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Dhruv Sen Singh *Editor*

The Indian Rivers

Scientific and Socio-Economic Aspects

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To a great human being, an excellent teacher and a renowned social worker, my father, Shri Bhadra Sen Singh.

Foreword 1

Since the birth of civilization India has been a land where its people have bonded with rivers. Religious scriptures mention how the Ganga gushed out from the holy frozen land and how ancient cities arose on its banks as it made its way leisurely to the sea. This book is unique as it pays much needed attention to the history and perception of rivers in mythology and ancient civilizations. This fascination with rivers continues today as more and more is learnt scientifically about them: All rivers have character, and some have cut through the mighty snow-capped Himalaya and fled to the ocean blue; other iconic rivers that were once believed to have been lost are now believed to have been found, still others occur as seasonal streams fed by the monsoon rains, living short lives before they are lost in the wilderness. Yes indeed, rivers have been the very lifeline of our existence creating fertile soils and helping man to till the land, feed him by its produce and help him to navigate great distances with ease. But they have also caused considerable loss when they have broken their banks in flooding sheets of water to cause mass destruction. The last 150 years have been crucial in upsetting their natural flow established over centuries as man manipulates and regulates them for his personal needs by building dams, barrages and reservoirs.

The current book is exemplary as it tries to cover all the major river systems of the country and is written by well-known experts in the field who have devoted their lives to the study. Each drainage system is analytically examined with regard to dynamic fluvial parameters, geomorphology and societal implications. The pride of place of course goes to the Ganga. The Brahmaputra and the Yamuna receive nearly equal attention. The minor rivers of the Indo-Ganga Plain are also discussed in detail. The Son is an important river that flows through central India through mainly the Vindhyan rocks and deserves special mention as does the Narmada. The East Coast rivers such as the Mahanadi, Godavari, Krishna and Cauvery are described in detail along with their basin characteristics. One of the most interesting sections is that on the Tethyan Himalayan drainage systems in Ladakh, Lahaul and Spiti, including those of the Jammu and Kashmir region. The rivers of the Subcontinent's North-East region have a chapter devoted to them.

This contribution is unique as it collects at one place all relevant data on the major and minor fluvial systems of the country and will form an invaluable asset to all those who wishes to read the subject either for pleasure or for knowledge. Professor Dhruv Sen Singh deserves special praise for marshalling resources and experts to come up with such an excellent presentation which serves both as a ready reference as well as a book that the common man will cherish.

Lucknow, India

Prof. Ashok Sahni
FNA, FTWAS

Foreword 2

I am happy to know that Dr. Dhruv Sen Singh, Professor of Geology, Centre of Advanced Study in Geology, University of Lucknow, is editing a book on "Indian Rivers: Scientific and Socio-Economic aspects". It gives me immense pleasure to write a few words before the book appears in print.

Rivers have vastly influenced man's life from time immemorial. They have played an important role in the development of human culture in every part of the world. Besides supplying drinking water, they are urgently required for industries and other developmental projects. Our civilization, as we see it today, would not have progressed far without rivers. Battles have been fought for gaining access to and using river waters for generations. As a result, rivers have become an integral part of many international meetings and political agenda of several states and countries. Sharing of river water has always been a major issue amongst the neighbouring states of our country.

In view of the above, any book on rivers would always be welcome. I hope the book will be relevant in the context of India's developmental work. Our agrarian economy is almost solely dependent on rivers. Our government, both State and Central, therefore, place rivers on the top priority in their agenda. They frame policies for maximum utilization of river water in a judicious manner for the benefits of citizens in urban and rural areas. For this purpose, an updated database on all rivers is a major requirement.

It is also very interesting to learn that all the 37 chapters have been contributed by experts from Universities, IITs and National research institutions from all parts of the country. It presents geomorphological studies of the major river basins—the Indus, Ganga and Brahmaputra and their tributaries. Besides major basins, the book explores peninsular rivers and other rivers state-by-state and so it includes all types of rivers, i.e. snow-fed, rain-fed and groundwater-fed rivers. The proposed book is going to be the first book in the world which gives expert opinion on all major rivers of a country such as India.

