Chapter-5

GEOMORPHOLOGY AND SURFACE WATER

Rivers are invaluable not only for humans but to all forms of life. Not only are rivers a great place for people, but people use river water for drinking-water supplies and irrigation, to produce electricity, to transport merchandise and to obtain food. Rivers are major aquatic landscapes for all manners of plants and animals. Rivers even help keep the aquifers underground full of water by discharging water downward through their stream beds.

The knowledge about stream flow is an essential requirement for construction of hydraulic structures such as dams. The first major human settlements in the Indus Valley (3000-1500 B.C.); called Indus civilization or Harrapan civilization, demonstrated a high degree of hydraulic engineering skills (Pandey, 2016). After the Harappan culture came to its abrupt end, the Vedic age was started. According to the Vedic knowledge, all life on this planet evolved from Apah (water). Literary references and archaeological data from about 6th century BC onwards indicate the development of embankments, canals and other hydraulic works. Literature suggests that there were a large number of hydraulic structures built (dams, canals and lakes) during the Mauryan period in Indo-Gangetic plains and other parts of the country for irrigation and drinking purposes (Shaw et al., 2007; Sutcliffe et al., 2011). Surprisingly, many of these structures were equipped with the spillways to consider the flood protection measures. This chapter briefly discusses about the ancient knowledge in the field of geo-morphology and surface water hydrology as available in the Vedas and other ancient literature.

The Rig Vedic hymns X.B2.1 and X.121.1 state that the creation had started with the origin of water and the cosmic golden egg (embryo) (हिरण्यगर्भ) which very well fits in the geological and biological evolution of the earth with the water age, origin of zoophytes, primeval fishes, reptiles, invertebrates, vertebrates and mammals.

चक्षुषः पिता मनसा हि धीरो घृतमेने अजनन्नम्नमाने।
यदेदन्ता अददृहन्त पूर्व आदिददयावापथिवी अप्रथेताम्।। R.V.X, 82.1 ।।

हिरण्यगर्भः समवर्ततात्रे भूतस्य जातः पतिरर्के आसीत्।
स दाधार पृथिवी घामुतेमां कस्मे देवाय हविषा विधेम्।। R.V.X,121.1 ।।

According to the Rig Veda, the earth abounds in heights, bears the burden of mountains and supports the trees of the forests in the ground (क्षमा). She quickens for she scatters rain, and the showers of heaven are shed from the lightning of its clouds. The Earth is great (मही), firm (दृढ़) and shining (अर्जुनी).

Perhaps the Rig Vedic Aryans had the concept of knowing slopes also of a region with the help of rivers as indicated (R.V.IX, 88.6) below:

एते सोमा अति वाराण्यव्या दिव्या न कोशासो अभ्रवर्षाः।
वृथा समुद्रं सिन्धवो न नीचीः सुतासो अभि कलशां असृग्रन।। R.V.IV, 88.6 ।।

Talking about the river flow whose turbulence is lost after meeting the oceans, the Rig Veda says:

समन्या यन्त्युय यन्त्यन्याः समानमूर्व नघः पृणान्त।। R.V.II, 35.3 ।।

In the verses IV,18.6 and IV,19.3 of the Rig Veda, it is said that the rivers are the daughters of sun and cloud. They run towards oceans breaking the soil, rocks etc. coming on their way. They flow in through zig-zap paths:

एता अर्षन्त्यलालाभवन्तीऋतावरीरिव संक्रोशमानाः।
एता वि पुच्छ किमिदं भतन्ति कमापो अद्रिंपिरिधिं रुजान्ति।। R.V.IV, 18.6 ।।

During the Rig Veda period, Aryans were probably acquainted with the river velocity at different stages. One verse (VI 24.6) mentions the high speed of mountainous rivers flowing down the slope as:

