Hydrology of Upper Indus Basin

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Abstract

The River Indus originates from mountains of the Himalayas of Baltistan-Pakistan and many of the smaller streams falls in Indus. The paper demonstrates the hydrology of the Upper Indus Basin at northern areas of Pakistan in order to know the flow trend, long term flow trend in river, catchment's properties, and changing in the flow and water resources due to climate change impact. During this research the 7 stations of upper Indus Basin Balakot, Chitral, Gilgit, Murree, Muzaffarabad, Peshawar and Skardu were hydrologically analyzed. The precipitation data was obtained from WAPDA. During Precipitation analysis it was found that Murre is the station that receives the maximum amount of rainfall throughout the year. The flow Trend of Tarbela and Mangla Dam, annually, monthly and summer is also analysed. Being an agricultural country the Tarbela and Mangla are very important for Pakistan economy but also its stability. The maximum flow was observed in 1973 that is 3235 m3/s and the minimum flow occurred at 1974 that was 1760 m3/s. During the analysis of the Discharge at Mangla Dam it was found flow behaviour of Indus and Jhelum Rivers catchments both are different. The maximum flow was observed in 1991 that is 1267 m3/s and the minimum flow occurred at 1997 that was 228 m3/s.

Keywords: Upper Indus Basin; Climate Change; Precipitation and Flow Trend.

1. Introduction and Literature Review:

The upper Indus Basin is located within the glaciers that have a big potential in water resources and hydropower generation. It is absolutely reasonable to understand the changes in the glaciers will be considered in the changes in volume and runoff from the mountain basins [1]. While the headwaters of the River Indus lie Within India and China, most of the basin is within Pakistan. The portion of the Indus just above Tarbela reservoir receives almost 80% of the flow from snow and the ice melt along with other western tributaries, the Swat and Kabul [2].

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As a result of the Indus Water Treaty-1960, India has the authority to deflect the large amounts of the flow of the Ravi, Sutlej, Chenab and Beas [3]. Some of those streams have already been changed putting increasing pressures on the Indus river demands, Jhelum, and tributaries at western sides. Due to that, Pakistan has to rely heavily on the water result of ice and snow melt. The Upper Indus Basin-IBS consists of the streak of mountain/hilly ranges of intense ruggedness and particularly high elevations. The ranges move almost west-east in an arc from the Hindu Kush and Pamirs in the west and north to the main Himalayan ranges. The Central Karakoram makes the main part and water sources of the Upper Indus. With hundreds of peaks in surplus of 6000 m elevation, it consists of a vast belt of high valleys and mountain ridges. On the main Karakoram Range there is huge formation of glaciers. This is in converse to some of the lesser ranges, and much of the Greater Himalaya chain to the east whose high, but a certainly not very large, massifs are disconnected by deeply incised former rivers, and do not back glaciers of such extent as in the Karakoram ranges [4].

The glaciers of the Karakoram ranges cover an area of about 16300 sq.-km [4]. While there are thousands of glaciers in this zone a few massive glaciers account for an excessive area Glacier grows or shrinks as a result of complicated interactions within the practice of mass gain in the form of snow and energy interchange, primarily as short and long wave radiation and sensible heat. These interactions figure out the mass balance of any glacier. The snow deposited per annum produce on the surface of a glacier represents a sink of heat. When snow deposited in the glacier transcend the amount of ice and snow that is eliminated by the annual amount of energy input, the mass balance is considered to be positive, and over time the glacier will grow and advance [5]. When the sufficient energy is received to melt both the annual snow stake and the ice composed from snow deposits of last years, the mass balance of glacier is negative, the glacier will retreat. Glaciers may retreat from each increase or decrease in the availability of energy [6].

The mean summer altitude of the 0°C isotherm, at which satisfactory snow and ice melt is possible to yield miserable runoff from a basin, is approximated to be 5,000 m [7]. A few valley glaciers in the Karakoram, Himalaya have extreme altitudes of 3,000 m. At these altitude ice melt is supposed to be develop during most of the months every year. This evolution represents a very minor fraction of the glacier surface of the UIB and produces insignificant runoff only [8]. The dominant altitude of the volume of the runoff raised by ice melt is immediately lower the yearly freezing level, where a sequence of energy exchange and surface area of glacier is maximized. In determination of the role of glacier melt in the south Asian rivers, it is important to know that, currently, there are altitudes of 5,000 m above in which the snow is deposited and never melts under present-day conditions [9].