I hope that the proposed book would provide useful information on Indian rivers. Apart from providing updated information on several major Indian rivers from all the major geographic segments, it incorporates results of studies into various rivers

by different experts from various disciplines. The book can be an excellent source to provide essential information on Indian rivers to students, teachers, researchers, planners and common public with a sound and updated scientific and socio-economic base. I wish a great success for the book.

New Delhi, India

Prof. Ashutosh Sharma
Secretary, Government of India
Ministry of Science and Technology
Department of Science and Technology

Foreword 3

I note with immense pleasure that a great initiative of presenting the updated information on the rivers of our country has been undertaken by Prof. Dhruv Sen Singh of Centre of Advanced Study in Geology, University of Lucknow, Lucknow. I hope that the book entitled 'The Indian Rivers: Scientific and Socio-Economic Aspects" will help to students, researchers, teachers and planners of our country.

Being an integral part of man's life, rivers have affected human civilizations since the earliest times. It is well known that people everywhere and everyday are dependent on it for their survival. Rivers are the life giver, cleanser and purifier and are also regarded very important to society in the context of spirituality.

Keeping in view the importance of rivers, any book on the rivers is always welcome. The book presents the geomorphological and socio-economic aspects of all the major rivers of India written by experts working on Indian rivers. The three river basins of India (Indus, Ganga and Brahmputra), their major tributaries, peninsular rivers and state-wise rivers have been explained. Besides, the chapters on Saraswati river, rivers in history and rivers in Hindi literature have also been added to provide overall information on rivers at a single place. All the chapters have been authored by Professors of Universities, IITS and Scientists of Indian Research Institutions.

Rivers, being one of the most sensitive components, their importance has increased multifold in environmental reconstruction. In modern era of industrialization and development which has brought us to the brink of disaster, we need an initiative to keep the common man aware of the contemporary situation of different rivers in the country and a perspective to retain a balance of riverine environment and development.

India is a country blessed with numerous rivers (referred to as the "Land of rivers") which bestow upon human society their utmost benefits be the social, religious and industrial. The book is an excellent compilation on rivers and their associated environments and utilization aspects. It will serve as a good reference on Indian rivers for those working on geological aspects and environmental development in the country.

I do hope the book acts as an eye-opener about responsibilities towards rivers which have been polluted and are in bad shape due to widespread urbanization, loss of the aesthetic sense as a result of discharge of industrial waste and excessive deplantation on river banks.

I wish all success for the book.

New Delhi, India

Prof. Talat Ahmad
FNA, FASc., FNASc., JC BOSE Fellow
Vice Chancellor
Jamia Millia Islamia

Preface

While working on rivers I have realized that all researchers, teachers, students and planners are providing different basic information about the rivers. There is not a single book which provides information at a single place about all the rivers. This compelled me to think about editing a book on rivers where one could get basic, accurate and precise information from a single source. And the effort is before you in the form of a book entitled "The Indian Rivers: Scientific and Socio-Economic Aspects", which would be the first book in the world to provide information about all major rivers of a country at a single source.

Water is the basic need of our survival, thus rivers are believed to be our lifeline. In India, different types of rivers with unique characteristics are present. India is a land of rivers, where rivers are worshipped like a mother. Rivers are a renewable natural resource. In view of this unique feature of the rivers, all ancient civilizations and cities of the world evolved and flourished near the banks of the rivers. For humans, rivers have become a way of life as they affect and control our culture, development and civilization. I have been privileged to see three rivers since my childhood (Chhoti Gandak, Rapti and Ghaghara) as they are situated within a periphery of about 10 km from my native place, Ropan Chhapra in Deoria district of Uttar Pradesh. Later, I got an opportunity to see and walk along all the major rivers of the Ganga Plain from their source to sink. Starting from the Gangotri Glacier where the Bhagirathi originates and the Satopanth Glacier, where the Alaknanda originates, up to the Kosi confluence with the Ganga in Bihar, I have seen all the confluences of the Ganga with its tributaries such as the Ramganga, Yamuna, Gomati, Ghaghara, Son, Great Gandak, Burhi Gandak and Kosi.

