RIVER BASIN MANAGEMENT:

A CASE STUDY OF NARMADA VALLEY DEVELOPMENT WITH SPECIAL REFERENCE TO THE SARDAR SAROVAR PROJECT IN GUJARAT, INDIA

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River Basin Management: A Case Study of Narmada Valley Development with Special Reference to the Sardar Sarovar Project in Gujarat, India

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ABSTRACT *Intra-basin and inter-basin transfer of water have become a necessity in view of severe regional imbalances in availability of water and drought conditions in India. This paper addresses the fundamental issues of river basin management in a multi-objective framework with a unique case study of Narmada River Valley Development, and demonstrates that the socioeconomic needs of the people override the rest of the working objectives. In inter-state water allocation, even a non-riparian state is considered when looking at the needs of the people. This paper focuses on the Sardar Sarovar Project on the river Narmada and highlights its rehabilitation, environmental and social aspects, and concludes that the project is a lifeline for people in western India.*

River Basin Management

River basin management is an activity that is usually motivated by the need to make a decision on how to develop and use the resources in the basin. This is particularly true since the water availability per unit of catchment area has come to be considered as an index of development. Mathematical planning models can be used to assist those responsible for identifying and analysing the important issues, and for evaluating and choosing the development alternatives that address these issues.

The complexity of planning and managing a river basin calls for an integrated approach consistent with the economic and environmental policies of the country concerned. In view of the several competing and sometimes conflicting demands for water, use of river basin planning models becomes necessary in evaluating the ability of river basin systems to meet the water demands.

Integrated Catchment Management

Integrated catchment management (ICM) may be defined as the coordinated and sustainable use and management of land, water, vegetation and other natural resources on a water catchment basis so as to balance resource utilization and conservation. This approach provides an opportunity to enhance policy, science and community linkages, and to forge meaningful integration between these across the range of priority issues facing the catchment. The strategy leads logically from an agreed broad 'vision' of a sustainable catchment, to long-term goals.

Inter-state Water Resource Apportionment

One of the hurdles in optimizing the water development in river basins is the sharing of water amongst the riparian states. Because of its life-sustaining value, water at times is required to be allocated even to the states not sharing the river basin. Dealing with water disputes calls for determination of the quantity of water available, its allocation amongst the claimant states and regulation and implementation of the ultimate decision. This also necessitates due consideration of other river basins, rather than isolated management of a single basin.

Decisions on such inter-state apportionment are generally guided by three different views. The first view is what is called the *Doctrine of Absolute Territorial Sovereignty* or *Harmon Doctrine*. According to this view, every state has, by virtue of its sovereignty, the right to do what it likes with the waters within its territorial jurisdiction, regardless of any injury that might result to a neighbouring state. The second view is known as the *English Common Law Principle of Riparian Right*. It says that the rights of riparian states should be determined by the common law principle, which applies to individual riparian owners in England. The third view advocated is that of *Equitable apportionment*, which holds that every riparian state is entitled to a fair share of the waters of an inter-state river.

The most satisfactory settlement of inter-state river water disputes is by agreement and once there is such an agreement, that itself furnishes the law governing the several party states until a new agreement is concluded (Indus Commission Report[3]). The same principle is enunciated in a judgement of the International Court of Justice in the Meuse Dispute between Holland and Belgium in 1937.[3]

In India, although in the federal system there are separate legislative powers for the state and central governments, the Indian Constitution aims to curb state legislative powers in the use, distribution or control of water of inter-state rivers. Article 262 of the Indian Constitution[2] recognizes the principle that no state can be permitted to use the waters of an inter-state river so as to cause prejudice to the interests of another riparian state or of a state in the river valley or of the inhabitants thereof (Article 262, Constitution of India).

Under the provision of Article 262, the Parliament of India enacted the Inter-State Water Dispute Act (1956) for adjudication of Inter-State River Water Disputes. This provides for the constitution of an Inter-State Water Dispute Tribunal, headed by a sitting Supreme Court Judge for settlement of any such disputes. The award of the Tribunal is obligatory for all parties and is not liable to judicial review.

Some Emerging Issues

Apart from the inter-state apportionment of water resources, within the geographical boundary of a state, the question of upstream versus downstream benefits of small rivulets and tributaries is also becoming important. Similarly, value differences also influence management. The value of water, land, agriculture, power etc. is a subjective matter and varies from place to place. For example, the drought-prone society facing acute drinking water shortage can never be aiming at water use in swimming pools. Similarly, vegetarian-dominated areas may not be interested in fishery development. An industrially

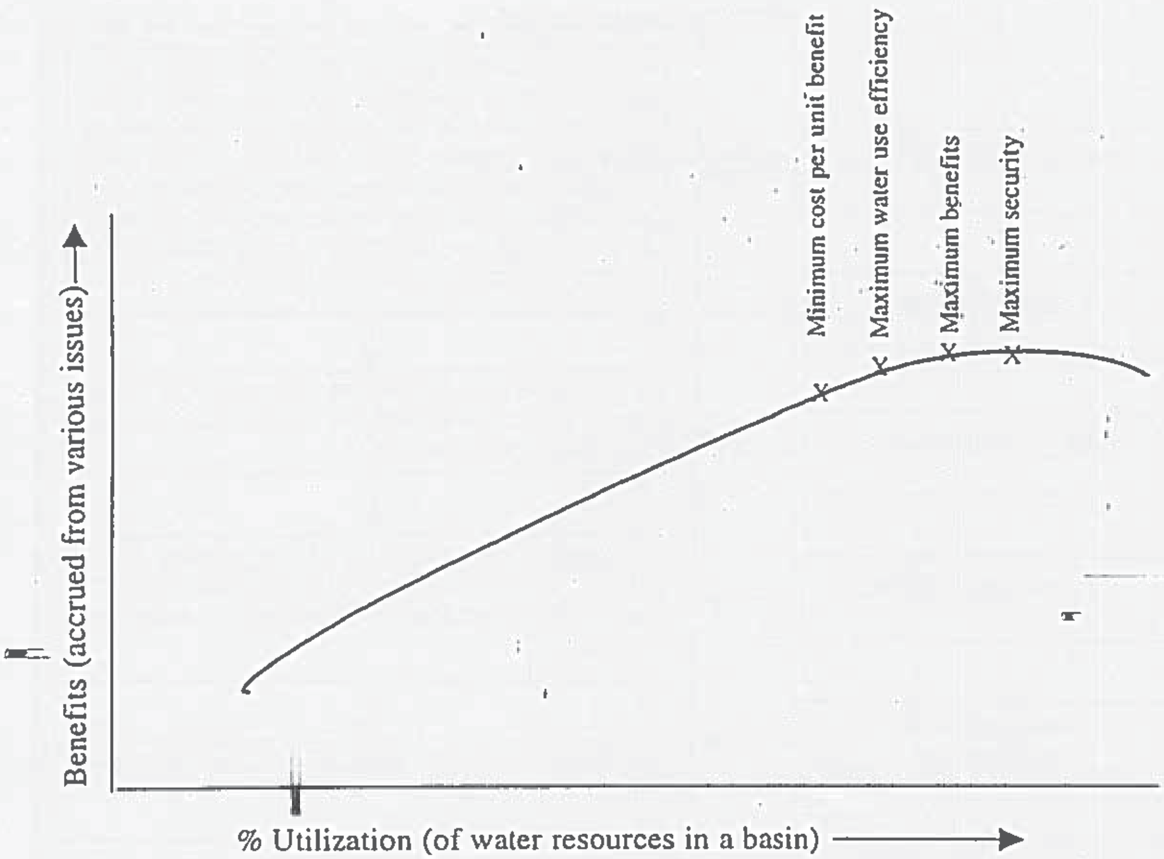

Figure 1. Characteristic curve of objectives.

forward state can appreciate the dire need for power, but others may not. A river basin manager is required to acknowledge such value differences and must know how to work with them.

Broad Objectives of River Basin Management

The basis for decision making is rooted in complex and interrelated physical, economic and social concepts, principles and procedures. These are most likely to be satisfied when the river basin planner adopts as his/her broad objective the formulation of projects and programmes that provide for development and use of water and related land resources for all purposes, both short and long term, which will contribute to maximization of national welfare. The fundamental basis for choice between the alternative courses of action must be economic efficiency. The presence of conflicts is the rule rather than the exception in a complex economy, and these must be resolved by reasonable choices. Before planning, it is, therefore, necessary to define the objectives to be served and to select the criterion that guides the choice between the alternative arrangements for meeting them.

