river and 21 for the New Tehri township). 2. Displacement of 70,000 people from their ancestral lands.	1. c f p 2. t E s d t
1978		Subarnarekha multipur-pose project on the Subrnarekha river, Bihar	1. Rehabilitation and resettle-ment 2. Displacement of tribals from ancestral lands, forests	1. Displacement of 120,000 people in Bihar and Orissa 2. Submergence of 17,603 hectares (ha) by Chandil dam, affecting 6,773 families in 120 villages.	1. 8 E 4 2. f g f M
1979	1998	Bedthi on the Bedthi river	1. Adverse environmental impact 2. Rehabilitation of tribals	Around 4,000 tribals would be displaced.	A incl fore

Year since struggle become active	**14. Year when struggle ended**	Name of dam/hydel project, the river on which it is proposed	Major issues of protest	Details of displacement	De
1982		Vishnuprayag on Alakananda river	1. Adverse environmental impact 2. Dislocation.	Dislocation around Joshimath township	Plar sen end
	1983	Silent Valley hydel project in Silent Valley forest range.	Adverse environmental impact, few people would have been displaced.		1. c u 2. V
1983	1984	Bhopalpatnam – Inchampalli on the Indravati river, Maharashtra	1. Rehabilitation and resettlement 2. Displacement and subsequent loss of livelihood and a unique lifestyle, which is relatively free of the money economy. 3. Adverse environmental impact	1. Destruction of 200 villages, residence of India's ancient people – the Gonds, displacing almost 75,000 2. Tribals might have to relocate on higher ground leading to degradation of forests, accelerate erosion and silting of rivers.	1. o 1 g 4 d tl E o 2. T N
1985		Sardar Sarovar Project on the Narmada river, Gujarat.	Rehabilitation and resettlement	Displacement of 400,000 people (also includes people whose land are not submerged and hence are not classified as project affected people)	The inur in Mal Pra prir thir

Year since struggle become active	15. Year when struggle ended	Name of dam/hydel project, the river on which it is proposed	Major issues of protest	Details of displacement	De
1986	1994	Bodhghat on the Indravati river Madhya Pradesh	Adverse environmental impact	Displacement of 10,000 local tribals – Murias, Madias, Halbas, and Hill-Marias.	1. f n f w a n n I 2. l b
1990		Mansi-Wakal project on the rivers Mansi and Wakal, Rajasthan.	1. Rehabilitation and resettlement 2. People were provided with no information 3. Need for water downstream	1. Submergence of 23 villages in a 4,000 ha. area, affecting nearly 7,000 people. 2. Water crisis downstream to almost 30 villages since the river-based wells are bound to dry up	1. 2.
1992		Maheswar on the Narmada river, Madhya Pradesh	Rehabilitation and resettlement	1. Over 400,000 people will be affected in 500 villages. 2. 13 villages will be submersed, affecting 11,821 people.	80,(whi be s

Year since struggle become active	**16. Year when struggle ended**	Name of dam/hydel project, the river on which it is proposed	Major issues of protest	Details of displacement	De
1993		Bisalpur at the confluence of the rivers Banas and Dai rivers, Rajasthan.	1. Rehabilitation and resettlement policy 2. No clearance was granted to the project.	Displacement of 70,000 people consisting of Keer, Kewat and Bhil tribals.	Sub lan of cro pro Incr whi of stip
1994		Bargi on the Narmada river, Madhya Pradesh	Rehabilitation and resettlement	Submergence of 162 villages	Tho esti 80,8 rese eve ha.
1994-1995	1997	Rathong Chu project on the Rathong River, Sikkim	1. The dam site is considered scared. 2. Hidden sacred lakes would be destroyed.	About a dozen families displaced and a dozen more to be indirectly affected by the canal.	Var alpi rea eve whi

Source : Citizens Fifth Report, 1999 – Centre for Science & Environment, New Delhi.

LESSONS LEARNT

The lessons learnt by the people, the activists, the government and the funding agencies from the anti-dam struggles that have taken place in India can be summarised as follows:

1. People learnt about their rights:

Apart from the high tide of environment consciousness that it triggered off, the anti-dam movement has been successful in giving a direction to the political rights of the hitherto neglected voices – that of the Dalits, tribals and other indigenous peoples, who face the adverse consequences of development projects.