We are trying to understand the behaviour of the rivers, their dynamics, their science, their socio-economic aspects and also about what they expect from us. I have seen rural folk fully devoted to rivers from morning till evening throughout their lives because of their respect and love for nature. They understand the behaviour of a river in totality and in a better way than urban and educated people.

Natural factors everywhere have controlled and guided man, but this is for the first time in the 4.6 billion year history of earth that man is also affecting the natural factors up to some extent since the last century, and this a matter of great concern to

all of us. These days rivers are causing loss of life and property due to the interference of man in its natural cycle. The encroachment of man has polluted the water, disturbed the ecosystem, changed the transporting capacity, and increased the sediment load of the river, which in turn has changed the river dynamics, ultimately leading to increasing number of disasters. India has 2.45% of the world's land area, 16% of the world's population and 4% of the world's water resources. The continuously increasing population and rapid urbanization, together with the climate change are resulting in water scarcity in many parts of the country. Therefore, there is an urgent need to ensure sustainable development of the rivers with proper management. We need to take necessary measures for optimal utilization of the rivers, making them free from all kinds of pollution and degradation. All sections of the society have to work together to address the environmental issues and the challenges facing the river sector.

Professors and Scientists from different universities, IITs and National Research Institutions with considerable experience have authored 37 chapters on various rivers. The book contains chapters on all types of rivers and their basin such as Ganga basin, Indus basin, Brahmputra basin and their tributaries, and Himalayan rivers, Ganga Plain rivers, Peninsular rivers, and also the rivers of ancient India, Hindi literature, and the Saraswati River. I hope this book will serve its main purpose of providing basic scientific and social information about all major Indian rivers to teachers, students and the common public. I am thankful to all the authors for their valued contributions.

During my journey from student stage to this stage as a teacher, I have learnt a lot from my mentors, students and society. The first chapter 'Concepts of River' is the manifestation of the same journey. I hope that this book will be accepted by all in its present form. I am looking forward to hearing from you and receiving your suggestions for improvement.

Lucknow, India Dhruv Sen Singh

Acknowledgements

I am highly thankful to the authors of the various chapters from different universities, IITs and national research institutions from all parts of the country who have contributed the chapters for a great academic and social cause. I am highly thankful to Dr. A. Sharma, Secretary, Department of Science and Technology, New Delhi, Prof. Talat Ahmad, Vice Chancellor, Jamia Millia Islamia University, New Delhi and Prof. Ashok Sahni, Lucknow for sparing their valuable time in writing the foreword of this book entitled "The Indian River: Scientific and Socio-Economic Aspects". I am grateful to my teacher, Prof. I.B. Singh, who inspired and trained me to understand the rivers and their importance. Prof. Ashok Sahni, Prof. M.P. Singh, Prof. N.L. Chhabra, Prof. A.K. Jauhri, Prof. A.R. Bhattacharya, Prof. K.K. Agarwal. Prof. R. Bali, Prof. M. Singh (CAS in Geology, University of Lucknow), Dr. Pradeep Srivastava, Dr. Jayendra Singh (WIHG, Dehradun) and Prof. U.K. Shukla (Geology Department, BHU) are thanked for their constant encouragement. Prof. Ashok Srivastava, Head, Geology Department, Amarawati University, Maharashtra helped at various stages in editing the book. The colleagues and students of the Centre of Advanced Study in Geology, University of Lucknow are thanked for their unstinted support. My students, Dr. Amit Awasthi, Dr. Vikram Bhardwaj, Dr. Bishwajeet Thakur, Dr. Dhirendra Kumar, Mr. Kailash, Dr. Nishat, Mr. Chetan Anand Dubey, Mr. Balkrishna and Mr. Neeraj Kumar are thanked for their help at various stages during the editing of the book. Department of Science and Technology, Government of India, New Delhi, and Higher Education, Government of Uttar Pradesh, Lucknow are acknowledged for financial assistance to work on rivers and the Ganga Plain. I am thankful to my undergraduate and postgraduate students who interacted and insisted me to write the basic concepts of the river.

