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Research Article

A COMPARATIVE STUDY ON THE NATURE OF CHANNEL CONFLUENCE DYNAMICS IN THE LOWER JALDHAKA RIVER SYSTEM, WEST BENGAL, INDIA

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ABSTRACT
River confluences are unique and most complex phenomena in a river network. They are unique as they possess numerous downstream effects upon the main stream while they are the complex nodal areas as processes across river confluences have merely been understood yet. The dynamics of confluence points in terms of their spatial locations and associated causative processes coupled with downstream morphological changes along the lower Jaldhaka River system has been studied systematically based on methods incorporating both field and geo-spatial technologies spanning for a period of 86 years (1928-2014). A comparative analysis has been worked out which attempted to focus on the nature and processes of dynamicity along two different river confluences. Our observations have cleared it out that, while an upstream confluence tends much stability in recent era after being unstable earlier, the downstream one follows uncertainty over much of the considered timeframe. The causative factors such as avulsions, aggradations, reactivation of palaeo-channels, river capture, junction angle and control of structural arrangements have been observed and their roles were justified during the assessment of movements of the confluences both towards upstream and downstream directions. Additionally, the confluence effects on main stream morphology in terms of width adjustment, sinuosity indices and braiding tendencies have also been assessed.

Keywords: *Aggradation, Jaldhaka River, Junction Angle, River Capture, River Confluence, Spatio-Temporal Shift*

INTRODUCTION
River confluences occupy significant position in a drainage network as they have immense effect towards downstream direction. Instead of having quite geomorphic and hydraulic significances, river confluences got very less attention by the scholars. However, there are quite a good number of researches that have been carried out particularly on flow character, flow structure and flow mixing, hydraulic geometry, bed morphology and channel scouring at channel confluences. The works of Mosley, 1976; Ashmore and Parker, 1983; Bristow and Best, 1993; Rhoads and Kenworthy, 1995; Benda *et al.*, 2004; Boyer *et al.*, 2006; Roy and Sinha, 2007; Lane *et al.*, 2008 and Stevaux *et al.*, 2009 etc. have set up some pioneering landmarks in the study of channel confluences. The meeting of two rivers, each of them having independent morphological nature, flow pattern and flow character and sediment discharge regimes creates complex riverine environment introducing both morphological and hydrological alterations. Such confluences play a major role in routing of the flow and sediment through the fluvial systems. In general, flow dynamics and mixing at confluences are highly variable both spatially and temporally and part of this variability is because of the momentum ratio between the two intersecting rivers and due to variations in the planform geometry and bed morphology of the junction (Boyer *et al.*, 2006). Such confluences determine the availability of water and the dispersal of sediments along the downstream reaches (Roy and Sinha, 2007). In fact, River confluences are sites of drainage systems with complex hydraulic interactions provided by the integration of two different flows which constitutes an environment of “competition and interaction” with gradual dynamism in flow velocity, river discharge and structure, physical and chemical properties of water and channel morphology (Stevaux *et al.*, 2009). From hydraulic perspectives, river confluences are active sites of occurrence of turbulence with convergent and divergent movements, resulting in upwelling and down welling of flows and formation of lateral vortex (Morisawa, 1968).

These in turn generates chaotic movements by forming secondary flows of different velocities and directions which may even follow the opposite direction of the main river's flow and consequently introduces alterations in channel planform and the movement of sediments (Stevaux *et al.*, 2009). Abrupt introduction of sediment and organic material at confluences trigger numerous types of changes in channel morphology in the vicinity of confluences. Large fans can displace a channel across the valley floor, forming a local restriction in valley width and channel steepening proximal to deposits and a corresponding valley widening and gradient shallowing upstream. Channel gradient induced longitudinal variations in sediment transport rates reduce the substrate size and increase floodplain width upstream of confluences, while at downstream side of confluences the substrates are coarser resulting in an increase in channel width, pool depth, and increased the formation of bars (Benda *et al.*, 2004). Additionally, rivers' confluence owe some aesthetic and social relevance too, particular in Indian perspective, where rivers are worshipped as Goddesses and settlements tend to favour riverine locations; the Ganga-Yamuna confluence at Allahabad can be cited as a blazing instance (Roy and Sinha, 2007).

The Eastern Himalayan foothills actually are wide and profound geomorphological research arena. The numerous criss-cross rivers which owe their origin from the Himalayas and subsequently reaches the foothills possess noteworthy hydro-geomorphic considerations. In fact, the Himalayan foothills are the exact geomorphological hotspots over which processes of alterations are occurring on gradual rates and their spatial signatures are quite common over vast spaces in northern parts of West Bengal. Signs of spatio-temporal adjustments by the rivers like Teesta, Jaldhaka, Torsha, Raidak and Sankosh etc. as a result of controlling fluvio-geomorphic, geologic and tectonic set-ups can be seen as palaeo-channels, meander cut-offs, abandoned tracks, ox-bow formations, crevasse splays etc. all over the places.

The present paper encompasses the study of two confluences at the lower course of the Jaldhaka River system in northern parts of West Bengal, namely (a) Murti-Jaldhaka Rivers' Confluence and (b) Diana-Jaldhaka Rivers' confluence. It incorporates the systematic description of historical as well as the contemporary location of the confluence points, their movements in chronological sequence, the processes behind such movements and the resultant downstream changes in the main stream (Jaldhaka River) morphology.