Until relatively recently, economic development considerations dominated the planning process, often with little regard for the effects on social and cultural systems and the natural environment, which is no longer the case. A typical characteristic curve of resource utilization versus benefits achieved indicates that target points corresponding to different single objectives are distinctly different, leading to ambiguity in river basin management (Figure 1). To avoid vagueness

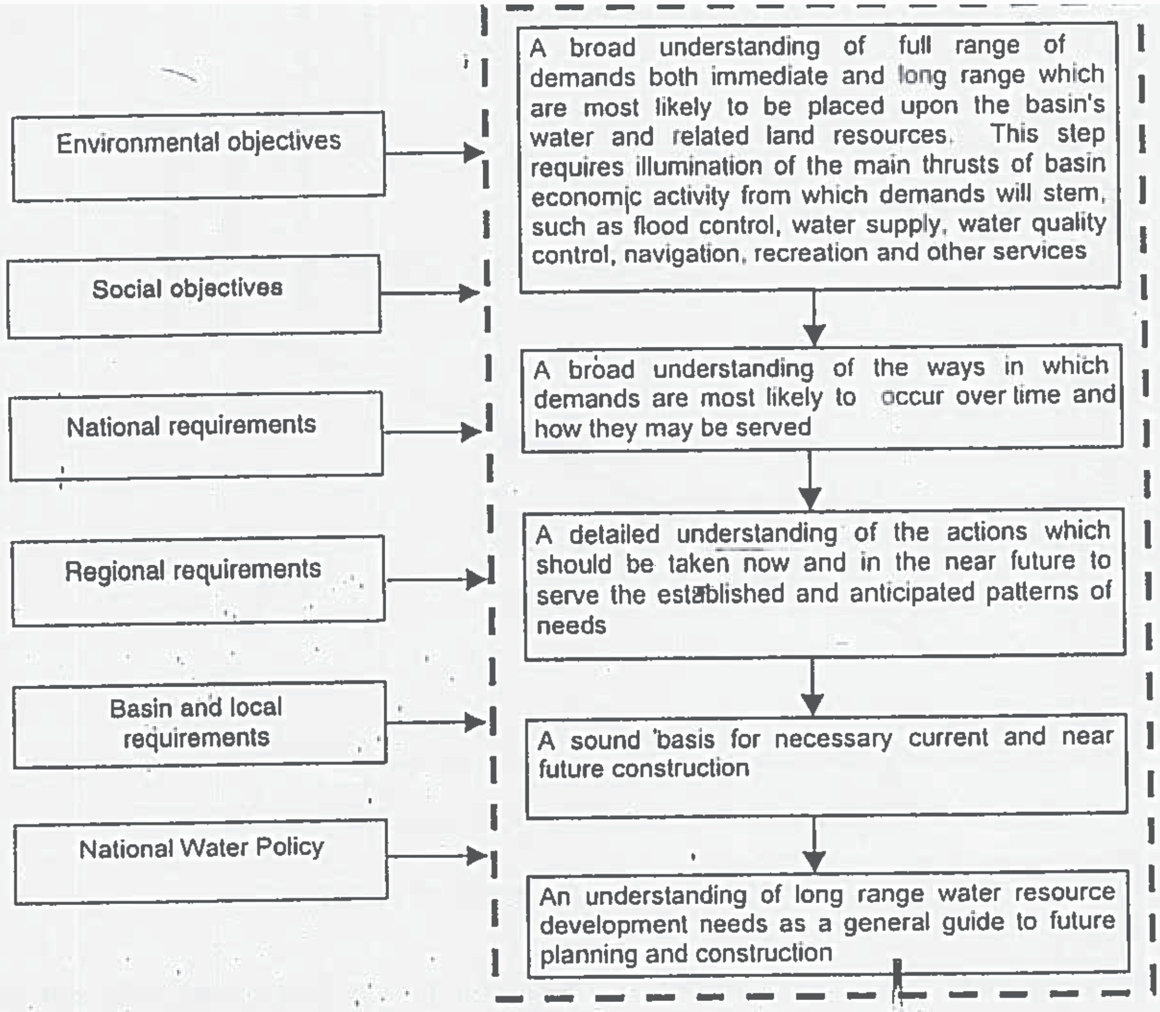

Figure 2. Working objectives of river basin management.

in the definition of system objectives, currently the planning of water resources projects is, formally or informally, multi-objective in nature involving a variety of economic, social and environmental considerations.

Having chosen the broad objectives, the working objectives of river basin management may include environmental and social considerations in addition to national, regional and local requirements (Figure 2).

Approach and Tools

Modelling river basin systems is an approach to determine the size, location and operations of multiple interdependent components, and to obtain an estimate of the tradeoffs between competing water user benefits over time and space. It also forces one to recognize all the assumptions inherent in the river system as a whole as opposed to considering each component separately. Conceptual, physical and mathematical models are used in almost every aspect of water resources development. Hydrologists use them to predict runoff from rainfall, and stream flow from runoff. Agronomists and agricultural engineers use them to predict erosion under different conditions of rainfall, topography and land cover. Sanitary engineers and ecologists use them to predict the quality of streams, lakes and estuaries. Planners, managers and economists use models to help assess the economic, social and environmental impacts among many alternative development and management policies.

Applicability of Models

The number and diversity of models that purport to be 'applicable' to water is somewhat overwhelming to a newcomer (and even to old hands). The question that is commonly asked is: which of these are the best models? There are two answers to this question. None and all. None, in the sense that no model can be expected to accomplish everything implied by general planning objectives, let alone the additional purposes of river basin management. All, considering that anyone or any group thereof could prove useful at some point in the analysis as it/they might be required to help answer particular questions that may (or may not) arise. The 'best model' could be the one that best reflects the essential characteristics of the system for the purpose for which it is used. For some purposes crude models known to be deficient are considerably better than elaborate and all-encompassing formulations of the same system, but with corresponding data requirements that are difficult to satisfy.

Simply having a model and sufficient data is not enough. Modelling wisdom is also required. The modeller must develop a sense of scale regarding the needs of modelling, realistic expectations of data availability, limits of computation equipment, and so on.

A Case Study: Narmada Valley Development

As a case study of river basin management, an important example is Narmada Valley Development with special reference to a multi-purpose inter-state river valley project: the Sardar Sarovar Project. This case study of planning and managing the Narmada river basin is unique in many respects—its size, its potential to quench the thirst of millions of people, its historical background, its meticulous and comprehensive planning based on detailed engineering studies, the great deal of debate on controversial issues, its socioeconomic importance and the tremendous support it has received from the people in the western part of India. It is vitally important from the viewpoint of its impact on the overall development of people in the states of Madhya Pradesh, Gujarat, Maharashtra and Rajasthan.

The Narmada River

The Narmada, the largest west-flowing river of the peninsula, originates near Amarkantak in the Shahdol district of Madhya Pradesh, at an elevation of about 900 m at latitude 22°40′ north and longitude 81°45′ east in the Malikala range. During the long path of 1312 km up to the Gulf of Cambay in the Arabian sea, the river traverses the states of Madhya Pradesh, Maharashtra and Gujarat. The river has 41 tributaries, of which 22 are on the left bank and 19 on the right (Table 1). The mean annual flow of the Narmada river is more than the combined flow of the Ravi, Beas and Sutlej rivers. The Narmada Basin has utilizable water resources per capita per year of 3020 m^3 and therefore has the potential to transform Madhya Pradesh, Gujarat and Southern Rajasthan into a

Table 1. Major tributaries of the Narmada

Name of tributary	Distance of confluence with Narmada from source (km)	Length of tributary (km)	Catchment area (km^2)
Right bank:			
Hiran	463	188	4789
Tendoni	602	117	1631
Barna	605	105	1786
Kelar	1039	101	1346
Man	998	88	1527
Uri	1035	74	1812
Hatni	1075	80	1942
Orsang	1191	101	4077
Left bank:			
Burhner	248	177	4116
Banjar	286	183	3624
Sher	497	129	2900
Shakkar	545	161	2291
Dudhi	574	129	1540
Tawa	676	172	6330
Ganjal	756	88	1929
Chhota-Tawa	829	169	5048
Kundi	943	121	3819
Goi	1038	129	1890
Karjan	1199	93	1489

granary. But current utilization of the Narmada river basin is hardly 10%, making it imperative for the nation to make best use of this water.

