Chapter 1
Purpose and Perspectives

Abstract Floods, once the basis for hydraulic civilizations, are now seen mostly as sources of hazard due to negative interaction between human systems and environmental conditions at particular historical junctures within specific economic and social conditions. The same phenomenon acquires a different dimension if seen rationally as an event with both possibilities as well as perils that one can plan for and guard against. In this study on the Damodar River, physical and human environmental research has been integrated, focusing on river morphology and ecology, human use of river and sandbars or *char* lands as a resource, and policies that shape a river. This leads us to a more holistic understanding of how the forms and ecological status of a river are shaped by the interplay of environmental and anthropological processes. In other words, this research reviews the impacts of control structures in the downstream environment and also provides a detailed study of human role in changing fluvial regime through descriptions of the way in which people, ranging from refugees to local settlers, driven by diverse cultural, economic, religious, and political forces, have transformed the fluvial landscape.

Keywords Anthropogenic · Char/Mana · Control structures · Floods · Fluvial landscape · Human-environmental research · Hazard · Hydraulic civilization · Resource

1.1 Purpose

Floods and control structures, once the basis for riverine civilizations of riparian landscapes, have, despite their enormous benefits, sometimes had disastrous social and environmental consequences at particular historical junctures. Are these consequences unavoidable or is it possible to achieve a judicious balance between the various forces at play so that the benefits of river control can be realized without large-scale ecological damage and human suffering? The answer can only be found in an unbiased and extensive review of data obtained from controlled rivers over a period of time through scientific measurements and intensive field surveys. Though no single study can fill such a need, this research aims at contributing to that effort by

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presenting a thorough, data-driven review and analysis of the human-made downstream environment of a controlled tropical river, the Damodar, from an applied geomorphological perspective within a wider geographical framework. Before getting down to the nitty-gritty details and spelling out the specific objectives of this research, I would like to elaborate a little on the broader purpose and framework of the endeavor. In this context, the following sections provide a brief overview of contemporary and historical water resource management efforts and the environmental, social and economic impact they have had in different parts of the world with particular reference to South Asia.

Major ancient civilizations are hydraulic civilizations and many river basins, even those without optimum combinations of atmospheric, hydrologic and geomorphic inputs, were the sites of these civilizations. These rivers were perennial but flood-prone with fluctuating river regimes. The ancient riparian communities, therefore, were forced to take flood disaster reduction measures on the one hand and implement flood management programs on the other so as to transfer excess floodwater from surplus areas to deficit areas and from surplus seasons to deficit seasons. Artificial levees, canals, dams and many other such artifacts associated with these civilizations were nothing but river control structures and these structures were components of the geomorphic landscape from the dawn of these ancient civilizations (Bhattacharyya 1998).

The first three major civilizations that thrived about 5,000 years ago were those of the Harappans in the Indo-Gangetic Plain, the Egyptians in the Nile Valley, and the Sumerians in Mesopotamia (Easton 1964; Biswas 1970). The Indus Valley Civilization was the largest of the three most ancient civilizations and was in existence between 3000 and 1500 BC (Agarwal and Narain 1997). The Nilotic or the Egyptian civilization prospered in the Lower Nile basin between 3000 and 1750 BC and ended in a catastrophic flood of the River Nile due to tectonic upheavals (Dales 1966). The Mesopotamian civilization flourished in the Tigris-Euphrates basin in Southwest Asia and was in existence between 4000 and 600 BC. The Chinese civilization developed on the banks of the River Hwang Ho in northern China but their contribution to hydrology, especially prior to 600 BC, is not so significant (Biswas 1970). A degree of rudimentary civilization, with some of the social skills and discipline the word entails, was represented by open villages not later than the fifth millennium in the foot-hills of northern Iraq, by Catal Huyuk near Konya in southern Turkey in 7000 BC and by agricultural settlements at Mehrgarh (also about 7000 BC) on the Bolan River in the Indian sub-continent (Mishra 1995). Another recorded practice of irrigated agriculture has been traced to Jericho in the arid Jordan Valley around 7000 BC (Hirsch 1959; Wheeler 1966; Saha 1981). It is the Mesopotamian civilization that flourished in the latter half of the fourth millennium (Wheeler 1966), however, that reached the level of sophistication needed to claim the distinction of being the first real civilization.

Development of the water management systems that allowed these ancient civilizations to flourish necessitated observation of flood behavior, type and nature of silt accretion and collection and maintenance of hydro-geomorphic data for rational use of river water. In Egypt, hydrologic data near Cairo dates back to 622 AD

(Mookerjee 1989), and basin irrigation, which was first introduced in Egypt some 6,000 years ago (Willcocks 1930), is still socio-economically relevant in many tropical countries. In Egypt, the Nile floods served as the basis of successful agricultural irrigation for more than 5,000 years. People have successfully harnessed the river and become accustomed to the natural flood regime. The most important date in the Egyptian calendar was the one on which the annual inundation took place (Ward 1978). An intricate system of basin irrigation involving longitudinal dykes parallel to the main channel of the Nile to regulate flood water, a network of cross dykes and canals to control the flood water into pre-assigned basins, and a diversion channel to the naturally formed Faiyum depression for creating a storage reservoir for excess flood water for later use was developed as early as 3400 BC (Hamdan 1961; Saha 1981). It is also recorded (Payne 1959; Biswas 1970) on the authority of Herodotus that, during the Middle Kingdom (2160–1788 BC), artificial lakes were used to store water and control the high floods of the Nile.