The Study Area

The study area falls within the ambit of Himalayan piedmont region of Jalpaiguri district of West Bengal, roughly bounded within the 26º38′ N and 26º48′ N latitudes and 88º50′ E and 88º58′ E longitudes. Jaldhaka being one of the mightiest rivers of the region flows almost through the middle of the district from a north to south-east direction. The Murti River originates from the Mo Forest in Darjeeling Himalayas at an altitude of 2211 meters above msl and meets the Jaldhaka River from its right side near Ramsai village of Maynaguri C.D. Block of Jalpaiguri district at an elevation of 102 meters above msl. On the other hand, the Diana River rises at an elevation of 3300 meters above msl in the Samtse province of Bhutan and entered into the Indian Territory along the 300 m. contour near Chengmari Tea Garden and ultimately debouches into the Jaldhaka River from the left side at an altitude of 98 meters above msl near Nathua Hat of Dhupguri C.D. Block of Jalpaiguri district (Figure 1). The area is a classic fluvio-geomorphologically dynamic area marked by the presence of numerous forms like abandoned tracks, palaeo channels, crevasse splays etc. and processes such as aggradation, avulsion and river capture activities. It is a transitional zone between the Himalayan Mountains and fertile alluvial Teesta-Brahmaputra plains commonly known as the 'Dooars' region.

The Murti River drains mostly of the mid-altitude intermediate fan surfaces in the north and follows almost straight path developing a radial drainage pattern. Significant structural control in terms of occurrence of two scarps, namely Matiali Scarp in the North and Chalsa Scarp in the south and several lineaments has dominant control over the Murti-Jaldhaka Interfluve. The courses of the major and minor rivers here are influenced by both E–W thrusts and the nearly N–S transverse faults. Two lineaments trending 13°–193° (NNE–SSW) and nearly N–S are also present, and parts of present day courses of the Murti River follows these lineaments. The major drainage pattern has changed from radial to sub-parallel pattern due to two NNE–SSW and N–S trending faults along the Murti River. After crossing the Chalsa Scarp the Straight path of Murti River becomes a meandering one (Goswami *et al.*, 2012).

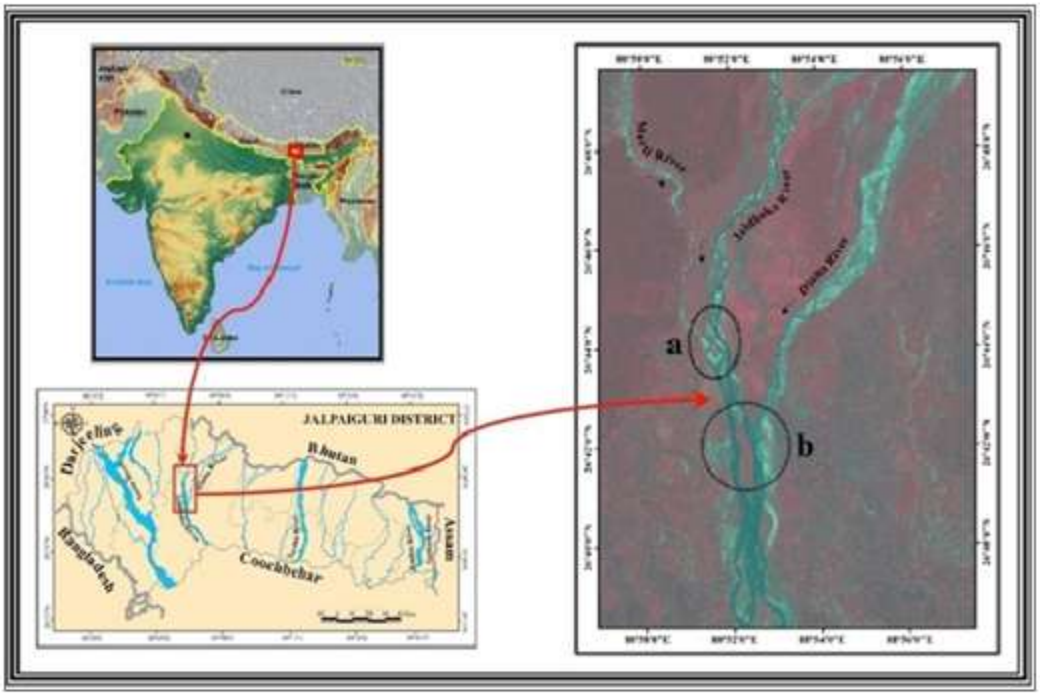
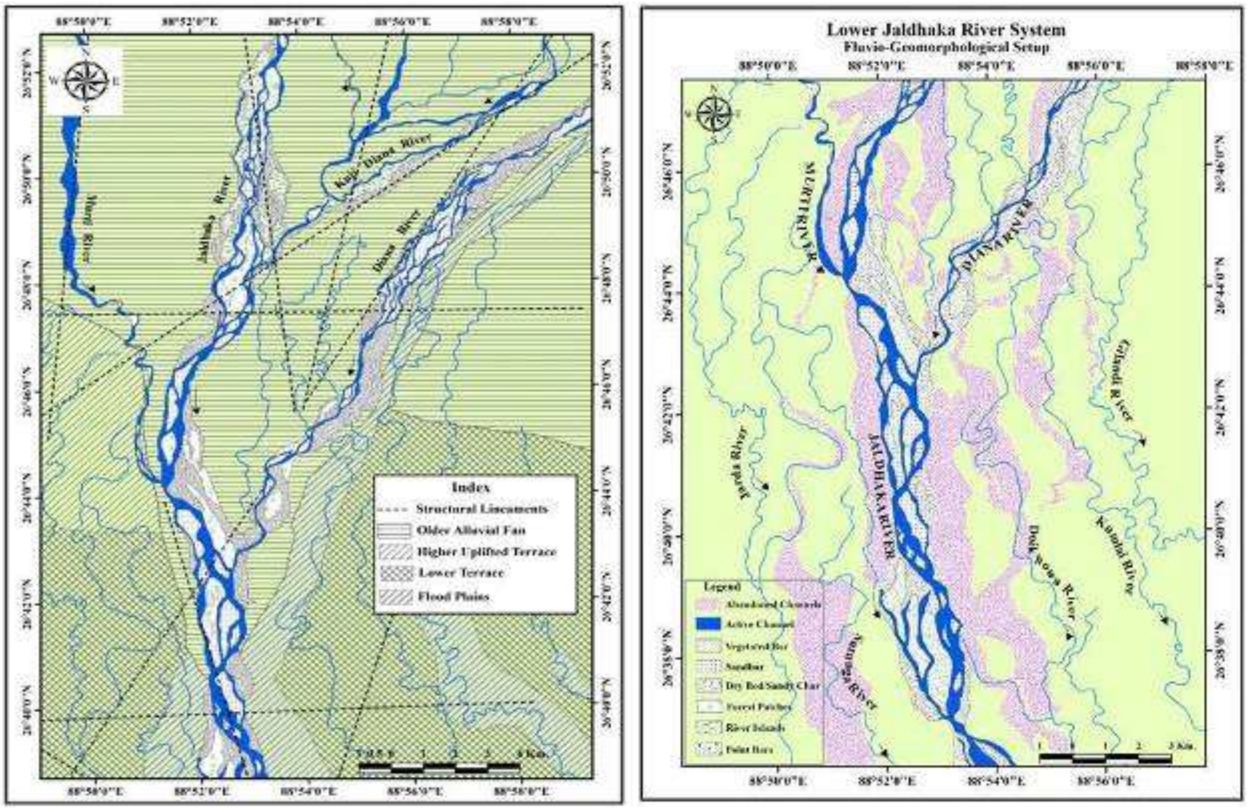


