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Design and Feasibility Study of River Interlinking in Odisha

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Abstract

The regional and temporal differences in rainfall throughout India have resulted in the designation of water "surplus" and "scarce" river basins in the country. The Indian River interlinking project intends to transport water from "surplus" basins to "scarce" basins. The study briefly mentions the interlinking proposal that was made to lessen water scarcity in the rain-scarce regions of western and southern sections of India, but it also raises concerns about whether this massive project is the best way to accomplish that goal. Before giving final clearance to the interconnection project, it is recommended that a completely transparent techno-economic and environmental feasibility analysis and comparison with other viable choices be conducted. Periodic flooding affects an area of the nation covering more than 40 million hectares. Floods harm around 7.5 million hectares of land in India each year, with crop land accounting for approximately 3.5 million hectares. Odisha, with its long coastal stretch and vast number of rivers, is especially vulnerable to floods caused by both frequent cyclonic storms and unpredictable rainfall, both of which have significant economic consequences. We have presented a proposal to create an outlet lined canal for the river Mahanadi-Brahmani-Baitarani using Google Earth in order to minimize flood disaster and send the surplus water to the drought prone areas in our state Odisha. This is due to the urgency for an assured supply of water for both people and animals in terms of environmental sustainability, regional justice, and economic viability. Rating curves are used to compute the normal discharge of rivers, and the surplus discharge of rivers is determined by subtracting the maximum discharge from the normal discharge of rivers.

Keywords: River Interlinking, Flood, Mahanadi River, Brahmani River.

1. Introduction

India is a large country with a 329 mha land area, and its water resources are unevenly distributed over both time and space (Misra, 2006). According to projections, by 2025 there will be about 3 million people who are expected to be living in acute water storage situations. India comprises 2.4% of the earth's surface area but is home to 16.7% of its inhabitants. India has only 4% of the world's water resources, and its average rainfall is roughly 4 billion cubic metres. However, most of India's rainfall falls between June and September, when it is very unpredictable in time and space due to its monsoonal environment (Mehta, 2018). Water surplus and deficit regions have formed as a result of regional changes in the distribution of this natural resource. Because of this uneven distribution, India experiences years of monsoons with droughts and floods. Water shortage causes regional socioeconomic inequalities, and these imbalances are harmful to sustainable development and have a negative impact on human rights (Vyas, 2016).

Floods are the most frequent natural disaster in India among all other calamities. In India, the monsoon season lasts for three to four months and accounts for about 75% of the country's yearly rainfall. As a result, river discharge is quite high during this time period, producing extensive flooding (Dasgupta, 2015). Floods are the result of natural, ecological, or manmade causes acting alone or in combination. The different causes of floods in India include heavy precipitation, a rising river bed, a tendency for river flow to meander, cyclones, silting in delta areas, obstruction of free-flowing rivers, inadequate drainage systems, earthquakes and landslides, deforestation, and cloud bursts (Ranjan, 2017). Humanitarian organisations have cautioned that the flooding will have a negative influence on children's future well-being and will disrupt their education. Although national disaster relief teams are contributing to the relief effort in their own limited capacity, the response mechanism has been lacking (Joshi, 2018). Environmentalists feel this could be improved if evacuated individuals had secure structures on stable land rather than in flood plains, which authorities have been unable to provide. Climate change is most likely to blame for these unpredictable trends. Officials think that effective flood forecasting and mapping is the best way to reduce damage caused by flooding. Unfortunately, India fails horribly at forecasting, as it does at flood risk mapping (Babu, 2016). This is complicated by climate change, though, as areas that had never seen flooding are suddenly receiving record amounts of precipitation. The government must invest in better flood forecasting policy and update the flood forecast network.

There are a few flood control techniques that have been used for centuries. The creation of flood ways, terracing hillsides to delay flow downwards, and growing vegetation to hold excess water are some of these techniques (man-made channels to divert floodwater). Levees, lakes, dams, diversion canals, reservoirs, retention ponds, river defences, and floodways are examples of additional techniques. These structures can hold more water during floods (Shah, 2018). In addition to these, a large-scale civil engineering project called "River Inter-Link" is being proposed. It aims to efficiently manage water resources by connecting rivers through a network of reservoirs and canals, reducing persistent flooding in some areas and increasing water storage in other areas of the reservoir (Agrawal, 2017).