1.1 Study Area: The main aim of conducting this research is to hydrologically analyse the upper Indus basin of Pakistan. Precipitation trend of Seven different stations Balakot, Chitral, Gilgit, Murree, Muzaffarabad, Peshawar and Skardu were analysed as shown in fig-1. In addition, flow trend of Tarbela and Mangla reservoirs are also determined in order to know the exact hydrological behaviour of the UIB. Here are the details of the stations hydrologically examined.

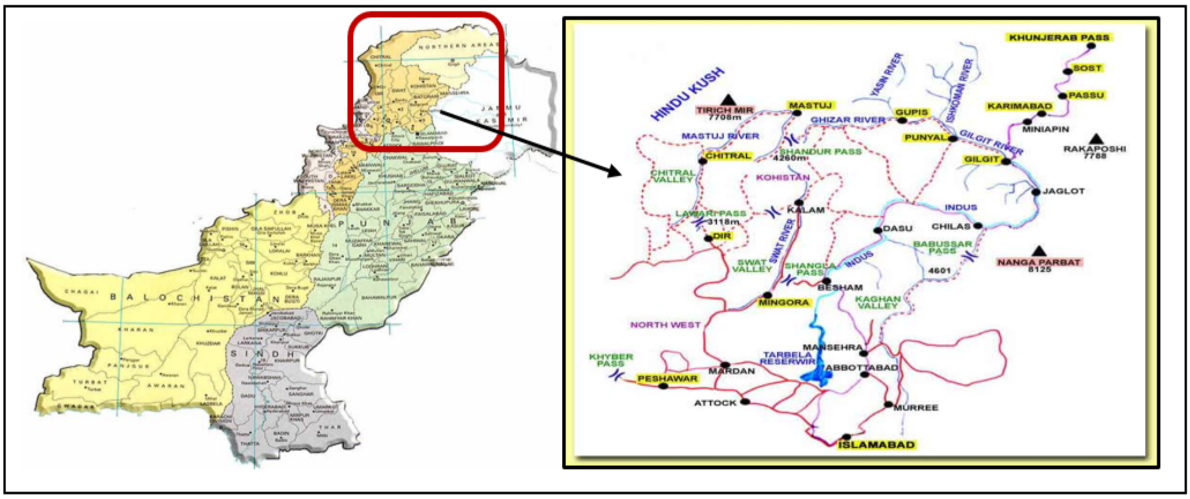

Figure 1 Study Area: Upper Indus Basin

1.1.1 Balakot: Balakot is positioned in Khyber-Pakhtunkhwa at a distance of thirty-eight kilometres from Mansehra city. The Kunhar river, originating from lake Lulusar , that flows from the city and joins with River Jhelum in Muzaffarabad Azad Kashmir. Balakot has hot summers and cool winters (humid climate).

1.1.2 Chitral: The District of Chitral is situated along the western bank side of the Chitral River, in Khyber Pakhtunkhwa, the elevation of 1,500 m makes it one of the highest place of Pakistan.

1.1.3 Murree: Murree is the outer Himalayan station with a very high altitude and is the subdivision of Rawalpindi District.

1.1.4 Gilgit: The Gilgit valley is situated in the northern part of Pakistan. The Gilgit city is the capital city of the valley. It is one of the highest place of the Pakistan with an elevation of 1500 mm.

1.1.5 Muzaffarabad: Muzaffarabad is the capital city of Azad Jammu and Kashmir of Pakistan and is located on the banks of Jhelum and Nelum rivers.

1.1.6 **Peshawar:** Peshawar the capital city of the Khyber Pakhtunkhwa province of Pakistan. Peshawar having very hot summers and comparably cold winters.

1.1.7 **Skardu:** Skardu district is located in Gilgit Baltistan and its valley consists of 10 km wide and 40 km long strip and having the altitude 2,500 metres.

2. Methodology:

The whole methodology is divided into three phases

2.1 **Data Acquisition:** Gauge Data of precipitation was acquired from Pakistan metrological Department of seven different stations including Balakot, Chitral, Gilgit, Murree, Muzaffarabad, Peshawar and Skardu at Upper Indus Basin from 1980 to 2014. The flow data from 1960 to 2014 of Tarbela and Mangla Dams were also acquired from WAPDA.