Figure 1: Base Map showing the Spatial Reference of the Study Area

The Diana River, on the other hand, starts its journey into the study area after meeting its tributary Chamurchi River from the east separating the southern blocks the Himalayas. These two rivers meet at the piedmont, where the steep scarp of the Himalaya rapidly turns south from latitudinal to longitudinal. Both these rivers form an extensive combined fan sloping to the SW–S. The fan is inclined at its root part at about 25‰ and then decline downstream to 15‰ (Starkel *et al.*, 2008). At its upstream the Diana River flows through the uplifted terraces. Here, the wide channel floor built of gravels and boulders is bounded on the left by a 12–15 m high scarp (lowering downstream to 5–7 m). The Diana River subsequently flows through the distal fan surface at its extreme lower courses accompanied by 2- 5 meter high floodplains.

This area is well under active Neo-tectonic activities and inherits certain structural weaknesses as well as instabilities which very often control the movement of river courses. The E-W, N-S, NW-SE and NE-SW trending structural lineaments are believed to be still active and possess serious control on the river courses (Figure 2a). For example, the western advancement of the Jaldhaka is highly influenced by a NW-SE trending lineament near the Diana-Jaldhaka confluence as well as Jaldhaka took a sudden bend here; the westward migration of the Diana is largely controlled by a NE-SW trending lineament at the present Diana-Jaldhaka confluence site and the active channel of the Diana is forced to switch itself along its eastern banks by causing heavy bank erosion and resultant lateral widening.

Morphologically, all the three rivers tend towards wide and braiding courses because of incessant deposition of sands, silt and gravels. As the rivers suddenly reached the foothills, abrupt changes in channel gradient caused much lowering in flow velocities which in turn clogged the river flow by gradual deposition of mountainous detritus. Except Murti river, both the Diana and Jaldhaka rivers have developed wide, shallow, braided-transitional (and in some instances anabranching) courses. All the three rivers are multi-thread rivers; for Jaldhaka River the number of channels is between 2 to5 and for both Murti and Diana Rivers it is around 1-3. The area is an active site of fluvio-geomorphic dynamism as numerous spatial signatures in forms of avulsion tracks, meander cut-offs, crevasse splays, ox-bow formations abandoned tracks as well as transitional courses are very common across the entire length of the rivers (Figure 2b).



(a) **(b)**

Figure 2: (a) Structural and Geomorphic Set-up of the Lower Jaldhaka River System (*Source: Geological Survey of India and NRSC*); (b) Fluvio-Geomorphic environment of the Lower Jaldhaka River System (*based on Google Earth™ Imagery, 2011*)

MATERIALS AND METHODS

The present research solely aimed at understanding the complex nature of confluence dynamics in the lower Jaldhaka river system. Objectives are threefold: (a) to observe the patterns of historical movement of confluence points over space and time, and (b) to examine the factors behind these movements and (c) to assess the induced results of confluence dynamism upon main stream morphology.

