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Transboundary Water Governance and Water Data Sharing in the Yarlung Tsangpo–Brahmaputra River Basin: Challenges and Implications for India

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Abstract

The Yarlung Tsangpo–Brahmaputra River is one of Asia's major transboundary river systems, originating in the Tibetan Plateau and flowing through China, India, Bhutan and Bangladesh before entering the Bay of Bengal. Its hydrological significance is accompanied by considerable ecological, socioeconomic and geopolitical complexity. For downstream India, particularly the north-eastern states, the river is simultaneously a source of water, agriculture, hydropower and livelihood security and a major source of recurrent flood and erosion hazards. In this context, hydrological information is not merely a technical resource but an important instrument of transboundary water governance.

This paper examines the institutional evolution, scope and limitations of hydrological data sharing between India and China in the Yarlung Tsangpo–Brahmaputra basin and analyses its implications for India's flood management and water security. The study is based on qualitative analysis of secondary data, including bilateral Memoranda of Understanding (MoUs), government documents, hydrological reports, international institutional publications and peer-reviewed academic literature. The analysis demonstrates that India and China have established mechanisms for the exchange of hydrological information, including data on water level, discharge and rainfall from selected upstream stations. However, the existing arrangement remains primarily oriented towards seasonal flood forecasting rather than comprehensive, real-time and basin-wide water governance. The spatial representativeness of the existing stations, restricted temporal coverage, limited institutionalisation and absence of a comprehensive multilateral basin mechanism create significant information asymmetry.

The paper argues that India's downstream hydrological monitoring capacity cannot fully compensate for limited access to upstream observations. At the same time, the evidence does not support simplistic claims that upstream infrastructure will automatically cause downstream water scarcity. Rather, the principal concern is the management of uncertainty associated with changes in flow timing, extreme events, sediment dynamics, ecological processes and infrastructure operations. The paper therefore proposes a three-level framework comprising technical data exchange, scientific cooperation and basin-level diplomatic dialogue. Strengthening predictable and transparent hydrological data sharing, integrating satellite-based observation with ground measurements and developing a multilateral Brahmaputra information architecture can significantly improve flood preparedness and long-term water security.

KEYWORDS: Yarlung Tsangpo, Brahmaputra, transboundary water governance, hydrological data, information asymmetry, India–China relations, flood forecasting, water security

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1. INTRODUCTION

Transboundary Rivers are increasingly recognised as critical spaces where hydrology, environmental change, economic development and international politics intersect. Unlike political boundaries, river systems operate according to ecological and hydrological processes that transcend national jurisdictions. Consequently, effective management of a transboundary river requires not only physical infrastructure but also institutions capable of producing, exchanging and interpreting reliable information.

The Yarlung Tsangpo–Brahmaputra is particularly significant in this regard. The river originates on the Tibetan Plateau and subsequently crosses or influences the territories of China, India, Bhutan and Bangladesh. The basin covers approximately 580,000 km², with about 50.5% located in China, 33.6% in India, 8.1% in Bangladesh and 7.8% in Bhutan. The basin supports more than 100 million people and is characterised by a combination of intense monsoonal flooding, dry-season water stress, high sediment loads, seismic activity and rapidly changing socioeconomic demands.

For India, the Brahmaputra is of particular importance because the river system enters the country through Arunachal Pradesh and subsequently flows across Assam before moving into Bangladesh. Assam is among India's most flood- and erosion-vulnerable regions. According to the Government of Assam, approximately 31.05 lakh hectares, or 39.58% of the state's geographical area, has been assessed as flood-prone, while the average annual area affected by floods is approximately 9.31 lakh hectares. The state government further reports that approximately 4.27 lakh hectares have been eroded by rivers since 1950, with an average annual erosion rate of around 8,000 hectares.

These figures demonstrate why upstream hydrological information is important for downstream disaster management. A flood forecast is meaningful only when information about upstream rainfall, river stage and discharge is received sufficiently early to permit downstream authorities to respond. Thus, the question of hydrological data sharing should not be viewed simply as an issue of technical cooperation between two water-resource agencies. It is closely connected with disaster risk reduction, environmental security and national water governance.

India and China have developed a limited institutional framework for this purpose. The first Memorandum of Understanding concerning the provision of hydrological information on the Yaluzangbu/Brahmaputra was signed in 2002. Subsequent arrangements expanded and modified the mechanism, while the Expert Level Mechanism on Trans-Border Rivers was established in 2006. The arrangements have included the sharing of water level, discharge and rainfall information from three designated upstream stations Nugesha, Yangcun and Nuxia during the flood season.