River interlinking literally refers to the connecting of natural channels. Since ancient times, river waters have been diverted to cultivate crops. The benefits of interconnecting rivers are numerous and include improved crop productivity, reduced drinking water deficit, improved navigation, and increased groundwater reserves. The National Water Development Agency (NWDA), a division of the Ministry of Water Resources, is in charge of managing the interconnected projects in India. NWDA has prepared reports on 14 Himalayan component inter-link projects, 16 Peninsular component inter-link projects, and 37 intrastate river connecting projects (Bhamore, 2018). River interconnection project proponents contend that the best way to address India's water shortage is to conserve an abundance of monsoon water, store it in reservoirs, and transport it through this interconnected river project to regions and times where water is in short supply. Beyond ensuring water security, the project may also enhance the transportation infrastructure through improved navigation and increase rural communities' economic streams through fish farming (Ghosh, 2016).

Flooding and drainage have been identified as major issues in the Orissa coastal plain. Almost all of Orissa's major rivers, which have large catchment areas both within and beyond the state, are supplied by rain water and discharge into the Bay of Bengal through this region. The majority of the Odisha Coastal Plain is made up of the compound delta produced by the lower reaches of the Mahanadi, Brahmani, and Baitarani rivers. During the south-west monsoon season, most of these rivers exceed their usual channel capacity, reach flood stage, and frequently overrun their banks, wreaking havoc on this coastal region. Almost all of Odisha's districts have experienced flood disasters in recent monsoon seasons, resulting in significant loss of life and property (Mahapatra, 2005). For most of recorded history, the Mahanadi has been known for its devastating floods. Severe floods in the Mahanadi river system have become routine, wreaking havoc on downstream settlements, particularly the Mahanadi delta area in Odisha's coastal tract. This impacts the districts of Jagatsinghpur, Kendrapada, Puri, Boudh, Sonepur, Cuttack, Nayagarh, and Sambalpur. According to an analysis of Odisha's historical and current flood scenarios, the Mahanadi River is responsible for the majority of floods with significant magnitudes and significant loss factors. The Mahanadi and its tributaries frequently produce flooding in the surrounding areas of the entire river courses as well as in low-lying land features including deltas and natural levees. In Odisha, the situation is critical since Brahmani is running above the danger level. Flooding in Brahmani has resulted in numerous fatalities in the Jajpur district.

Basically, the proposed plan is to design line channel between the river convey in the Mahanadi, Brahmani and Baitarani river basins and also design an outlet channel to the Bay of Bengal. The major objectives of this study include Planning and design of interlinking channels to manage the water in different rivers and to design of an outlet channel to supply surplus water during flood.

2. Materials and Methods

2.1 Study Area and Data Source

2.1.1 Baitarani River basin

Baitarani is one of Orissa's major rivers, and it originates in the Gonasika Hills. The Baitarani is known as Guptaganga in Gonasika, Keonjhar district, Odisha state, India, at an elevation of 3,000 feet above sea level. The river generates a deltaic zone at Akhuapada and reaches a plain near Ananadpur. After leaving the Brahmani at the Dhamra outlet in Chandabali, the river travels 360 kilometres (220 mi) to empty into the Bay of Bengal. A total of 65 tributaries join the river, with 35 joining from the left and 30 from the right. Many rivers flow into Baitarani, including Budhi, Kanjori, Ambajhara, Mushal, Kusei, and Salandi. Over 61,920 hectares of land are irrigated by the river basin in Odisha, which is divided among eight districts. More dams will be built across this river and its tributaries as part of the multi-purpose Bhimkund and upper Baitarani projects, which will offer irrigation to an area larger than 1,000 square kilometres. Flooding is a frequent occurrence in the Baitarani basin. To control floods in Jajpur

and Bhadrak districts, as well as the overflow of the river Baitarani during the monsoon season, the area is studied and data is gathered for the design of the outlet channel to discharge the surplus water.
The town of Anandpur was chosen for the study because it is located along the banks of the River Baitarani, which flows along its southern border. The town has an average elevation of 141 feet and is located in the Keonjhar district. Using Google Earth, an outlet channel from Ananadpur to Jenapur is created to control the Baitarani River flow. From Anandpur to Jenapur, the outflow channel's length is calculated to be approximately 41.3 kilometres (25.7 miles) **(Figure 1)**. The outlet channel's origin, Anandpur, is discovered to have a reduced ground level of 115 feet. The reduced ground level at Jenapur, where the channel connects with the Brahmani River, is found to be 74 feet. The elevation profile obtained from google earth is used to compute the bed slope of the outlet channel. The outlet channel's bed slope was found around 1 in 3300.