For a comprehensive and systematic analysis of historical confluence locations as well as channel positions topographical maps prepared by the Survey of India for two different time periods (1928-30 and 1964-1966) along with U.S. Army Corps. Of Engineers Series- U502 maps (1955-56) and a wide spectrum of repetitive multi-spectral and multi-temporal satellite imageries have been consulted. A GIS database for 85 years (1928-2013) has been prepared using the ArcGIS 10™ software package. Additionally, extensive fieldworks have been conducted during January and February of 2014 to observe the ground realities guided by instrumental and GPS aids. Observations and measurements of present channel widths, depths, flow velocities, sediment characters etc. have been done along with perception surveys among the local residents. Furthermore, the calculation of sinuosity indices and braiding tendencies has been done following Friends and Sinha (1993) to observe the confluence effects upon the Jaldhaka River. For this task, the Jaldhaka, Diana and Murti rivers were divided into 5 Km. long reaches and then, the corresponding lengths were measured digitally from satellite images. The data that have been used in developing the 85 years long GIS database is as follows (Table 1).

Table 1: Summary of Data used in Preparation of GIS Database

Sl. No	Types of Data	Publisher	Index/Map no.	Spatial Coverage	Survey year		Scale
1	Topographical Maps	Survey of India	78 B/13, 78 B/14	Jalpaiguri district	1928-1930		1:66,360
2			78 B/13, 78 B/14	Jalpaiguri district	1964-1966		1:50,000
3	Edition-2 Army Map Service (AMS) Series-U502	US Army Corps of Engineers	NG 45-8	Jalpaiguri and Kochbihar districts	1955-1956		1:250,000
Sl. No	Satellite images	**Satellite/Sensor**	**Path/Row**	**Spatial Reference**	**Acquisition Date**	**No. of Bands**	**Spatial Resolution (in Meters)**
4		LANDSAT-2 MSS	138/41, 138/42, and 139/41 for LANDSAT	UTM Zone: 45 Datum: WGS 84	25/02/1977	4	60.00
5		LANDSAT-5 TM			14/11/1990	7	28.50
6		LANDSAT-7 ETM+			20/11/2001	8	14.25
7		LANDSAT -8 OLI/TRIS			16/10/2013	11	30.00 (15 m for PAN)

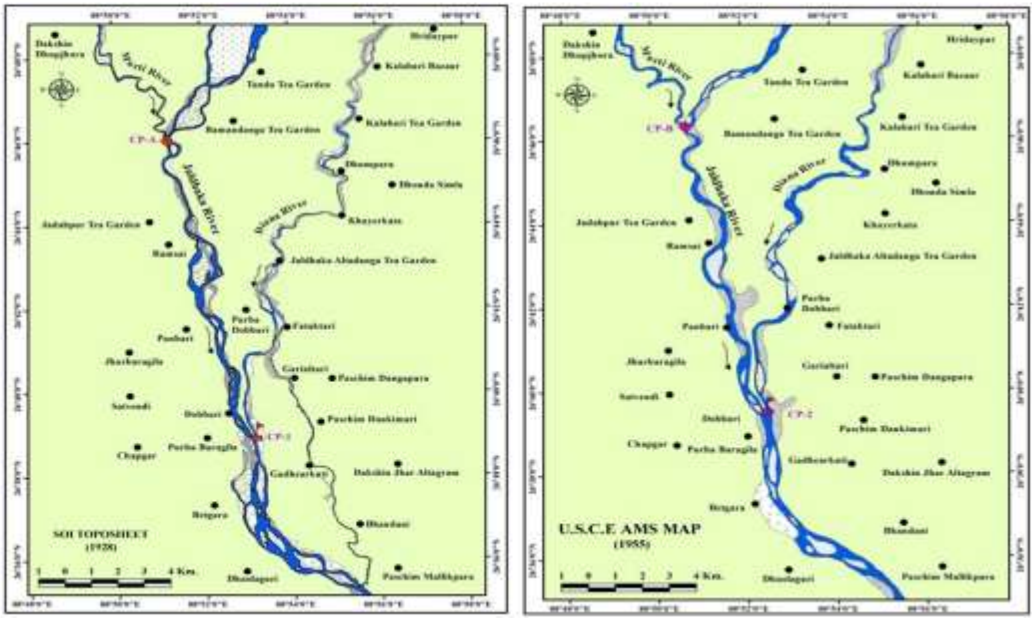
RESULTS AND DISCUSSION

***Description of Spatio-Temporal Confluence Dynamics*:** The systematic analysis of the database have revealed that, channel positions as well as confluence points were quite different in earlier times as it is now. It has also been noticed that, in spite of their close vicinities both confluences are much different in character, i.e. both confluences were mobile in earlier times but in recent decades the Murti-Jaldhaka Rivers' confluence favours stability while the Diana-Jaldhaka Rivers' confluence shows contrasting uncertainty and instability in its recent locations.

Changes Between 1920's and 1950's: The earliest map of 1928 represents a well simplified drainage network. The Murti-Jaldhaka Rivers' confluence (CP-A) was far upstream (about 3.23 Km in North-West direction) from its present position near Ramsai. The Jaldhaka River was a meandering one and had merely a width of only 307 meters. On the other hand, the Diana-Jaldhaka Rivers' confluence (CP-1) was near Purba-Baragila village which was 6.54 Km downstream from its current position. At the confluence the Jaldhaka (577 m wide) showed tendency towards meandering but at downstream near Betgara it becomes much braided and wide almost around 1 Km. The meandering course of Diana followed a two-way track then, one was flowing though the Doikhowa river and the other was near its present course (Figure 3a).