However, the existence of a data-sharing mechanism does not necessarily mean that a comprehensive system of transboundary water governance exists. Previous studies have identified limitations related to seasonal rather than year-round exchange, the narrow geographical coverage of monitoring stations, the absence of a basin-wide institutional mechanism and the broader political asymmetry between upstream and downstream states.

The central argument of this paper is therefore that hydrological information should be understood as a governance resource. The problem facing India is not simply whether data are shared or not; rather, it concerns the adequacy, timeliness, spatial representativeness, continuity and institutional reliability of the information exchanged.

2. Study Area and Hydrological Context

The Brahmaputra basin represents a highly complex transboundary geographical system. The upper course is known as the Yarlung Tsangpo in Tibet. After traversing the Tibetan Plateau, the river turns southward through the eastern Himalaya and enters India, where it becomes the Siang/Dihang and subsequently the Brahmaputra. It eventually enters Bangladesh as the Jamuna before joining the Ganges system.

The basin's physical characteristics are fundamental to understanding the politics of hydrological information. The river is influenced by multiple water sources, including monsoonal precipitation, snow and glacier melt and groundwater. Its hydrological behaviour changes substantially along its course. The World Bank describes the Brahmaputra as one of the world's largest, most flood-prone and most unstable rivers, with substantial sediment loads and complex geomorphological characteristics.

Table 1: Spatial Distribution of the Brahmaputra Basin

Riparian country	Approximate share of basin
China	50.5%
India	33.6%
Bangladesh	8.1%
Bhutan	7.8%
Total	**100%**

Source: World Bank basin assessment.

The geographical distribution immediately establishes an important governance asymmetry. China occupies the largest share of the basin and controls the upper reaches of the Yarlung Tsangpo, whereas India contains a substantial downstream portion and is exposed to the consequences of upstream hydrological variability.

This upstream–downstream relationship does not automatically imply political conflict. Nevertheless, it creates a structural difference in access to information. Upstream states can directly observe changes in river conditions before they reach downstream territories. Consequently, downstream states depend to a greater extent on the willingness and institutional capacity of upstream states to exchange information.

3. Conceptual Framework: Hydrological Information as a Governance Resource

The paper conceptualises hydrological data as a form of governance infrastructure.

Conventional approaches to transboundary water politics generally focus on three issues: water allocation, infrastructure development and interstate conflict. However, these approaches can overlook the importance of information. In reality, decisions concerning flood forecasting, reservoir operation,

disaster preparedness and long-term water planning depend upon reliable information.

The relationship can be represented as:
Upstream hydrological observation → information exchange → downstream forecasting → disaster preparedness → reduced uncertainty → improved water governance

The concept of information asymmetry is therefore more analytically useful than the term "data monopoly." Information asymmetry does not necessarily imply intentional withholding. It can result from differences in monitoring capacity, institutional priorities, political relations, data standards, infrastructure or bilateral agreements.

In the Brahmaputra case, information asymmetry emerges from at least four dimensions:

1. **Spatial asymmetry** – upstream and downstream countries do not possess equivalent observation coverage.
2. **Temporal asymmetry** – data may be exchanged during specific flood-season periods rather than continuously.
3. **Institutional asymmetry** – there is no comprehensive basin-wide institution covering all riparian states.
4. **Analytical asymmetry** – countries may possess different capacities to interpret hydrological, meteorological and satellite information.

This framework allows the Brahmaputra issue to be examined without assuming that upstream infrastructure necessarily produces downstream water scarcity.

4. REVIEW OF LITERATURE

Existing scholarship on the Yarlung Tsangpo–Brahmaputra can broadly be divided into four strands.

4.1 Transboundary Water Cooperation

The first strand examines the evolution of India–China cooperation. Research indicates that bilateral cooperation gradually developed through agreements concerning hydrological information and Transboundary Rivers. The 2002 MoU was followed by subsequent arrangements, while the Expert Level Mechanism was established in 2006.

This literature demonstrates that India–China river relations cannot accurately be characterised as an absence of cooperation. Rather, cooperation exists but remains issue-specific and limited in institutional scope.

4.2 Hydrological Data Sharing

The second strand focuses specifically on hydrological data. Existing agreements have provided for information relating to water level, discharge and rainfall from Nugesha, Yangcun and Nuxia during the flood season. The implementation arrangements also established specific timings for transmission of information.