वि त्वदापौ पर्वतस्य पृष्ठादुक्थेभिरिन्द्रानयन्त यज्ञैः।। R.V.VI, 24.6 ।।

By the time of Sam Veda, Yajur Veda and Atharv Veda, the Indians had come to acquire sufficient knowledge of physiography and geomorphology. This is established by the geographical technical terms – उपह्वर (mountain slopes, SV.II, 5.9), इरिण (cleft or ऊपर), शिला (stony place), क्षयण (habitable place), काट (forest having a difficult communication), हद् (lake), लोप (rugged lands or bad lands) (TS,IV,5.9.1). In the Sam Veda, we come across a brief but fine

description of a river mouth and a wave of the sea opposite to the mouth of a river sends into it a portion of its water (SV XIV, 4). The prithvi sukta (XII) of the Atharv Veda, furnishes a concise account of physiography – mountains, snowcapped mountains, forest lands, plain areas (सम) and perennial stream or slopes (प्रवत). Following hymn of Atharv Veda illustrates that if the water source is on mountains, then the river formed will be perennial and will flow with high speed (AV.I.,15.3) as:

ये नदीनां संस्त्रवन्त्युत्सासः। A.V.I.,15.3 ।।

Similarly, verse II, 3.1 of the Atharv Veda reveals the same fact saying that the rivers originating from snowclad mountains will keep on flowing in summer also.

अदो यदवधावत्यवत्कमाधि पर्वतात्।। A.V.II,3.1 ।।

In the Gopatha Brahmana, the nomenclature for a meandering river is विपाट (II.8). It was also acquainted with two types of springs or falls, namely hot and cold (शीतोष्णाविहोत्सौए G.B.II,8). The celebrated epic Ramayana also reveals very rich and accurate knowledge of various types of geomorphological patterns. Some of the geomorphological patterns as mentioned in the Ramayana related to water are rivers and rills and plateaus, caverns and fountains (II,54.42.) the plain tracts (II,56.11), sandy banks of rivers (Rama. II,55.31):

सरित्प्रस्त्रवणस्थान् दरीकन्दरनिर्झरान्।। Rama. II, 54.42 ।।
समभूमितले रम्ये द्रुमैर्बहुभिरावृते। पुण्ये रंस्यामहे तात चित्रकूटस्य कानने।। Rama.II.56.11 ।।

विचित्रवालुकजलां हंससारसनादिनाम्।
रेमेजनकराजस्य सुता प्रेक्ष्य तदा नदीम्।। Rama. II,55.31 ।।

Those lands watered by the Ganga have been described as dense and hard to track (Rama. II,85.4) as:

कतरेण गमिष्यामि भरद्वाजाश्रमं यथा।
गहानोयं भृशं देशो गङ्गानूपो दुरत्ययः।। Rama. II,85.4 ।।

Knowledge of water falls (II,94.13) and descent of a river (II,103.25) is described as below:

जलप्रपातैरुदभेदैर्निष्पन्दैश्च क्वचित्।
स्त्रवदिभर्भत्ययं शैलः स्त्रवन्मद इव द्विपः।। Rama. II,94.13 ।।

नर्दी मन्दाकिनी रम्यां सदा पुष्पितकाननाम्।। Rama. II,103.24 ।।

शीघ्र स्त्रोतसमासाघ तीर्थ शिवमकर्दमम्।
सिषिचुस्तूदकं राजे तत एतद् भवत्विति।। Rama.II,103.25 ।।

How after melting of snow, a mountainous topography becomes charming is spoken of thus – हिमात्यये नगमिव चारुकन्दरम् (Ramayana II, 7.15). The author of the epic has also marked "river erosion on non-resistant or soft steep river bank (II,63.46; V,34.19; VII,14.18) as:

रुणद्वि मृदु सोत्सेधं तीरमम्बुरयो यथा ।। Rama.II,63.46 ।।
चित्तं हरसि मे सौम्य नदीकूलं यथा रयः।। Rama.,V,34.19 ।।
सीदन्ति च तदा यक्षाः कूला इव जलेन ह।। Rama.,VII,14.18 ।।

In the verse VII, 23.42 of the Ramayana, we read about the erosive action of the downpour of rain on mountains. viz.

सायकैश्चापवकभ्रष्टैर्वज्रकल्पैः सुदारुणैः।
दारयन्ति स्म संकुद्वामेघा इव महागिरिम्।। Rama., VII, 23.42 ।।

The Mahabharata divides the Himalayan mountains into three regions. It mentions large tracts of desert several times (I, 70.2). In certain context the word नदीकच्छ is used. Most probably it indicates the land form which now-a-days is called delta.