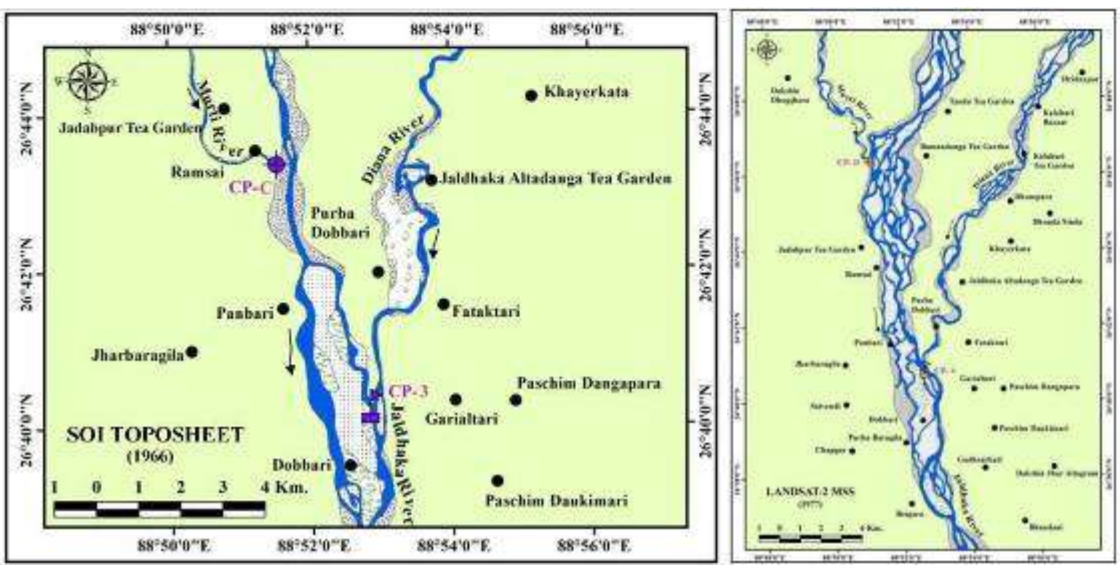
During 1955 the Murti-Jaldhaka Rivers' confluence (CP-B) shifted almost 973 meters in upstream direction due to westward migration of the Jaldhaka River while the Diana-Jaldhaka Rivers' confluence (CP-2) moved upstream near Dobbari. The width of the Jaldhaka River increased to 444 meters along the Murti-Jaldhaka Rivers' confluence but fell (528 meters) along the Diana-Jaldhaka Rivers' confluence. Both Jaldhaka and Diana showed the tendencies to follow meandering courses however, braiding rates seemed increased. The major fact was that, Diana completely left its two-way track and started to flow near its present course due to partial avulsion along its lower course because of a massive flood during the 1940's (Figure 3b)

Changes between 1950's and 1960's: Records showed rapid alterations in the main stream morphology and also changes in spatial locations of the confluence points solely due to the eastward migration of the Jaldhaka River which took place as a result of re-activation of its pre-existing channels which was left abandoned for a short while (Figure 4a). The Murti-Jaldhaka Rivers' confluence (CP-C) moved even downstream to its present position for about 3.91 Km. and the Diana-Jaldhaka River's confluence (CP-3) also went downstream for about 2.85 Km. at Dobbari village. The Murti River was forced to drain a little further to reach Jaldhaka while a secondary channel of the Jaldhaka captured the lower course of the Diana River. The Jaldhaka became much wider and the growth of an island resulted in a fall of sinuosity of the River.



(a) (b)

Figure 3: Reconstruction of confluence dynamics scenario between the period (a) 1928 and (b) 1955.

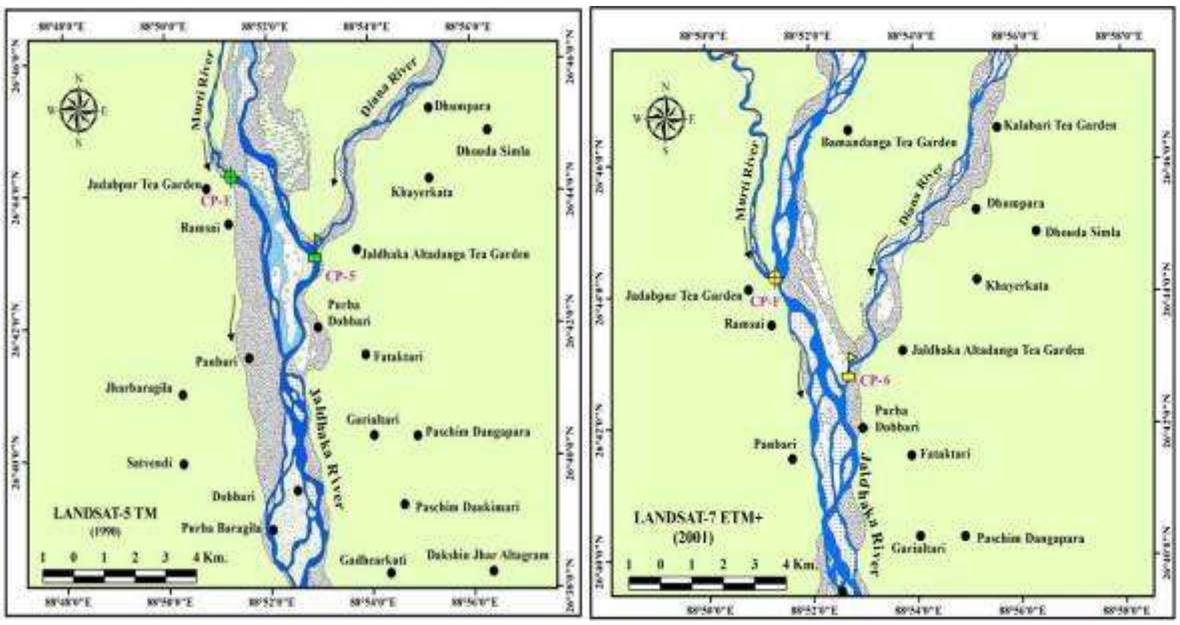


(a) (b)