However, researchers have questioned whether the existing stations are sufficient for comprehensive downstream flood forecasting. Ghosh, Bandyopadhyay and Modak argue that the location of the three stations in relatively dry Tibetan areas limits their usefulness for understanding the monsoon-dominated hydrology of the downstream Brahmaputra. This critique is particularly important because it shifts the debate from **whether data are exchanged** to whether the exchanged data are sufficiently representative for the intended governance purpose.

4.3 Power Asymmetry and Hydro-politics

The third strand interprets the Brahmaputra through the lens of hydro-politics. Scholars have argued that the absence of a comprehensive basin-level institutional mechanism and the limited scope of bilateral agreements create structural weaknesses in cooperation. Data sharing has historically been concentrated on flood-season requirements rather than integrated basin management.

4.4 Hydropower and Strategic Concerns

The fourth strand concerns hydropower development in the upper reaches of the river. China and India both possess significant hydropower interests in the wider Himalayan region. The debate surrounding upstream infrastructure frequently links dam construction with concerns about downstream flows. However, the relationship between dams and downstream water security is scientifically more complex than a simple increase/decrease model. Impacts can vary according to reservoir characteristics, operating rules, seasonal flows, sediment transport, environmental processes and extreme hydrological events.

5. Research Gap

Although substantial literature exists on India–China water relations, three important gaps remain.

- First, much of the literature treats hydrological data primarily as a technical input for flood forecasting rather than as an independent dimension of transboundary governance.
- Second, existing research frequently concentrates on whether China shares data, while comparatively less attention is given to the **quality, representativeness, timing and institutional reliability** of the information exchanged.
- Third, discussions of Chinese upstream infrastructure often dominate public discourse, while the relationship between infrastructure, information and downstream uncertainty receives comparatively less systematic analysis.

This study addresses these gaps by connecting three variables:
Hydrological data sharing + information asymmetry + downstream water security

6. OBJECTIVES OF THE STUDY

The study has five principal objectives:

1. To examine the institutional evolution of hydrological data sharing between India and China.
2. To assess the nature and limitations of the existing data-sharing mechanism.
3. To analyse the relationship between upstream information availability and downstream flood vulnerability in India.

4. To examine the implications of information asymmetry for India's water security.
5. To propose an institutional framework for improved transboundary hydrological governance.

7. Research Questions

The study addresses the following questions:

1. How has India–China hydrological data sharing evolved since 2002?
2. What types of hydrological information are exchanged under existing arrangements?
3. To what extent are the existing monitoring arrangements adequate for downstream flood forecasting?
4. How does information asymmetry affect India's transboundary water security?
5. What institutional reforms could strengthen cooperative governance of the Brahmaputra basin?

8. METHODOLOGY

The study adopts a ***qualitative-dominant mixed secondary-data methodology***.

No primary survey has been used. Instead, the study analyses documentary, institutional and quantitative secondary evidence.

8.1 Sources of Data

The principal sources include:

- Government of India documents;
- Ministry of External Affairs documents;
- Central Water Commission publications;
- Government of Assam water-resource reports;
- World Bank basin assessments;
- bilateral India–China MoUs;
- peer-reviewed academic literature;
- Research reports dealing with Brahmaputra hydrology and flood forecasting.

8.2 Methods of Analysis

The study employs:

Document analysis: Bilateral agreements and institutional documents were examined to identify the evolution and scope of data-sharing arrangements.

Descriptive statistical analysis: Available basin-level and flood-vulnerability indicators were organised to establish the physical significance of the river.

Institutional analysis: The study examines the Expert Level Mechanism and bilateral data-sharing arrangements.

Comparative analysis: The paper compares the requirements of basin-wide water governance with the narrower focus of existing bilateral data-sharing arrangements.

8.3 Limitation

A major limitation is that upstream hydrological datasets are not available to the researcher as a complete open-access time series. Therefore, the paper does not attempt to independently model downstream discharge attributable to individual Chinese infrastructure projects. Instead, it evaluates the governance implications of data availability and institutional arrangements using verifiable secondary sources.

9. Evolution of India–China Hydrological Data Sharing

The institutionalisation of hydrological information exchange represents an important development in India–China river relations.

The first major bilateral arrangement was the 2002 MoU concerning provision of hydrological information on the Yaluzangbu/Brahmaputra. The agreement was principally motivated by downstream flood concerns. Subsequent arrangements modified the duration and operational details of data exchange.

The Expert Level Mechanism on Trans-Border Rivers was established in 2006, creating an institutional forum for discussion of hydrological information, emergency management and transboundary river issues.

