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ner par altération physico-chimique de l'eau des perturbations dans des usages de l'eau et la vie aquatique surtout pour les retenues situées à l'aval des villes.
Le rejet de sédiments à l'aval de la retenue provoque une augmentation des taux de matières en suspension (MES) qui contiennent des matières réductrices organiques lesquelles s'oxydent au contact de l'eau et provoquent un déficit en oxygène dissous.
Cette augmentation du taux de MES a une action directe sur les poissons en réduisant ses possibilités de nage et en colmatant les branchies d'où asphyxie, en fragilisant leur résistance aux toxiques industriels, sels amoniacaux... provenant de l'amont et stockés dans les sédiments.
De même l'occurrence d'un déficit en oxygène dissous accélère les mouvements respiratoires rendant sensible l'absorption par les poissons, de toxiques relargués après stockage dans les sédiments de la retenue, ce qui peut entraîner un taux de mortalité croissant ou des perturbations physiologiques. Tous ces effets dépendent du temps d'exposition. De même la sédimentation des matières en suspension à l'aval de la retenue peut provoquer le colmatage temporairedu lit, porter atteinte à la vie benthique, cette nuisance disparaît généralement à la première crue.
A la remise en eau, il ne paraît pas y avoir de problème de régénération des populations planctoniques et benthiques mais la restauration des populations piscicoles dépend des apports amont et de l'alvinage.

POTENTIALITE DES RETENUES

Il convient d'insister à nouveau sur la capacité des retenues à soutenir les débits en période d'étiage exceptionnel comme cela a été le cas lors de la sécheresse catastrophique dans certaines régions en 1989, et comme cela pourrait être le cas éventuellement en 1990.
Certaines retenues ont été prévues pour une utilisation agricole dès leur construction, ainsi la retenue de SERRE PONCON (1030 hm³ de capacité utile) sur la Durance dispose en réserve dès le mois de Juillet pour le trimestre suivant d'un potentiel de 200 millions de m³ d'eau pour l'irrigation en situation de besoin agricole.
On oublie parfois le rôle important que peuvent jouer les retenues, en cas de pénurie d'eau pour la réfrigération des centrales nucléaires situées en bordure de rivière à l'aval de celles-ci. Pour éviter un réchauffement au-delà des normes de tolérance imposées pour la vie aquatique il peut être rentable de faire des lachûres de soutien d'étiage.
Une autre potentialité des retenues et non des moindres concerne les pollutions industrielles accidentelles en rivières ou fleuves. Il est en effet primordial de pouvoir disposer de stocks d'eau amont pour pouvoir diluer et enrayer ce type de catastrophe dont les conséquences écologiques sont lourdes.
Enfin, les plans d'eau importants des retenues constituent une base de loisirs privilégiée pour le tourisme et les activités nautiques, mais avec des contraintes de remplissage qui ont une incidence non négligeable sur l'exploitation hydroélectrique.

CONCLUSION

Malgré quelques problèmes locaux pour lesquels existent des solutions et remèdes, l'énergie hydraulique est une énergie propre et renouvelable. On constate de plus en plus d'intérêt de la part des différentes communautés, associations dans divers secteurs, pour la houille blanche stockée dans les retenues. Jusqu'à présent EDF a géré l'eau pour satisfaire la consommation française en énergie électrique dans le cadre de sa mission de service public, et se propose de mettre en 1990 et ultérieurement à disposition son potentiel et son expérience de gestionnaire de l'eau au temme d'un contrat entre l'entreprise nationale et l'Etat. Un exemple de ses capacités a déjà été donné lors de la sécheresse de 1989 de ce partage de l'eau en fournissant un supplément de 160 millions de m³ en lachûres.
Bien entendu pour ces volumes destockés, et donc détournés de la production d'énergie en période de besoin, il est normal d'envisager une retribution de cette eau.
Il est en effet plus qu'opportun de développer une approche économique des ressources en eau, en dotant ce «marché» d'un prix qui reflète leur rareté ou leur utilité.
Cette approche est fondamentale si l'on veut définir le cadre d'une gestion intégrée des ressources en eau cohérente économiquement et physiquement qui permette d'effectuer un arbitrage entre les différents usages de l'homme tout en assurant en parallèle la protection de lavie aquatique par des actions adaptées et approfondies dans les domaines de l'hydrobiologie et de la qualité des eaux.