The Narmada River Basin

The Narmada Basin extends over an area of 98 796 km^2 and lies between latitudes 21°20′ to 23°45′ north and longitudes 72°32′ to 81°45′ east. Lying in the northern extremity of the Deccan plateau, the basin covers large areas in the states of Madhya Pradesh (85859 km^2) and Gujarat (11 399 km^2) and a comparatively smaller area in Maharashtra (1538 km^2) (Ministry of Irrigation and Power, 1972). The basin has an elongated shape with a maximum length of 953 km from east to west and a maximum width of 234 km from north to south (Figure 3).

Basin Delineation System

A five-stage delineation system, namely Water Resources Region, Basin, Catchment, Subcatchment and Watershed, has been followed. As per the *National Watershed Atlas*, the Narmada basin forms a part of Water Resources Region No. 5, which represents all the drainage flowing into the Arabian Sea. The portion upstream of the Sardar Sarovar Dam is divided into five well-defined physiographic zones (catchments), 16 subcatchments and 116 watersheds. The size of the watersheds varies from about 27 000 ha to 138 000 ha. Of the five catchments,

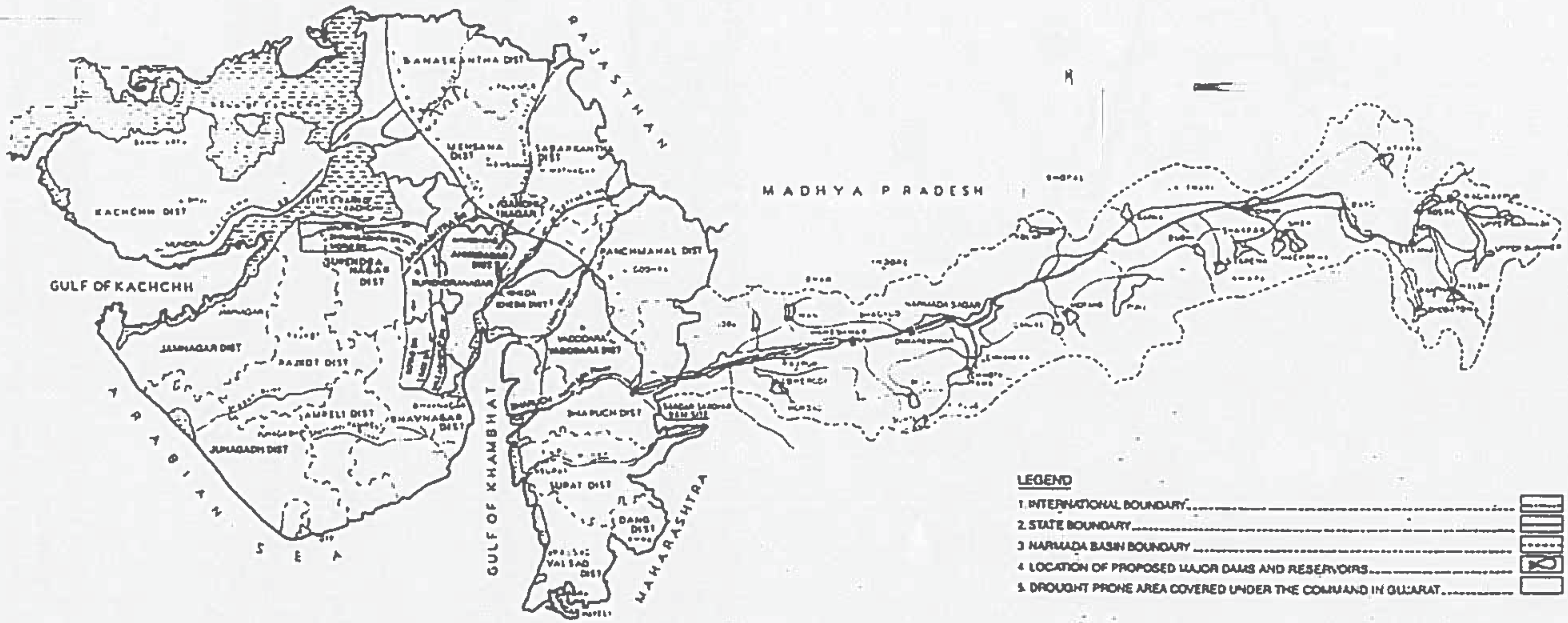

Figure 3. Index map of Narmada Valley. *Note*: International boundaries shown on this map may not be exact.

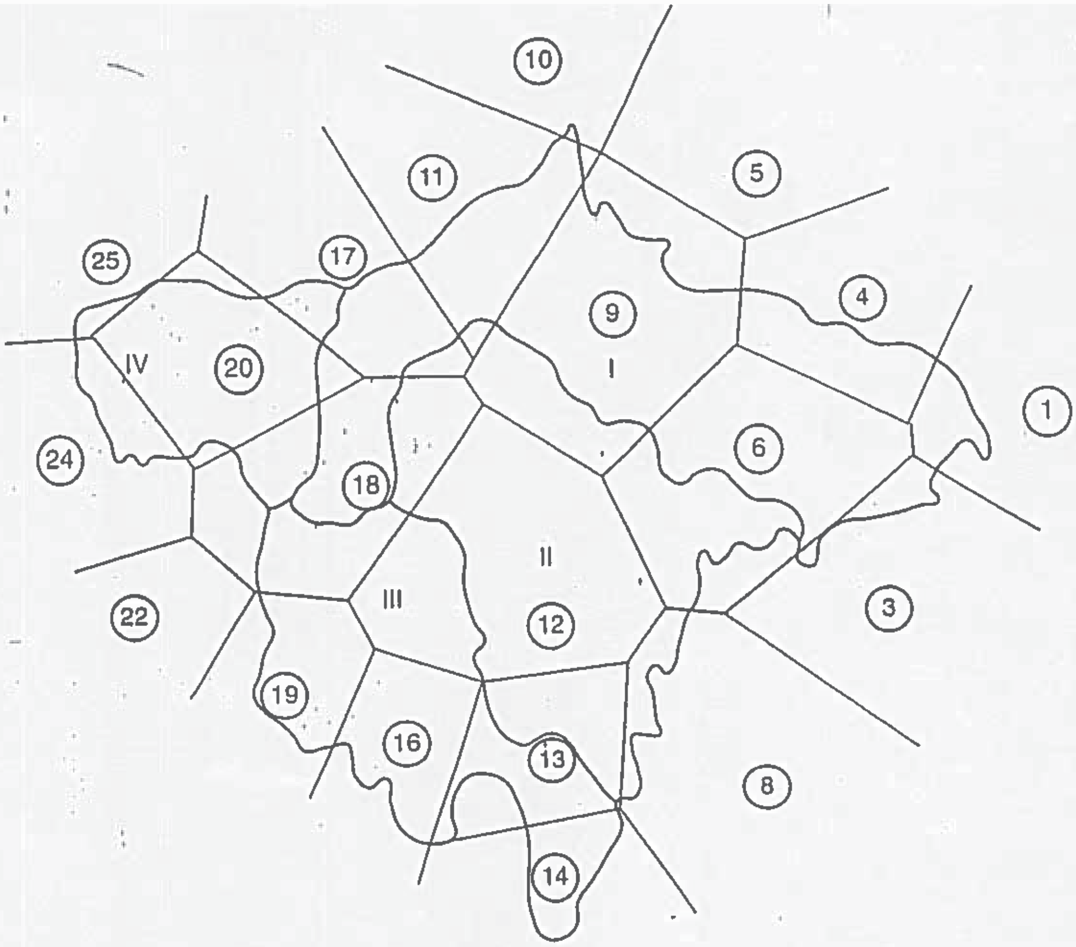

Figure 4. Basin delineation example in the upper Narmada catchment. *Note*: 1, Pendra road. 3, Kharai. 4, Pasaparajgar. 5, Sohagpur. 6, Bajag. 8, Kawardha. 9, Dindori. 10, Umaria. 11, Shahpura. 12, Bahhla. 13, Palhere. 14, Suleteka. 16, Baihar. 17, Niwas. 18, Maadla. 19, Jamasis. 20, Narayanganj. 22, Roomal. 24, Ghansore. 25, Jabalpur.

the Upper Narmada River Catchment is typically subdivided into four subcatchments (Figure 4).

