Status-quo of the different canal systems of Punjab, India

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Abstract: In India, Punjab is a state which grows large proportion of countries agricultural products and the dependence of cultivatable land, for irrigation, is highly shifting towards the use of surface water. Currently, there are three major fresh water rivers that flow through Punjab i.e., Ravi, Beas and Satluj. Since, India's independence and its partition, several reforms have taken place with respect to the modifications in the flow of these rivers. As several activities of the state such as, industrial, domestic, geo-political etc., are dependent on the availability of the fresh water, therefore, it is imperative to provide the status-quo of the changes in the rivers of Punjab. This article brings forward, the present condition of the three rivers of Punjab with respect to the development of canals, construction of headworks, dams etc. It is expected that this article will provide an insight of the complete fresh water distribution in the state Punjab, India, to the various stakeholders of associated fields.

\textit{Keywords:} Fresh water management, sustainable development, depletion, sustainable development goals.
1. Introduction

Surface water is one of the most exploited source of fresh water and it is available in different forms viz., rivers, water vapors, [1–4] swamps, marshes, moisture etc. Among all the water resources, the proportion of surface water is only 1.2% out of which 0.49% is in the form of rivers. The proportional distribution of surface water is shown in Figure 1.

![Figure 1. Distribution of global fresh water resources](image)

Although, overall proportion of rivers with respect to the total fresh water content, is very less yet, they play an important role in various geo-political issues. In India there are approximately, 400 rivers which are categorized into four major types i.e., 1) Himalayan rivers; 2) Peninsular rivers; 3) Coastal rivers and 4) Inland drainage basin. These rivers fulfill various needs of the Indian citizens such as, agrarian, hydro-electricity, domestic, industrial, tourism etc [5–8]. In this way, these water bodies can substantially impact the overall growth of a country. Therefore, distribution of the amount of water and its management within
the different territories, needs to be done very carefully and responsibly. This is a crucial step with regard to comprehensive development of the various associated United Nation's Sustainable Development Goals (SDGs). Some of the SDGs associated with the management of fresh water are SDG 3, SDG 6, SDG 11, SDG 12 and SDG 15

In this regard, this article will present a comprehensive review of the surface water distribution in Punjab, India. This geographical region is one of the most important regions of India with respect to the agricultural production. Therefore, since the independence of India and finalization of the Indus-Water Treaty, several canals have been drawn from the rivers and various structures have been built. Considering the importance of the issue for current times, this article will bring forwarded the status-quo of the canal system of Punjab [9–12].

2. Surface water distribution in Punjab and its importance

Punjab has a tremendous cultivatable land as out of its total geographical area i.e., 50,362 km², 83% is agrarian land. Major source of irrigation i.e., 95%, of this much land is dependent on natural water resources. Since last three decades, agricultural production of Punjab contributes in about 30% to 50% and 60 to 65% of India's rice and wheat production, respectively. In this way, Punjab has assisted India in becoming self-reliant with respect to food production [13–16].

With the several technological interventions, in the last three decades, the use of area for the cultivation of food grains has increased by approximately 62%. Similarly, it has also been reported that the unit area production of rice and wheat has increased by 77.78% and 95.55%, respectively (MAFW 2018). Subsequently, the area coming under the artificial irrigation has increased by almost 83% . Out of the total irrigated area, the ratio of area under groundwater irrigation and surface water irrigation is 3:1 . Moreover, surface water in the canal system of Punjab also serves the domestic and industrial needs of the State. Therefore, it is imperative to discuss the canal system of Punjab [17–20].
3. Surface water supply system

Surface water system of Punjab relies on the three rivers i.e., Beas, Ravi and Satluj. As per the Indus water treaty concluded between India and Pakistan in the year 1960, water of these three rivers is to be exclusively utilized by India. Another river that passes through Punjab is Ghaggar however, it is a monsoon fed river and its sources lie in Himachal Pradesh. The Ghaggar river after crossing the Narwana branch of Bhakra Canal System flows down to Ottu weir and then on to Rajasthan territory where it merges in the sand drones of Hanumangarh beyond which the bed towards the Indo-Pak border is dry. An elaborated description of the Punjab's surface water system, including important dams, is shown in Figure 2.

![Illustration of Punjab's Dams and canal systems](https://irrigationapp.punjab.gov.in/Login.aspx?type=canal)

**Figure 2.** Illustration of Punjab's Dams and canal systems (source: https://irrigationapp.punjab.gov.in/Login.aspx?type=canal)

Further, as per Irrigation Commission (1972) report vol. III (part 1), the drainage area of the Indus system of rivers comprising, Ravi, Beas and Sutlej, in three different states of India is, 1) Punjab (50,30,400
hectare); 2) Rajasthan (15,81,400 hectare), and 3) Haryana (9,93,900 hectare). Therefore, in order to regulate the flow of the surface water, several dams and reservoirs have been constructed on the heads of these rivers.

