Central Ground Water Board

1. Remote Sensing Survey	Krishna, Nizamadad, Karimnagar, Vishakapatnam,Vijaynagram. Adiladad, Nalagunda, Vikarabad dists. of A.P.
2. Identify ground water targets in river basins	Ganga, Yamuna, Ghaghra, Betwa, Vedavati Noyil, Ponnani, Amaravati, Poini, Penganga, Penhar, Peddanagu Gudipalli, Gadidala vegu sub basin of Krishana river, Brahmputra river valley
3. Identify ground water targets in river	A.P., Karnataka, Tripura, Mizoram, basins Nagaland and Assam
4. Identify ground water targets in river basins	Chhitor dist., Nalgonda taluk, Tirupati (AP), Ramanathpuram (TN), Hamirpur & Jhansi dist. and Sharda Sahayak Command Area (U.P.), Bangalore, Badami taluk (Karnataka)

Dept. of Geology and Mines-Orissa

1. Detailed Landsat Survey	Northern Orissa
2. Detailed Geological Survey	Puri Distt.

Dept. of Geology & Mines-Tamilnadu

1. Natural Resource Survey	Ponnaiyar basin (NRSA Project)
2. Mapping of land slide prone	Nilgiris (NRSA Project) areas

Karnataka Power Corporation Limited (KPCL)

1. Geological, Geomorphological and river	Catchments Gangavati and Saravathi and Kali Landuse Mapping
2. Environment and test site location assessment	Hydropower projects in Western Ghats
3. Geological Studies	Pittoragarh-Tehri Gahrwal Region

Remote Sensing Application Centre, U.P.

1. Ground Water Survey	Bundelkhand region
2. Assesment of mining in Ecoenvironmental Studies	Doon Vallay
3. Geological Studies	Pittoragarh-Tehri Gahrwal Region

Centre of Studies in Resources Engineering, IIT, Bombay

1. Study for dam construction	Khobragarhi river basin
2. Ground Water Survey	Chandrapur dist. (Maharashtra)

Institute of Remote Sensing (IRS), Anna University

1. Integrated Resources Survey	Western Ghats

Space Application Centre, Ahmedabad

1. Ground Water Exploration	Chittor dist. A.P. (collaborated with CGWB)

National Remote Sensing Agency, Hyderabad	
1. Natural resources Survey	Idukki Reservoir area (Periyar Catchment), Kerala
2. Natural Resources Survey	Silent Valley, Kerala,
3. Studies of the hydrological	Punjab (Sutlej, Beas & Rabi river) Characteristics of major river basin
4. Ground water & land use cover survey	Madras city and environs.
5. Studies of engineering geological purpose	Kalkumbhe
6. Integrated Survey	Mewate Region
7. Integrated Survey	Kanhar Sub basin

Indian Institute of Remote Sensing, Dehradun	
1. Geological & Geomorphological mapping	West Rajasthan
2. Land use survey	Ukai,Kakrapara Command area
3. Photo-Geological Study	Parbathi Hydel Project (H.P.)
4. Tube well site location	Doon Valley & adjouning areas
5. Integrated land resources	Kanhar sub-basin and parts of North Koel sub survey basin, Son Valley
6. Satellite R.S.Surveys	Son river basin
7. Ground Water Surveys	Parts of Chandrapur and Yaotmal districts of Maharashtra

Source : Based on Gupta and Ganesha Raj (1986) : Technical Report, ISRO, Bangalore