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DAMS IN INDIA'S MOUNTAINOUS AREAS AND ENVIRONMENT INTERACTIONS

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ABSTRACT In the physiographic sense the Himalayas constitute the Mountains of India. There are, however, other hill ranges too that are sources of important rivers some of which are east-flowing, while the others are west-flowing. The rivers of Himalayan origin discharge a total of 98 MHM compared to the total discharge of 70 MHM from the other rivers. In the last three decades, over 600 storage dams of various sizes have been built that have created a storage capacity of 16 million hectares. While the positive gains are impressive, the negative consequences are environmental and ecological. There is understandably concern among people which has caused rethinking on large projects like the Tehri and Narmada.

INTRODUCTION

India is a land of severe contrasts in more ways than one. Climatically in the west is the desert of Rajasthan, extremely arid, with an annual rainfall not much more than 10 to 13 cm, whereas in the east lies Cherrapunji, one of the world's wettest spots, where it is in excess of 1,125 cm. Similarly, the winter temperatures are well below 0°C in parts of Kashmir, whereas Ganganagar in Rajasthan may have a temperature approximately 50°C in July! The physiographic features too are equally unique, as

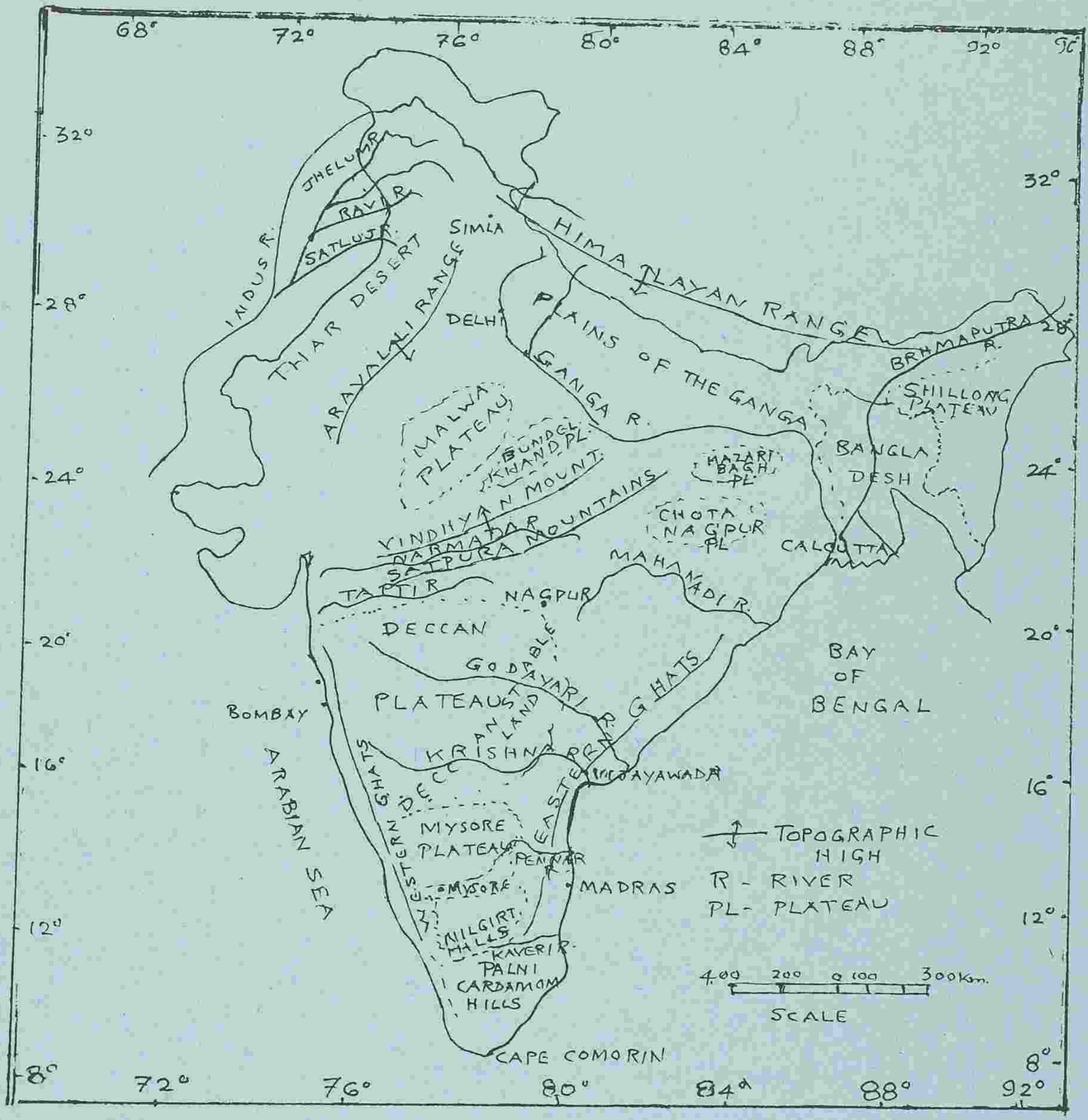

Fig. 1. Mountain ranges and Plateaus in India (after Yerma, 1985).

also the rocks, their age, structure and formation. On consideration of relief, structure and rock formations, India can be divided into three units:

1. Peninsular India a very ancient land mass with an average elevation ranging from 300 to 2,000 metres, generally sloping from west to east and with mountains composed of harder rocks and broadly divided as Eastern Ghats and Western Ghats, the latter being tne source of major rivers like the Godavari, the Krishna and the Kavery which have built up broad, shallow valeeys;