Rainfall in the Basin

The normal annual rainfall for the basin works out at 1178 mm. Nearly 90% of this is received during the five monsoon months from June to October. About 60% is received in the months of July and August (Table 2). From the source to Sardar Sarovar the coefficient of variation (100 times the standard deviation) varies from 19% to 37% (Figure 5).

Co-riparian States

Since the river passes through Madhya Pradesh, Maharashtra and Gujarat, they have obvious rights to Narmada water. In addition to these three states, Rajasthan was also considered as a co-riparian state while planning for the

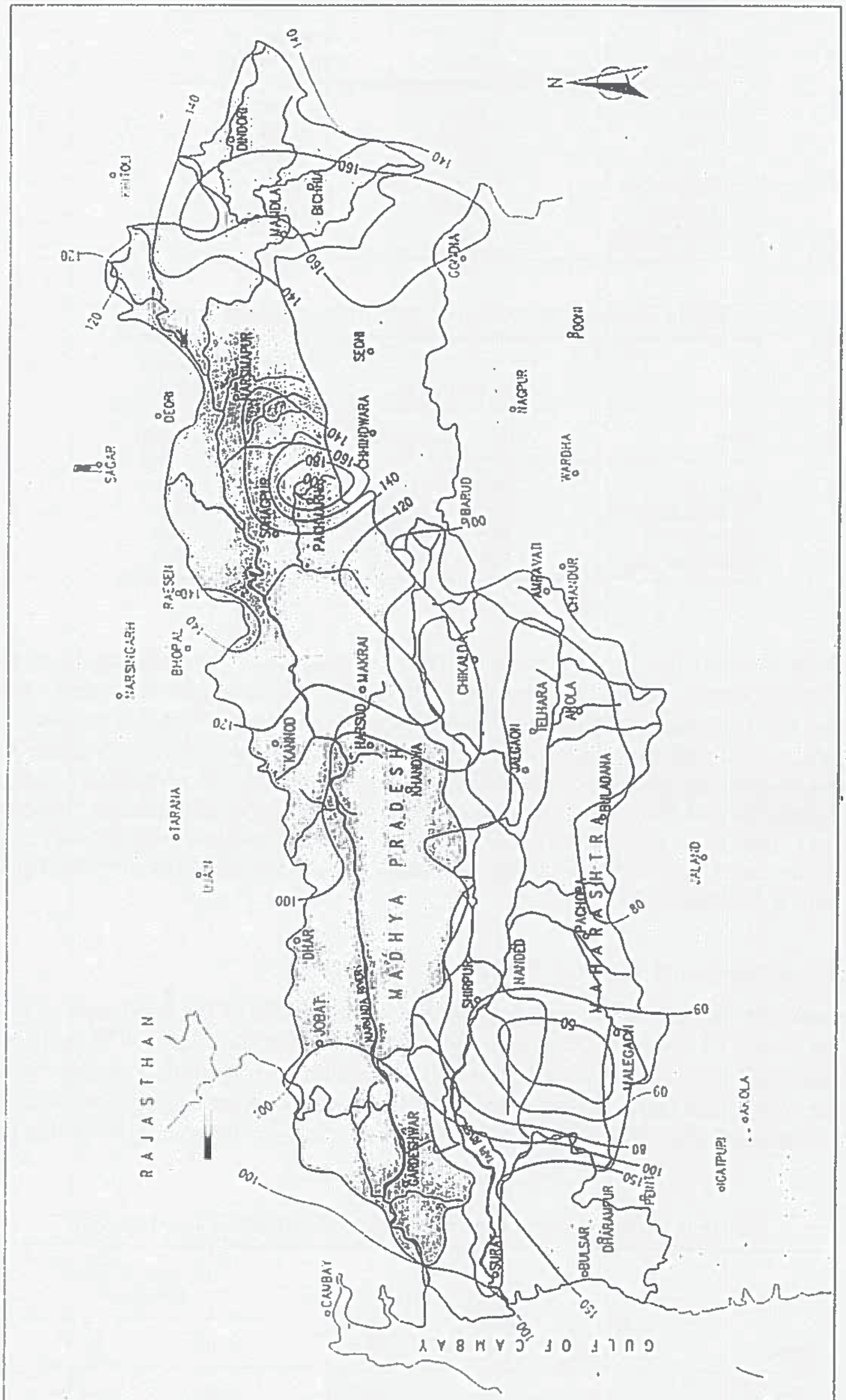

Figure 5. Rainfall in the Narmada basin.

Table 2. Monthly distribution of normal rainfall

Month	Rainfall (mm)	Percentage of annual rainfall
June	152.4	12.97
July	392.4	32.84
August	314.8	26.93
September	199.7	16.77
October	40.6	3.49
Dry months	78.1	7.00

Table 3. Statewise area of arid and semi-arid zones

State	Area (km^2)		Percentage against area of state	
	Arid	Semi-arid	Arid	Semi-arid
Gujarat	62 180	90 520	31.72	46.18
Madhya Pradesh	—	59 470	—	13.41
Maharashtra	1 290	189 580	0.42	61.61
Rajasthan	196 150	121 020	57.31	35.36

terminal dam in the basin, i.e. the Sardar Sarovar dam, considering its water scarcity problems. Statewise, the percentage area of arid and semi-arid zones among the co-riparian states speaks about the dire need for water. The area and population affected by drought in the main two states of Madhya Pradesh and Gujarat reflect the gravity of the problem of water scarcity. For Madhya Pradesh, Maharashtra and Gujarat, the approximate number of inhabitants in the basin (as per the 1991 census) are 12.82, 0.313 and 3.6 million respectively. The statewise land use pattern in the Narmada basin indicates the importance of irrigation (Tables 3, 4, 5, 6).

Status of Forests and Irrigated Agriculture in the Basin

Forests and the cultivable area occupy 32.1% and 59.8% of the total area of basin respectively. Of the total cultivable area of 5.90 million ha, nearly 4.76 million ha are annually cultivated; 4.5% of the cultivated area is irrigated annually. Wheat is the most important irrigated crop in the basin covering nearly 28.1% of the total irrigated area. The cultivable area in the basin is about 3.02% of the total

Table 4. Area and population frequently affected by drought

State	No. of districts	No. of Tehsils/ Talukas	Geographical area (km^2)	Approx. population (millions)	
				1961	1991
Gujarat	11	60	70 700	5.480	10.970
Madhya Pradesh	9	24	40 900	3.070	6.270

Table 5. Population in the Narmada Basin

State	Approx. population (millions)	
	1971	1991
Madhya Pradesh	8.070	12.820
Maharashtra	0.200	0.313
Gujarat	2.330	3.600
Total	10.600	16.733

cultivable area of India. The total cropped area in the basin forms 2.92% of the total cropped area in India.

Brief History of the Narmada Water Dispute

The present scheme of harnessing water resources in the Narmada Basin is an outcome of a great deal of debate that started even before the independence of India. It dates back to 1946, involving the Central Waterways, Irrigation and Navigation Commission (CWINC), Central Water and Power Commission (CWPC), Narmada Water Resources Development Committee and the state governments concerned. The competing, rather conflicting claims by various state governments made river basin planning all the more challenging and a galaxy of technical experts was consulted from time to time.

Table 6. Land-use details in the Narmada Basin (area in km²)

Item	Name of state			Total
	Madhya Pradesh	Maharashtra	Gujarat	
Gross area	85 860	1 540	11 400	98 800
Reporting area	85 840	1 540	11 290	98 670
Area under forests	29 370	690	1 610	31 670
Area not available for cultivation	6 630	50	1 310	7 990
Cultivable area	49 840	800	8 370	59 010
Uncultivated cultivable area	13 030	—	990	14 020
Net area sown	36 810	800	7 380	44 990
Area sown more than once	2 410	70	150	2 630
Total cropped area	39 220	870	80	40 170
Net area irrigated	1 300	50	670	2 020
Gross area irrigated	1 320	80	730	2 140
Percentage of net area sown to cultivable area	74	100	88	262
Percentage of net area irrigated to cultivable area	3	7	8	17
Percentage of net area irrigated to net sown area	4	10	10	23

Source: *Irrigation Commission Report* (1972) Vol. III, Part I, p. 234.