Some scholars believe that the oldest dam was constructed in the desert land of Jawa (Jordan) around 3000 BC. Others believe that dam building began on the Nile. Near Memphis, there are relics of a masonry wall built across the river by King Menes in 4000 BC. The Romans built dams for water storage so well that some of the structures in Jordan are still in working condition today (Reifenberg 1955; Pereira 1973). Though probable, there is little known proof to show that the science of dam construction appeared in a particular place and from there it was taken to others (Agarwal and Narain 1997). About 28.8 km south of Cairo, Egypt in Wadi-el-Garawi, the ruins of Sadd-el-Kafara dam, which was built sometimes between 2950 BC and 2750 BC, are still to be observed (Biswas 1970; Ward 1978; Costa 1988). The Egyptian engineers built another dam in Syria between 1319 and 1304 BC when the first dam failed to serve its purpose. The Egyptians made great advances in water resource development during the Middle Kingdom (2160–1788 BC). Artificial lakes were built to divert high flood flows of the Nile into the historic lake Moeris through canals (Payne 1959). When the inundation came to an end, the stored water of the lake was returned to the Nile and the storage capacity of the lake was made available for the next flood period (Biswas 1967).

The Mesopotamian contemporaries of the Egyptians could not develop a similar system based on one annual inundation whose benefits could be reaped through the growing season. They were obliged to develop perennial irrigation (Brittain 1958). They reclaimed as well as irrigated land long before 3000 BC in marshes in the lowlands near the gulf and along the Lower Euphrates. Traces of these lands can still be seen from airplanes (Sarton 1952). They devised a sophisticated canal system for the twin purposes of irrigation and navigation. The canals built were very often wide enough to reduce bank erosion from rushing water from the off take points of the canals. Silt banks which were created by cleaning canals are now major topographic features (Leopold et al. 1964). The canal banks, therefore, became sites for industrial and commercial centers. Multiple uses of canals were thus one of the characteristics of the agrarian civilization of Mesopotamia (Willcocks 1930).

In the Middle East, where evapotranspiration is a severe problem and channels are lost in sand deposits, a very special system of irrigation referred to as “Quanat” or “Kanat” was developed. In this system, an artificial underground channel or a canal is used to carry water over long distances, either from a spring or from water bearing strata. This system indicates that, faced with water scarcity, the people developed knowledge about water resource engineering (Biswas 1970). The Quanat may be a Persian creation but this human-made underground river is the sole source of water for millions in Iran, the Middle East as well as in Central Asia.

The Indus Valley Civilization (3000–1500 BC) which came to light with the excavation of Harappa and Mohenjodaro in the early 1920s by Rakhaldas Bandyopadhyay, an Indian Historian, covered a vast area, more than seven times the extent of Sumer in Mesopotamia (Easton 1964). The Indus Valley and Mesopotamian civilizations were connected by close trade relations and strongly influenced each other (Garbrecht 1985; Agarwal and Narain 1997). The story of the rise and fall of the Indus valley civilization in a semiarid bio-climatic environment is the story of humans’ struggle to conquer nature and build an integrated coherent society. In this struggle for existence, the Harappans’ response to the challenge of nature, which mainly came from the River Indus, was a positive one. They adopted measures to control annual and abnormal floods. In Sind, for example, there are hundreds of kilometers of single and double lines of embankments (Framji and Garg 1976). Some of the settlements of the Indus Valley Civilization, dating back to 3000–1500 BC, had water harvesting and drainage systems. The most recent to come to light are the settlements at Dholavira, a major site of the Harappan or Indus Valley Civilization, located in the Great Runn of Kutch in Gujarat. The inhabitants of Dholavira fashioned several reservoirs to collect monsoon runoff flowing in the flanking streams of the Manhar and Mansar. These bunds or dams raised across the streams are evocative of the gabarbands of Baluchistan. The purpose of these gabarbands was mostly to collect a “layer of alluvial soil over dry and barren rock, combined with the retention and economic control of distribution of flood water” (E. Hughes-Buller 1906; Agarwal and Narain 1997). Some evidence of irrigation in the Indian subcontinent dates back to the beginning of the third millennium BC when farming communities in Baluchistan impounded rainwater to use in their fields. Dams made of stone rubble have been found in Baluchistan and Kutch. Excellent water supply and sewage disposal systems were well-known features of these cultures. The standard of their hydro-technical infrastructure was not equaled even 2,000 years later by the Romans whose water systems are generally considered outstanding. As in Mesopotamia, protection against annual flooding of the Indus River, irrigation to secure and increase crop yield, and drainage of large alluvial areas were preconditions to the survival of kingdoms in the Indus valley (Agarwal and Narain 1997). According to Leopold et al. (1964), silt accumulation in alluvial areas of the Indus River at Mohenjodaro are of the same order of magnitude (about 33 feet) as that found by archaeological soundings in other alluvial areas during the last 5000 years.

Indian scriptures are rich in examples of human attempts to undertake rational water harvesting measures. The scriptures also refer to the significance of water bodies, natural or artificial, during war. The *Puranas, Mahabharata, Ramayana* and various *Vedic* scriptures make multiple references to canals, tanks, embankments and wells (ICAR 1964). Among the scriptures, the Vedas are the oldest and the Vedic period extends between 2000 and 800 BC (Chattopadhyay 1990). These early Hindu texts, written around 800–600 BC reveal certain knowledge of hydrological relationships. The Vedic hymns, particularly those in the *Rig Veda*, contain many notes on irrigated agriculture, river courses, dykes, water reservoirs, wells, and water lifting structures.