2. Extra-Peninsular mountains of India, i.e. the mountains of the Himalayas and associated ranges, a very young, folded group of mountains; and
3. Indo-Gangetic lowland, the great plains of India between the Peninsula and the Himalayas, an extremely young land mass dominated by its low-lying, horizontal topography.

THE MOUNTAINS OF THE PENINSULA AND THE RIVERS

The Aravallis, the Western Ghats, the Eastern Ghats, the Vindhyans and the Satpuras constitute the mountain system of the Peninsular region (Fig. 1). The Aravallis extend for a distance of 700 kilometres from Gujarat to Delhi, with their highest peak attaining a height of nearl 1,300 metres. They form the major watershed of North India, separating the drainage of the Bay of Bengal from that of the Srabian Sea. The Luni, the Sabarmati and the Banas originate from this range.

The Western Ghats form a conspicuous group of mountains running parallel to the coast from the Tapti Valley to Kanyakumari (Cape Comorin), enclosing a narrow track of coast land. They have steep slopes towards the Arabian Sea but the land slopes very gently towards the tableland in the east. They form the watershed of the Peninsula from which rise the major rivers, the Godavari, the Krishna and the Kavery and flow across the entire Peninsula southeastwards to the Bay of Bengal (Fig. 2). The deep valleys these rivers have cut in the Western Ghats suggest that there must have been recent uplift and the drainage has not had time to adjust itself to the altered conditions.

The Eastern Ghats are not a continuous chain of mountains like the Western Ghats, but a group of isolated hills and the rivers draining the interior of the Peninsula enter the Bay of Bengal through the discontinuous structures and form the great deltas along the east coast. The Western Ghats lie in a direction perpendicular to that of the south-west monsoon causing heavy rainfall along the west coast, whereas the Eastern Ghats beig parallel to the same monsoon direction, resulting in less rainfall along the east coast. The two Ghats meet in the Nilgiri plateau, forming the apex of the Peninsula with a maximum height of 2.633 metres at Dodabetta.