Initial Approach

(1) National interests should have overriding priority. The plan should therefore provide for maximum benefits in respect of irrigation, power generation, flood control, navigation etc., irrespective of state boundaries.
(2) Rights and interests of the state concerned should be fully safeguarded subject to (1) above.
(3) Requirements of irrigation should have priority over those of power, subject to the provision that suitable apportionment of water between irrigation and power may have to be considered, should it be found that with full development of irrigation, power production is unduly affected.
(4) Irrigation should be extended to the maximum area within the physical limits of command, irrespective of state boundaries, subject to the availability of water and, in particular, to the arid areas along the international border with Pakistan in both Gujarat and Rajasthan to encourage sturdy peasants to settle in these border areas (later events have confirmed the imperative need for this).
(5) All available water should be utilized to the maximum extent possible for irrigation and power generation and, when no irrigation is possible, for power generation. The quantity going to waste to the sea without irrigating or generating power should be kept to the unavoidable minimum.

Narmada Water Dispute Tribunal

In spite of earnest efforts on the part of the Government of India for about six years to persuade the contending states to settle the water dispute by negotiation, it was not found possible to arrive at a mutually agreed settlement in regard to the distribution, control and use of the Narmada waters and the height of the Sardar Sarovar Dam. Hence, in October 1969, acting under Section 4 of the Inter-State Water Dispute Act, 1956, the Government of India constituted the Narmada Water Dispute Tribunal (NWDT) for adjudication of the dispute concerning Narmada waters. After detailed deliberations with the party states and consultations with various technical experts, the NWDT declared its final award in 1978.

Assessment of Available Water

The availability of water in the Narmada river has been assessed in the most sophisticated and systematic manner in consultation with the Central Water Commission (CWC), the highest expert technical body in the country, by utilizing rainfall series from 1891 to 1992 and actual river flow series from 1948 to 1992. The actual rainfall series for 45 years is not adequate for planning a mega project with a life of more than 100 years and a large catchment with coefficient of annual flow variations of 0.35 which may need a minimum of 130 years' data on both rainfall and river flows. Therefore, combined actual and hindcast available data for about 100 years have been used as per international practice. Based on this method, 75% dependable availability is 27.22 MAF, at the Sardar Sarovar Project Dam site. Taking the 75% dependable flow as 27 MAF and allowing for evaporation losses (− 4 MAF); regeneration of flow (+ 2 MAF)

Table 7. Design floods, observed highest floods and revised spillways for some projects in Gujarat

River valley projects	Total catchment (km^2)	Spillway design flood as per project report (cumecs)	Highest observed flood (cumecs)	Revised spillway (cumecs)
Ukai	62 225.00	40 917.00	49 490.00	
Kadana	25 206.00	41483.79 (SPF)	33 000.00	49 544.00
Dharoi	5 475.84	11 213.00	14 150.00	21 662.00
Dantiwada	2 862.00	6 654.00	11 950.00	18 123.00
Machhu-II	1 928.71	5 663.00	16 307.00	20 925.00
Damanganga	1 813.00	11 100.00	12 900.00	12 854.00
Machhu-I	735.00	3 313.00	9 340.00	5 947.00
Brahmani	699.00	3 228.00	5 450.00	
Moj	440.00	2 548.00	3 981.00	5 851.00
Patadungri	212.00	878.00	1 177.00	

and effect of carry-over storage (+3 MAF), the net utilizable flow is 28 MAF (34 537.44 MCM).

Experience of other major irrigation projects in the state shows that in most of the projects, a flood greater than the design flood (100 year return period flood or standard project flood) has been observed, consequently requiring revision of the spillway design at a later stage (Table 7). This shows that the assessment of dependable flow has been made on the realistic, conservative side.

Assessment of Water Requirements by the Riparian States

Water Demand Scenario (Irrigation, Domestic and Industrial)

Demands expressed by Madhya Pradesh and Gujarat were vetted by the Tribunal with due consideration of the factors such as areas proposed to be irrigated, climate, effective rainfall available for crops proposed, consumptive use of water, evaporation data evapotranspiration, crop coefficient and other relevant factors, intensity of irrigation suggested, the chemical and physical qualities of soils and their suitability for proposed or modified crop pattern, the present and future crop patterns etc. (Table 8). In the assessment of irrigation demand for Gujarat, the Tribunal also considered the encroachment of command areas of various projects (CCA 0.3 Mha) for the seven other river basins crossed by the Narmada main canal.

Utilizable Inflows from the Rivers en route *in Gujarat*

It was reasonable to adopt the appropriate percentage for each river for a year of 75% dependability and for a flow available for eight days in a canal operation period of 10 days. The quantity of water at 75% dependability from rivers *en route* (Men, Mahi, Watrak, Meshwo, Khari, Sabarmati, Rupen, Banas and rivers of Saurashtra) for use in the Narmada Canal command was thus estimated to be 0.282 MAF.

Table 8. Assessment of water demands

	Irrigation		Domestic and industrial water quantity (MAF)
	CCA (Mha)	Water quantity (MAF)	
Claim of Madhya Pradesh	2.83	23.279	0.800 (for 2021)
Assessment by NWDT	2.72	17.891	1.519 (for 2021)
Claim of Gujarat	2.83	22.020	1.000 (for 2000)
Assessment by NWDT	2.00	10.927	1.059 (for 2021)

Equitable Allocation of Water

Based on the geographical and drainage areas, contribution of water, rainfall, drought area, economic and social needs, population etc., Madhya Pradesh claimed that of the total available water, its share should be 25.9 MAF. In a similar manner, based on the considerations of CCA, proportion of area under less retentive soils, relative water needs etc., Gujarat claimed that it should get 18.56 MAF.

The Tribunal accepted the well-established principle of International Law—'Equality of Right' or 'Equitable Utilization' of the whole course of the inter-state river as laid down in the International Commission on the River Oder Case.[4] The argument stressed by the state of Madhya Pradesh that drainage area, rainfall, contribution of water by each basin state etc. are important factors and should be given equal weight along with other factors mentioned in the Helsinki Rules and also reference by Madhya Pradesh to Articles 2 and 3 of the Helsinki Rules regarding the 'basin state', was rejected by the Tribunal, which accepted the principle that flowing water is 'publici juris' or 'res communis' and not subject to individual ownership. Hence, the following factors were considered for inter-state allocation of water, keeping in mind that executive action by one state should not adversely affect the interests of other states:

(1) the cultivable area of the state;
(2) the population dependent on the waters of the basin in each state;
(3) the drought areas in each state;
(4) the economic needs, including irrigation requirements of each state.

The Tribunal decided that the equitable apportionment of the normal share, the excess waters and also sharing of distress would be in the proportion of 18.25 MAF:9 MAF:0.5 MAF:0.25 MAF respectively for Madhya Pradesh, Gujarat, Rajasthan and Maharashtra.

Period of Operation of the Order of Apportionment

The order of apportionment can be made subject to review at any time after a period of 45 years from the date of the Orders of the Tribunal.

Sharing of Costs and Benefits and Payment for Downstream Benefits

The principle of payment for downstream benefits somewhat similar to that recognized by the United States of America–Colombia Treaty of 1961 applies in the present case. It follows, therefore, that as a matter of law, Madhya Pradesh is entitled to payment for downstream benefits (1) for regulated releases of Narmada waters from the Narmadasagar Project for the benefit of Sardar Sarovar Dam and (2) for flood control benefits, if any, obtained by Gujarat as a result of construction of upstream reservoirs in Madhya Pradesh.

The Tribunal decided that of the net power produced at canal head and river bed powerhouses on any day, the share of Madhya Pradesh will be 57%, that of Maharashtra will be 27% and that of Gujarat will be 16%. In view of this, Madhya Pradesh and Maharashtra shall also pay Gujarat in the same ratio for the capital cost of the power portion of the Sardar Sarovar headworks and for the operation and maintenance costs of the Sardar Sarovar complex each year. Gujarat should credit to Madhya Pradesh each year 17.63% of the expenditure on account of the Narmada Sagar dam.