A pilot project on Geological Information System was initiated by Geological Survey of India (GSI) working on new projects-project Singhbhum and project Bhusampada (on lines similar to project "Vasundhara") in Eastern and Northern region, respectively. Some of its achievements have been in delineating the bauxite-capped plateaus in the eastern Ghats of Andhra Pradesh and Orissa and location of buried deposits of calcareous nodules in the alluvial tracts of Uttar Pradesh and desert terrain of Rajasthan. Similarly, airborne multi-spectral scanner data (Subrahmanyam, 1983) is being used in locating zones of geothermal energy like hot springs, hot spots, etc. Another aerial survey of geology of Maner-Godavari valley (Andhra Pradesh) was conducted covering an area of 2900 sq km. Photo interpretation helped in delineating formational boundaries on the basis of photo recognition elements, tones and textures, etc. (Perumal and Thillaigovindrajan, 1980). Construction of a 56.58 meter high composite dam across the Tapi river, downstream of its confluence to the Sipra Nadi was studied extensively through aerial photography of 200 sq km area. The scale chosen was 1:60,000 and the focus was to examine the geologic and geomorphic structure of the proposed dam-site. Landsat imagery of precambrian hardrock and desert terrains of Rajasthan were visually analysed and compared with ground data compiled on similar scale to determine their potentiality for regional geological interpretation (Gadekar, 1981) and feasibility of preparing small scale geological and tectonic maps of the region (Gupta, 1991).

The first category of ongoing projects comprise ground water potential zone mapping, national drought monitoring, prioritization of watershed in the Brahmaputra basin (Krishnaunni and Duara, 1980) and flood plain management for major river basins (Dhanju,1980). Other projects refer to water management in command area, environmental studies of major river valley projects, snow-belt (Ramamoorthi, 1991) run-off model development, microwave remote sensing, digital terrain models, etc. Sensing water is done mainly through infrared scanning for instance, warm water emits more energy thus appearing brighter than cool water and it becomes easy to record the temperature of water bodies. In India, remote sensing is used for monitoring the aspects such as measurement of evapotranspiration, measurement of water surface roughness, rainfall distribution and infiltration pattern, ground water discharge, identification of subaquous features of large lakes and reservoirs, salt content of water and light absorption (Deekshatulu, 1992).

The potential of ground water has been investigated with reference to the geomorphic units and relevant geological aspects. The occurrence and potential of geomorphic hazards has been evaluated for the five major geomorphic units as river-built plain, broad valleys with infilled sediments, narrow valleys, active pediment, and piedmont zones which have been recognised and delineated on aerial photographs and Landsat imagery. Several abandoned channels provide good aquifers for the accumulation of sub-surface water. Other structural features, e.g. fracture and faults, can be identified also (Krishna Bhagavan and Ramana Rao, 1985).

The emerging technique of image Bathymetry is very useful in the areas of mobile sea bed and in the studies of coastal erosion where no recent hydrographic survey is available. With the help of the image Bathymetry, coastal features (Sharma, 1980) and depth of coastline, low water line reefs and islands, etc. delineated particularly using observed spectral reflectance by the sensors as recorded in Landsat Imagery specially in bands 4 and 5 (Prakash and Jha, 1986). Another study describes the lineaments in the coastal area of Goa identified on aerial photographs (Wagle, 1982).

6.3 FLOOD DISASTER

Indian flood prone area is estimated to be one-eighth (40 million ha) of the geographical area of which one-fifth of flood prone area is subjected to floods every year. The total area affected annually is about 8 million ha. On an average 1439 lives are lost every year due to floods. The total loss on account of flood damage to crops, houses, cattle and public utility was estimated about US $ 871 million since 1954 to the end of the 7th plan (Table 6) (Figure 10).