The Vindhya Mountains run from the western shores to the river Yamuna. They appear to be a line of prominent escarpments with altitudes between 800 and 1,400 metres, though the crests are not much more thann 150 metres above the general level of the surrounding land. The Satpuras are south of the Vindhyas, running from Rajpipla in Maharashtra in the west to Rewa in Madhya Pradesh in the east. The Satpuras form a major watershed of the Peninsula, with the Narmada and the Son rising on their northern slopes, and the Tapti, the Wardha, the Wainganga, the Brahmani and others draining their southern slopes. The Vindhyas and the Satpuras together constitute the main dividing

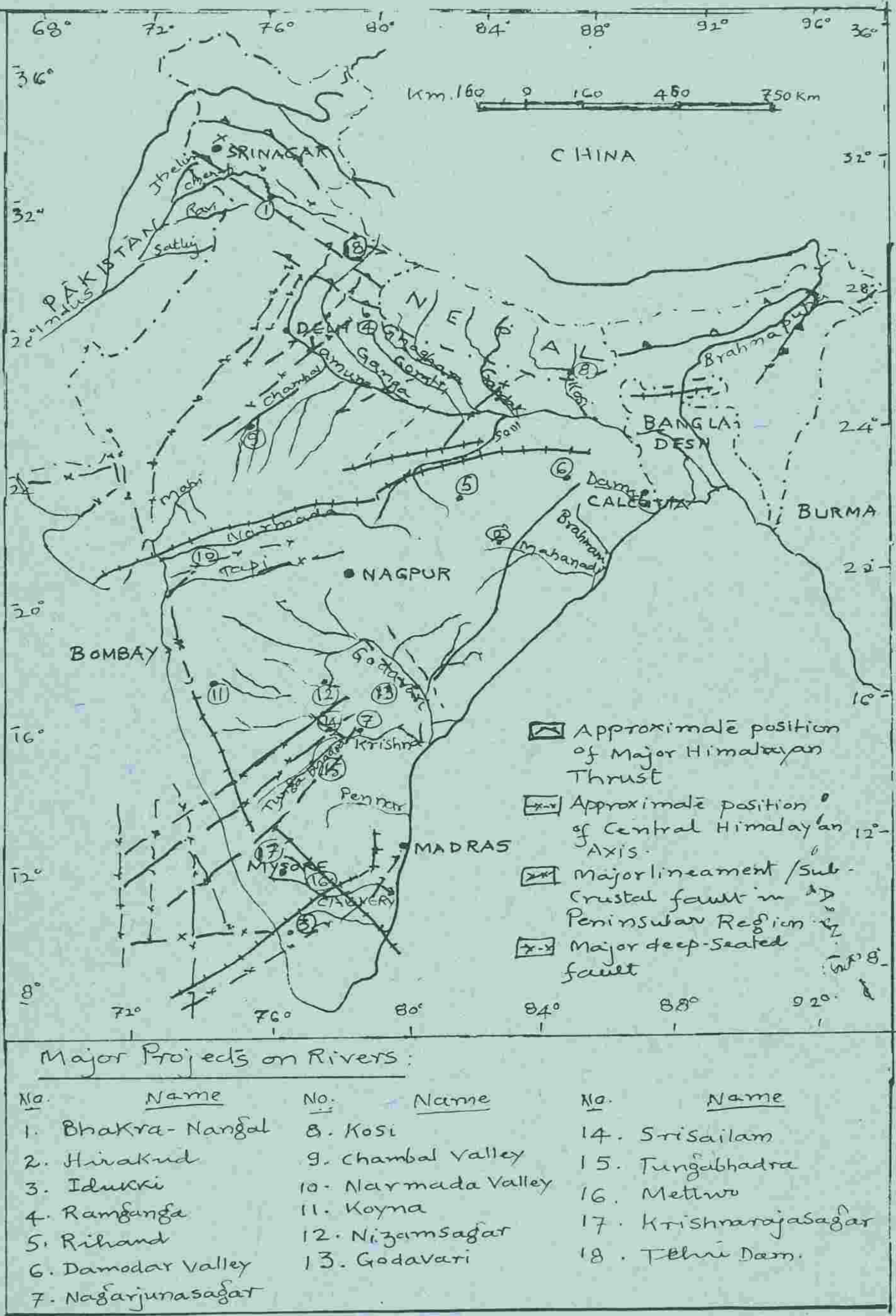

Fig. 2. Tectonic framework, Rivers, and Major Dams: India.

line between northern and southern India in many respects.

Until recently, the Peninsular region has been believed to be free from seismic activity. The Koyna and Bhadrachalam earthquakes have disproved this belief and the seismic zoning has had to be redrawn as a consequence. Tectonically, the region is active (Fig .2).