The Rig Veda (2000–1500 BC, an ancient sacred book of wisdom) uses a term *Avata* to signify a well. The dictionary of Nighanta mentions fourteen types of well. At the same time, there are mentions of *Kulya* an artificial river or canal. In another passage, there is a reference to a dried up reservoir. The *Yayuraveda* also refers to canals and dams which were known as Kulya and *Sarasi*. Sarasi, in fact, denotes an artificial reservoir and a natural lake as well. The *Atharva Veda* (III, 13) gives a description of the construction of canals from rivers. A canal is fed by a river or, in other words, a canal takes off from a river. To convey this sense, the Atharva Veda describes a canal as a calf and the feeding river as a cow (Sarava 1954). The Chandogya, one of the principal *Upanishads* (the philosophical reflections of the Vedas, numbering 108 in all), points out (Garbrecht 1985 as cited in Agarwal and Narain 1997, p. 13): "The rivers…all discharge their waters into the sea. They lead from sea to sea, the clouds raise them to the sky as vapour and release them in the form of rain….". This is probably the oldest reference to the natural processes within the hydrological cycle. It shows that as early as about 1000 BC attempts were being made to interpret and explain recurrent natural phenomena on the basis of direct knowledge. The linkage between the environment and the water system was understood even at the time of the Greek Philosopher Plato (427–347 BC) who has written a vivid description of erosion he observed at Attica in Greece.

Manu, the first man and the legendary author of an important Sanskrit code of law, the *Manu-Smrti* (second century AD), prescribes a punishment of death for a person causing a breach in a dam. He also writes in his work (VII. 196) that a king, wishing to conquer his enemy, should first destroy all types of dams (tataka) in his territory (Sarava 1954). Bishnugupta Kautilya (third century BC), the prime minister of the King Chandragupta Maurya (321–297 BC), in his Arthasastra or book on polity, gives the same advice i.e., during war the land of the enemy should be flooded by breaking or breaching lakes, dams and embankments (Sarava 1954; Bhattacharyya 1998). The purpose behind such practices was to disrupt the transportation system so that enemies could not move through the flooded terrain. Similar steps used to be taken by the Chinese. During war, enemy lands were flooded by forced breaching of dykes and dams (Schnitter 1994). With a similar purpose, even now, river bridges are destroyed during war. Ramayana, the first Hindu epic (before fifth century BC) describes in detail several advanced engineering works. Valmiki, the author of this epic, gives an account of how King Bhagiratha and his group of engineers diverted the course of the Ganga from the Himalayas towards the present Ganga delta.

The acquisition and protection of state territories, for which Kautilya required finance is the central theme of the Arthasastra and this was Kautilya's major concern. Kautilya, therefore, looked for agriculture as a source of state revenue.

Kautilya's book confirms that the people were acquainted with rainfall regimes, soil types and suitable irrigation techniques in specific micro-ecological contexts. In his book, he gives detailed instructions on exemptions from taxes, fines for misuse of water from the dams, and failure to renovate or maintain the tanks or structures based on rivers. The Arthasastra says that the ideal distribution of annual rainfall should be one-third of the annual rainfall in the first and the last months and two-thirds in the intervening months (Kangle 1969; Agarwal and Narain 1997).

Indian historical records and reports are full of descriptions of such water management policies and programs (Bhattacharyya 1998). The inscription of Rudradaman I on the Girner Rock in Kathiawar records the construction and repairs of Lake Sudarsana by successive viceroys of the Maurya Chandragupta (321–297 BC) and perfected under the Maurya emperor Asoka (260–222 BC) (Kotriah 1959).

In his report, Willcocks, an Egyptian engineer, writes that many of the distributaries of the Lower Ganga are nothing but artificial canals modified by natural riverine processes (Willcocks 1930). The Lower Bengal was inhabited by very advanced people known as Gangarides or Gangaridaes (Basu 1989) and it was reported by Megasthenes, an ambassador of Alexander, that the Ganga valley, ruled by an emperor known as Chandragupta Maurya (Brittain 1958), was occupied by highly civilized people who practiced irrigation with a skill at least equal to anything known in Mesopotamia. It was not unnatural for a highly civilized agrarian society to construct artificial canals for irrigation purposes. The system of overflow irrigation was very popular in India's richest agricultural area, the flood plain of Bengal in the pre-British period. People here developed indigenous techniques to use the threatening flood water of the rivers Ganga, and Damodar along with monsoon rainfall to irrigate and fertilize fields. This water was also used to control diseases such as malaria by allowing the fish in the flood water or rice field to eat away the mosquito larvae. William Willcocks studied the system in the early part of the twentieth century and reported, "This system is as perfectly suited to meet the special needs of Bengal as "basin irrigation" suits those of Egypt or "perennial irrigation" meets those of Babylonia" (Willcocks 1930, p. 4). This system of overflow irrigation was properly controlled. It enriched the soil, ensured a supply of water to every individual field and checked malaria (Willcocks 1930; Bhattacharyya 1998, 2000).