2.2 Data Process: Data was available in daily basis that was further processed and converted into monthly average, annual so that the trend can be easily analysed, mean annual, mean monthly graphs was also generated of all 7 stations, Tarbela and Mangla reservoirs.

2.3 Data Analysis: Finally, the data was analysed to check the hydrological trend, variation, impact of climatic change and temperature.

3 Results:

3.1 Hydrological Analysis of Upper Indus Basin:

Rainfall in Upper Indus Basin

Figure-2 shows the cumulative rainfall per year from 1980 to 2014 at 7 different stations of Balakot, Chitral, Gilgit, Murree, Muzaffarabad, Peshawar and Skardu of Upper Indus Basin.

Balakot: In Balakot the rainfall is much greater than the other parts of country. A huge rainfall occurs from February to March that is the late winter in Pakistan and from June-August in the monsoon season. The maximum rainfall 2033 mm observerd during the year of 1991.

Chitral: The annual average temperature of Chitral is 15.6 °C. During the year a very little rainfall is observed, that is about 418 mm annually. The maximum precipitation was recorded 729 mm in 1991.

Murree: Precipitation is observed around the year with two tenures, first in winter and second one at the summer. The total annual average precipitation is 1,789 mm (70.4 in). The maximum rainfall occurred during the year of 1992 and it was 2433 mm.

Gilgit: Gilgit has a very cold deserteous conditions of weather. The main season of Gilgit is winter, that consists around eight-nine months a year. Gilgit observes significant amount of rainfall, averaging in 120 to 240 mm annually. Irrigation for land cultivation is obtained from the rivers, enough with melting snow water from higher altitudes. The maximum rainfall occurred during the year of 1996 and it was 251.7 mm.

Muzaffarabad: The maximum rainfall observed 1813 mm during the year of 1997.

Peshawar: The rainfall occurs in both summer and winter, the maximum rainfall in winter was measured 236 mm in February 2007, while the maximum rainfall at summer was observed 402 mm in July 2010. In this month, a historical 274 mm' rainfall fallen within a day. The average rainfall levels in winter are much higher than the summer. Based on the 30 years of record, the average mean rainfall level was recorded as 400 mm and the maximum annual rainfall level of 904.5 mm was recorded in 2003.

Skardu: The climate of Skardu is moderate, the mountains block the monsoon rains, due to this the rainfall in summer is thus very low. However, due to these mountains a very severe winter weather is observed. In monsoon period April-October, temperatures changes from a maximum of 27°C and a lowest 8°C in the month of October. The maximum rainfall 495.4 mm occurred during the year of 2010.