Table 2: Major Elements of the Hydrological Data-Sharing Arrangement

Element	Existing arrangement
Main purpose	Flood forecasting and mitigation
Upstream country	China
Downstream recipient	India
Major stations	Nugesha, Yangcun, Nuxia
Data	Water level, discharge, rainfall
Principal period	Flood/high-flow season
Institutional mechanism	India–China bilateral arrangement and ELM
Character	Technical and bilateral
Basin-wide mechanism	Absent

Source: Compiled from India–China hydrological cooperation literature and bilateral arrangements.

The significance of this arrangement lies in the fact that it established a formal channel through which upstream information could reach Indian authorities. However, its limitations are equally important.

10. The Problem of Spatial and Temporal Adequacy

Data sharing should not be evaluated merely in binary terms—shared or not shared. The more relevant questions are:

- Where are observations collected?
- How frequently are they transmitted?
- What variables are included?
- How rapidly are they transmitted?
- How representative are the stations?
- Are extreme-event observations available?
- Are data available throughout the year?

Existing arrangements have historically concentrated on three upstream stations and flood-season information. Academic analysis has raised concerns regarding the geographical representativeness of these stations for predicting downstream monsoon floods. This issue is crucial because the Brahmaputra's downstream hydrology is not controlled solely by the upper Tibetan reach. Major tributaries and intense monsoon rainfall in the eastern Himalaya and north-eastern India contribute substantially to downstream discharge. Therefore, the usefulness of upstream information depends

upon its integration with Indian rainfall, tributary and river-stage observations.

The appropriate model is consequently not:
Chinese data → Indian flood forecast
Chinese upstream data + Indian hydrological observations + satellite observations + rainfall forecasts + tributary data → integrated flood forecast

11. India's Downstream Hydrological Vulnerability

India possesses substantial institutional capacity for hydrological monitoring. The Central Water Commission maintains hydrological observation networks across major river basins. Nevertheless, downstream monitoring cannot entirely substitute for upstream information. A downstream station records a river condition only after the hydrological event has already travelled downstream. Upstream information can potentially provide additional lead time for forecasting and emergency management. The importance of this lead time becomes evident in Assam.

Table 3: Selected Flood and Erosion Indicators for Assam

Indicator	Value
Geographical area of Assam	78,438 km²
Flood-prone area	31.05 lakh ha
Flood-prone share	39.58%
Average annual flood-affected area	9.31 lakh ha
Area eroded since 1950	4.27 lakh ha
Average annual erosion	~8,000 ha

Source: Government of Assam, Water Resources Department.

These figures demonstrate that flood information has direct implications for livelihoods, infrastructure, and agriculture and settlement security. Thus, even a relatively short improvement in warning lead time can have considerable practical importance.

12. Hydropower Development and the Water-Security Debate

The expansion of hydropower development in the Himalayan region has intensified debate concerning the future of the Brahmaputra.

However, it is analytically necessary to distinguish three different questions:

1. Will upstream infrastructure reduce annual downstream water availability?
2. Can infrastructure alter the timing and variability of flows?
3. Can infrastructure increase uncertainty regarding sediment, ecology and extreme events?

The annual discharge of a large transboundary river is influenced by precipitation, snow and glacier melt, groundwater, tributary inflows and basin-scale climatic processes. Consequently, the mere construction of a hydropower facility does not establish that downstream water availability will necessarily decline. The more defensible concern is the possibility that infrastructure operations may alter flow timing, sediment transport, ecological conditions and the predictability of downstream hydrological behaviour.

13. Information Asymmetry and India's Water Security

The principal analytical finding of this study is that information asymmetry constitutes a distinct dimension of transboundary water insecurity. Water security is generally understood through availability, accessibility, quality and reliability. In a transboundary river system, however, reliability also depends on the availability of information.

A downstream state may possess sufficient water-resource potential but still experience governance insecurity if it cannot adequately anticipate:

- *extreme upstream rainfall;*
- *sudden changes in river discharge;*
- *landslide-related river blockages;*
- *reservoir releases;*
- *unusual hydrological events;*
- *seasonal flow changes;*
- *Sediment-related impacts.*

Water security = physical water security + informational security + institutional security

This conceptualisation extends conventional water-security approaches by placing information at the centre of governance.

14. Climate Change and Increasing Importance of Real-Time Data

Climate change further increases the importance of hydrological information.

Himalayan river systems are exposed to changes in precipitation patterns, glacier and snow dynamics, extreme rainfall and geomorphological instability. These processes may increase uncertainty in flood forecasting. Under such conditions, a data-sharing arrangement designed primarily around fixed seasonal transmission is less adequate than a dynamic real-time information architecture.