TABLE 6: INDIA · FLOOD DAMAGE DURING 1953 TO 1990

SL No.	Year	Area Affected **	Population millions	Crops Damage Area	Crops Damage Value *	Houses Damage No.	Houses Damage Value *	Cattle Lost No.	Human Lives	Damage Public Utilities*	Total Damages Col:6+8+11*
1	2	3	4	5	6	7	8	9	10	11	12
1	1953	2.290	24 280	.930	13.64	264924	2 41	47034	37	0.94	16 99
2	1954	7.490	12.920	2.610	13.13	199984	2.13	22552	279	3.29	18 55
3	1955	9.440	25 270	5.310	25.22	1666789	6.79	72010	865	1 29	33 30
4	1956	9.240	14.570	1.110	14.41	725776	2.61	16108	462	0 37	17.38
5	1957	4.860	6.760	.450	4.58	318149	1.61	7433	352	1 38	7.58
6	1958	5.260	10.980	1.400	12 41	382251	1.26	18439	389	0 58	14.25
7	1959	5.770	14.520	1.540	18.40	648821	3.05	72691	619	6.49	27.94
8	1960	7 530	8.350	2.270	13.79	609884	4.64	13908	510	2.05	20.48
9	1961	6.560	9.260	1.970	7.79	533465	0.29	15916	1374	2.09	10.17
10	1962	6 120	15.460	3.390	26.96	513785	3 45	37633	348	0.34	30.76
11	1963	3.490	10.930	2.050	9.78	420554	1.20	4572	432	0.89	11.87
12	1964	4.900	13.780	2.490	18 43	255558	1.49	4956	690	1 67	21.59
13	1965	1.460	3.610	.270	1.90	112957	0.06	7286	79	0 35	2.31
14	1966	4.740	14.400	2.160	25.98	217269	0.82	9071	180	1.86	28.66
15	1967	7 120	20.460	3 270	43.21	567995	4.62	5827	355	2.55	50.38
16	1968	7.150	21.170	2.620	46.88	682704	13.33	130305	3497	8.22	68.43
17	1969	6.200	33.220	2.910	91.38	1268660	17.64	270328	1408	22.08	131.10
18	1970	8.460	31.830	4.910	52.77	1434030	15.76	19198	1076	24.78	93.30
19	1971	13 250	59.740	6.240	137.16	2428031	26.01	12866	994	41.85	205.02
20	1972	4 100	26.690	2.450	31.95	897301	4.04	58231	544	15.29	51.28
21	1973	11.790	64.080	3 730	138.75	869797	17.01	261016	1349	28.68	184.44
22	1974	6.700	29 450	3.330	133.43	746709	23.48	16946	387	27 53	184 45
23	1975	6.170	31 360	3.850	88.00	803705	11.05	17345	686	53.82	152 88
24	1976	11 910	50.460	6.040	192.88	1745501	29.87	80062	1373	65.31	288.07
25	1977	11.460	49.430	5.840	233.59	1661625	49 36	556326	11316	106.63	389.58
26	1978	17.500	70 458	9.960	295.33	3507542	54.32	239174	3396	121.91	471.56
27	1979	3.990	19.520	2 170	55.10	1328712	68.27	618248	3637	75.73	199.09
28	1980	11.460	54.120	5.550	118.76	2533142	55.38	59173	1913	98.31	272.45
29	1981	6.120	32.490	3.270	170.04	912557	51.74	82248	1376	166.07	387 84
30	1982	8.870	56.010	5.000	191.05	2397365	124.43	246750	1573	217.70	533.19
31	1983	9.020	61.030	3.290	416.81	2393722	107.72	153095	2378	283.12	807.65
32	1984	10.710	54 550	5.190	293.71	1763603	42.56	141314	1661	265.21	617.69
33	1985	8.380	59 590	4.650	462.03	2449878	189.26	43008	1804	664.52	1315.81
34	1986	8.810	55 508	4.580	399 22	2049277	173.23	60450	1200	642.64	1215.08
35	1987	8.890	48.340	4.940	374 28	2919380	150 56	128638	1835	308.13	839.46
36	1988	16 290	59.550	10.150	813.91	2276533	240.39	150996	4252	446 61	1500.91
37	1989	8 060	34.150	3.810	310.13	782340	48 56	75176	1718	421.00	779.69
38	1990	9 303	40.259	3.179	225.48	1019930	69.28	134154	1855	147 57	553.94
TOTAL		301.863	1248.539	139.079	5522.23	46310200	1635 59	3810383	58199	4278.86	11548.61
AVE		7.944	32.856	3.660	145.32	1218690	43.05	102905	1532	112.60	303.91
MAX		17 500	70.450	10.150	813.91	3507542	240.39	618248	11316	664.52	1500 91
YEAR		(1978)	(1978)	(1988)	(1988)	(1978)	(1988)	(1979)	(1977)	(1985)	(1988)