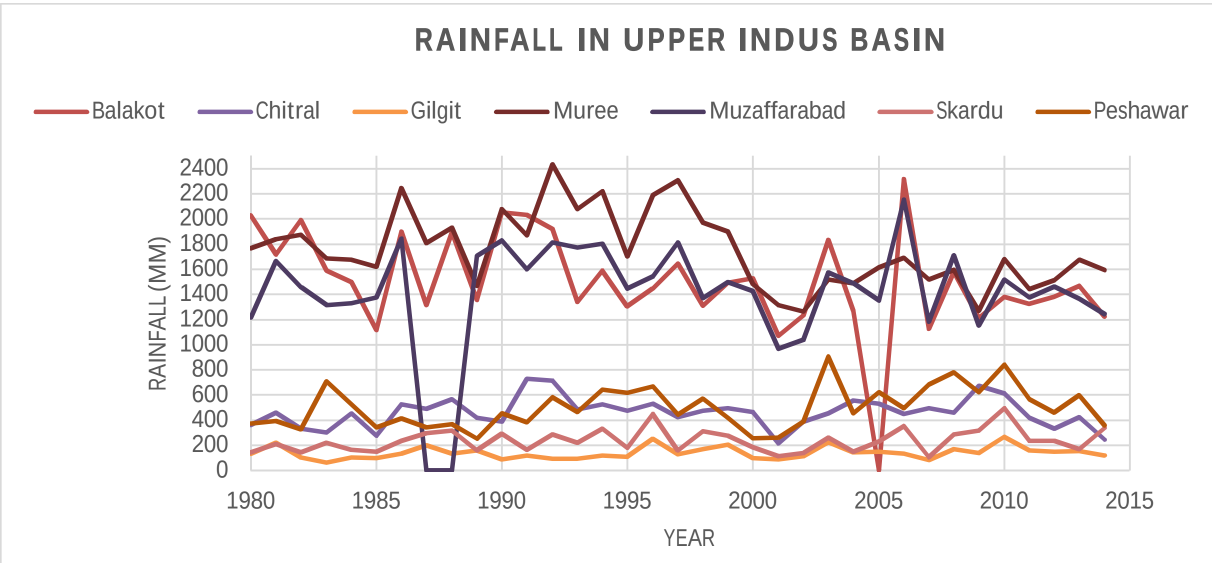

Figure 2 Rainfall in Upper Indus Basin

3.2 Flow Trend at Tarbela Dam:

During the analysis of the Discharge at Tarbela Dam the extreme events are found consecutive, like in the year of 1963 flow was minimum 2093 m^3/s, at 1964 flow was 2576

m^3/s, at next year flow again decreased, in 1965 the flow was 2143 m^3/s this trend shows that the floods and droughts are directly interlinked. In a year if there is a flood condition then the next year there was a drought at downstream side. In 1973 the maximum flow was observed that is 3235 m^3/s and the minimum flow occurred at 1974 that was 1760 m^3/s. The annual flow trend of Tarbela is shown in fig-2 below.

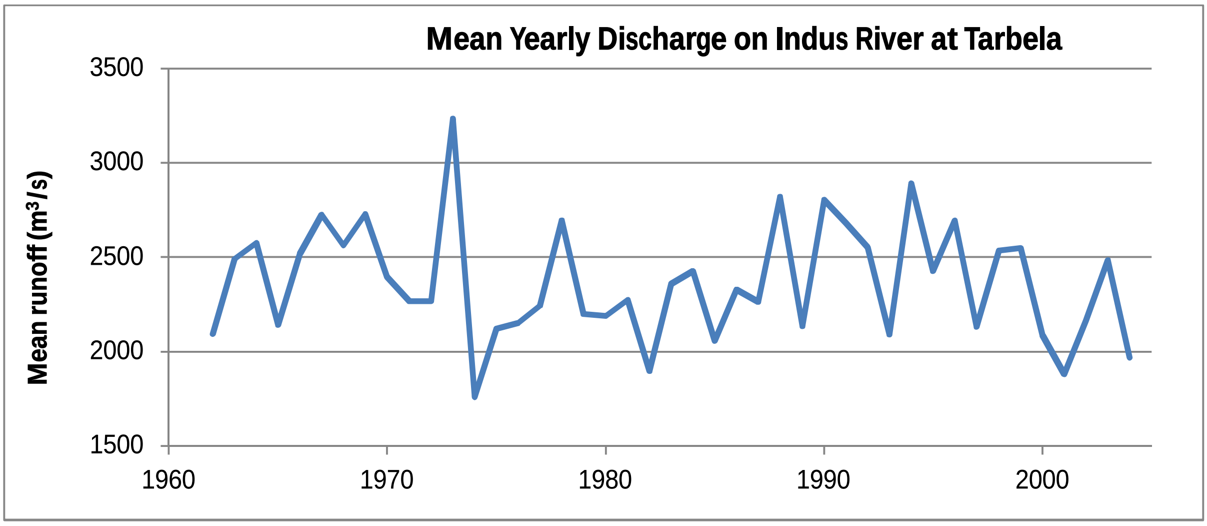

Figure 3 Average Yearly Discharge on Indus River at Tarbela

The figure-3 is the graphical representation of the Mean Monthly Discharge per Year from January 1960 to December 2013 at Tarbela Dam on Indus River. The trend shows that flow starts to increase in May, with maximum runoff occurring in July in Tarbela. The July peak flow (i.e 7056 m^3/s) is constant in all years this is because of the end of a snowmelt as a major source of surface runoff, as the winter snow deposit is removed due to higher temperature at upper Indus basin.