2. Need for integrated planning stressed:

One of the most important lessons of the two-decade old anti-dam struggle is that there is no integrated, holistic, multi-disciplinary planning *ab initio* (from the beginning). While planning and implementing dam projects, there is no consultation with the people affected and no sharing of information.

3. Change in government attitude:

United Front Government which recognised the need for transparency, and set up two independent committees, in consultation with the movement's leaders, to review the safety, rehabilitation and environment aspects.

4. Construction work should not precede rehabilitation:

5. Government considers rehabilitation policy:

Government responses manifest themselves in a shift in policy and legislative measures. For example, the Land Acquisition Act of 1984, which provided only cash compensation for the oustees, was amended in 1984 to facilitate "land-for-land" compensation policy. The R&R policies of the governments of Gujarat, Maharashtra and Madhya Pradesh, namely, the states affected by the Sardar Sarovar project, were an improvement on the award of the Narmada Water

Dispute Tribunal (NWDT) in several aspects. Landless agricultural labourers were not to get any kind of compensation as per the NWDT award, but Madhya Pradesh offered a cash compensation of Rs.29,000 to them while Gujarat and Maharashtra offered 2 ha. and 1 ha. of land, respectively. Experts feel that the government, over the years, has softened its stance on big dams.

Appendix – 2

Statewise distribution of large dams (as of May 1994)

India / State	Number of dams completed							Year of construction not available	Number of dams under construction	Total
	Up to 1900	1901-50	1951-60	1961-70	1971-80	1981-89	1990 and beyond			
India	**42**	**251**	**234**	**461**	**1,190**	**1,066**	**116**	**236**	**695**	**4,291**
Andhra Pradesh	3	24	16	20	18	18	2	57	26	184
Arunachal Pradesh	0	0	0	0	0	0	0	0	1	1
Assam	0	0	0	0	0	2	0	0	1	3
Bihar	1	0	12	6	14	23	0	5	33	94
Gujarat	5	47	60	76	133	131	8	6	71	537
Goa	0	0	0	0	1	4	0	0	2	7
Haryana	0	0	0	0	0	0	0	0	0	0
Himachal Pradesh	0	0	0	1	2	1	0	0	1	5
Jammu and Kashmir	0	0	0	0	2	2	0	3	2	9
Karnataka	6	16	11	35	45	40	0	35	28	216
Kerala	0	1	4	16	7	5	0	5	16	54
Madhya Pradesh	1	86	39	81	256	397	77	9	147	1,093
Maharashtra	16	35	25	146	589	324	10	84	300	1,529
Manipur	0	0	0	0	1	0	0	1	3	5
Meghalaya	0	0	1	3	2	0	0	0	1	7
Mizoram	0	0	0	0	0	0	0	0	0	0

Nagaland	0	0	0	0	0	0	0	0	0	0
Orissa	0	2	3	5	48	72	0	1	18	149
Punjab	0	0	1	0	0	0	0	0	1	2
Rajasthan	5	5	30	19	20	16	0	27	4	126
Sikkim	0	0	0	0	0	0	0	0	0	0
Tamil Nadu	1	10	10	24	27	9	0	3	13	97
Tripura	0	0	0	0	1	0	0	0	0	1
Uttar Pradesh	4	25	21	28	19	12	14	0	22	145
West Bengal	0	0	1	1	5	10	5	0	5	27

Source: Anon 1996, *Water and Related Statistics*, Information System Directorate, Performance Overview and Management Improvement Organisation, Central Water Commission, Government of India, New Delhi, p.39