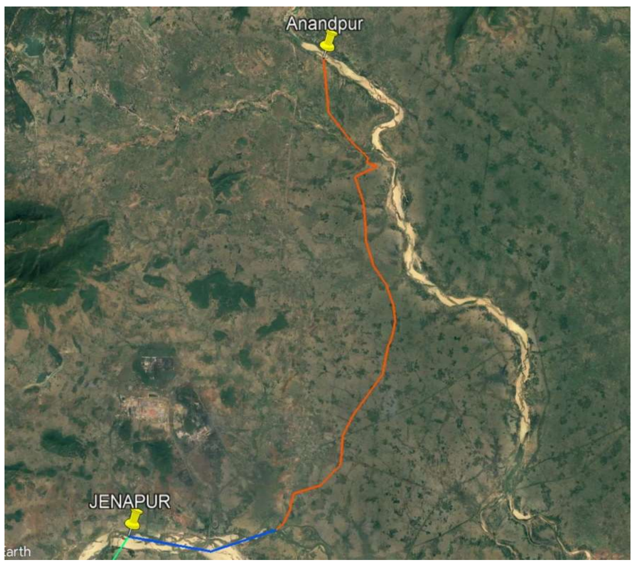

Figure 1 Alignment of Baitarani-Brahmani River interlinking channel at Anandpur to Jenapur

2.1.2 Brahmani River

The Brahmani River is situated in Odisha's eastern region. It is an important seasonal river in Odisha. The Sankh River and Koel River converge near Rourkela to form the Brahmani River. After the Mahanadi, it is the second largest river in Odisha. The river runs through Sundargarh, Deogarh, Angul, Dhenkanal, Cuttack, Jajpur, and Kendrapada districts. Bramhani joins the Mahanadi and Baitarani rivers and forms a vast delta near Dharma before emptying into the Bay of Bengal. The basin covers around 39,033 square kilometres. In the Angul area, the Rengali dam is built over the Bramhani River.

The town of Jenapur is chosen as the study area for the Brahmani River. In the Indian state of Odisha, Jenapur village is found in the Jenapur tahasil of the Jajpur district. The village has a total size of 303 hectares. Jenapur hamlet is roughly 100 kilometres from the coastline. To regulate the flow of the Brahmani River, an outlet channel from Jenapur to Naraj is being designed using Google Earth. The reduced ground level at Jenapur, where the outlet channel originates, is discovered to be 74 ft. The reduced ground level at Naraj, where the channel connects with the Mahanadi River, is found to be 68 feet. Google Earth is used to obtain the channel bed's elevation profile. The channel's bed slope is computed by dividing the elevation difference between Jenapur and Naraj by the distance between Jenapur and Naraj. The outflow channel's bed slope is calculated to be 1 in 3333. The outlet canal is approximately 47.3 kilometres long **(Figure 2).** The outlet channel's cross section is chosen to be trapezoidal.

Figure 2 Alignment of the Brahmani-Mahanadi interlinking channel at Jenapur to Naraj.

2.1.3 Mahanadi River

Mahanadi is located in east central India. The Mahanadi River is Odisha's largest and most important river. It covers an area of about 141,600 square kilometres, and its entire length is 858 kilometres. It's a seasonally flowing Indian river. It is a confluence of numerous mountain streams. After entering Odisha, the Mahanadi travels roughly 80 kilometres north and drains to the Raipur district. It passes through Cuttack, Sonepur, Boudh, Banki, and Kantilo. At Kendrapara, it creates a delta and empties into the Bay of Bengal. Mahanadi has a maximum discharge of 56,700 cumecs and an average discharge of 2,119 cumecs. The basin has 66.9 square kilometres of surface water on average per year. Only 50 square kilometres of this are used. Approximately 57,000 cumecs are released. During the monsoon's peak, Mahanadi cause disastrous floods in Odisha. Therefore, Hirakud Dam is built over the river to manage flooding. However, the continued downpour of rain caused flooding in some areas of Odisha. The outlet canal from the Brahmani River connects with the Mahanadi at Naraj **(Figure 3)**.