एक एवोत्तमवलः क्षुत्पिपासाश्रमान्वितः।
स वनस्यान्तमासाघ महच्छून्यं समासदत्।। M.B.,I,70.2 ।।

नदीकच्छोद्भवं कान्तमुच्छतध्वज संनिभम।। M.B.,I,70.17 ।।

In Panini's Astadhyayi (600-700 BC), we come across several important geomorphological patterns. The grammarian calls a river moving and breaking its banks as भिन्द्य and that whose water overflows the banks as उद्ध्य (III,1.15). Glacier is named हिमानी (IV,1.49) as:

इन्द्रवरुणभवशर्वरुद्मृड़हिमारण्ययवयवनमातुलाचार्याणमानुक।। Astadhya.,IV,1.49 ।।

Topography and geomorphology have been discussed very well in the Arthasastra by Kautilya (4th century BC) during the Mauryan period. Various types of lands such as "forests, villages, waterfalls, level plains and uneven ground", stretching between the Himalayas and ocean (Arthasastra, Trans. by Shamshastri P.404) have been mentioned there. At various places he speaks of fertile, infertile, cultivable, uncultivable and waste land, which reveals that he must have possessed good knowledge of the science of soil also at that time.

The Vayu Purana refers to various types of topography namely lakes, dales, barren tracks (Chapter 38), rocky through between mountains (अन्तद्रोणी) (38.36).

पश्चिमायां दिशि तथा येन्तरद्रोणिविस्तराः।
तान्वर्ण्यमानांस्तत्वेन श्रृणुतेमान्द्विजोत्तमाः।। Vayu.,38.36 ।।

The chapter 38 of Vayu Purana also speaks about the large number of hot springs in a mountainous region (38.78).

तथा हयनलतप्तानि सरांसि द्विजसत्तमाः।
शैलकुक्ष्यन्तरस्थानि सहस्त्राणि शतानि च।। Vayu.,38.78 ।।

In the Markandeya Purana (53.21-22), we come across a peculiar type of topography found "in the Kimpurusaversa and seven other countries" where water bubbles up from the ground as:

नवस्वपि च वर्षेषु सप्त सप्तकुलाचलाः।
एकेकस्त्रिस्त था देशे नघश्चाद्रि विनिः सृताः।। Markandeya P.53.21 ।।

यानि किं पुरुषाघानि वर्षाण्यष्टौ द्विजोत्तमः।
तेषूदिभज्जानि तोयानि नैवं वार्यत्र भारते।। Markandeya P.53.22 ।।

The Vishnu Purana (II,5.3) classifies the soils of sub-terranean region in seven categories viz. (1) black, (2) white or yellowish, (3) blue or red, (4) yellow, (5) gravelly, (6) hilly or boulder and (7) golden hued, as:

शुक्लकृष्णाः पीताः शर्कराः शैलकाज्वनाः।

भुमयो यत्र मैत्रेय वरप्रासादमाण्डिता।। Vishnu.,II,5.3 ।।

The Vrhatsetrasamsa (6-7 century AD) (Tripathi, 1969) has many scientific and mathematical enumerations conforming to some hydrographical or hydrological laws. Anguttaranikaya (before 400 B.C.) classifies lakes into four categories (part II, page 105, Tripathi, 1969).

Epilogue

From the above discussions, we see that in ancient India, the knowledge of streamflow and geomorphology was well developed on scientific lines. A number of hydraulic structures were constructed during that time for irrigation and domestic purposes. The techniques of knowing slope of an area by means of a flowing river and dimensions of river at various stages along with velocity were developed. That the mountainous rivers are generally perennial and deposition of fertile soil takes place periodically on flood plains was understood which is in accordance to the modern experiences. The arrangement of sluice gates was also made in the dams for flood protection purposes. Various types of topographies such as springs, water falls, mountainous, plateau, eroded land etc. along with many geographical terms such as शिला, इरिण, क्षयण, लोप were used. Land classification such as fertile, infertile, cultivable, waste land etc. and soil classifications, such as black, yellow, red, gravelly, boulders etc. was well in vogue before 4^{th} century B.C. These are in vogue even at present and hence, can be regarded as the important achievement of the ancient Indians in this field.