In Lower Bengal, the history of embankments predates the British period (Willcocks 1930) and there were extensive embankment systems prior to British rule. There are volumes of reports on the Bengal embankments published during the British era containing papers from 1852 to 1923 (Voorduin 1947; Bhattacharyya 1998, 1999–2000a). In Bihar, there were artificial cuts on river levees or canal banks. These cuts were known as Kanwas in Bhagalpur of Bihar. The word Kanwas is derived from the word "Kan", an old Persian or Arabic word meaning "to dig". These cuts were made for overflow irrigation in Bengal (Willcocks 1930; Bhattacharyya 1998, 1999–2000a). According to Willcocks (1930), the Chola Kings who lived in Bengal about 2,000 years ago (probably first century BC) were the inheritors of this system of irrigation which they took with them to the Tanjore delta when they conquered the extreme southern part of the Indian peninsula. In South

India, these early Chola Kings (first century AD) were pioneers in the construction of reservoirs. The River Cauvery was a flood-prone river and the king Karikala I first introduced the concept of flood control measures by constructing dams and embankments (Sarava 1954). The construction of a dam by Karikola is mentioned in an inscription of the Saka year 1277 (1355 AD) (Saka Calendar is a lunar calendar originally from South India and it was brought to Indonesia around 465 AD. One Saka year has 12 month and each month ends on a new moon). During the reigns of the Chalukya, Hoyasala and Kakatiya rulers (twelfth century AD), several tanks and a few anicuts were constructed. This policy continued during the Vijayanagar period between 1336 and 1564 AD when great emphasis was placed on developing irrigation facilities for the improvement of agriculture (Kotriah 1959; Bhattacharyya 1998).

Water has been harvested in different places of India since antiquity and many places show evidence of advanced water harvesting systems. The Bhopal Lake created in the eleventh century (1010–1055 AD) was one of the largest artificial lakes of the Indian Peninsula covering an area of over 650 km^2 (Schnitter 1967). The twelfth century (1148–1150 AD) chronicle of Kashmir, Kalhana's Rajatarangini, describes a well-maintained irrigation system in which notable structures existed around the Dal and Anchar lakes and the Nandi canal. Ganapati (1973) reports that almost all the major and minor rivers and their tributaries have been dammed in South India to form human-made lakes. In the eastern states of West Bengal and Orrisa, "pond" and "tank" are interchangeable expressions, while in states like Andhra Pradesh, Karnataka and Tamil Nadu, tanks refer to a section of irrigation reservoirs including small and medium sized water bodies.

Ceylon (present Sri Lanka) also has evidence of human's effort to control water resources by control measures. For example, the Minneriya tank was constructed by the King Mahasena in the third century BC. The embankments date back to 370 BC (Schnitter 1994). The inhabitants were very careful in handling the liquid resources and the tanks were built in an orderly way at slightly varying elevations so that there was a series of reservoirs to take the overflow from the one above it. The exit of water was controlled by means of sluices to the rice fields (Brohier 1934a, Part I, p. 3). Reservoirs for irrigation have been introduced from the ancient period for rice cultivation. Sri Lanka abounded in canals strongly bunded; it had a bund with a volume of over 17 million cubic yards (Agarwal and Narain 1997). But warfare and malaria subsequently obliterated the irrigation communities and most of the earthworks were breached and overgrown with forest (Brohier 1934a, b, Parts I and II; Pereira 1973).

In adjacent Burma, present Myanmar, the Irrawady shows extensive embankment systems which are quite old in origin. In this system, the alignment of the embankment was in a horseshoe pattern around the areas between the river distributaries so as to leave the downstream ends of the compartment open. In the event of extreme floods, the lower portion of the embankment acted as a flood basin thus reducing, though slightly, the flood peaks. The system of open embankments could be a compromise solution to the controversy surrounding flood protection by dyking in any deltaic area (Volkar 1964; Bhattacharyya 1998).

In China, emperor Yau constructed dams and dykes in 2280 BC. There is an ancient Hongze reservoir in central China. The Chinese subjects used to assess their emperors as good or bad on the basis of waterway maintenance measures adopted by the rulers (Biswas 1970). Dykes and canals were in existence in the upper reaches of the Hwang Ho (Yellow) River in 603 BC. It is a well-known fact that the Hwang Ho River was notorious for its flood disasters with the first flood recorded in 2297 BC (Hoyt and Langbein 1955). In later years, the concept of flood zoning also developed in China. In 8 BC J. Chia, the highest authority in charge of the Hwang Ho River, prepared a flood control plan. He recommended abandoning the densely populated foreshore and resettling the people somewhere else. The primary purpose behind his plan was to keep enough space for flood flow. Another purpose, of course, was to save people from flood disaster. Reclamation of flood-prone areas for agriculture was in practice nearly 4,000 years ago in the same Hwang Ho plain. In order to reduce vertical erosion, rivers were confined within close lateral dykes. This system was known as Loute and it was invented by C.H. Pan between 1521 and 1595. Together with these close or loute dykes, Yaote or distant dykes used to accommodate flood waters were common (Framji and Garg 1976). The major floods in the Chang Jiang (Yangtze River) are well documented in inscriptions and flood marks (Luo Cheng-zheng 1985).

Moving from tropical to temperate countries, we find that the history of reservoirs in Europe goes back over 200 years. The use of dykes in the Po valley of Italy is quite ancient (Framji and Garg 1976). Unlike tropical Asia, the history of control structures in the USA is relatively recent. The Anasazi constructed small check dams on the Colorado River in Mesa Verde 800 years ago to hold storm runoff for later use on their crops (Ortiz 1979). The first levees, 1.2 m high on the Lower Mississippi, were constructed in 1717 when the city of New Orleans was founded. The Mississippi and its major tributaries now have one of the most extensive embankment systems in the world.

These few examples of river regulation from all over the world and from Asia in particular indicate that, from the very beginning of civilization, river water was put to human use and rivers had to be trained for the socio-economic benefit of society. With the first human settlements about 7,000 years ago began a two-fold struggle with water. On the one hand, people had to protect themselves against floods; on the other hand, they had to ensure a safe water supply for domestic use and irrigation. As a consequence, hydro-technical installations were among the earliest technological achievements of humankind (Agarwal and Narain 1997). Antecedent to the river training programs, observation on the behavior of the target river was imperative. Observation was followed by an analysis of river behavior and the final step was the construction of various artifacts to meet specific objectives. In a contemporary geomorphic language and sense as well this was the beginning of applied geomorphology that is application of geomorphic knowledge to solve socio-economic problems.