3.1. Canal system of Punjab

Punjab canal system flows through the state with total length of 14,500 km and the major canal irrigation systems are categorized into two types i.e., perennial and non-perennial. As shown in Figure 2, there are seven major canal irrigation systems in Punjab and they are, Sirhind Canal, Bist Doab Canal, Ferozepur Feeder/Sirhind Feeder, Eastern Canal, Makhu Canal, Bhakra Main Line Canal, Upper Bari Doab Canal, Kashmir Canal, Shahnehar Canal and Kandi Canal. Among these canal irrigation systems only the Eastern Canal system is non-perennial and all others are perennial systems. Details of these canal systems i.e., length and canal command area (CCA), are further provided in Table 1.

| S.No. | Canal system          | Length (km) | CCA (km²) |
|-------|-----------------------|-------------|-----------|
| 1     | Sirhind canal         | ~60         | 135.90    |
| 2     | Bist Doab canal       | 42          | 199       |
| 3     | Upper Bari Doab canal | 43          | 54        |
| 4     | Sirhind Feeder        | 137         | 36        |
| 5     | Eastern canal         | 8           | 21        |
| 6     | Bhakra Main line      | 162         | 3.81      |
| 7     | Shahnehar canal       | 25          | 3.30      |
| 8     | Bikaner canal         | 112.02      | 29.15     |

Further, in order to manage the distribution of surface water, several headworks are constructed on these canal systems and some of them are enlisted in Table 2.

| S.No. | Canal system | Length (km) | CCA (km²) |
|-------|--------------|-------------|-----------|
| 1     | Sirhind canal| ~60         | 135.90    |
| 2     | Bist Doab canal| 42      | 199       |
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| 7     | Shahnehar canal        | 25      | 3.30      |
| 8     | Bikaner canal         | 112.02  | 29.15     |
| S.No. | Headworks          | River(s)               | Regulatory body    |
|-------|--------------------|------------------------|--------------------|
| 1     | Nangal headworks   | Satluj                 | BBMB               |
| 2     | Rupnagar headworks | Satluj                 | Punjab irrigation  |
| 3     | Harike headworks   | On confluence of Satluj and Beas | Punjab irrigation |
| 4     | Hussainiwala headworks | Satluj              | Punjab irrigation  |
| 5     | Madhopur headworks | Ravi                  | Punjab irrigation  |
| 6     | Shahnehar Barrage  | Beas                  | Punjab irrigation  |

3.2. River Ravi

Ravi river is one of the tributaries of the Indus river and it flows in the north-western India and north-eastern Pakistan. In India, this river originates in Himachal Pradesh and then passes through Jammu and Kashmir and then finally passing through Punjab it enters in Pakistan.

3.2.1. Ranjit Sagar Dam

It is also known as the Thein Dam and it is shown in Figure 3. Ranjit Sagar Dam was constructed on Ravi river near Pathankot city of Punjab. It is located approximately 24 km up-stream of the Madhopur headworks. The water of Ravi stored by this dam is used for generating electricity and providing water for irrigation. This hydroelectric dam generates 600 MW electricity form four power units of 150 MW capacity.
3.2.2. **Ravi River Canal Systems**

3.2.2.1. **Madhopur Headworks**

Madhopur headworks, built in 1902, is located on the Ravi River. Madhopur headworks is located 24 kms downstream Ranjit Sagar Dam. From Madhopur headworks, three canals are generated and these are: 1) The Madhopur Beas link (MB link); 2) Kashmir Canal and 3) Upper Bari Doab Canal (UBDC).

3.2.2.2. **Madhopur Beas link (MB link)**

The MB link, having a design capacity of 10,000 cusecs (1.02 MCM/h) was constructed in 1955-1957. Its current linking capacity is of 6,000 cusecs and it links the Ravi River with Beas River.

3.2.2.3. **Upper Bari Doab Canal (UBDC)**

The UBDC is a perennial irrigation canal branchin off from Madhopur headworks and supplying the districts of Gurdaspur, Amritsar and Lahore in the Bari Doab or the area between the Beas and Ravi irrigating 335,000 hectares of land. The length of UBDC is 42.35 km and it was constructed in 1693. In
coming years, several changes were done in its structure and during independence of India its capacity was reported to be 9000 cusecs.