SOURCE · CENTRAL WATER COMMISSION
NOTE * : Million US $
** . MILLION HECTARES

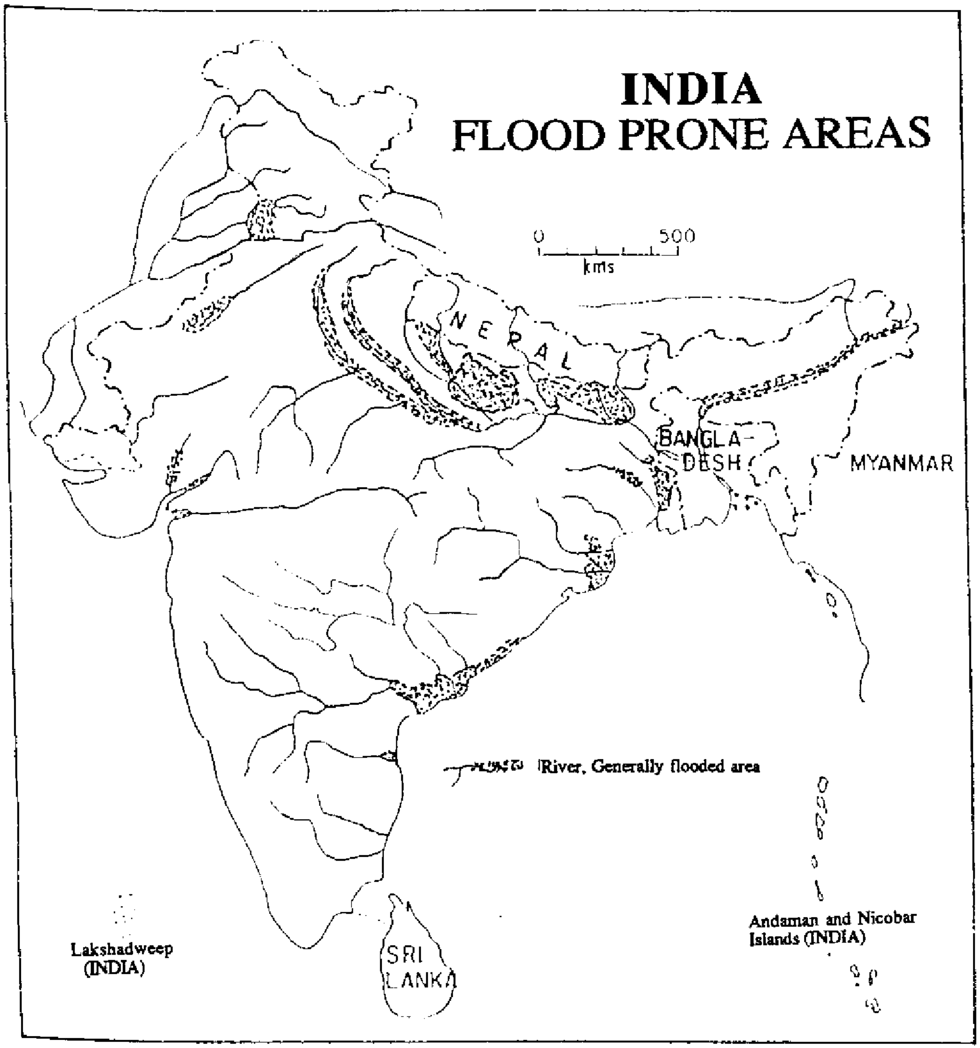


Figure 10: India: Flood Prone Areas
(Source: Central Water Commission)

Flood frequency is increased by environmental degradation (deforestation and erosion), inappropriate land-use and high population density in flood-prone regions. The 8th Five Year Plan focuses on disaster management for India, extending forecasting network to all flood prone river areas through close coordination and participation by the Indian Meteorological Department (IMD) and the National Remote-Sensing Agency of the Indian Space Research Organisation.

Hydrological and hydrometeorological data from nearly 550 Hydro-meteorological stations are collected, analysed and utilised for flood forecasting by Central Water Commission (CWC). The hydrological Models are being used for inflow and flood forecasting using powerful computers. Firstly, flood forecasts can be made using the channel routing models which in turn uses the observed flow at the base station as input and computing the likely flow at the forecast points. However, the warning capability can be increased by using the catchment response models with precipitation as input, to predict, rather than observe the flow at base station.