Appendix – 3

Details of select large dams – 1991

Name of dam	State	Year of completion	Type of dam	Height above lowest foundation (metres)	Reservoir capacity (cubic metres)
Balimela	Orissa	1977	Earth dam	--	36,100
Bhakra	Himachal Pradesh	1963	Gravity dam	226	96,210
Chamera	Himachal Pradesh	Under construction	Gravity dam	141	--
Cheruthoni	Kerala	1976	Gravity dam	138	--
Damanganga	Gujarat	Under construction	Earth dam, gravity dam	--	--
Dantiwada	Gujarat	1965	Earth dam	--	--
Highway's dam	Tamil Nadu	1979	Earth dams, gravity dam	--	--
Hirakud	Orissa	1957	Gravity dam, earth dam	--	81,050
Idamalayar	Kerala	1986	Gravity dam	100	--
Idukki	Kerala	1974	Arch dam	169	--
Kakki	Kerala	1966	Gravity dam	110	--
Kangsavati Kumari	West Bengal	1965	Earth dam	--	--
Kerjan (lower)	Gujarat	Under construction	Gravity dam	100	--
Kishau	Uttar Pradesh	Under construction	Earth dam, rockfill dam	253	--
Koyna (Shivaji Sagar)	Maharashtra	1961	Gravity dam	103	--
Kulamavu	Kerala	1977	Gravity dam	100	--
Lakhwar	Uttar Pradesh	Under construction	Gravity dam	192	--
Linganna Makki (Sharavathy project)	Karnataka	1965	Earth dam, gravity dam	--	44,180
Machhanala	Gujarat	1982	Gravity dam, earth dam	--	--
Nagarjuna Sagar	Andhra Pradesh	1974	Earth dam, gravity dam	125	115,550
Paithon (Jayakwadi Stage-I)	Maharashtra	1976	Earth dam, gravity dam	--	--
Pong dam (Beas project)	Himachal Pradesh	1974	Earth dam	133	85,700
Ramganga	Uttar Pradesh	1978	Earth dam	128	--
Salal	Jammu &	Under	Gravity dam, rockfill	118	--

	Kashmir	construction	dam		
Sardar Sarovar	Gujarat	Under construction	Gravity dam	163	95,000
Sholayar	Tamil Nadu	1972	Earth dam, gravity dam	105	--
Srisailam hydroelectric project	Andhra Pradesh	1984	Gravity dam	143	87,220
Supa (Mahanadi project reservoir)	Karnataka	Under construction	Gravity dam	101	--
Tehri	Uttar Pradesh	Under construction	Earth dam, rockfill dam	261	35,400
Tenu Ghat	Bihar	1973	Earth dam	--	--
Thein dam (Ranjit Sagar)	Punjab	Under construction	Earth dam	160	32,800
Ukai	Gujarat	1972	Earth dam, gravity dam	--	85,110
Warna	Maharashtra	Under construction	Earth dam, gravity dam	--	--

Source: Anon 1991, *Some Typical Dams of India,* Publication No.219, Central Board of Irrigation and Power, New Delhi, pp 47-48.

Appendix – 4

Statewise and riverwise distribution of large dam

State	Name of river	Name of dam
Andhra Pradesh	Godavari	Sriram Sagar dam
	Koddam (Tributary of Godavari)	Koddam dam
	Krishna	Nagarjuna Sagar dam
	Krishna	Srisailam hydroelectric project
	Machkund	Jalaput dam
	Sileru	Forebay dam
Bihar	Badua	Badua reservoir
	Barakar	Maithon dam
	Barakar	Tilaiya dam
	Chandan	Chandan reservoir
	Damodar	Panchet hill dam
	Damodar	Tenughat dam
	Konar	Konar dam
	Subarnarekha	Getalsud dam
Gujarat	Banas	Dantiwada dam
	Machhundri	Machhundri irrigation scheme
	Mahi	Kadana reservoir
	Raval	Raval irrigation scheme
	Sabarmati	Dharoi dam
	Sakra	Tapar dam
	Shetrunji	Shetrunji irrigation scheme
	Tapi	Ukai dam
Himachal Pradesh	Beas	Beas dam at Pong
	Beas	Pandhoh dam
	Sutlej	Bhakra dam
Karnataka	Arkavally and Kumudwathy	Chamarajasagar dam
	Bhadra	Bhadra reservoir
	Ghataprabha	Hidkal dam
	Harangi	Harangi reservoir
	Kabini	Kabini dam
	Krishna	Narayanpur dam