I am thankful to many people from my place of Birth Ropan Chhapra, Deoria district of Uttar Pradesh, who have travelled with me through the ever changing terrain of the various rivers. My mother Smt. Jagdamba Singh, wife Mrs. Meena Singh, daughters Sansriti Sen and Ananya Sen and brother Dr. Chandra Sen Singh

who motivated me to write this book are highly acknowledged. The book is dedicated to a great human being, an excellent teacher and a renowned social worker my father, Shri Bhadra Sen Singh.

Contents

About the Editor

Dr. Dhruv Sen Singh is an eminent Professor and a renowned teacher at the Centre of Advanced Study in Geology, University of Lucknow, India. Dr. Singh has 21 years of experience in teaching and research, primarily in the areas of climate change, glaciology, Quaternary geology, rivers of India (Ganga Plain) and natural hazards. He has published over 50 research papers in international and national journals and presented several papers in International and National conferences. He has edited and authored four books and supervised ten Ph.D. students. While working on the Gangotri Glacier, he has observed some important geological phenomena and concluded in the year 2001 and again in 2016 that retreat of a glacier is controlled by glacier and local characteristics apart from global warming and so there is no threat to the Gangotri glacier. On the basis of this observation and geological records, he explained that melting of glaciers and climate change is a natural process and had taken place earlier during the history of the earth much before the evolution of man on the planet earth. He also identified lateral erosion as a new fluvial hazard in the year 2011. He was also involved in developing the model for evolution of the Ganga Plain foreland basin. He explained and highlighted in 2002 in the Gangotri Glacier area and again in 2014 in the Kedarnath area that how the landforms and landscape in a glaciated terrain are modified by secondary processes. He is actively involved in the scientific, mainly geological knowledge dissemination and trying his best to apply Geology for the human welfare.

Dr. Singh was a member of the first and second Indian Expedition to the Arctic (North Pole Region) in 2007 and 2008. He is recipient of the Vigyan Ratna Award in 2010 by the Council of Science and Technology (CST), Government of Uttar Pradesh. His teaching capabilities and research work achieved new heights when the Department of Higher Education, Government of Uttar Pradesh, Lucknow, conferred him with the highest award of education 'Shikshak Shree' in 2013 and Saraswati Samman in 2014.

Concept of Rivers: An Introduction for Scientific and Socioeconomic Aspects

Dhruv Sen Singh

1 Introduction

Rivers are water bodies which flow in a definite direction in a channelized way and affect our culture and civilization. The rivers were the only source of water during the early phases of man's evolution. This is the reason why all the ancient civilizations evolved along the banks of rivers, e.g., the Indus Valley Civilization at Indus, Egypt at Nile, Babylon at Tigris, and Mesopotamia between Euphrates and Tigris and ancient cities also developed on the bank of rivers. Even in such a modern and scientific world, many of the cities are famous only because of the rivers which drain through them such as Haridwar, Rishikesh, Ayodhya and Varanasi etc. With the passage of time, humans interacted and started performing festivals, fairs, social and religious activities at the bank of the rivers. Many rituals are believed to be complete, only after taking a dip/bath in a holy river, even during adverse weather conditions. Taking a bath in a river, such as during the Kumbh Mela and Makar Sankranti, is not just a festival but it is a sense of responsibility of common citizens, as a tradition to sustain and preserve the rivers which are our lifeline. Later on, men established a day-to-day genetic relationship with the river, and in this way, the flowing water known as rivers became a way of life and icons of our culture. Therefore, they are regarded as our mother and are considered as lifelines.