Flood forecasting and early warning are important measures for flood mitigation. The Central Water Commission (CWC) has established a network of 157 flood forecasting and warning stations (Table 7) covering 62 river basins/sub-basins. The 8th Plan (1992-97) highlighted the need for effective forecasting system by involving Indian Meteorological Department and National Remote Sensing Agency for utilising the remote sensing technology and telemetry. The total number of centers will be increased to 200 by the end of the 8th Five Year Plan in 1997. Aerial photographs are utilized to get information regarding regional water storage, seasonal and long term fluctuations of lake and river surface aerial extent, assessment of underground (Seelan, 1982) and soil moisture, flood coverage and damage, etc. Water pollution can also be detected by the interpretation of aerial photographs (Verma, 1986, 1988, Sharma and Sinha, 1983).

TABLE 7: STATE-WISE DISTRIBUTION OF FLOOD FORECASTING STATION

State	Number
Andhra Pradesh	11
Assam	23
Bihar	36
Delhi	2
Dadra and Nagar Haveli	2
Gujarat	10
Haryana	1
Karnataka	4
Maharashtra	7
Madhya Pradesh	3
Orissa	11
Uttar Pradesh	33
West Bengal	14
Total	157

The weather satellite imagery is used to monitor ice and snow cover conditions providing important inputs for water management and flood prediction. The Central Water Commission (CWC) has deployed Data Collection Platforms (DCPs) in the Yamuna catchment area for flood forecasting. Even within a week the inundated areas can be mapped. Nine such flood maps were already prepared for the Brahmaputra and the Godavari basins between June and September. Various maps were prepared for flood affected areas of the Brahmaputra, Ganga, Godavari and Jhelum river basins using IRS and Landsat images. Such maps are used by State and Central Government officials for Flood Relief Management.

It is further supplemented by SAR data from ERS-1 satellite to map floods during cloud covered periods in 1992. The application of Remote Sensing for flood mapping and mitigation measures is as follows:

1. Mapping post flood river configuration to identify vulnerable reaches of embankment using high resolution SPOT and Landsat satellite data.
2. Identification of erosion prone areas along the Brahmaputra river through multiyear satellite data to delineate river reaches for flood mitigation measures.
3. Study of drainage congestion and duration of flood inundation along the Kosi river based on sequential satellite imagery for flood plain management.
4. Preparation of flood risk zone maps along the Kosi and the Brahmaputra rivers using multiyear satellite imagery corresponding to different flood magnitudes and return periods.

Conventional aerial photographs and topographic sheets do not lend an adequate support for effective mapping of dynamic relief features, e.g. in case of flood plain. For quick appraisal of the dynamic nature of flood plain, it is necessary to use remote sensing data either in the visual interpretation or digital data for correct estimates (Vaidyanathan, 1983).

6.4 CYCLONE DISASTER

The long eastern coastline of India is exposed to cyclone disaster. Meteorological satellites like NOAA -AVHRR and INSAT- VHRR are highly effective in monitoring and forecasting cyclones. This includes cyclone tracking, intensity assessment and prediction of storm surges. This should be supplemented by the ground meteorological observations and radars for the accurate assessment of rainfall intensity.

The multipurpose INSAT sends information at the interval of half-hourly, in the infrared band, and imagery of the weather systems over India and adjoining areas. This gives vital information for a detailed monitoring of the weather and entails an accurate forecasting. Bulletins based upon INSAT cloud imagery are issued every three hours by the Indian Meteorological Department (IMD). It also relays information sent by 100 unmanned Data Collection Platforms (DCPs). These DCPs have been installed in remote and uninhabited areas from where they keep transmitting meteorological data. The regular reception of the imagery of data has vastly improved weather forecasting.

Special advise is issued every hour on the position and intensity of cyclonic storms in the Bay of Bengal and Arabian Sea for use at IMD'S Cyclonic Warning Centers. The damages caused by cyclones to communications, infrastructure and crops were quantified using the high spatial resolution data of IRS-IA during the May 1990 cyclone of Andhra Pradesh.