3.2.2.4. Kashmir Canal

As the name suggests, the Kashmir canal transfers the water from the Ravi river to the state of Jammu and Kashmir. It is constructed in the upstream of Madhopur headworks and its length is ~ 5.26 km and its capacity is 1050 cusecs. Further, this canal is divided into two feeders i.e., 1) Chakandar feeder and 2) Kathua canal. Both the canals are having a discharge capacity of 400 cusecs.

3.3. River Beas

Beas is a contributory river of the Indus system. It is 460 km long and originates from two sources i.e., Beas Kund and Beas Rishi which are located in the south and right side of the Rohtang Pass, Himachal Pradesh. As the Beas river is a glacier-fed river therefore, it is a perennial river, however, its discharge highly varies in different seasons of the year.

Before entering in Punjab, water of the Beas river was stored by the Pong Damin Himachal Pardesh. Water released from Pong Dam enters into Punjab near Talwara, Hoshiarpur where, it is immediately subjected to further distribution in canals for providing water for irrigation. In this way, Shah Nehar Canal is carved that draws 4170 to 8611 cusecs of water. Near district Gurdaspur, its discharge is regained as some water resources from Ravi river mixes with it and finally, it mixes with river Satluj near Harike.

3.3.1. Pong Dam

Pong dam, as shown in Figure 4, is built on Ravi river in district Kangra, Himachal Pradesh and it was built in 1974. The initial purpose of building this dam was power generation, irrigation and flood control. It is an earth-core-cum-gravel shell dam having height of 132.59 m and has a catchment area of 12,561 km². The Pong dam has 4 outlets, two in each tunnel and 6 turbines are installed for power generation of 396 MW.
3.3.2. Pandoh dam

Diversion dam on river Beas located upstream of pong dam and about 21 km away from the town on Mandi, Himachal Pradesh. Pandoh dam, as shown in Figure 5, is a part of Beas-Satluj Link project and through this dam 3.82 MAF water is transferred from Beas river into Satluj river using two tunnels and an open channel. During this process, 990 MW electricity is also generated at the Dehar power station. The reservoir of this dam has a capacity of 4.1 MCM.
3.3.3. Beas River Canal System

One of the major canals that are drawn from Beas river is the Rajasthan canal which starts from Harike headworks. This canal, of 149.53 km length, was constructed during the period of 1958 to 1961 and its capacity is 18,500 cusecs. This canal runs through three major districts of Punjab i.e., Ferozepur, Muktsar and Faridkot. Another canal that is drawn from Beas river is Ferozepur Feeder and its capacity is 11,192 cusecs. This feeder also provides water to Sirhind feeder and Eastern Canal system and Bikaner Canal.

3.3.3.1. Shahnehar Headwork

Shahnehar headwork was constructed on river Beas in 1983 and it is located downstream of Pong dam. The Feeder No. 1 and No. 2, which start from the Mukerian Hydel Channel, have taken place of the old Shahnehar canal. These canals provide 0.32 MAF water for irrigation to Kandi region.

3.3.3.2. Mukerian Hydel Channel

After drawing water into Mukerian hydel channel, the rest of the water of Beas river is sent towards Harike. This Mukerian hydel channel was constructed in 1982 and 207 MW of electricity is generated.

Figure 5. Pictorial view of Pandoh dam
using the flow of its water. Four power houses were used for the power generation and they are located a reduced distance of 6.5 km, 16 km, 19 km and 27 km away from the Mukerian Hydel headworks.

3.4. River Satluj

Satluj is a glacier-fed river and its origin is located in Mansarover, Himachal Pradesh, India. From Mansarover, the river Satluj flows toward North-West direction and crosses the Himalayas near Shipki-pass. Further, it heads toward the Gobind Sagar Lake upstream of Bhakra dam and then 14 km downstream toward the Nangal headworks. From the Nangal headworks, it flows southwards to the plains of Punjab. About 50 kms away from the Nangal headworks, near Ropar, a headwork is constructed on it to provide water for irrigation to the larger part of Punjab. Therefore, large amount of water is drawn at these headworks to fill the nearby canals. After crossing this headwork, the Satluj river meets the Beas river near Harike, where their confluence lead to an issue of flooding during the monsoon season. It in this way, the catchment area of this river is comparatively large i.e., 20,303 km².

3.4.1. Bhakra Dam

The construction of Bhakra-Nangal project, as shown in Figure 6, initiated in 1948 and ended in 1963 during which four radial gates were allocated at the top of the dam for flood control. The Bhakra dam as well as two other dams along the Ravi and the Beas rivers, allows to control and to regulate water for irrigation and power. Downstream of the Gobind Sagar lake and while crossing the state of Punjab, the Satluj meets with the Beas at Harike and flows to Pakistan.