Various Projects Being Planned within the Narmada Basin

In the Narmada Basin, 31 major, 135 medium and 3000 minor dams are to be constructed on the main river as well as on its tributaries. Upstream of the Sardar Sarovar Dam, all other projects are located within Madhya Pradesh (Table 9, Figure 6). A few important major projects are the Narmada Sagar, Omkareshwar, Maheshwar and Sardar Sarovar (Table 10).

Submergence under Various Projects

Construction of a dam and reservoir inevitably results in submergence of land upstream. The extent of submergence and the land-use pattern in such areas are very important while vetting a project proposal. Sometimes even prospective sites for future projects also become submerged. Maximum harnessing of water resources in a river basin leads to a situation where the cascade effect of reservoirs literally leaves no space for the river to flow freely (Figure 7).

The Narmada Sagar Project and the Tawa Project are likely to submerge 91 348 ha and 22 107 ha of land respectively. The Sardar Sarovar Project, with a total submergence of 37 533 ha (Table 11) renders the percentage of area submerged to area irrigated as low as 1.65%, which is much lower as compared with 4–5% in many projects in India and around the world. The ratio of beneficiaries of the project to affected persons is as high as 100:1.

Environmental Safeguards and Promotional Measures

For every hectare of forest land submerged or diverted for the Sardar Sarovar Project, compensatory afforestation has been carried out on 1 ha of non-forest land and 2 ha of forest land. For every tree clearfelled, 78 trees have already been planted; 0.22 million trees have been planted in project colonies. The entire catchment in Gujarat is being treated. Such catchment area treatment is complete in 27 042 ha of forest area and 1953 ha of non-forest area. A remote sensing study reveals reduction of degraded forests by 22% during 1986–94 (Figure 8).

Table 9. Thirty-one projects envisaged in the Narmada Basin

Sr. No.	Name of project	Catchment area (km^2)
1	Upper Narmada	1 243
2	Raghavpar (Hydel)	6 160
3	Rosa (Hydel)	4 312
4	Upper Burhner	1 606
5	Halon	715
6	Basania (Hydel)	9 583
7A	Dhobatoria	1 854
7B	Matiyari	159
8	Bargi	14 556
9	Ataria	554
10	Chinki	22 414
11	Sher	881
12	Machrewa	470
13	Shakkar	1 479
14	Sitarewa	202
15	Dudhi	808
16	Barna (E)	1 176
17	Tawa (E)	5 983
18	Kolar	508
19	Morand	1 041
20	Ganjal	436
21	Sukta (E)	469
22	Chhota Tawa	969
23	Narmada Sagar	61 642
24	Omkareshwar	64 880
25	Maheshwar	69 184
26	Upper Beda	544
27	Man	690
28	Lower Goi	1 119
30	Jobat	792
31	Sardar Sarovar	88 000

Sardar Sarovar Project: Meeting the Challenges of Development

Emerging Scenario of Water and Energy Needs in Gujarat State

Since its constitution in 1960, the state has faced 12 years of severe drought in last 40 years. The water scarcity problem is becoming more and more acute over the years. The underground water available at an average depth of 700–1000 feet in North Gujarat is contaminated with fluoride, which causes almost incurable fluorosis. The quality of drinking water has become a serious concern for Gujarat. Of 18 028 villages, around 2800 have excessive fluoride, around 800 have excessive nitrate and around 1000 have excessive salinity, causing serious health problems such as incurable dental and skeletal fluorosis, kidney diseases etc. In many areas, rechargeable reservoirs of groundwater were pumped dry long ago. Now, the water which has collected in the deeper recesses of the earth for hundreds of years is being pumped out. Salinity ingress at an alarming rate of 2 km per year poses serious threats to human life in the affected areas.

As at 28 April 1999, aggregate storage in all the 174 major and medium dams

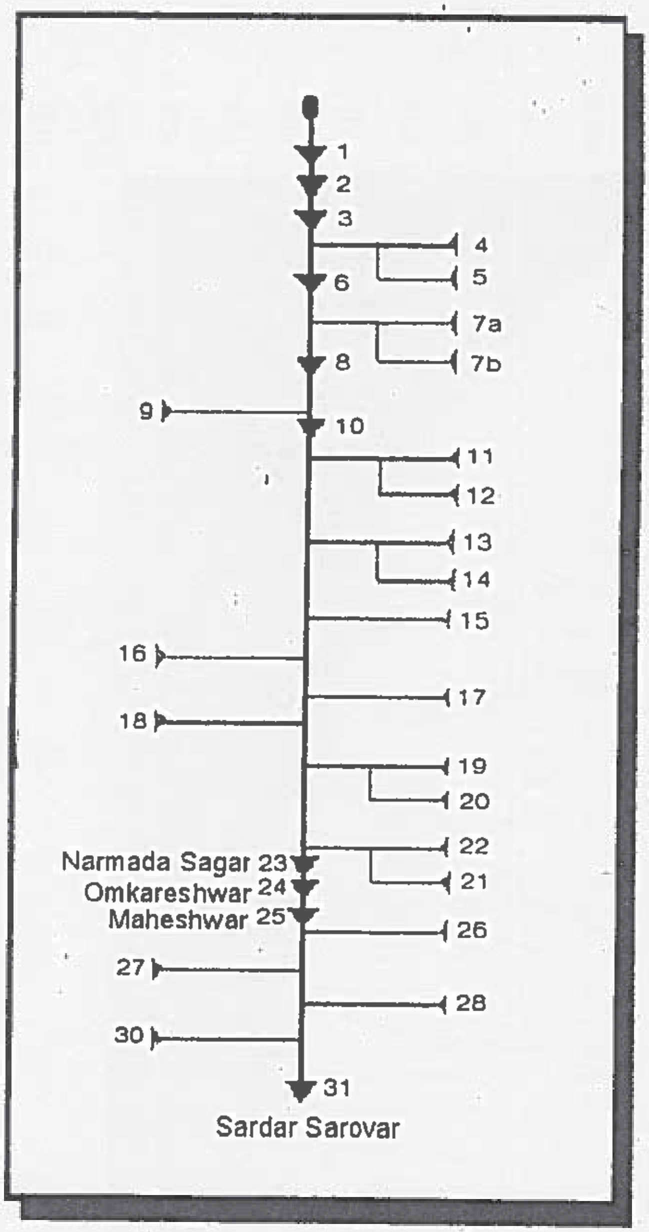

Figure 6. Thirty-one projects envisaged in the Narmada basin.

in the state was less than 25%. Summer had just set in but 104 of 143 dams in Saurashtra, Kutch and North Gujarat (accounting for 13 of 16 districts facing water scarcity) were already dry. The other 39 dams had only sufficient water to last a fortnight.

Thus, 1999 proved to be the worst summer in the last 100 years and water riots began in various parts of the state. Non-availability of replenishment of the reservoirs due to failure of the monsoon resulted in a severe drinking water crisis in major urban centres. In the wake of an impending acute water crisis, curbs were put on drawing water from as many as 17 dams in Rajkot district. More than 2000 villages were supplied with water from tankers. Even the urban centres of the drought-hit areas were under the grip of acute drinking water scarcity and received water for only half an hour on alternate days or once in three or four days.