Figure 3 Alignment of outlet channel from Naraj to Gokulpur.

The alignment of whole project consisting of proposed river interlinking channels and outlet channel is shown in **Figure 4**.

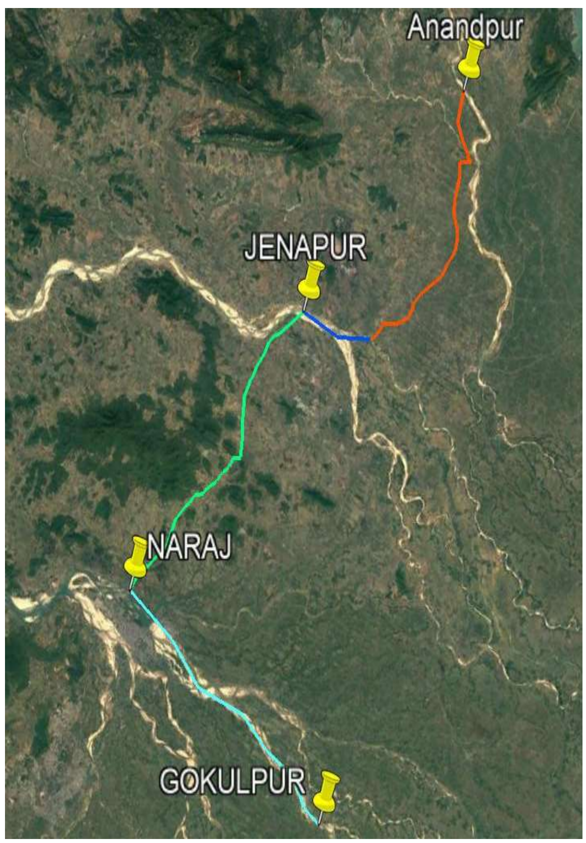

Figure 4: Alignment of the whole project

2.1.4 Data collection

The information on the Baitarani and Brahmani Rivers was gathered from the India-WRIS (Water Resources Information System) website. Anandpur and Jenapur gauge discharge data is acquired from the website. The greatest flow of the Baitarani River and Brahmani River was found around 10353.9 cumecs and 10372 cumecs. Additionally, a rating curve between stage and discharge is plotted using the gauge discharge data. The rating curve calculation aids in establishing the river's normal discharge. The cross section of the rivers Baitarani and Brahmani, Mahanadi can be calculated and plotted using the X section data from Anandpur, Jenapur and Pubanasa regions. The India-WRIS website is also used to obtain the X section data for Anandpur, Jenapur and Pubanasa regions. Using these statistics, the excess discharge of the rivers is calculated as the difference between the maximum and average discharge of the river.

2.2 Methodology

2.2.1 Surplus Discharge and stage Calculation

The difference between the maximum and normal discharge in a river is used to compute the surplus discharge. The river's gauge discharge data is used to determine the river's rating curve. An equation for the relationship between depth and discharge is then deduced from the rating curve. The river's X section data is used to plot the cross section of the river. The flow depth for the river's normal discharge is then determined as the difference between the maximum and minimum bed levels. The typical discharge is then computed by entering the flow depth value into the depth-discharge equation. The river's gauge discharge statistics are then used to determine the maximum discharge. Finally, the difference between the river's greatest discharge and its average discharge is used to compute the surplus discharge of the river.

2.2.2 Design of interlinking canals

The channels should be positioned and oriented so that the flow velocity is constant under all circumstances and that the water enters the irrigated region at a sufficient elevation to ensure a uniform and cost-effective distribution. Trapezoidal channel was the most suitable channel for interlinking of rivers.

The Trapezoidal Channel Section is designed for high discharge rates. To boost the A/P ratio, the corners are rounded, and attempts are made to utilise deeper areas by limiting depth. The Manning formula is used to design the channel. Rugosity coefficient (n) values vary depending on the roughness of the channel boundary and the type of lining used. Because we are utilising cement plastered masonry, the value of n=0.012. Figure 5 depicts a typical cross-section of a trapezoidal section. In lined channels, higher velocities can be used safely. When the lining is not reinforced, velocity up to 2.5m/sec is allowed. As a result, the speed for cement concrete lining without reinforcement is 2.5m/sec.