Figure 4: (a) Confluence Positions as rebuilt from 1966's Survey of India's topographical map; and (b) from LANDSAT-2 MSS data (1977)

Changes between 1960's and 1970's: Vigorous micro-scale movements of the Jaldhaka River assisted by incessant aggradation activities dominated this decade and the confluences moved upstream again (Figure 4b). Rapid valley fill deposition of sands and silts clogged Jaldhaka River and altered it into wide and braided one. The entire main channel went back again towards the right bank along the Murti-Jaldhaka Rivers' confluence (CP-D) while it massively turned towards the left bank along the Diana-Jaldhaka Rivers' confluence (CP-4). These contrasting micro-scale movements captured the lower courses of both Murti and Diana Rivers. As a cumulative result, the Murti-Jaldhaka Rivers' confluence went upstream for about 5.60 Km. at the opposite side of Bamandanga Tea Garden while the Diana-Jaldhaka Rivers' confluence moved upstream for about 2.35 Km just a little downstream to Purba Dobbari village.

Changes between 1970's and 1990's: This entire episode is marked by the alteration of Jaldhaka River into a much wider and braided stream guided by the gradual increase in aggradation which can be seen from the formation of numerous bars and islands throughout the entire studied reach of the Jaldhaka River (Figure 5a). Except the active main channel other secondary flows get dried up and due to heavy deposition the Murti River could not meet the main channel of the Jaldhaka River and thus, the confluence point (CP- E) shifted almost 4 Km. downstream near Jadabpur Tea Garden. Meanwhile, the re-activation of some intermediate short streams at the Diana and Jaldhaka Interfluve resulted in a diversion of the main channel of Jaldhaka River through those short streams. This culminated an upstream capturing of the lower course of the Diana River and the confluence (CP-5) moved at much closer to the Jaldhaka Altadanga Tea Garden.



(a) **(b)**

Figure 5: (a) Confluence scenario along Lower Jaldhaka River System in 1990 and (b) in 2001

Changes between 1990's and 2000's: This phase marked the beginning of contrasts in the stability of the confluence points. The braiding tendencies, width adjustment processes of the Jaldhaka River g*et al*most stabilized as it seems that these processes have attained their maxima. However, the meandering tendencies of the Jaldhaka River get re-activated (Figure 5b). Contrasts came in scene when our careful observation revealed the fact that, the Murti-Jaldhaka Rivers' confluence (CP-F) showed a mere upstream movement of only 59 meters from its previous position, moreover the westward migration of the main channel of Jaldhaka has also supported this stable or almost nil-movement. On the other hand, the Diana-Jaldhaka Rivers' confluence (CP-6) was still unstable; however, the distance involved in the movement was much lesser in comparison to the earlier movements, it involved only 1 Km. shift towards downstream direction. This shift was resulted as a culmination of the westward migration of the main channel of the Jaldhaka River and local avulsion at the lowermost course of the Diana River. Additionally, two large floods of 1998 A.D. and 2000 A.D. had modify this confluence site by depositing huge amount of sediment load across both the Jaldhaka and Diana river beds which in turn has forced the rivers to carve out newer tracks along their valleys.

Changes between 2000's and 2014: In this ultimate phase the contrasts between confluence shifting rates lowered down at much faster rates. Shifts are quite insignificant (Figure 6a). At this phase the Jaldhaka has migrated towards the eastern bank mainly along the Diana-Jaldhaka Rivers' meeting point while remain almost unchanged across the Murti-Jaldhaka Rivers' confluence. The Murti-Jaldhaka Rivers'