THE EXTRA-PENINSULAR MOUNTAINS AND THEIR RIVERS

The mountain ranges of the extra-peninsular region owe their origin to a series of earth movements which proceded from outside India. The Himalayas are not a single continuous chain but a series of parallel ranges intersected by deep valleys and broad plateaus. Their width is between 160 and 400 kilometres and the great Himalayas, the central ranges, are approximately 2,400 kilometres long. Geologically the Himalayas are classifiable into five zones from south to north on the basis of their tectonic features and lithology: Sub Himalaya, Lesser Himalaya, Higher Himalaya, Tethys Himalaya and Indus Suture zone (Verma, 1985). The zone of glaciation, zone of ablation and the zone of fluviation constitute the high altitude area and they form the catchment area of 22 major rivers (Prasad, 1982). The drainage in the Himalayas is not wholly consequent, but most of the major streams are antecedentwith deep transverse gorges, with their sources not at the highest peaks, but north of them. There are three river systems (Table 1) which have their origin in the Himalayas, viz., the Indus river system, the Ganga river system, and the Brahmaputra Barak river system.

The Himalayas constitute a very active seismic belt. It originated due to the collisinn of two continents - India and Eurasia (Verma (1985), with the development of Indus Suture line as the plate boundary. At least fourteen major earthquakes occured in the Himalayan region between 1897 and 1980, which caused landslides, floods and changes in the courses of rivers.

DAMS AND ENVIRONMENTAL INTERACTIONS

Dams have been constructed across major rivers of India bef ore and after Independence in order to store water for irrigation, electricity generation and flood control or moderation. Most of them are multi-purpose as shown in Table 2.

India has so far invested over Rs. 100,000 million in the last three decades and built over 600 storage dams of various sizes accounting for a storage capacity of 16 million hectares metres for irrigation, flood control and power generation. Self-sufficiency in food grain production which is now about 150 million tonnes though not in the case of power generation or flood control. Developmental activities cause a variety of environmental impacts which can be classified as physical, chemical, biological, social and economic (Pendse, 1986). Submergence of fertile land and villages, displacement of people from their original habitation, loss of forest area and precious fauna, water-logging, salinity of soils, floods incidence increasing and induced seismicity are some of the consequences among many others. So far, the area submerged by reservoir waters totals to about 2.1 million hectares, ranging from a minimum of 130 hectares to a maximum of 79,000 hectares only when 62 dams are considered (INCOLD, 1979, 1979 a). 2800 villages have been displaced and over 1.5 million people have been displaced (IIPA, 1988). About 0.2 million hectares have become water-logged, while about 0.35 million hectares have turned saline (IIPA, 1988). It has been estimated that river valley projects have caused loss of forest area to the tune of O.4 million hectares (11.8%) and the loss due to road construction is about 0.05 million hectares). Damage caused due to floods between 1953-81 hag been estimated at Rs. 93390 million while the crop-affected area is about 10.25 million hectares (RNCF,

Table 1. – Major River Systems of the Himalayas.

River System	Catchment area (lakh sq. kms.)	Average annual flow Overall (MIA cu. metres)	In India	Estimated water reserves (In MHM)
Indus	11.65	170.0	59.4	76.91
Ganga	10.86	317.0	317.0	50.96
Brahmaputra	5.8	492.0	442.5	54.11

Table 2. – Dams on some major rivers of India.

Dam	River (State)	Situation (Mountain System)	Purpose	Gross Reservoir Capacity (million m^3)
Bhakra	Satluj(H.P.)	Himalaya	I & E	9621
Idukki	Periyar(Ker)	W. Ghats	E & F	1996
Koyna	Koyna(Mah.)	W. Ghats	E & I	2796
Srisailam	Krishna(A.P.)	E. Ghats	E	8722
Nagarjuna Sagar	Krishna(A.P.)	E. Ghats	EI & F	11550
Sardar Sarovar	Narmada(Guj.)	Satpuras	IE & F	9492(U.C.)
Hirakud	Mahanadi(Ori.)	E. Ghats	I & F	8105
Kalagarh	Ramganga(UP)	Himalaya	I & F	2443
Machkund	Machkund (AP)	E. Ghats	E	--
Tehri	Bhagira-thi (UP)	Himalaya	IE & F	3.22(U.C.)