From Manning's Equation:
$v = \frac{1}{n} R^{2/3} S_0^{1/2}$
Where, V=Flow velocity in m/sec, R=Hydraulic Mean Depth in meter, S_0=Channel Bed Slope
For Trapezoidal Lined Channel R=A/P
Where A=Area of channel = y (B + yθ + ycotθ)
P = Wetted Perimeter = B + 2y + 2ycotθ
Where y=Depth of channel, B=Width of the channel, θ = Side slope

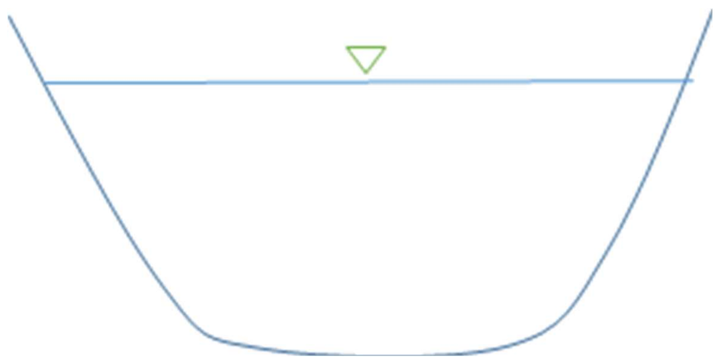

Figure 5 Typical cross-section of a trapezoidal lined channel

3. Results and Discussions

3.1. Interlinking of Baitarani-Brahmani River

3.1.1 Flood Flow Calculation of Baitarani River

Surplus discharge in Baitarani River (Q) is given as difference between Maximum discharge in the river and the Normal discharge in the river. The rating curve of the Baitarani River is obtained from Gauge discharge data of Anandpur (**Figure 6**).

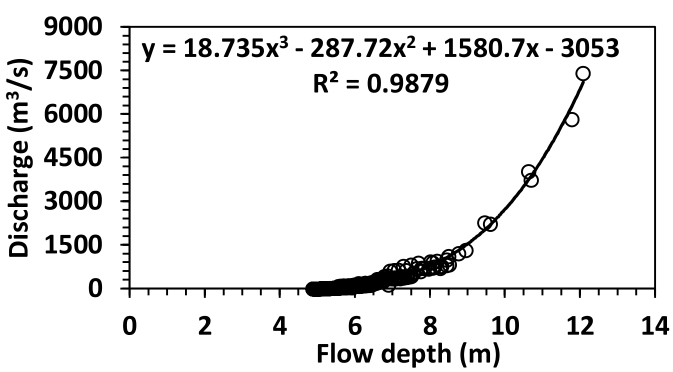

Figure 6 Representation of rating curve at Anandpur station of Baitarani River Basin

From rating curve, the equation of Depth- Discharge relationship is given as:
$Q = 18.75y^3 - 287.72y^2 + 1580.7y - 3053$

The cross-section of the river at is Anandpur gauging station is plotted as shown in **Figure 7**.

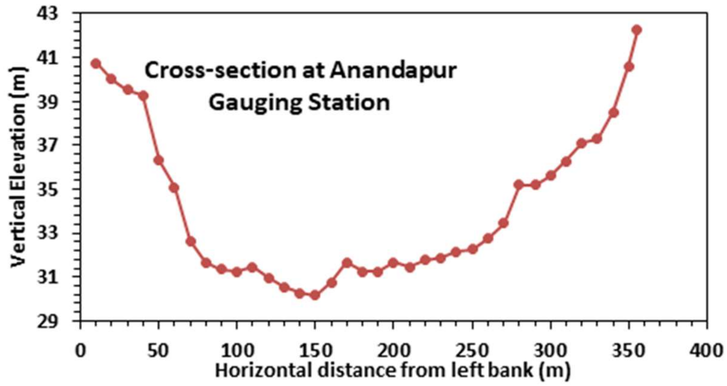

Figure 7 Channel cross-section of at Anandpur station

The depth at which normal discharge of the river occurs= Maximum bed level of the river-Minimum bed level of the river (y) = 40.02-30.16 = 9.86 m

Putting the value of y in equation obtained from rating curve, the normal discharge value will be calculated as $Q = 18.75 \times 9.86^3 - 287.72 \times 9.86^2 + 1580.7 \times 9.86 - 3053$ = 2519.77

Maximum discharge of the Baitarani River is found to be 10,353.9 cumecs, which is obtained from Gauge discharge data, Anandpur. Hence, the surplus discharge obtained = 10353.9-2519.77 = 7834.2 cumecs

3.1.2 Design of the Connecting Channel

A trapezoidal lined outlet channel is designed. The surplus discharge from flood flow calculation is obtained as 7834.2 cumecs.