During the initial phases of man's evolution, the population, urbanization, industrialization (cottage industry), and farming/agriculture were in equilibrium with the rivers and the environment. The rapidly growing population, urbanization, and industrialization are no longer in equilibrium with the river and its environment and thus, adversely affect the society and the lifeline river. In this way, the river which served as a boon has now become a bane to the society (Singh 2009).

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Man has been controlled and guided by natural factors everywhere but this is for the first time in the history of the Earth that man is also affecting and controlling the natural factors up to some extent since the last century, which is a matter of great concern to all of us. Indian rivers are characterized by narrow channels confined within the wide valleyes (Singh et al. 2010; Singh and Awasthi 2011a). Continuously increasing pressure of population growth on land has led to the intensification of settlement even within the floodplain and wide valley of the rivers. The encroachment of man within the natural cycle of river has polluted the water, disturbed the ecosystem, changed the transporting capacity, and increased the sediment load of the river, which in turn changes its dynamics. Hence, rivers cause loss of life and property due to the interference of man in its natural cycle (Singh and Awasthi 2011b).

Rivers are renewable natural resource, though their present situation is very critical. Therefore, we should plan for sustainable development and efficient management in such a way that the lifeline rivers can fulfill the growing demands of water and maintain their natural cycle.

Rivers are millions of years old whereas man (Homo sapien) is only ten thousand years old. The water of the rivers was pure for millions of years in the absence of man and was capable of supplying pure water, when men evolved on planet Earth. However, man at the cost of unplanned development in the last few decades has completely destroyed the natural system of the rivers. The rivers which served as lifelines for thousands of years for the survival of man are now looking toward man, for their survival.

2 Classification of Rivers

Rivers are classified into various catogories on the basis of different criteria.

2.1 On the Basis of Origin

The rivers can be classified into three categories on the basis of origin:

Snow-fed rivers are those which originate from the glaciers and receive water from the melting of snow and ice (Fig. 1). These are perennial rivers with high discharge and high sediment load. The fluctuation of water budget is very high between monsoon and summer seasons such as in the Ganga, Brahmaputra, Yamuna, Ghaghara, Great Gandak, and Kosi.

Groundwater-fed rivers are those which receive water mainly from the groundwater/subsurface (Fig. 2). These are the rivers with medium discharge and medium to low sediment load. The discharge is high during the monsoon season and very low during the summer such as Gomati, Chhoti Gandak, and Sai.

Fig. 1 Snow-fed River Ganga at Allahabad, Ganga Plain

Fig. 2 Groundwater-fed River Chhoti Gandak in Deoria district, Ganga Plain

Fig. 3 Rain-fed River Narmada at Jabalpur, Madhya Pradesh

Rain-fed rivers are those which receive water during the monsoon from the rain (Fig. 3). These are ephemeral rivers having water mainly during monsoon season with low suspended load such as Godavari, Kaveri, Krishna, and Narmada.

2.2 On the Basis of Stage

Rivers can be classified into three categories on the basis of stage:

Youth stage rivers are characterized by a V-shaped cross valley profile without any floodplain. The valley depth depends upon the upliftment of the river, and elevation of the region above the mean sea level. In this stage, valley deepening takes place (Fig. 4).

Mature stage rivers are characterized by valley widening through lateral erosion (Fig. 2). The sinuosity increases in the downstream direction. The river meanders in the plain regions and forms the point bar deposits, oxbow lakes, etc.

Old stage rivers neither deepen their valley like youth stage nor widen like mature stage (Fig. 5).

Fig. 4 Youth stage of the river which forms 'V'-shaped valley of the Ganga River in Himalaya at Rishikesh, Uttarakhand

Fig. 5 Dhuandhar Waterfall in Narmada at Jabalpur, Madhya Pradesh

2.3 On the Basis of Sinuosity and Channel Pattern

Braided rivers—In which the water flows through many channels separated by channel bar deposits. The sediment load and discharge are high. It is characterized by low sinuosity (less than 1.5), multiple channels, and huge channel bar deposits such as Ganga, Ghaghara, and Great Gandak.