River regulation represents a natural and prerequisite condition of civilization (Wittfogel 1956; James and Marcus 2006). This is the cardinal factor

behind selection of the research theme, which focuses on applied geomorphological and human-environmental issues connected with river control structures.

The need to apply scientific knowledge for economic and social benefit has been strongly felt in decolonized developing countries in the tropics since the early nineteen forties. To feed growing populations, planning objectives in newly independent countries of Latin America, Africa and Asia included the exploration of native resource potential so as to lessen dependence on foreign assistance. Scientists were requested to use their theoretical knowledge to solve practical problems. As a part of planning policy, the resource which was developed first was river water and almost all major rivers in decolonized Latin American, Asian and African countries are now controlled, though in different phases. Thus river water utilization and river control structures are now two of the major issues in developing countries in the tropics. India is one of these countries where harnessing of river water resources received top priority in planning programs just after independence in 1947.

The purpose is, therefore, to select a theme, which has national significance, and a theme, which is relevant at international level as decolonization is a continuous process, and river training policies and programs are still crucial issues in all countries (Petts 1984; Bhattacharyya 1998).

Ancient civilizations developed in the flood plains as has been mentioned earlier. But are we aware of the fact that the riverbed itself is often a site for human settlement? In tropical Africa and Asia, alluvial bars are used for agriculture in case of seasonal rivers when bars are exposed due to lowering of the river level. This is a common practice throughout the Indian sub-continent. Emergence and submergence of riverine bars, particularly in the deltaic tract, are common phenomena and there are often disputes over the occupation of these bars particularly in the border districts and states. For reasons that are obvious, the riverine bars are preferred sites for agriculture, though the extent of the agricultural season depends on the survival potentiality of these bars. These bars have also provided temporary shelter for war victims (Semple 1911). These sandbars are used as campsites in the Colorado River (Schmidt and Graf 1990). About 219 sandbars in the Colorado River between Glen Canyon Dam and Diamond Creek provide a fertile environment for biological life and many of the sand bars are used for public recreation (Budhu and Gobin 1994). It has been noticed that throughout West Bengal, India the riverine alluvial bars provide shelter for millions, most of whom are Bangladeshi refugees who came from the erstwhile East Pakistan (present Bangladesh) after 1947 and again during the Bangladesh war in 1970. They are not only political and economic victims but also social victims. A sizeable number of these refugees who came from the farming sector rejected government-sponsored refugee colonies where they would be doomed to a dole-sustained existence. They preferred the riverine islands in the Ajay, Damodar, Hooghly-Bhagirathi, and even Mahanadi for self-sought settlements. These rivers are now dotted with such settlements some of which are quite prosperous (Basu 1988; Bhattacharyya 1999, 1999–2000b, 2008b). The alluvial sand bars are also inhabited by displaced people from flood-affected

West Bengal. The control structures on these rivers have brought several changes to the riverbed environment and the refugees and local displaced people are constantly struggling with this changed environment for their survival (Bhattacharyya 1999, 2008b). Moreover, the refugee problem, which started almost 50 years ago, still plays a crucial role in Indian politics, particularly in the eastern part of the country where constant infiltration of Bangladeshi refugees in the Border States creates political tension. The problem is aggravated when the question of granting of "patta" or land deeds in the self-sought settlements comes to the forefront. The question has taken on greater significance in the Damodar Valley Corporation (DVC) command area where there are several self-sought refugee settlements in the riverine sandbars.

For selecting the research theme and the research area these questions and their magnitudes were pondered over. These are the distinctive facets of the purpose behind the research theme.

The decade of the 1990s was declared the International Decade for Natural Disaster Reduction (IDNDR) and this IDNDR forced people to refocus their attention on hazardous processes such as floods and cyclones. It is sad to state that, despite tremendous improvement in technology and a revolution in information technology, people all over the world, not necessarily only in the tropics, are still affected by floods, droughts, hurricane, earthquakes and other natural disasters. Floods are of universal concern and reference to them is found in the mythology of all religions, in traditional anecdotes, and in historical records. The evidence of deluge is found in the Biblical story of Noah. There are clear parallel example in Hebrew and Babylonian traditions (Lambert and Millard 1969; Ward 1978). In India, the *Satapatha Brahmana* (sixth century, BC), an important treatise on sacred rituals, makes a reference to a devastating flood and how Manu, a glorious sage, saved mankind from that flood (Shastri 1950).

Therefore flooding, an issue of mythological, traditional and contemporary relevance was included as part of the research theme. Moreover, flooding is an issue which stands at the interface between theoretical geomorphology and applied geomorphology.

The modern history of River Basin Planning can be traced back to two major developments that took place in the 1930s. The first was the formation of the Tennessee Valley Authority (TVA) in the United States in 1934 and the second was the presidential address given at India's National Institute of Sciences in 1938 by notable Indian physicist and planner, Meghnad Saha (Saha and Barrow 1981). After 1947, throughout India, several rivers have been trained to reduce flood risk. Several multipurpose projects have come up and dams have been constructed like the Maithon, Panchet, Tilaiya and Konar on the Damodar and its tributaries. The Bhakra Nangal on the Sutlej, the Hirakund on the Mahanadi, Tungabhadra, on a tributary of the Krishna, the Chambal reservoir on the Chambal, and the Kosi reservoir on the Kosi have been completed. In India, River Basin Organizations (RBOs) first emerged as a mechanism for integrated planning of large projects, especially as a means of balancing the requirements for power, agriculture, flood-proofing and industry. One such RBO, the DVC, came into existence in 1948 along the lines of the Tennessee Valley Authority, USA (Chandra 2003; Pangare et al. 2009). The fully integrated development of entire basins was subsequently pursued in many basins throughout the world, notably in the Volga River Basin, USSR and in the Snowy Mountains scheme of Australia (White 1977).