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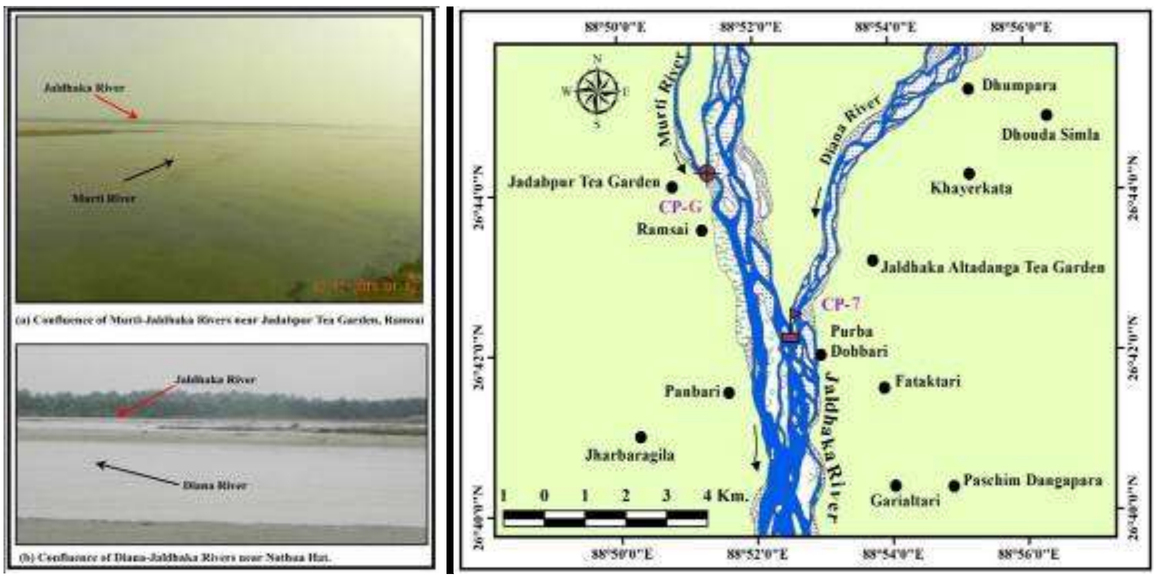
confluence (CP-G) remains almost immobile as it has shifted only 27 meters in downstream direction due to the formation of a mid-channel bar. Similarly, the Diana-Jaldhaka Rivers confluence (CP-7) has moved only 210 meters from its earlier location in 2001 to 2013. Our field investigations revealed that, these confluences remained almost constant; neither it is shifting gradually nor it is switching its direction (Figure 6b). In fact, gradual aggradation and processes of river capture tend to assist these stable conditions. The processes of lateral widening seem to have almost reached its ultimatum while braiding indices have also fell down considerably. In addition with this, Jaldhaka River has again developed a straight course through the entire studied reach as some of its secondary channels have been left abandoned again, particularly along its western or right bank. Moreover, the intermediate short streams lying between lowermost parts of the Diana-Jaldhaka Interfluve also have been left deserted.



(a) **(b)**

Figure 6: (a) Reconstruction of recent (2013) confluence situations based on LANDSAT- 8 OLI/TRIS image; (b) Field photographs showing latest (2014) meeting points along the Lower Jaldhaka River System

***Probable Factors behind Confluence Dynamics*:** There are a bunch of processes which are operating over the entire sub-Himalayan piedmont region primarily responsible for overall fluvio-geomorphic alterations. Both natural and anthropogenic controls are exhibiting immense effect upon the river systems of the concerned region; however, in this study natural ones are especially important. Primarily, we have found six prominent factors which are controlling and modifying the riverine landscapes and the stream behavior. These are as follows,

Channel Avulsion: Avulsion as defined is the sudden and abrupt change in a river course which originates from a node. Avulsions become obvious when a river is choked up by gradual deposition of load and unable to maintain its flow and carry its load particularly during peak monsoons or during flood situations. Avulsions are quite common in the sub-Himalayan piedmont zone of northern parts of West Bengal when rivers which originate from the Himalayas suddenly reached the foothills and due to lowering of channel gradient they become forced to favour immense deposition of mountainous detritus across their beds. In fact, over most of the parts of this region has negligible slope which often trigger vigorous deposition and rivers become strained to change their courses abruptly.

Aggradation: As most of this region has negligible slope, rivers cannot transport their entire loads to their master streams and thus, continuous deposition of sediment load particularly gravels, boulders and coarse sands has raised the river beds as well as this aggradation also favours the growth of bars, shoals, islands and temporary micro dune-like features through the entire lower courses of the rivers (Figure 7a).

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River Capture: Capturing of lower courses of the tributaries is quite common phenomenon in the study area. In most cases, the main stream Jaldhaka captures the lower courses of both Murti and Diana Rivers much before they could meet the Jaldhaka River. One such instance can be seen near Nathua Hat where, the lower course of the Diana has been captured by the Jaldhaka River almost 1.50 Km. upstream from their current meeting point (Figure 7b).
Temporal movements of the Main Stream: Periodic movements of the main stream i.e. Jaldhaka River, either toward its western banks or towards its left bank also controls the stability of the confluence points.

(a) **(b)**

Figure 7: (a) Aggradation activities and resultant formations and their feedbacks to the river systems; (b) Capturing of Lower course of Diana River by the Jaldhaka River near Nathua Hat

Stream junction angle: Junction angle has certain significant control upon the stability of the confluences as well as it also possesses some control on the main stream morphology towards downstream. A wide junction angle signifies a higher slope variation between the confluent streams while low angle denotes almost equal slope conditions. Roy and Sinha (2007) observed that, confluences with wide junction angles are much dynamic which favours instability and flooding while confluences having low angles are tend to be stable. Mosley (1976) noticed during his flume experiments that, junction angles if exceed 60º then it could introduce the formation of a mid-channel bar just downstream to the confluence, in fact at such cases the main stream become addict to bank erosion and channel widening. In the meantime, confluences having less than 60º junction angle tend to be more stable. Relatively lesser junction angles of Murti-Jaldhaka Rivers' confluence in comparison with higher junction angles of the Diana-Jaldhaka Rivers' confluence have proved the above concepts regarding stability of the confluences (Figure 8).
Structural control: Structural weaknesses and the arrangement of geomorphic and structural lineaments also have significant control over the drainage patterns as well as they also determine the behavioral pattern of rivers such as meandering tendencies which have already been discussed in previous section.