State	Name of river	Name of dam
	Main Cauvery	Krishnarajasagar dam
	Malaprabha	Indira Gandhi dam
	Sharavathy	Linganamakki dam
	Talakalale	Talakalale dam
	Tungabhadra	Tungabhadra dam
	Vedavati	Vani Vilasa Sagar dam
Kerala	Ayalar	Pothundy dam
	Karuvannur	Peechi dam
	Malampuzha	Malampuzha dam
	Neyyar	Neyyar dam
	Periyar	Idukki dam
	Wadakkancherry	Vazhani dam
Madhya Pradesh	Barna	Barna dam
	Chambal	Gandhi Sagar dam
	Mahanadi	Mahanadi reservoir project
	Tawa	Tawa dam
Maharashtra	Ambi	Tanaji Sagar dam
	Aner	Aner dam
	Bagh	Sirpur dam
	Bhagawati	Radhanagari dam
	Boladwadi Stream	Kolkewadi dam
	Garvi	Itiadoh dam
	Godavari	Paithan dam
	Kadwa	Karanjwan dam
	Katepurna	Kotepurna dam
	Koyna	Koyna dam
	Krishna	Dhom dam
	Mula	Mula dam
	Mutha	Khadakwasla dam
	Nira	Vir dam
	Nirguna	Nirguna dam
	Pawna	Pawna dam
	Pench	Kamthikhairy dam

State	Name of river	Name of dam
	Pravara	Wilson dam
	Purna	Sidheshwar dam
	Purna	Yeldari dam
	Pus	Pus dam
	Waghadi	Waghadi dam
	Wuna	Kanholi dam
	Yelwandi	Bhatghar dam
Orissa	Kolab	Upper Kolab dam
	Machkund	Balimela dam
	Mahanadi	Hirakud dam
Rajasthan	Chambal	Jawahar Sagar dam
	Chambal	Rana Pratap Sagar dam
	Gomti	Jaisamand tank
Tamil Nadu	Aliyar	Upper Aliyar dam
	Amaravati	Amaravathi dam
	Avalanche Stream	Avalanche dam
	Bhavani	Lower Bhavani dam
	Bhavani	Upper Bhavani dam
	Cauvery	Mettur (Stanley) dam
	Emerald	Emerald dam
	Gatanandi	Gatanandi dam
	Karuppanadhi	Karuppanadhi dam
	Kodayar	Kodayar dam I
	Kodayar	Kadayar dam II
	Kodayar	Peechiparai dam
	Kundah	Kundapalam dam
	Manimuthar	Manimuthar dam
	Mukurthi	Mukurthi dam
	Nirar	Lower Nirar dam
	Palar	Thirumurthi dam
	Palar-Porandalar	Palar Parandalar dam
	Paralayar	Perunchani dam
	Parambikulam	Parambikulam dam

State	Name of river	Name of dam
	Parappalar	Parappalar dam
	Parson's Valley Stream	Parson's valley dam
	Pegumbahalla	Pegumbahalla dam
	Periyar	Periyar dam
	Pannaiyar	Sathanur dam
	Porthimund Stream	Porthimund dam
	Ramanadhi	Ramanadhi dam
	Sandy Nullah Stream	Sandy Nullah dam
	Sholayar	Sholayar dam
	Thambraparani	Thambraparani dam
	Tributary of Karampuzha	Wester catchment No.2 dam
	Vaigai	Vaigai dam
	Varahapallam West	West Varahapallam dam
Uttar Pradesh	Betwa	Matatila dam
	Bhagirathi	Maneri Bhali hydro electric project (stage 1)
	Ramganga	Ramganga dam
	Rihand	Obra dam
	Rihand	Rihand dam
	Tons	Ichari dam
West Bengal	Kangsabati and Kumari	Kangsabati-Kumari dam
	Mayurakshi	Massanjore dam

Source : Anon 1987, *Large Dams in India*, Publication No.197, Vol. I, Central Board of Irrigation and Power New Delhi.