In recent history, the Tehri Dam on the Bhagirathi River is expected to be higher than the Bhakra. As far as reservoirs are concerned, several dams such as the Sriram Sagar, Srisailam and Sardar Sarovar on the Narmada exceed the Hirakud in size (Rangachari et al. 2000). India's most ambitious project, the interlinking of peninsular rivers is also referred to as "inter-basin transfers" i.e., water transfers from the "surplus" basins to the "deficit" basins (Iyer 2002). In 2007 the Supreme Court of India ordered the national government to proceed with the hydrologic interlinking of all of the subcontinents major river basins. If implemented, it would augment lean season flow in the lower riparian country, moderate floods, mitigate droughts, turn parched areas into fertile land, create millions of jobs and promote hydropower (Prabhu 2003; Sarkar 2003). Critics of this project point out that it would bring severe environmental ecological and social consequences (Ghosh 2003; D'Souza 2003; Thakkar 2003; Ray 2003). This riverlinking project is also viewed as an extremely cost-effective measure for the expansion of an efficient traditional irrigation system (Bandyopadhyay and Perveen 2004). The USA, a water rich and scarcely populated country is transferring 45 billion m^3 (BCM) of water through inter-basin transfer and planning to add 376 BCM. In Canada, the existing schemes have been designed to transfer 268 BCM. China has a scheme under implementation to transfer about 45 BCM. India, in comparison, transfers 10 BCM through the existing schemes and is planning to add about 200 BCM. So India is already late in implementation of water transfer links as mentioned by Suresh P. Prabhu, former Chairman, Task Force on Interlinking of Rivers (Prabhu 2003).

Despite extensive river control measures, floods still visit India. Some of the reservoirs in India have raised crucial political issues. S.L. Bahuguna, a social activist, was agitating against the construction of the Tehri dam in the Ganga-Jamuna Valley. Very recently, a large number of religious leaders and former IIT Professor AD Agarwal had been protesting against the proposed Loharinag Pala dam on Uttarakhand and claiming that it will threaten the existence of the river and block free flow of the Ganga. A group of ministers (GoM) announced they would scrap the project completely to ensure a free flow (The Economic Times 2010). A water sharing dispute has been going on for decades between the two states of Karnataka and Tamil Nadu. The government of Karnataka is raising the height of the Almati Dam and it is feared that after the completion of the project Tamil Nadu will receive a lesser amount of water which will ultimately affect the interest of farmers in the state. At the center of current tensions between the two states is Tamil Nadu's Hogenakkal Fall drinking water project on the Cauvery River. Similar questions have been raised regarding other reservoirs and barrages as well. For example, Boro cultivation in West Bengal to a great extent depends on the release of water from the Tenughat reservoir on the Damodar Valley in Jharkhand (Bihar) during drought years. If there is a lack of understanding between these two states the Boro cultivators have to suffer. Moreover, if there is a sudden release of water from the Tenughat, the lower reach of the Damodar gets flooded. During the monsoon season releases from this dam affect the operation of the Panchet reservoir as the Tenughat dam is the uppermost dam in the Damodar Catchment (CWC 2001).

These political issues have taken on very strong social nuances. Ms. Medha Patkar, a well-known social activist, supports the movement against the Narmada Valley Development program which is an overall master plan for building 30 major and 130 or more medium dams to harness the largest west-flowing river on the subcontinent for hydropower as well as for irrigation and regulation of seasonal flows. According to critics, the entire project will cause involuntary resettlement of over one million people without actually delivering the promised benefits. A World Bank sponsored environmental impact report on the Sardar Sarovar and Narmada Sagar complex (Dixon et al. 1989, p. 39; Levenhagen 1987) reported that “the major and continuing degradation of land and water resources in both project areas, (is) largely due to overpopulation and poverty. The projects should help alleviate some of these problems, although they will create others, especially in terms of resettlement”. On the other hand, a concise description of the Narmada projects written by Mr. Christoph Dlewald reported, “there are major economic benefits from the Narmada project and associated environmental and social concerns” (Dixon et al. 1989, p. 39). It is also stated that the availability of water from the Sardar Sarovar Project will benefit about 191,000 people who live in 124 villages in arid and drought-prone border areas of Jalore and Barmer Districts of Rajasthan and have been suffering grave hardship on account of the dearth of water and the extent of the desert increasing every year (The Economic Times 2001). The Bhakra-Nangal project, described by first Prime Minister Jawaharlal Nehru as a modern temple of resurgent India, is a legend of India’s developmental history. The “success” of Bhakra dam is used to justify most large dam projects in India and is often used as the last word in any debate or discussion related to the impacts, benefits and desirability of water management in the country. Even this iconic project, however, has come under attack in recent years. Shripad Dharmadhikary (2005) stated that the agriculture revolution of Punjab and Haryana is unsustainable even if one accepted the inevitability of the agricultural revolution, the primary drivers of which were HYV seeds, fertilizers, pesticides, and groundwater resources. The Dharmadhikary study, however, has been critiqued by Prof. V. Ranganathan as lacking in a rigorous approach to cost-benefit analysis and being extremely one-sided. He highlighted the need for big dams by citing the case of developed countries, where over 90% of hydro power potential has been exploited. It was stated that the essential question was how to improve management of dams and not necessarily shun them (Rangachari 2006).