Meandering rivers—In which the water flows through a (zigzag) meander in a single channel. The sediment load and discharge are low as compared to braided river. It is characterized by high sinuosity (more than 1.5), single channel, and point bar deposits such as Gomati, and Chhoti Gandak.

Straight rivers—In which the water flows through a single and straight channel. Both sediment load and discharge are low. It is characterized by low sinuosity (less than 1.5), single channel, and channel bar deposits.

Anastomosing rivers—In which the channels split and rejoin in the downstream part of the river. Sinuosity is generally less than 1.5. The Great Gandak River exhibits it in the middle reaches.

2.4 On the Basis of Water Storage

Perennial rivers—The rivers which are permanent, having water throughout the year.

Ephemeral rivers—The rivers which are temporary, having water mainly during monsoon season and remain dry for most part of the year.

2.5 On the Basis of Drainage Pattern

The pattern which is formed by the streams/rivers in a region and the area from which a stream gets runoff.

(a) Consequent—The river which flows in the direction of the slope of the region and is younger to the upliftment of the area, e.g., Krishna, Kaveri, and Godavari.
(b) Antecedent—The rivers which are older than the upliftment of the area such as Indus and Brahmaputra.
(c) Subsequent—A river which is tributary to the consequent river is known as subsequent such as Chambal and Ken.
(d) Dendritic—The pattern of the river which appears like a tree, as most of the Ganga Plain rivers.

2.6 *Indian Rivers can also be Classified on the Following Basis*

2.6.1 On the Basis of Location

Himalayan Rivers—which originate in the Higher Himalaya and are generally snow fed in origin such as Ganga, Ghaghara, Great Gandak, and Kosi.

Ganga Plain Rivers—which originate in the Ganga Plain region and are generally groundwater fed such as Gomati, Sai, and Chhoti Gandak.

Peninsular Rivers—which originate in the peninsular India and are generally rain fed such as Godavari, Krishna, and Narmada.

2.6.2 On the Basis of Catchment Area

Eighty-three river basins of India are divided into three groups on the basis of size of the catchment area (Rao 1975)

Group 1—Rivers having more than 20,000 km^2 catchment area are fourteen in number.

Group 2—Rivers having catchment area between 2000 and 20,000 km^2 are forty-four in number.

Group 3—Rivers having less than 2000 km^2 catchment area are fifty-five in number.

2.6.3 On the Basis of Water Divide and Catchment Area

Indus River Basin—The Indus system comprises the Indus and its tributaries, such as the Zanskar, Dras, Shyok, Jhelum, Chenab, Ravi, Beas, and Sutlej.

Ganga River Basin—The Ganga system consists of the Ganga and its tributaries such as Ramganga, Yamuna, Tons, Gomati, Ghaghara, Son, Great Gandak, Burhi Gandak, Kosi, and Mahananda. The Ganga has a large number of spill channels draining into the Bay of Bengal such as Hooghly and Gorai.

Brahmaputra River Basin—The Brahmaputra system consists of Brahmaputra known as Tsangpo in Tibet and its tributaries such as Raka Tista, Tsangpo, Subansiri, Ngang Dibang, Lohit, Kameng, Manas, Kopili, and Dhansiri.

3 River-Related Terminology and Geomorphology

- Channel—The V-shaped depression on the earth surface which is carved by the river under direct control of climate and tectonics. It is that part of the river which is filled with water.