The Bhakra dam is one of the world's highest gravity dam and distance between the lowest foundations and top of the dam is 225.5 m. Upstream of the Bhakra Dam, 3.82 MAF water of the river Beas mixes with the Gobind Sagar Lake via the Beas-Satluj Link. The Pandoh Dam is a diversion dam that diverts 3.82 MAF of Beas river's water in Bhakra reservoir after generating ~990 MW electricity at Dehar. The water stored at Bhakra also has a tremendous potential of generating hydroelectricity. In this regard, two hydroelectric power stations were built at the 2 banks, with total capacity of the power plant = 1343 MW.
3.4.2. Satluj River Canal System

3.4.2.1. Nangal Dam and Headworks

The confluence of Satluj and Beas has been a cause of floods near Harike, Punjab and in this regard, the Nangal dam was constructed approximately 13 km downstream of Bhakra Dam. This dam smoothens the diurnal variations in releases of water from Bhakra power plants. Nangal dam on river Satluj, diverts water to two main canals namely to Nangal Hydel Channel with capacity of 12,500 cusecs and to Anandpur Sahib Hydel Channel with capacity of 10,150 cusecs. At its tail Nangal Hydel Channel is renamed as Bhakra Main line canal (BML canal) which has a discharge capacity of 12,455 cusecs, after considering 45 cusecs water lost during the transit in Nangal Hydel channel. The BML canal carried mainly supplies of irrigation water. The Nangal dam also controls releases of water in Satluj river to be supplied for utilization in Sirhind Canal system and Bist Doab system at Ropar headworks. The Nangal Hydel Channel houses two power generating units at Ganguwal and Kotla with total installed capacity of 169 MW.

3.4.2.2. Rupnagar headworks
It is located near Rupnagar city in Rupnagar district of Punjab. At this point water is diverted from Satluj River to the Sirhind Canal which is one of the biggest and the main irrigation canals in Punjab feeding the Sirhind Canal System. It was inaugurated in 1882 and at this headwork, the water of Satluj is also diverted to Bist Doab Canal.

3.4.2.3. Harike Headworks

Harike headworks is situated at confluence point of river Satluj and Beas. This barrage is of paramount importance as inter-state regulation of Ravi-Beas water to Punjab and Rajasthan for irrigation and control of flood water is carried out from this barrage. The barrage has been designed to pass a highest flood of 6.50 lacs cusecs. The original storage capacity of Harike reservoir was 67,900 acre feet but due to siltation with time and vegetation etc., capacity has reduced to 9,300 acre feet only. Three canals off taking at Harike are Rajsthan Feeder, Ferozepur feeder and Makhu Canal.

Water goes to Rajasthan through Rajasthan feeder and to Bikaner Canal via Sirhind Feeder. Punjab gets water supplies through Ferozepur Feeder, Sirhind Feeder and Makhu canal. Eastern canal of Punjab is fed from Ferozepur feeder and partly from Hussainiwala headworks, Makhu canal caters to supply of irrigation water to Punjab.

3.4.2.4. Sirhind Canal System

This canal system originates at the Ropar headworks and from their it carries 12,620 cusecs of water in order to irrigate the culturable command area of $13.59 \times 10^5$ hectares. The total length of this canal system is about 3,215 km.

3.4.2.5. Makhu Canal System

This canal system originates at the Harike headworks and its capacity is of 292 cusecs. With a length of 92.8 km this canal system irrigates approximately 20,600 hectares of the agricultural land.

3.4.2.6. Eastern Canal System
It is the only canal system of Punjab which is non-perennial. Initially, in 1927, after its construction, it originated from the Hussainiwala headworks however, since the completion of Harike headworks, its origin shifted to the latter one. Currently, only 8.02 km stretch of the Eastern canal receives water from the Hussainiwala headwork. This canal system is of length = 856 km² and carries 3197 cusecs of water and its culturable command area is 2.16 lac hectares.

3.4.2.7. Hussainiwala headworks

Hussainiwala headworks was built in 1920 on Satluj river. Two canals originate from this headwork and their details are as follows:

1. Eastern Canal: It feeds the two districts i.e., Ferozepur and Zira
2. Bikaner Canal: It initial 75 miles pass through two districts of Punjab i.e., Ferozepur and Faridkot.
   After that it enters the Rajasthan state where it assists in irrigation of large part of Bikaner city.

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