I = Irrigation, E = Electricity, F = Flood, U.C.= Under Construction. Control

1980). Dams have also been reported to have induced floods in the Satluj, Damodar and Mahanadi, making thousands of people homeless and causing loss of life in hundreds (Dogra, 1986). Strangely enough, the actual rate of siltation far exceeded the expected rate, by a mean of 579.01 per cent the maximum being in the case of Nizam Sagar (1,646.23) and minimum being 146.72 % in Bhakra. It has also been noted that as the Gross Irrigation Potential rose from 29.05 million hectares in 1960 to 54.00 million hectares in 1978, the incidence of malaria rose from 0.10 million to 4.14 million people (Sharma and Mehrotra (1982). Studies by the National Institute of Nutrition (NIN) have pointed to the spread of diseases like fluorosis around the Nagarjuna Sagar, Parambikulam-Aliyrar and Hospet dams, due to water seepage from the dam's reservoir and canals that has changed the fluoride, calcium and trace elements composition of the soil (CSE 1985). Fluorosis has caused the syndrome of knock-knees (genu-valgum). Earthquakes have occured in Radhanagri, Mula, Parambikulam, Koyna and Idukki reservoir areas while about 30 such cases have been reported by Gupta and Rastogi (Gupta and Rastogi, 1975).

CONTROVERSY OVER MAJOR DAMS

The intensity and range of the ecology movements in independent India picked up momentum in the last two decades as predatory exploitation of natural resources to feed the process of development has gone up in extent and intensity. The resource demand of development has led to tne narrowing down of the natural resource base for the survival of the economically poor and powerless. The Chipko movement was initiated by the hill people of the State of Uttar Pradesh to save the forest resources from exploitation by contractors from outside and it evolved to an ecological movement that aims at the maintenance of the ecological stability of the major upland watersheds in India (Bandopadhyay and Shiva, 1988). This became the Appiko movement in the South, that involves people in stopping large scale tree-felling and planing of multi-purpose broad-leaved tree species. Government of India refused sanction of the Silent Valley Project in Kerala State on environmental grounds as it would have submerged one of the most unique tropical forests. Two major projects are now involved in controversy the Tehri Dam over the Bhagirathi and the Narmada Projects over the Narmada. Located in the Himalayas, the former project is feared to displace about 70,000 people from their original places of habitation, which would be submerged by the reservoir waters, apart from causing earthquakes because of impounding and location in seisimically active area. Gupta (1984) has warned about the danger to the reservoirs in the Himalayan region which experienced earthquakes of high intensity in the past. The Tehri reservoir might cause floods in the Ganga river rising to over 600 metres above the present level (Nautiyal, quoted by Dogra, 1987).

The Narmada Valley Project, spanning the States of Madhya Pradesh, Maharashtra and Gujarat, has raised more controvergy than any other in the recent times. A chain of 30 big and more than 3,000 smaller dams constitutes this more ambitious project, considered to be a panacea for the problems of the region. But the ecological and socio-cultural impact of the project, particularly that of the two super dams, Narmada Sagar and Sardar Sarovar, would be enormous. The first one is envisaged to irrigate 1.23 lakhs hectares and generate 1,000 MW of power, but it will submerge 91,348 hectares, of which 40,322 ha is forest which is precious while the culturable land is 44,363 ha. About 0.13 million people will be displaced, that include 30,000 tribals. The Sardar Sarovar Project has an irrigation potential of 1.87 million ha and an installed capacity of 1,500 MW, but will submerge an area of 39,134 ha, of which forests comprise 13,744 ha and culturable land, 11,318 ha. The cost of these two Projects is estimated at RS. 150,000 million at 1987 prices. Magsaysay Award Winner, Baba Amte is leading the movement against these two dams, while Sunderlal Bahuguna leads the anti-Tehri Dam movement.

There is rethinking on this issue of major dams in government circles, though environmental clearance has been given in case of a few dams. "Small is Beautiful", the glogan is catching on.

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