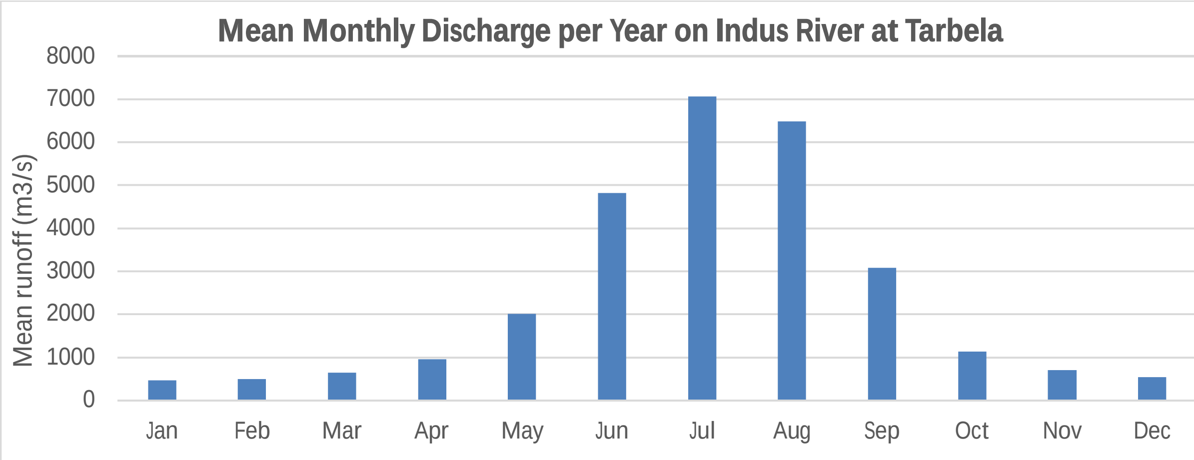

Figure 4 Average Monthly Discharge per Year on Indus River at Tarbela

The flow trend in the summer that starts in Himaliyan tributary from May is shown in fig-4. After April there is a sudden shift has observed, more than 1000 m3/s flow uses to increase this is because of rapid melting of snow at upper Indus basin due to change in temperature.

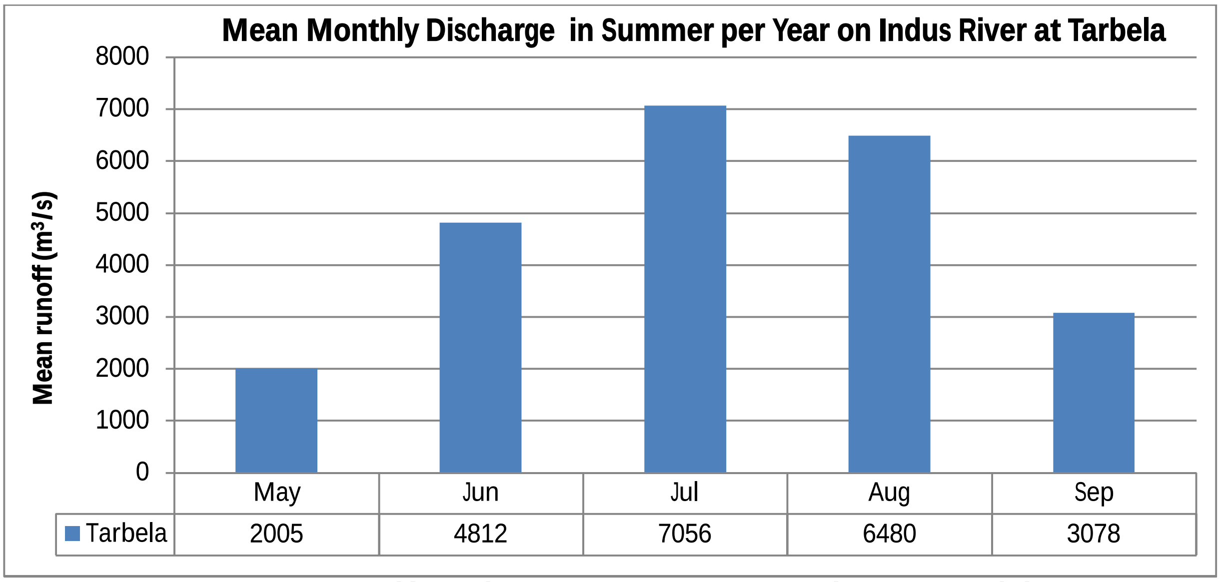

Figure 5 Mean Monthly Discharge in summer per Year on Indus River at Tarbela

3.3 Flow Trend at Mangla Dam: During the analysis of the Discharge at Mangla Dam it was found flow behavior of Indus and Jhelum Rivers both are different that is further described in next graphs, the fig-5 shows the hydrological behaiour of Mangla during the years of 1964 to 2004. The maximum flow was observed in 1991 that is 1267 m^3/s and the minimum flow occurred at 1997 that was 228 m^3/s.