These questions are socio-economically relevant, not only in India but in adjacent countries as well. The most controversial international issue between India and Bangladesh is the issue of the Farakka Barrage. The Farakka Barrage was constructed in 1970 in order to divert part of the Ganges into the Bhagirathi-Hooghly to save Calcutta port. It was presumed this barrage would reduce flood risk in the Lower Padma. But instead, the Bangladesh Government has a feeling that because of the Farakka Barrage the Padma is not getting adequate water from upstream in lean periods and that the flood propensity has increased due to shallowing of the river.

In 1996 there was an agreement that more water would be given to Bangladesh. However, future success in the implementation of this agreement depends entirely on political perceptions and not on technical solutions (Reddy and Char 2001).

While selecting the research theme a question was addressed whether river training programs and river control structures ultimately solve social, economic problems for which these plans were executed and these structures were constructed.

The twenty-first century has been declared the age of water scarcity although flood losses continue to rise (Kundzewicz and Kaczmarek 2000). In spite of extensive flood control measures, flooding is still a major issue in a tropical country be it developed, developing or under-developed. The effects of Hurricane Katrina in New Orleans on August 29, 2005 were devastating and long-lasting. It was labeled the most devastating disaster in American history; unprecedented and resulting in record high financial losses. The great flood of 1993 in the Midwest, USA has been labeled a hydrometeorological event unprecedented in recent times (IFMRC 1994; Kundzewicz and Kaczmarek 2000). The damage was extreme in some places due to extensive development of the flood plain. At some locations, the 1993 flood ranked as a once-in-100-year event and in other locations it challenged the once-in-500-year event design flood model (Changnon 1993). Bhowmik (1993, p. 130) reported "The main lesson from this event is that it is environmentally and economically better to work with a river than to work against it. The river can and will reclaim its flood plains whenever conditions are just right". In 1995, 250,000 people had to be evacuated in Netherlands when flood water on the Rhine River threatened the dyke (Begum et al. 2007). In 1996, half a million people had to be evacuated in order to repair a breached dyke along the Yangtze River and its tributary due to unusual floods in the month of June 1996 (The Telegraph 1996). In South Asia, even today, we are faced with newspaper headlines asserting that "Hundreds killed, millions stranded by floods in India and Bangladesh" and "What caused the floods and why Indus so flood-prone?" (Report 2000; Bosshard 2010). In 2008, the Kosi River created panic during monsoon season and Bihar was in the headlines (Priyadarshi 2008). In 2009 the flood water submerged the Krishna and Tungabhadra rivers and the Karnataka government released up to 67,968 cumecs[1] (24 lakh cusec) of water from the Almatti and Narayanpur dams in a single day. In August 2010, flooding in Pakistan, affected 17 million of its 167 million people.

These few examples show how catastrophic floods continue to play havoc in the lives of people all over the world. Thus, in assessing the benefits and risks of having dams, their significant role in mitigating the effects of floods should not be underestimated. The drought in the northwest in 2000 and floods in the Kosi River in the year 2008 prompted a far-reaching discussion of fundamental approaches to flood and water resource management and use in the country including the role

[1]Cumec is a metric unit of measurement for water discharge. It stands for a cubic meter of water passing through any given point per second. There are 35.31 cusec to every cumec.

of all levels of government and local riparian communities in the decision-making processes.

Since 1969–1970 the globally acclaimed concept of Environmental Impact Assessment (EIA) and, since 2001, the so called Strategic Environmental Assessment (SEA) of the European Union are being applied for large engineering projects. Any research venture we believe should have some significance not only at local, regional or national level but also at international level.

Floods have been a worldwide concern throughout history and today, together with unprecedented climate change leading to severity of flood and drought in some areas, remain an international concern. Therefore sustainable water resource management has been selected as a research theme for this study.

Dams were once hailed as great symbols of progress and of the power of people to harness nature for the good of humanity. About 45,000 large dams have been built around the world in the last century (ICOLD 1998). More than 1,500 large and medium-sized dams are in India and 100 barrages on all major river systems (Gopal 2000). Such engineering devices on river systems have raised questions with social, economic and political significance (Dharmadhikary et al. 2005, 2008). In many cases, it has been alleged that rural communities have been displaced by rising water upstream or have been denied sufficient water downstream. Many have questioned whether some control structures like dams and barrages augment the resource potential or enhance the hazard propensity of floods.

Beginning in 1997, decommissioning of large dams in the United States has exceeded their construction rate (Keller et al. 2000). Between July 1997 and July 1998, the Secretary of the United States Department of Interior, Bruce Babbitt decommissioned six large dams (Babbitt 1998). The removal of two dams from Washington's Elwha River will be one of the most significant restoration projects in recent time. Two hydroelectric dam construction in the early 1900s resulted in the loss of approximately 95% of the anadromous salmon spawning habitat on the river (Warrick et al. 2005). Removal of dams in Elwha is like destruction in the name of creation. While nearly 450 dams have been removed in the United States, there are few published studies documenting post-dam removal effects. The acknowledgement of the potential costs of future dam removal as well as sediment management may make other options of water supply like ground water storage and off stream reservoirs more competitive (Minear 2002).