India is ravaged by severe cyclonic storms in the east coast. In the cyclone-prone areas of coastal Andhra Pradesh and Tamil Nadu, 100 Disaster Warning Systems (DWSs) have been installed. When a cyclone is detected heading for the coast, the satellite relays a signal from the Area Cyclone Warning Center in Madras to DWSs in the villages in its path. The DWSs emit a siren which warns the villagers to head for shelters. The ideal case in witness, regarding the usefulness of remote sensing in forecasting cyclones, is the timely warning of impending cyclone in coastal Andhra Pradesh in May 1990. If the warning had not sounded, the damage could have been devastating. The Disaster Warning System (DWS) helps to alert people in coastal area regarding an impending cyclone. The system has proved its efficiency during cyclone of Andhra Pradesh on May 9, 1990 enabling the Government to evacuate over 170,000 people and saving a large human and livestock population. The initial deployment of 100 specially designed DWS receivers is now being expanded to cover more areas (Rakshit, 1987).

The GIS technology may be used for operationalised storm surge model at following four DOD's CODAPS (Coastal Ocean Design and Prediction System) Centers:

1. Jadavpur University, Calcutta
2. Andhra University, Waltiar
3. Indian Institute of Technology, Madras
4. Space Application Center, Ahmedabad

Detailed coastal topography maps enable accurate assessment of inundation of coastal areas. This includes detailed mapping at 1:25,000 scale and 0.5 meter contour interval for the most vulnerable stretch of coast. At present the region includes Nellore to Machilipatnam in Andhra Pradesh in phase 1. It is followed by Paradip to Indo-Bangla Border in phase II. Data on storm surge along with data on detailed coastal topography will be input into the model. The findings show the extent of inundation and coastal areas. Such map will be used by State Governments and district authorities of coastal States for evacuation of coastal population. Such studies will minimise damage to life and property during cyclones and storms.

The Satellite Microwave Radiometer (SAMIR) has been functioning to provide water vapor content of atmosphere, rainfall pattern over oceanic regions, and surface winds over oceans. Abnormal composition of atmosphere, cloud cover and location of depressions, can be detected well in time.

6.5 EARTHQUAKE DISASTER

More than half of the geographical area is vulnerable to seismic activities of varying intensity. The nature and extent of disaster due to earthquakes is caused by several environmental factors, i.e. (1) failure of geological structures, landslides, soil liquefaction, and ground slumping, (2) the built-up environment system consisting of the nature and quality of construction, etc. Earthquake disaster mitigation programmes require substantial information on the hazard through improved monitoring using local as well as national seismological and strong motion networks. The preliminary task is to plot the epicenters of earthquakes in the region for depicting seismic hazards. The distribution and rate of their occurrence in the past should be considered as important indicator to show expected earthquake hazard. The characterization depicts the likelihood of the effective peak ground accelerations caused from shaking by earthquake waves. Such prediction is made based on seismic gaps. On the basis of remote sensing applications various maps are being prepared showing potential landslides, soil liquefaction, and active geological faults and estimates of hazard risk for earthquake disaster. A few studies have pointed out the dangers associated with masonry buildings and indicates the possibilities of improvement in their seismic behaviour (Arya and Chandra, 1987) (Figures 11-13).