From Manning's Equation: $V = \frac{1}{n} R^{2/3} {S_0}^{1/2}$

Q= AV= A $\frac{1}{n} R^{2/3} {S_0}^{1/2}$

For Trapezoidal Lined Channel R=A/P

Where A=Area of channel = y (B + yθ + ycotθ)

P = Wetted Perimeter = B + 2y + 2ycotθ

In this case side slope (θ) is assumed to be 1V:1.5H. So, cot θ= 1.5

Hydraulic Mean Depth (R) is written as:

$$R = \frac{A}{P} = \frac{y(B + y\,0.59 + y\,1.5)}{B + 2y \times 0.59 + 2y \times 1.5} = \frac{y(B + 2.09y)}{B + 4.18y}$$

Substituting the values of Q, R, S, n in Q= AV= A $\frac{1}{n} R^{2/3} {S_0}^{1/2}$, we get:

$$7834.2 = \frac{1}{0.012}\left\{\frac{y(B+2.09\ \ )}{B+4.18}\right\}^{\frac{2}{3}}\left(\frac{1}{3300}\right)^{\frac{1}{2}} y(B + 2.09y)$$

Assuming the values of y and B as 13 m and 70 m, we obtain the value of discharge. So, a trapezoidal lined channel will be proposed to be constructed of width=70 m and depth= 13 m.

3.2. Interlinking of Brahmani- River

3.2.1 Flood flow calculation for Brahmani River

A rating curve is drawn for last 20 years flood data at Jenapur gauging station of Brahmani River Basin (**Figure 8**).

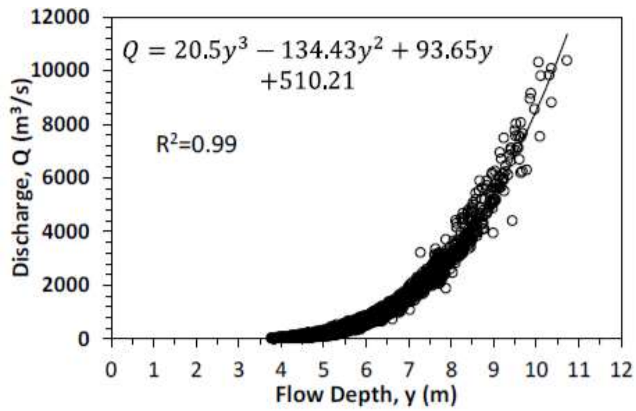

Figure 8 Representation of rating curve at Jenapur station

From rating curve, the equation of Depth- Discharge relationship is:
$Q = 20.5y^3 - 134{,}43y^2 + 93.65y + 510.2$
The cross section of the Brahmani river at Jenapur gauging station is shown in **Figure 9**.

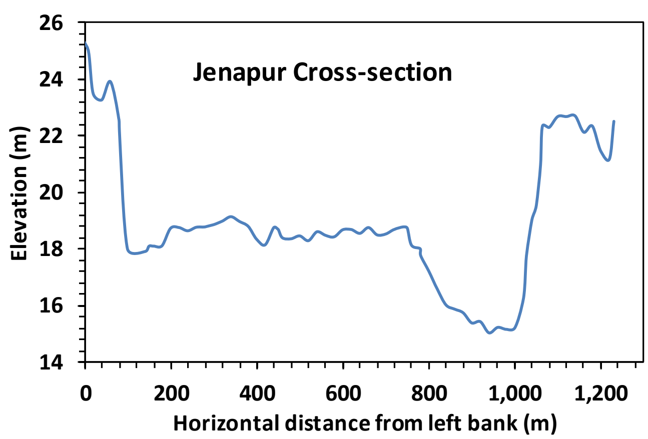

Figure 9 Channel cross-section of Jenapur gauging station.