Appendix – 5

Government investment in different plan periods in major / multipurpose and medium projects (Rs. in crores)

Plan Periods	Investment	Investment at the 1996-97 constant prices
First Plan (1951-56)	376.24	7,803.42
Second Plan (1956-61)	380.00	6,013.98
Third Plan (1961-66)	576.00	6,674.84
Annual Plans (1966-69)	429.81	3,943.90
Fourth Plans (1969-74)	1,242.30	7,976.41
Fifth Plan (1974-78)	2,516.18	12,519.42
Annual Plans (1978-80)	2,078.58	7,949.67
Sixth Plan (1980-85)	7,368.83	19,625.50
Seventh Plan (1985-90)	11,107.29	21,207.15
Annual Plans (1990-92)	5,459.15	8,125.60
Eighth (1992-97	21,071.87	31,057.63
16.1.1 Total	**52,606.25**	**132,897.52**

Source : Anon 1998, Planning Commission, Yojana Bhavan, New Delhi, *Personal Communication*

Appendix – 6

List of the Projects selected by Environmental Monitoring Committee for Monitoring

ANDHRA PRADESH

1. Singur Irrigation project
2. Nagarjuna Sagar Tail Pond Reservoir at 21.65 km. From Dam
3. Jurala Multipurpose project
4. Telugu Ganga Project

ASSAM

1. Puthimari Project

BIHAR

1. Auranga Dam
2. Punasi Reservoir Scheme
3. Sone Canal Modernisation Project
4. North Keol Reservoir
5. Subernarekha Multipurpose Project

GOA

1. Mandavi Irrigation Project

GUJARAT

1. Janakari Reservoir Project
2. Watrak Reservoir Project
3. Goma Reservoir Project, Ani and Men Irrigation Project
4. Sipu Reservoir Project
5. Ukai Kakarapar Project
6. Hydroplus Fuse Gate on Wanakbori Weir (Mahi Stage-I)

HARYANA

1. Western Yamuna Canal
2. Hathnikund Barrage
3. Remodelling of Diversion Drain No.8

HIMACHAL PRADESH

1. Bbhabha
2. Baner
3. Uhl Stage-III
4. Kol Dam

KARNATAKA

1. Kalindi Stage-II
2. Bennithora Irrigation Project
3. Upper Krishna Stage-I

KERALA

1. Idamalayar Irrigation Project
2. Kallada Irrigation Project (Power Generation Scheme)
3. Lower Periyar
4. Malampuzha Irrigation Project (Power Generation Scheme)
5. Kuttiyadi Augmentation Scheme
6. Muvattupuzha Irrigation Project (Power Generation Scheme)
7. Chimoni Irrigation Projecct (Power Generation Scheme)
8. Muvattupuzha Valley Project

MADHYA PRADESH

1. Bodhghat
2. Hasdo bango Multipurpose Unit-II
3. Mahi Project
4. Mahan Project
5. Mahi subsidiary Dam
6. Man river Project
7. Kolar Project
8. Bansagar Project
9. Pench diversion project
10. Jobat Multipurpose Project
11. Pench Valley Group Water Supply
12. Haseo Bango Project
13. Mahanadi Reservoir Project

MAHARASHTRA

1. Nandur Madhmeshwar Project
2. Lower Tima Project
3. Lower Dudhna Project
4. Dudhganga Irrigation Revised
5. Lower Penganga Project
6. Talamba Irrigation Project
7. Ghatghar Pumped Storage
8. Wan River Project
9. Gosikhud
10. Bawanthadi Multipurpose Project
11. Koyna Krishna Irrigation Scheme

ORISSA

1. Smakoi Irrigation Project
2. Mahanadi Irrigation Project
3. Upper Indravati Multipurpose Project
4. Naraj Barrage Project

PUNJAB

1. Thein Dam Multipurpose Project
2. Anandpur Sahim Hydropower Project
3. Punjab Irrigation Project Linking of Water Courses

RAJASTHAN

1. Suratgarh Branch Canal
2. Gosunda Irrigation Project
3. Nohar Irrigation Project
4. Som Kamla Amba Irrigation Project
5. Indira Gandhi Feeder Ganga Canal Link Channel
6. Jaisamand Modernisation Project