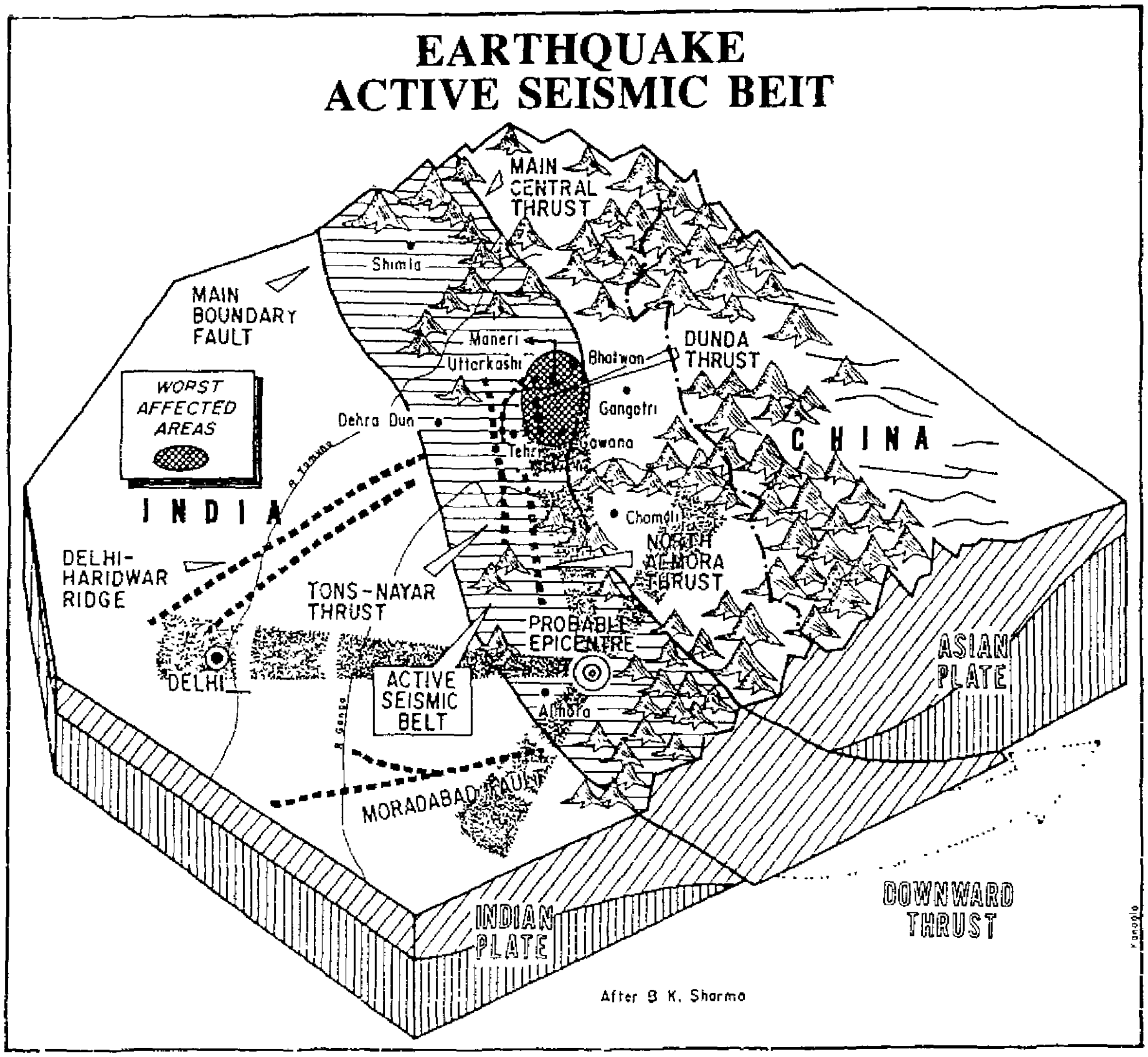
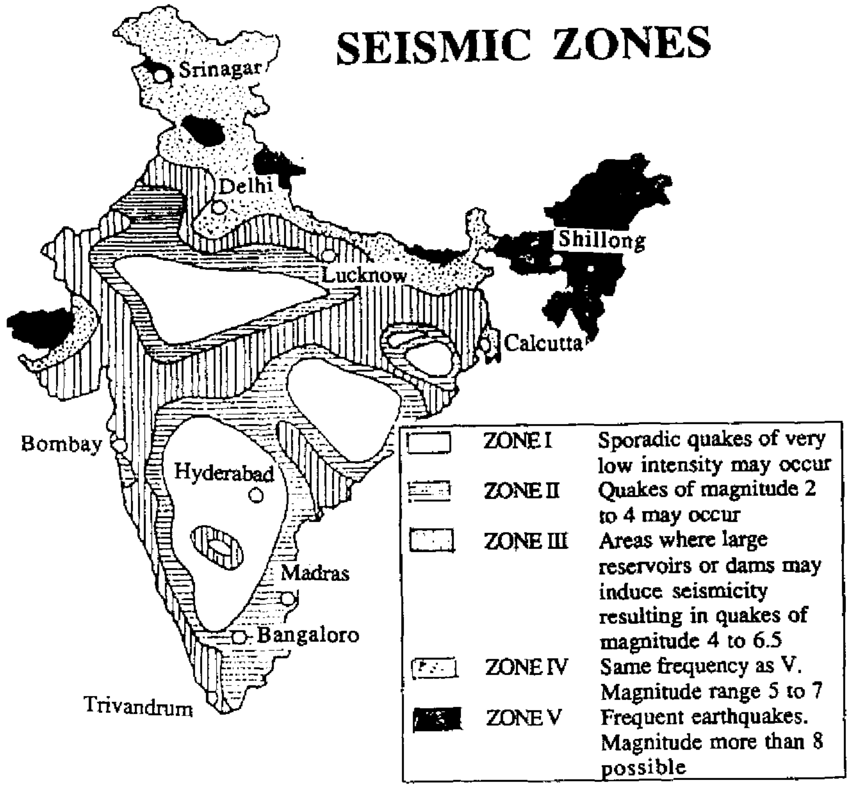