Depth of normal discharge (y) = (Maximum bed level-Minimum bed level) = 7.68 m
Putting the value of y in equation obtained from rating curve we get,
$Q = 20.5 \times 7.68^3 - 134{,}43 \times 7.68^2 + 93.65 \times 7.68 + 510.2 = 2586.63$ Cumecs

3.2.2 Design of Connecting channel

A trapezoidal lined outlet channel is designed. The surplus discharge from flood flow calculation is obtained as 7785 cumecs.
We know that Q = AV= A $\frac{1}{n}$ $R^{2/3}$ ${S_0}^{1/2}$ and for Trapezoidal Lined Channel R=A/P
Where A=Area of channel = y (B + yθ + ycotθ)
P = Wetted Perimeter = B + 2y + 2ycotθ
In this case side slope (θ) is assumed to be 0.5V:1H. So, cot θ= 2
Hydraulic Mean Depth (R) is written as:

$$R = \frac{A}{P} = \frac{y(B + y\,0.47 + y \times 2)}{B + 2y \times 0.47 + 2y \times 1.5} = \frac{y(B + 2{,}47y)}{B + 4.94y}$$

Substituting the values of Q, R, S, n in Q= AV= A $\frac{1}{n}$ $R^{2/3}$ ${S_0}^{1/2}$, we get:

$$7785 = \frac{1}{0.012} \times (\frac{y(B+2.47y)}{B+4.94y})^{\frac{2}{3}} \times \left(\frac{1}{3333}\right)^{\frac{1}{2}} \times y(B + 2.47y)$$

Assuming the values of y and B as 15 m and 70 m, we obtain the value of discharge. So, a trapezoidal lined channel will be proposed to be constructed of width=70 m and depth= 15 m.

3.3. Design of Outlet Channel Connecting Brahmani-Mahanadi to Bay of Bengal

The plotting of cross section of the river at Pubansa gauging station is shown in **Figure 10**.

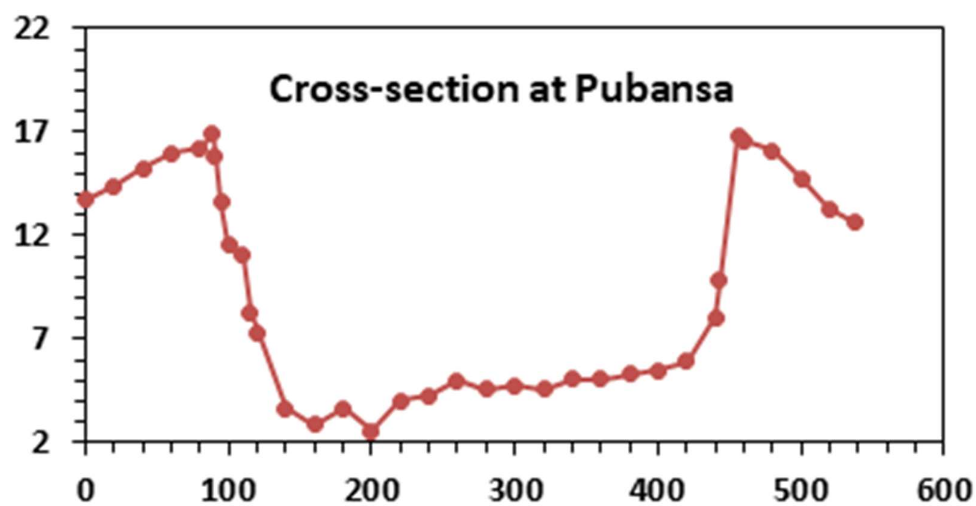

Figure 10 Channel cross-section of Pubansa gauging station.
Total surplus discharge coming from Baitarani and Brahmani = 7785+7834.2=15619.2cumecs. The width of the cross section is found to be 325m which obtained from the plotted cross section of the river. The depth of excavation is found out by assuming that the area to be excavated is rectangular in cross section and depth of the cross section is 5.25 m. Then discharge can be obtained by using Manning’s formula.
Q= AV= A $\frac{1}{n}$ $R^{2/3}$ ${S_0}^{1/2}$

From Manning's equation, $V = \frac{1}{n} R^{\frac{2}{3}} S_0^{\frac{1}{2}}$

For rectangular cross section, $R = \frac{A}{P}$

A= $B \times y = 325 \times 5.25 = 1706.25$ m^2

P = $B + 2y = 325 + 2 \times 5.25 = 335.5$ m^2

Putting the values of A and P we get,$R = \frac{A}{P} = 5.08$

Putting the value of R in equation (17), we get,

$Q = \frac{1}{0.012} \times 5.08^{2/3} \times (\frac{1}{667})^{2/3} \times 1706.25$ = 16269.50 cumecs

So it is concluded that if we are going to excavate up to 5.25 m depth, it will be able to sustain the surplus discharge coming from Baitarani and Brahmani River.