On the other hand, it is an irony that during a year of acute water shortage,

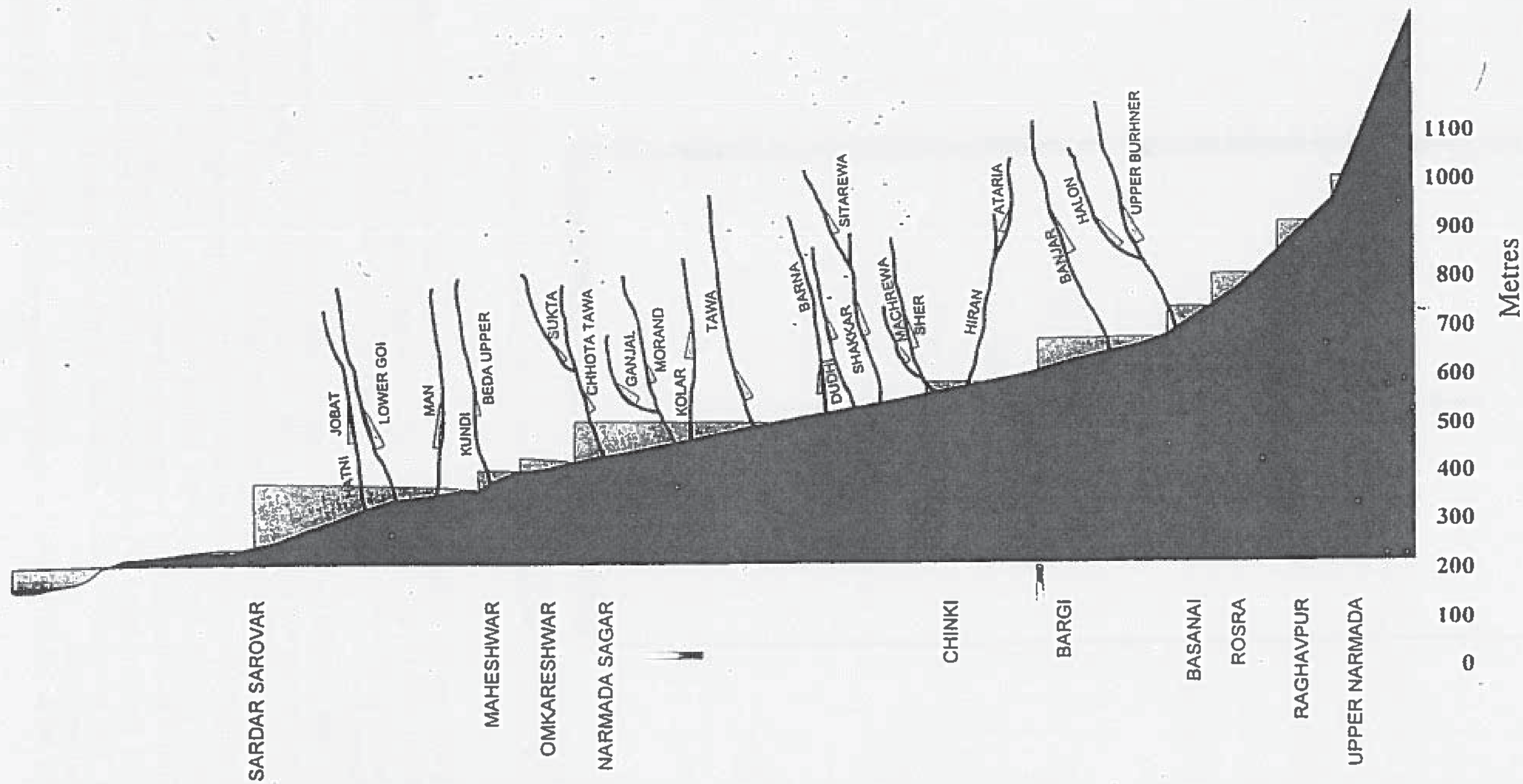

Figure 7. Cascade of submergence in Narmada basin.

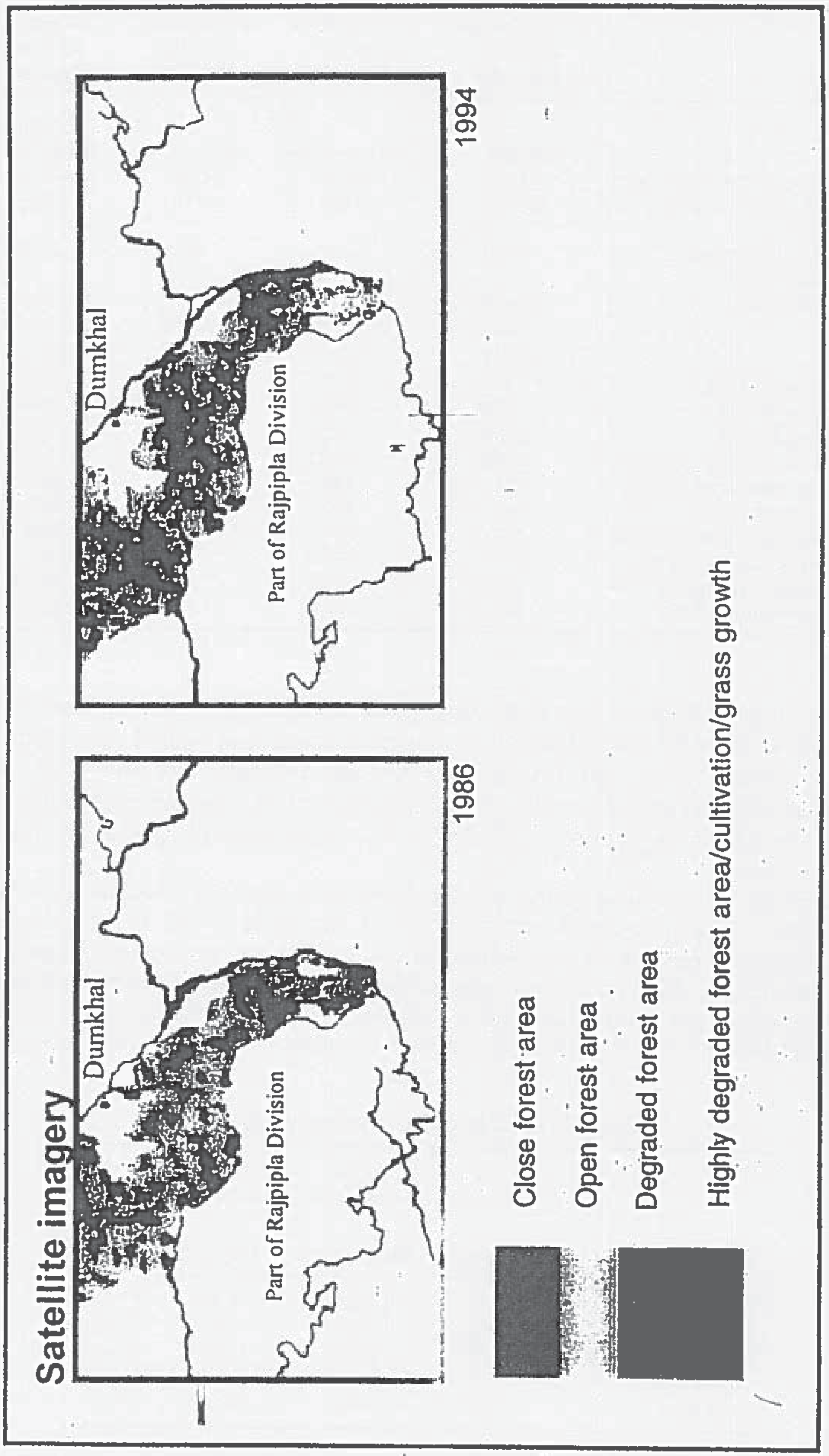

Figure 8. Environmental safeguards and promotional measures in Sardar-Sarovar Project.

Table 10. Salient features of the major [illegible]

Particulars	Narmadasagar (Madhya Pradesh)	Omkareshwar (Madhya Pradesh)	Maheshwar (Madhya Pradesh)	Sardar Sarovar (Gujarat)
Location	Punasa	Omkareshwar	Maheshwar	Navagam (Kevadia)
Distance from river origin (km)	845.000	900.000	941.000	1164.000
Catchment area from river origin (km²)	61 880	64 880	69 184	88 000
Inflow from immediate upstream (MAF)	0.600	1.600	2.268	2.960
Purpose of project	Irrigation and hydro power	Irrigation and hydro power	Hydro power	Irrigation and hydro power
Gross storage (MAF)	9.900	1.216	0.396	7.700
Live storage (MAF)	7.900	0.658	0.023	4.400
Dead storage (MAF)	2.000	0.558	0.375	2.970
Design flood (million cusecs)	2.302	1.542	1.756	3.000
Maximum water level (ft)	864	665	541	460
Full reservoir level (ft)	860	660	534	455
Minimum drawdown level (ft)	804	635	532	363
Average tail water level (ft)	637	534	457	85
Annual irrigation (million ha)	0.250	0.270	—	1.794
Power generation (MW)	832	225	400	1450

in a short spell of about four days during the monsoon (18–21 September 1999), as much as 20 MAF (24 700 MCM) of Narmada water had spilled over from the Sardar Sarovar Dam and flowed into the sea without any prior use. This quantum of water as such could quench the thirst of 26.2 million people (today's project beneficiaries population) living in the areas affected by scarcity for the next 18 years!