Figure 11: Earthquake Active Seismic Belt of India (After Sharma, 1980)



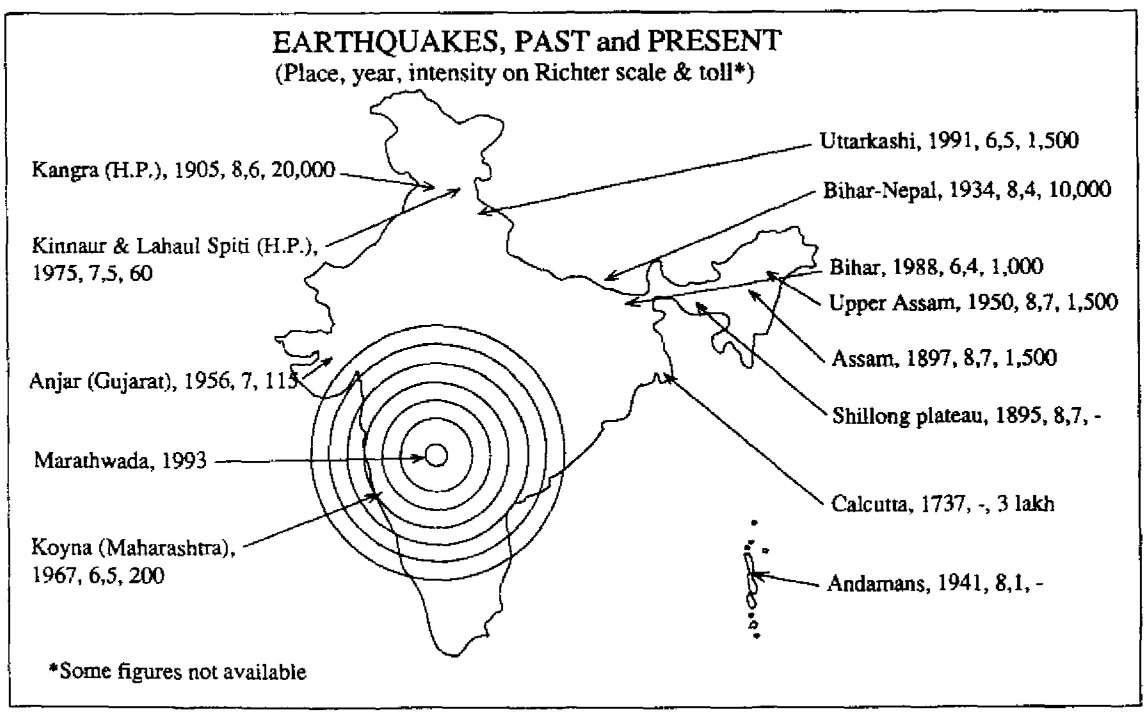


Figure 12: Seismic Zones of India
(Source: India Today)