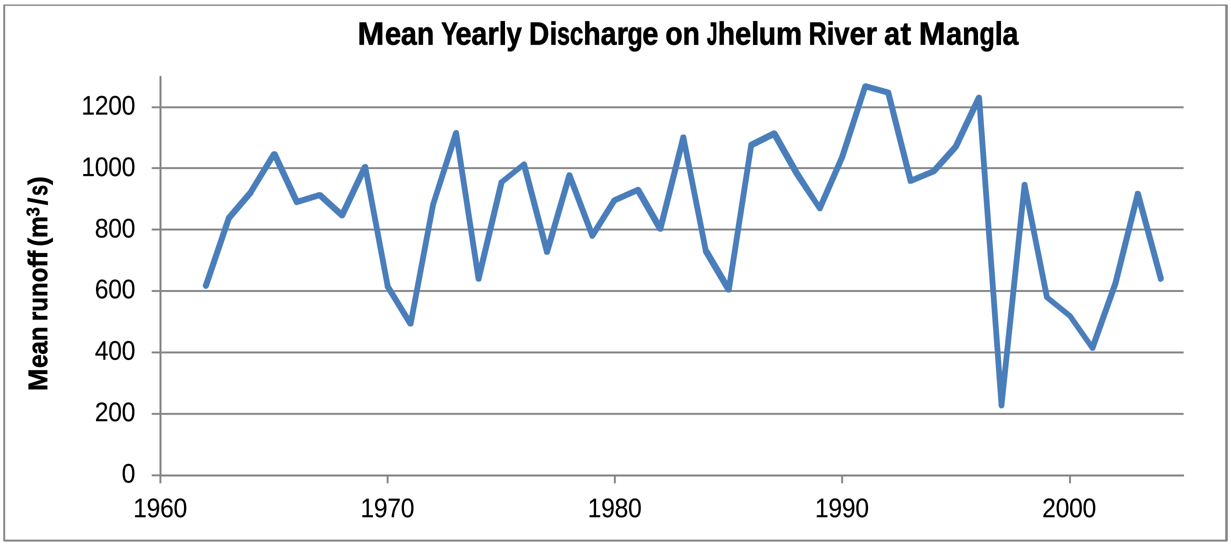

Figure 6 Mean Yearly Discharge on Jhelum River at Mangla

Fig-3 shows the Mean Monthly Discharge on Jhelum River at Mangla from 1960 to 2013, the trend shows that the maximum flow occurred at June 1711 m3/s.