Currently, the total installed power generation capacity in Gujarat is 8017 MW. The annual per capita consumption of electricity is 848 kWh (as against India's present per capità consumption of 446 kWh), for the current population of 46.48 million. Assessment of future energy requirements can be made roughly on the basis of per capita consumption of electricity. However, in order to attain a higher level of development, the power consumption would also have to be

Table 11. Details of land being submerged

Type of land	State			
	Gujarat	Maharashtra	Madhya Pradesh	Total
Cultivable land	1 877	1 519	7 883	11 279
Forest land	4 166	6 488	2 731	13 385
Other land including river bed	1 069	1 592	10 208	12 869
Total land	7 112	9 599	20 822	37 533

Note: All figures are in ha.

increased. If the level of 1000 kWh/capita is considered as a target for 2021, and a population of 56.57 million is considered for 2021, the total capacity requirement works out at 13 924 million kWh, requiring an installed capacity of about 14000 MW.

Contribution of Sardar Sarovar Project

The Sardar Sarovar Project is a crucial project in making the dreams of millions of people a reality, specifically in the context of its potential to solve water and energy supply issues. It will bring irrigation to 1.793 million ha of land covering 3360 villages of 62 talukas in 14 districts of Gujarat, generate 1450 MW of hydropower and supply drinking water to 8215 villages and 135 urban centres in Gujarat. The project will also irrigate 75 000 ha of land in the strategic desert districts of Barmer and Jallore in Rajasthan and 37 500 ha in the tribal hilly tract of Maharashtra. This project has tremendous socioeconomic significance for the entire western region of the country. It will also prevent the rapid progress of desertification, salinity ingress and rural to urban migration being experienced in various parts of western India as a result of scarcity of water.

A total of 0.543 Mha of land in Saurashtra (south-western Gujarat) and 0.113 Mha of land in Kutch (Western Gujarat) are planned to be supplied with irrigation water through the conveyance network of the Sardar Sarovar Project. At present, irrigation in these areas is mainly through groundwater extraction from an average depth of about 200 m. Agriculture consumes around 43% of the total power, i.e. around 2700 MW in Gujarat State. In absolute terms this works out at 2700 MW of electricity. It is estimated that around 50% of this (1350 MW) will be saved as a result of the Sardar Sarovar Project by way of surface water irrigation and recharge of groundwater aquifers. Taking into consideration the 1450 MW power generation through the river bed and canal head powerhouses, the project will contribute around 2800 MW of power. Added to this will be an increase in agricultural income, drinking water, prevention of desertification, effective drought mitigation, prevention of forced migration of millions of people and cattle, flood control etc.

The Generous Resettlement and Rehabilitation Package

The number of families that will be displaced and will require rehabilitation, counting each major son as a separate unit, will be 40 727, and the total population affected as per the 1991 census will be 127 000. The ratio of submergence to area irrigated in this project is 1.65% against an average of 4–5% of other major irrigation projects.

The Resettlement and Rehabilitation Policy provisions now available for those displaced by the Sardar Sarovar Project are considered to comprise a package that carries the promise of development opportunities for the dispossessed for the first time in India. As in the case of other irrigation projects in India, the incremental approach (*pari passu*) to resettlement is being followed, meaning thereby that people have been shifted and resettled according to the construction and submergence schedule. For the first time, the concept of 'land for land' is being prescribed for all those landholders who are losing more than 25% of their landholdings in the submergence of the reservoir. The main benefit of this liberal rehabilitation package goes to such categories of affected people as joint holders, landless agricultural labourers, encroachers etc. in the affected villages, who have been made eligible for a minimum of 2 ha of land as well as other facilities such as a house plot of 500 m², besides additional monetary benefits. Minimum infrastructural facilities such as a primary school, dispensary, children's park, drinking water and approach road are also provided at the rehabilitation sites. Sustainable income-generating packages have been designed to enable the displaced persons to improve on their former standard of living.

Inter-agency synergies have been built up between the existing programmes of integrated rural and tribal development, and the resettlement and rehabilitation efforts. Impoverishment risks inherent in involuntary displacement have been carefully analysed and the resettlement efforts are being guided by a philosophy that turns the resettlers into active participants in the new socioeconomic system rather than being marginalized. Hence, in addition to the earlier *property compensation focus* for rehabilitation and resettlement issues, a *people-centred development focus* has now been developed.

Construction Status of Sardar Sarovar Project

The construction works of the main dam, powerhouses and canal network are at an advanced stage of implementation and so far approximately US$2 billion have already been invested. As regards the main dam work, 85.78% of the estimated 6.82 MCM has been completed by September 2000. Construction of the canal head powerhouse is almost complete and that of the river bed powerhouse is in an advanced stage. A unique feature of project implementation is the simultaneous progress of the canal network. The main canal of 40 000 cusecs capacity is a 532 km long concrete-lined canal. Phase I, i.e. a 144.5 km length of the Narmada Main Canal, is almost complete including the necessary structures and work is in an advanced stage on Phase II, i.e. up to 263 km. Construction work on branch canals, distributaries, command area development etc. are also in full swing. As regards resettlement, of the total 40 827 project-affected families, 8616 families had already been resettled by August 2000 by allotting agricultural land and other benefits.

The Debate Continues

The debate as to whether sustainable development is compatible or incompatible with large-scale, ambitious, centrally controlled schemes continues to haunt the Sardar Sarovar Project. This has led to a dispute in India's apex court and also to the constitution of a Grievances Redressal Authority (an independent regulatory authority), to guide and monitor the resettlement and rehabilitation process. However, work on the project continues unabated.

Conclusion

Spatial and temporal variations in water resources in and around a river basin necessitate the transfer of water from regions with more water and less land to regions with less water and more land for sustainable development. The types of problems encountered in river basin management are typically complex, involving technological, ecological, social, economic and political issues. The creation of a learning environment where participative problem solving is facilitated enhances the possibility of identifying system synergies and harnessing them in the problem-solving process. The present case study has shown that as the total utilization of the water resources in a river basin tends to be equal to the potential available, the conflicts and difficulties in planning to satisfy water needs greatly increase.

As seen in the case study of the Narmada River Valley, a projection of national requirements should precede the formulation of development plans for regions and individual river basins, although the assessment and identification of resource potentials eventually require detailed consideration of resources at a regional scale. Much of the demand for the basin water comes not only from the areas within the basin but also from other regions outside the basin that cut across physical or hydrological boundaries. The Narmada River Valley case study presents such an example of allocating water to the neighbouring state of Rajasthan in view of its severe water scarcity problems, although it does not share the basin area. The influence of the encroaching command areas of other irrigation projects and that of the river basins *en route* has been effectively considered while apportioning the Narmada river water. Thus, an important early step in the planning process for a particular basin is to determine the types and levels of development which will best contribute to satisfying basic local needs but which at the same time are consistent with fulfilling national goals. Intensive study and appraisal of the adverse impacts of drought, flooding, impaired drainage, waterborne diseases and shortages of irrigation water on the stability and viability of the economy of the area assumes prime importance in this regard.

The most important stage is implementation of the final decisions. It is the time frame always that decides the correctness of any decision. Lingering of the project beyond a reasonable time limit results in delayed benefits, increased costs and creates doubt about its economic viability.

In managing a river basin, mathematical models can only consider what can be quantified. They are limited in the sense that they cannot yield information about what is not or cannot be included in them. In a complex decision environment like the one presented here, the socioeconomic needs of the people govern the decision making although technological, environmental and political factors have a role to play. Essentially, the solution reached in a participatory framework like the one in the present case study itself becomes a '*model*' that can be emulated elsewhere.

Notes

1. The views expressed in this paper are those of the author and do not necessarily reflect those of the Government of Gujarat or Government of India.
2. 'Article 262', *Constitution of India*. Adjudication of disputes relating to waters of inter-state rivers or river valleys. (1) Parliament may by law provide for the adjudication of any dispute or complaint with respect to the use, distribution or control of the waters of, or in, any inter-state river or river valley. (2) Notwithstanding anything in this Constitution, Parliament may by law provide that neither the Supreme Court nor any other court shall exercise jurisdiction in respect of any such dispute or complaint as is referred to in clause (1) (http://alfa.nic.in/const/p11262.html).
3. Indus Commission Report, Vol. 1, p. 10, para. 14.
4. PCIJ Series A/B, No. 70 (1937).
5. PCIJ Series A, No. 23 (1929).

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