3.4. Discussion

The flood in Brahmani, Baitarani, Mahanadi River caused more damage in Odisha. According to the flood data in Odisha, in 2008, due to floods around 258155 houses, and 4.45 lakh Hectare were damaged. Floods in 2006 resulted in the loss of Rs. 2043.00 crores. To overcome the flood problems and to control the drought in Odisha, outlet channels are proposed to be designed to connect Baitarani-Brahmani-Mahanadi Rivers and the surplus water is discharged to Bay of Bengal.

The starting point of the outlet channel is chosen at Anandpur at Baitarani River basin which is connected with Brahmani River at Jenapur. The outlet channel is designed in such a way that it will be able to accumulate the surplus water due to flood. The surplus discharge of the river is calculated from the difference between maximum discharge and normal discharge in the river. Width and depth of the trapezoidal outlet channel is calculated using Manning`s formula. This procedure is also followed for the design of the outlet channel from Jenapur to Naraj to connect the river Brahmani and Mahanadi to accumulate the surplus water due to flood. After designing the the outlet channels from Baitarani to Mahanadi river, to accumulate the combine surplus water from Brahmani and Baitarani River, excavation is done at Gokulpur. There should be river interlinking project implemented in Odisha by connecting the river Baitarani, Brahmani, and Mahanadi to save crores of rupees which would be lost due to flood in Odisha. It can also be helpful saving lots of life, crop fields, public properties etc.

There are many profits of the river interlinking project that serves for both man and nature such as the surplus water due to the flood can be utilised in the area where the scarcity of water is more, River interlinking projects can also be helpful in increase GDP from the present GDP of 20% in respect of the agricultural sector, to meet the need of the water requirement in industries and domestic uses. The main advantage of the river interlinking project is, it is useful in controlling the flood problems and saves lots of life, crop fields, public properties etc. The river interlinking project is also helpful in fisheries development, environmental safety, employment generation, socio economic development and health improvement. The river interlinking project is also useful in generating hydropower.

There are also many challenges and constraints in implementing the river interlinking projects as the cost of the project is very high and it requires skilful engineers to complete the project. For executing the river interlinking project, it will take about 5 to 8 years of long span. Careful planning is also necessary for the execution of the river interlinking project. The project is also implemented under certain legal norms. Beside the challenges and constraints, states like Rajasthan, Gujarat, Tamil Nadu, and Madhya Pradesh have supported the concept of river interlinking project. So, the government of Odisha should support the river interlinking concept and implement the river interlinking project in Odisha to get the maximum advantage from it.

4. Conclusions

The interlinking of rivers will reduce India's water shortage in some areas, but safety precautions must be taken to avoid flooding . Today, water shortage has arisen as a worldwide issue, and as a result, a more informed approach is being recognised and articulated all over the world. Keeping in mind many difficulties such as environmental, social, economic, political and inter-state disputes, international conflicts of river water sharing, and so on, we developed the lined outlet channel for the river Mahanadi-Brahmani-Baitarani utilising the discharge flow rating curve and Google Earth. The goal of the river interlinking is to connect the country's many surplus rivers to its deficient rivers so that extra water from the surplus region can be redirected to the deficient region. As a result, the country's irrigation intensity would increase, and there would be more water available for drinking and industrial uses, as well as some mitigation of the effects of drought and flooding. After building the dams and reservoirs and storing the water, hydroelectricity might be produced. From the results we can say that interlinking of Mahanadi-Brahmani-Baitarani can be done to avoid floods and droughts. The dimensions of interlinking canal can be width of 70m and depth of 13m to 15m. The government should take more initiative in river interlinking while keeping biodiversity and natural resources in mind.

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