TAMIL NADU

1. Upper Amravati Kumber Unit
2. Modernisation of Cauvery Delta System

TRIPURA

1. Gumti Uprating Scheme

UTTAR PRADESH

1. Vishnu Prayat
2. Kanhar Project
3. Rajghat Dam Project
4. Pathrai Dam Project
5. Lakhwar Vyasi Project
6. Dhauliganga Project
7. Modernisation of Upper Ganga Canal

MANIPUR

1. Khuga Multipurpose Project

Environmental Safeguards Stipulated for the Projects being Monitored closely by the Environmental Monitoring Committee (EMC), CWC

Sl. No.	**Name of Project (State)**	**Environmental Safeguards stipulated**
1.	2.	3.
1.	Telugu Ganga Project (Andhra Pradesh)	1. Action Plan in respect of rehabilitation and command area development will be implemented before filling up of the reservoir commences. 2. Adequate fuel arrangements for the labourers. 3. Restoration of construction areas. 4. Special arrangements should be made restricting the entry of the labourers into the nearby forest areas for avoiding damage to the vegetation cover. 5. To prevent spread of communicable diseases screening the work force at the dam site should be done. 6. Special Monitoring Committee must be constituted with experts from various fields such as ecology, environment, watershed management, soil conservation, sociology etc. to oversee the effective preparation and implementation of various environmental action plans and detailed master plan must be prepared.
2.	Singur Project (Andhra Pradesh)	1. Green belt to be created along the periphery of the reservoir. 2. To preserve important archeological sites and sculptures. 3. Rehabilitation Master Plan to be prepared avoiding location of new settlements on reservoir periphery. 4. Land-user in the catchment to be converted to forestry wherever possible.
3.	Auranga Reservoir (Bihar)	1. All project activities should be confined to the right bank of the river Auranga, the left bank should not be disturbed. 2. The impact of the submergences caused by Auranga dam has to be considered along the submergence to be caused by Kutku dam over North Koel river for which the infrastructure development has already been completed. 3. No reserve forest area should be released for rehabilitation. 4. Compensatory afforestation to be implemented in the project area. 5. Census of wildlife should be undertaken before the commencement of the dam and again after their completion. 6. Adequate fuel arrangements for the labourers. 7. Anti-poaching measures to be strictly enforced. 8. A Monitoring Committee to be constituted.

Sl. No.	Name of Project (State)	Environmental Safeguards stipulated
1.	2.	3.
4.	North Koel Reservoir (Bihar)	1. Adequate fuel wood. 2. Master plan for rehabilitation 3. Green belt 500 m in forest and 50 m. in non-forest be created around reservoir periphery. 4. Monitoring committee be constituted. 5. Buffer Zone of Palamau National Park be extended upto river Koel. 6. Equivalent forest submerged be transferred from Revenue land for afforestation. 7. Restoration of construction areas.
5.	Subernarekha Multipurpose Project (Bihar)	1. Adequate fuel arrangement 2. Restoration of construction area. 3. Preparation of Landuse map for identifying critically eroded areas. 4. Area equivalent to submergence to be acquired for afforestation (in command area) 5. Clear falling to be restricted to 2 m below the FRL. 6. A green belt of 50 m wide be created around reservoir 7. Detailed study to be undertaken by State PCB to ensure water quality of Jamshedpur 8. Master Plan for rehabilitation 9. A CAD Project be prepared and implemented 10. Constitution of Monitoring Committee.
6.	Sipu Reservoir (Gujarat)	1. Adequate afforestation Project catchment 2. Pisciculture in the reservoir to be ensured 3. Proper drainage facilities in the command area 4. Monitoring of Committee to be constituted.
7.	Upper Krishna Project (Stage-I Karnataka)	1. Adequate fuel wood 2. Restoration of the construction areas. 3. Detailed studies/surveys as assured by the project authorities will be carried out for preparing action plans with clear-cut time schedule 4. Action Plan in respect of catchment area treatment, command area development and rehabilitation will be drawn and the implementation completed before commencing the project. 5. To prevent spread of communicable diseases screening of the work force at the site be done and a network of health centres created.