- Valley—Valleys are carved by river dynamics under direct control of climate and tectonics. It is a negative landform of varying shape and size evolved by river deepening, widening, and lengthening of the valley. Generally, they are much more extensive than the channel.
- Valley/channel pattern—The geometry and the pattern of the channel adjust according to the water discharge and sediment load of the river. Therefore, the valley and the channel width will provide the information about the change in the nature of river channel. The valley and channel width indicate the stream flow characteristics. The wide valley indicates the natural capacity of the river to accommodate the high discharge of the river. It explains that the river was carrying higher discharge in the past when the wide valley was carved during humid climate.
- Floodplain—The flat area located adjacent to the river which floods when the water level rises in the river.
- Cliff—The river cliffs are the raised and vertical portion at the bank of a river.
- Sinuosity—The degree of meandering/curve is known as sinuosity. It is the ratio of distance between two points along the channel to the shortest distance between the same two points. If sinuosity is greater than 1.5, then the river is called meandering; if it is less than 1.5, then the river is braided in nature.
- Base level—Base level is the maximum limit of valley deepening; generally, it is the sea level.
- Graded stream—A stream which is capable for transportation of its total load. It neither degrades nor aggrades its valley.
- Aggradation—When shoreline (boundary between land and sea) shifts toward land, it results in the alleviation or valley filling in the upstream part of the river.
- Degradation—When shoreline (boundary between land and sea) shifts toward the sea, it results in deepening of valley in the downstream part of the river.
- River piracy—It is the erosional attack on one stream by another stream. The most common cause of stream piracy is the ability of one stream to extend its valley at a level lower than the adjacent stream. It takes place mainly due to headward erosion and lateral shifting.
- Tributary—which contributes and increases the discharge of a river, e.g., Yamuna is a tributary to Ganga River.
- Distributary—which distributes and decreases the discharge of a river, e.g., Hooghly is a distributary to Ganga River.
- Misfit River—The narrow channel confined within the wide valley. The channels are not proportionate in size to the valley that they occupy.
- Yazoo stream—The tributary stream which runs parallel to the main stream for tens of kilometer and then joins the mainstream.
- Alluvial fans—A cone-shaped deposits formed when a river debouches from the mountains on to the plains. Due to a sudden decrease in its velocity, the river drops down most of its load and forms a deposit which is fan-shaped and consists of alluvium known as alluvial fan (Fig. 6).
- Channel bar deposits—The deposits of sand, silt, and gravel within channel/valley of a river are known as channel bar. Its shape and size are

Fig. 6 Alluvial fan at Ny-Alesund, Arctic (Photograph taken during First Indian Expedition to Arctic in 2007)

Fig. 7 Point bar deposits in the Rapti River, near Gorakhpur, Uttar Pradesh, Ganga Plain

Fig. 8 Braid bar and lateral bar deposits in Ganga River at Rishikesh, Uttarakhand

controlled by discharge of the river, supply of sediments, and accommodation space available. The largest channel bar is formed when the discharge, sediment load, and depth of the river are high. Depending on the shape, size, and their association with various types of rivers, different types of channel bar deposits are identified such as point bar, braid bar, and lateral bar.

1. Point bar deposits—These are the crescent shape deposition of sand and gravel present at the inner side of bend of a meandering river. Deposition on point bar results from lateral migration of a meandering river during flooding (Reineck and Singh 1980) and may be as thick as the depth of the river (Fig. 7).
2. Braid bar deposits—The bedload of sand and gravel deposited within the channel of braided river are known as braid bar deposits (Fig. 8).
3. Lateral bar deposits—If channel bar is deposited at one side of a braided river, then it is known as lateral bar deposit (Fig. 8).

- Natural levee deposit—During the time of flood, river water overtops its bank and enters into the floodplain and deposits the sediments. Coarser sediments are deposited along the river bank, and finer sediments are further carried on the floodplain. Repeated deposition of sediments raised the river bank known as natural levees which dips away from the channel at a very low angle (Fig. 9).
- River terraces—River terraces are the former river valley floor surfaces. These are made up of sand, silt, and clay. Terraces are largely the products of river rejuvenation due to sea level changes under direct control of climate and tectonics and represent remnants of a river channel or floodplain when the river