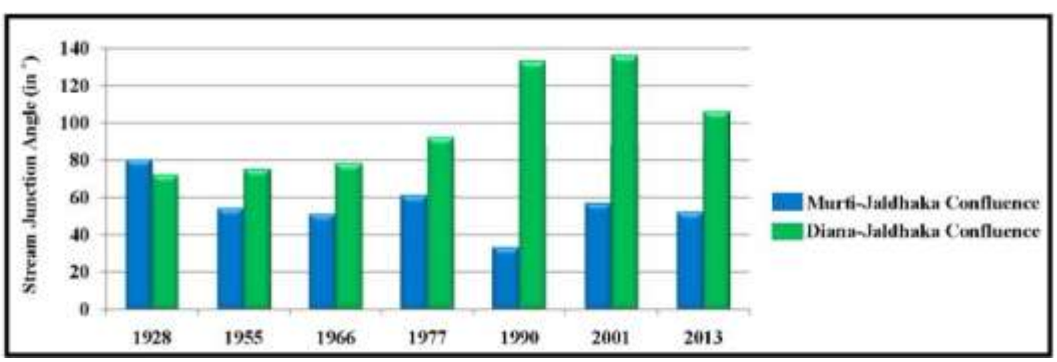

Figure 8: Stream junction angles of the confluences over the last 85 years (1928-2013)

Human dimensions: In addition with these natural factors, anthropogenic intervening activities have emerged in the scene primarily as a moderating factor. Human processes especially agricultural expansion towards the dry bed of the Diana River and engineering operations such as flood embankments, boulder pitching, chicken neck concrete walls for bridge protection etc. are constantly restricting the channel movements in lateral and downstream direction. Although the Murti-Jaldhaka Rivers' confluence site have meager engineering controls but is at the stake of losing its stability because of encroaching agricultural fields which are particularly heading to occupy the dry riverbed of the Jaldhaka.

***Summary of Confluence dynamics and their downstream effects on main stream morphology*:** It is quite clear now that the confluences are highly dynamic in nature and they have exerted significant influence upon the main stream morphology during the entire timeframe of 86 years by altering the process of width adjustment as well as also are controlling the morphological parameters like channel sinuosity (*p*) and braiding indices (*b*) of the master stream Jaldhaka River. The overall dynamics of these confluences and their culminated downstream impact upon the main stream Jaldhaka River has been summarized in the following table:

Table 2: Confluence dynamics and resultant downstream morphological alterations

Sl. No.	Confluence	Phase	Direction of Confluence shift	Factors	Shift	Net Shift (1928-2014)	Width (in meters)	Changes in *p*	Changes in *b*
1	Murti-Jaldhaka	1928-55	Upstream in N-W direction	Westward migration of Jaldhaka	0.97 Km.	*Murti-Jaldhaka Rivers' confluence shifted 3.238 Km. in Downstream and towards S-E direction*	+137	+0.04	+1.38
	Diana-Jaldhaka		Upstream in N-W direction	Partial avulsion of the Diana River	4.65 Km.		-49	+0.07	+0.68
2	Murti-Jaldhaka	1955-66	Downstream in S-E direction	Eastward shift of Jaldhaka River	5.65 Km.		+46	-0.11	-0.10
	Diana-Jaldhaka		Downstream in S-E direction	Westward shift of Jaldhaka	2.85 Km.		+957	-0.08	-0.33
3	Murti-Jaldhaka	1966-77	Upstream towards Northern direction	River capture	5.6 Km.		+1135	+0.10	+2.27
	Diana-Jaldhaka		Upstream towards Northern direction	Gradual aggradation	2.35 Km.		+409	+0.02	+2.49
4	Murti-Jaldhaka	1977-90	Downstream towards southern direction	Aggradation	3.88 Km.	*Diana-Jaldhaka confluence shifted towards upstream in N-W direction for 6.584 Km*	+177	-0.18	-1.68
	Diana-Jaldhaka		Upstream towards N-E direction	River capture	4.08 Km.		+231	-0.02	-1.13
5	Murti-Jaldhaka	1990-2001	Upstream towards Eastern direction	Westward shift of Jaldhaka	0.0059 Km.		-202	+0.07	-0.32
	Diana-Jaldhaka		Downstream S-W direction	local avulsion of the Diana River	0.92 Km.		-204	+0.66	+0.18
6	Murti-Jaldhaka	2001-13	Downstream in S-E direction	Bar formation	0.0027 Km.		-381	-0.05	+1.25
	Diana-Jaldhaka		Upstream in N-E direction	Aggradation and river capture	0.21 Km.		+64	-0.60	+1.16

Conclusion

The confluences of the Murti and the Diana Rivers with their trunk stream Jaldhaka have immense significance in terms of hydraulic and morphological perspectives. Overall at river basin scale, these two confluences largely determine the behavior of the Jaldhaka River at its downstream courses. During the whole period of 86 years and through all the six phases, these confluences remained mobile; movements occurred both towards upstream and downstream direction. Some of the movements are massive while there are also records of almost nil-movements. In spite of being located at close vicinities, both the confluences have recorded differential movements although their causative factors were almost the similar as a result of this close proximity. However, regarding their dynamicity, no definite pattern or trend has been observed for both the confluences to foresee their future movements as well as to assert any predictive statements for future watershed management programmes and river engineering activities. In the meantime, the processes of change are constantly operating over the study area and among them particularly the processes of channel aggradation, river capture and lateral movement of the Jaldhaka River may fetch even more dynamicity in the stability of the concerned confluences in the upcoming future. Aggressive human interventions are also expected to exaggerate the situation. The universal truth is that, dynamicity is a natural tendency of rivers to adjust and adapt with their changing environmental circumstances and this dynamicity or flow of alteration will go on silently and uninterruptedly alike the flow of water.

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