The intense social and environmental debate over large dams led to the establishment of the World Commission on Dams (WCD) in 1998. WCD prepared country review studies for India and China. However, in the report, WCD has sidelined a number of key issues and the related problems that developing countries like India face (Navalawala 2001). In reference to the World Commission on Dams final report "Dams and Development – A New Framework for Decision Making" launched on 16th November 2000 at London, the Government of India, Ministry of Water Resources has rightly rejected the draft of the India Country Report. A Sekhar, Commissioner, Government of India, Ministry of Water Resources stated "On a detailed perusal of the Final Report it is seen that WCD has leaned heavily on the Consultants Country Report, totally ignoring government's view on the report and the data on the successful projects in India furnished by us to WCD. The references relating to India in the report are not based on factual and authentic information".

Water resource issues facing India are very different from those in other developed countries. In India there is spatial and temporal variation in rainfall and rainwater needs to be stored properly for efficient use. Small dam and rainfall harvesting is possible where the population is dispersed and there is a reasonable amount of annual rainfall. A series of smaller dams, even if feasible, would involve higher costs, greater submergence, far more displacement, greater evaporation losses, increased maintenance and far less benefits (CBIP 1987; The Economic Times 2001). Therefore monsoon countries like India require large-scale storage in order to assure the necessary food supply, employment and electricity generation, ecosystem conservation and mitigation of adverse impacts of floods and droughts. The question is not whether dams are necessary, but rather how these can be constructed and managed, where essential, so that the overall benefits to the society are maximized (Biswas and Tortajada 2002).

Environmental concerns worldwide have become more urgent than ever before and one of the most controversial aspects of this has been the human role and its impact on fluvial systems and on the socioeconomic environment. Geomorphologists, planners and Scientists following the lead of G. P. Marsh (1864) have historically tended to examine the effect of a range of anthropogenic changes on the riverine environments (Thomas 1956; Strahler 1956; Wolman 1967; Schumn 1969; Graf 1977, 2006; Gregory 1977, 2006; Goudie 1989, Goudie 2006a, b; Meybeck and Vörösmarty 2004; Vörösmarty et al. 2004; Kondolf et al. 2007; Naiman et al. 2005; James and Marcus 2006; Wohl 2004, 2006; Wohl et al. 2009; Braatne et al. 2008; Montgomery 2008; Bhattacharyya 1998, 1999–2000a, 1999–2000b, 2008b, 2009). M. Gordon (Reds) Wolman from Johns Hopkins University, commenting on riverbed settlers in the Damodar River, wrote (personal communication dated April 10, 1996, January 11, 2007) that controlled releases can minimize the rate of flooding in spite of canalizing common floods in other ways. "How much water can you release from the dams upstream, assuming controlled releases are possible without excessive flooding of the populated islands while still maintaining sufficient channel capacity to carry many common floods of frequent recurrence? I assume that the biggest floods requiring use of spillways on the dam will result in flooding the islands in any case. Simply put, is there a set of design flow releases that will at least reduce frequent flooding?" He continued, "it is remarkable the way in which immigrants unfamiliar with the riverine environment adapted to the altered hydrologic regime of the regulated Damodar River settling on and modifying the alluvial bars." Anthropogenic processes of the kind within riverbed *Char* lands/*Mana*[2] remarked on by Reds Wolman has not been adequately studied by geographers.

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[2] All types of sandbars are referred to as *Char* in Bengali. In Bangladesh Chars are locally known as *Mana* derived from Mohana which usually denotes a confluence of river and sea. The sandbars in the Damodar would have remained as uncultivable waste land had there been no population transfer between India and erstwhile Pakistan (presently Bangladesh) between 1947 and 1971 following Independence and Bangladesh war respectively (Bhattacharyya 1998, 1999–2000b).

According to James and Marcus (2006), "The lack of a priori model on anthropogeomorphic change, however, presents a challenge for the next generation of geomorphologists with this rapidly growing subfield". They continued that we need to enrich our understanding of how humans alter rivers (James and Marcus 2006) and at the same time how to protect and care for the river system through presence of floods, dams and community involvement. The drastic alteration of World's river systems has received much less attention than global climatic change, and it has been suggested that "the global impact of direct human intervention in the terrestrial water cycle (through land cover change, urbanization, industrialization, and water resources development) is likely to surpass that of recent or anticipated climatic change, at least over decadal time scales" (Meyback and Vörösmarty 2004; Vörösmarty et al. 2004).

This is yet another purpose behind selecting a research theme which focuses on the engineering structures on a river and human impact on fluvial environments.

From this perspective, a review of the first Indian multipurpose river valley project and its human and environmental impact through construction of control structures is timely.

1.2 Perspectives

Floods, flood control measures and physical and socio-economic significance of such measures are examined by several disciplines such as geography, sociology, economics, hydrology, and engineering sciences. Each addresses flood-related issues from a distinct disciplinary perspective. Geography is an observational or spatial science; therefore, the geographic perspective is a spatial perspective. All phenomena, physical and socio-economic are registered on this space, which is complex but concrete, coherent and predictable as well (Beaujeu–Garnier 1976). In other disciplines space enters tangentially or peripherally. In geography, space is the focusing center (Basu et al. 1995). The word space here refers to social space which is physical space with all its complexities and through which people living in it interacts, perceive, and adapt to their new-found resource base (Personal communication with Basu M, February 23, 1994). The questions raised, discussed and answered here are within the geographic perspective. Secondly, emphasis has been placed on the exogenetic landforms, land forming processes and materials. Here perspective is, therefore, a geomorphic perspective although the admission of anthropogenic forms, processes and materials in geomorphological enquiry has been acknowledged. Here the focus will be on issues which relate geomorphology to other disciplines. This is the perspective of applied geomorphology i.e., application of geomorphic knowledge in planning and managing the fluvial environment. All applied geomorphological questions, however, are addressed within a wider geographical perspective.

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