Sl. No.	Name of Project (State)	Environmental Safeguards stipulated
1.	2.	3.
8.	Muvattupuzha Valley (Kerala)	1. Afforestation in the project areas and water conductor system. 2. Restoration of the construction areas. 3. Adequate fuel arrangement for the labourers 4. Extensive afforestation both in catchment and command 5. Master Plan for rehabilitation of oustees 6. Critically eroded areas in the catchment should be surveyed and detail programme of soil conservation prepared.
9.	Hasdeo Bango Project (Madhya Pradesh)	1. Adequate fuel arrangement. 2. Detailed plan for rehabilitation 3. Provision for anti-malarial measures be made 4. Immediate measures for siltation in the catchment area 5. Adqequate measures to avoid subsidence 6. Monitoring Committee to be constituted by the project authority.
10.	Mahanadi Reservoir (Madhya Pradesh)	1. Restoration of the project construction area. 2. Afforestation in the project areas and water conductor system 3. Adequate fuel wood for the labourers. 4. No forest area be utilised for the project work or its appurtenant works.
11.	Kolar Project (Madhya Pradesh)	1. Adequate fuel arrangements for labourers 2. Restoration of construction areas 3. Compensatory afforestation 4. Green belt around the reservoir periphery be created 5. Project for CAD be implemented.
12.	Khuga Multipurpose Project (Manipur)	1. Restoration of the project construction area. 2. Adeuate fuel wood for the labourers
13.	Wan Reservoir (Maharashtra)	1. Adequate fuel arrangements for the labourers 2. Restoration of the construction areas 3. Afforestation in the project area and water conductor system 4. No forest are be utilised for any work 5. Command area development to be implemented 6. A Monitoring Group to be constituted by the project authorities.

Sl. No.	Name of Project (State)	Environmental Safeguards stipulated
1.	2.	3.
14.	Bhwanthadi Project (Maharashtra)	1. Restoration of the construction areas 2. Adequate fuel arrangement for the labourers and fuel depots 3. Detailed studies/surveys to be completed by December 1989. Action Plan of catchment area treatment covering both forest and non-forest areas and rehabilitation plan should be drawn as to be executed and completed before filling up of the reservoir. Rehabilitation master Plan to be reviewed for land compensation to prevent spread of communicable diseases. A network health centres to be provided for initial screening and subsequent health care of the people.
15.	Upper Indracvati (Orissa)	1. Adequate fuel wood for the labourers 2. Restoration of the construction areas 3. Detailed Master Plan for rehabilitation 4. Adequate step to prevent incidence of malaria and also water and soil-borne diseases. 5. Compensatory afforestation in the catchment. 6. Enforcement of anti-poaching laws. 7. Monitoring groups to be constituted.
16.	Modernisation of Upper Ganga Canal (Uttar Pradesh)	1. Adequate fuel arrangements. 2. Restoration of construction areas 3. Green belt of trees be created on both sides of the canal 4. Mechanism for continuous monitoring of the ground water level and measures to be adopted to avoid waterlogging and salinity be evolved. 5. Cropping pattern suggested be strictly implemented 6. Multidisciplinary Monitoring Committee be constitude.
17	Rajghat Dam Project (Uttar Pradesh)	1. Adequate fuel arrangements for the labourers. 2. Restoration of construction areas 3. Extensive afforestation in the catchment area is imperative to arrest soil erosion. A 500 m. wide green belt along the periphery of the reservoir should be planted to check the direct impact of sediment flow into the reservoir. 4. Adequate arrangement to prevent the incidence of any endemic health problems due to water/soil-borne diseases. 5. To develop pisciculture in the reservoir. 6. Extensive blasting in road construction preparation is a major cause of land and solid erosion hence adequate precautions for road construction in catchment. 7. Suitable drainage should be provided to prevent salinity and waterlogging by keeping in view the soil structure in the area 8. Monitoring Group be constituted.

Source : Environment Monitoring Committee – Annual Report, 1993-94, CWC.

Fig. – River Basins of India

Source : MOWR, Govt. of India, New Delhi.

Fig. – Status of River Basin Organisations
Source : MOWR, Govt. of India, New Delhi.

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