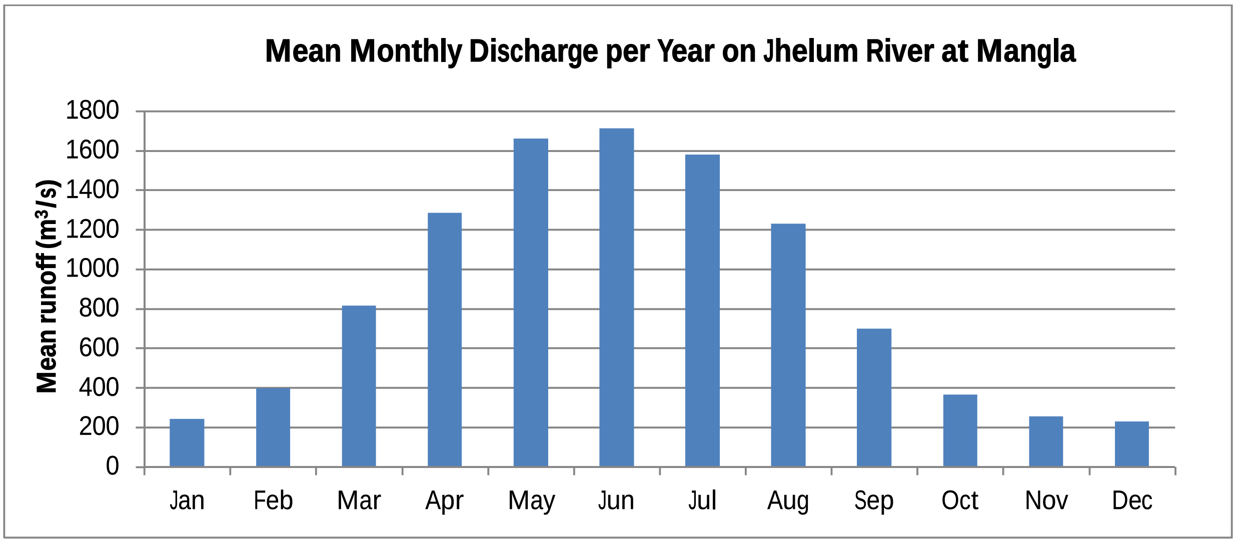

Figure 7 Mean Monthly Discharge per Year on Jhelum River at Mangla

Fig-7 shows the Mean Monthly Discharge in summer on Jhelum River at Mangla Dam. Here after the month of February the temperature starts increasing and the snow starts melting in March. The maximum flow has observed during the months of May and June because at these months almost all snow has been melted that has fallen during the winter.

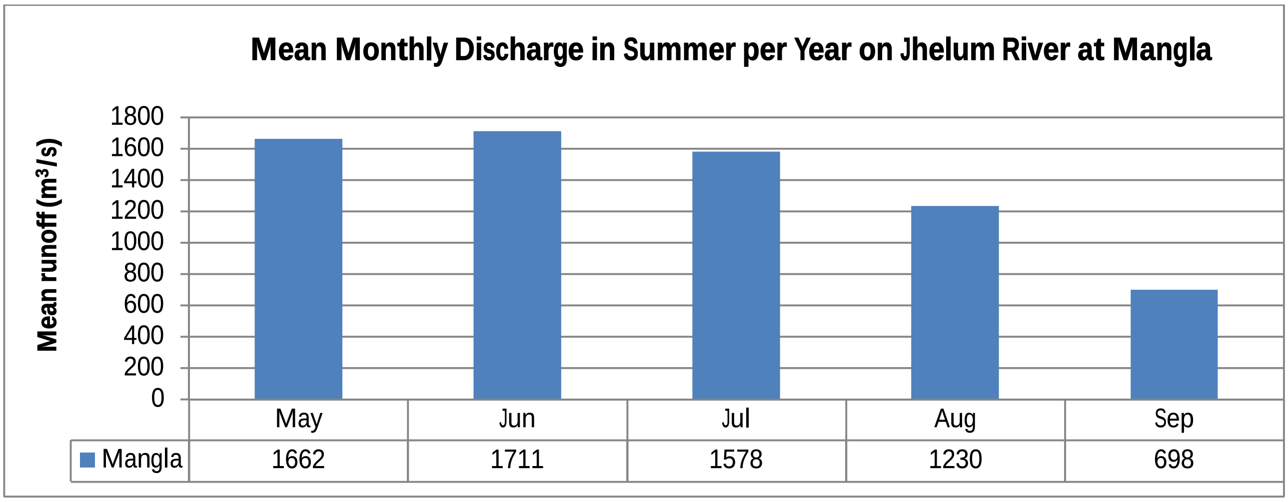

Figure 8 Mean Monthly Discharge in summer per Year at Mangla

Conclusion:

During this study the all major stations of upper indus basin were analyzed, the precipitation trend, reasons of changes are studied. The precipitation data was obtained from WAPDA. During Precipitation analysis it was found that Murre is the station that receives the maximum amount of rainfall throughout the year. Total mean precipitation annually in Murre is 1,789 mm (70.4 in). The maximum rainfall occurred during the year of 1992 and it was 2433 mm. The Skardu is a region which has a minimum temperature and it receives minimum amount of precipitation throughout the year. The maximum rainfall occurred during the year of 2010 and it was 495.4 mm only in Skardu.

The flow of the Dams depends on the rainfall at the upper Indus Basin if rainfall is more the flow is maximum in Tarbela. The maximum flow was observed in 1973 that is 3235 m^3/s and the minimum flow occurred at 1974 that was 1760 m^3/s. During the analysis of the Discharge at Mangla Dam it was found flow behavior of Indus and Jhelum Rivers catchments both are different. Here after the month of February the temperature starts increasing and the snow starts melting in March. The maximum flow has observed during the months of May and June because at these months almost all snow has been melted that has fallen during the winter. The maximum flow was observed in 1991 that is 1267 m^3/s and the minimum flow occurred at 1997 that was 228 m^3/s.

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