Future cooperation should therefore move towards:

- hourly or near-real-time data during extreme events;
- automatic data transmission;
- joint flood alerts;
- satellite-based verification;
- standardised metadata;
- Emergency communication protocols.

The objective should not be to create dependence on one country's information but to establish multiple independent information streams.

15. Bilateralism versus Basin-Wide Governance

One of the structural weaknesses of the present arrangement is its bilateral character. The Brahmaputra is not exclusively an India–China river. Bhutan and Bangladesh are also integral to the basin's hydrological and ecological system. A bilateral mechanism may therefore be useful for specific upstream–downstream issues but cannot substitute for basin-wide governance.

A comprehensive framework should involve:

China – India – Bhutan – Bangladesh
And should address:

- hydrological data;
- flood forecasting;
- sediment;
- environmental flows;
- disaster management;
- climate adaptation;
- ecosystem conservation;
- hydropower information;
- Drought and low-flow conditions.

The World Bank has similarly emphasised the importance of knowledge generation, technical capacity and cooperation in addressing the basin's complex environmental and developmental challenges.

16. Major Challenges in Transboundary Hydrological Data Governance

The analysis of the existing India–China hydrological cooperation framework reveals several structural, institutional and technological challenges that constrain the effectiveness of transboundary water governance in the Yarlung Tsangpo–Brahmaputra River system. These challenges are not limited to the availability of hydrological information; they also concern the timeliness, spatial representativeness, standardisation, institutional reliability and scientific usability of the data exchanged. The major challenges are discussed below.

Temporal Limitations in Hydrological Data Sharing

One of the major limitations of the existing hydrological information-sharing mechanism is its historically seasonal orientation. Data exchange has primarily been associated with the flood season and the requirements of flood forecasting. While such an arrangement is useful for short-term disaster preparedness, it is insufficient for comprehensive annual water-resource management. The hydrological behaviour of the Brahmaputra varies considerably across seasons. Information on high flows alone cannot adequately explain low-flow conditions, seasonal variability, drought risks, sediment dynamics or long-term changes in river behaviour. Furthermore, climate variability is increasing the frequency and unpredictability of extreme hydrological events. Consequently, dependence on periodic or seasonal data transmission may reduce the capacity of downstream institutions to anticipate rapidly developing hydrological conditions. For India, particularly in the Brahmaputra-dependent regions of the Northeast, a transition from seasonal information exchange to continuous or near-real-time hydrological data sharing would significantly strengthen flood forecasting, disaster preparedness and long-term water-resource planning.

Spatial Limitations and Representativeness of Monitoring Stations

A second challenge concerns the geographical coverage of upstream hydrological monitoring. Existing bilateral arrangements have relied on information from a limited number of designated stations in the upper reaches of the Yarlung Tsangpo. Although these stations provide valuable information, a small number of observation points cannot necessarily capture the complete hydrological variability of an extensive and geographically complex river basin. The Brahmaputra system is influenced by variations in precipitation, snow and glacier melt, tributary inflows, topography and geomorphological processes across different parts of the basin. Moreover, the hydrological conditions of the Tibetan Plateau are substantially different from those of the eastern Himalaya and Assam. Consequently, information collected at particular upstream locations may have limited predictive value for all downstream locations.

This creates a significant methodological issue: the availability of data does not necessarily guarantee the adequacy of data. For India, the key requirement is therefore not simply an increase in the volume of information received from China, but greater spatial coverage and improved integration of upstream observations with Indian rainfall, tributary and river-discharge data.

Absence of a Comprehensive Basin-Wide Institutional Framework

The Brahmaputra is a transboundary river system shared by China, India, Bhutan and Bangladesh. However, cooperation concerning the river has largely developed through bilateral arrangements rather than through a comprehensive basin-wide institution involving all riparian countries. This institutional fragmentation creates limitations for integrated management. Floods, sediment transport, ecosystem degradation, climate change and hydropower development are not confined within political boundaries. Decisions taken in one part of the basin may consequently have implications for communities and ecosystems located elsewhere.

A basin-wide institutional mechanism could provide a common platform for the exchange of hydrological and environmental information, joint scientific assessment, flood forecasting, climate adaptation and disaster management. The absence of such an institution remains one of the principal structural weaknesses of Brahmaputra governance.

Political Trust Deficit and Strategic Sensitivities

Hydrological cooperation cannot be separated entirely from the broader political relationship between India and China. Although the two countries have developed institutional mechanisms for transboundary river cooperation, strategic differences and periodic political tensions can influence the broader environment within which technical cooperation takes place.

The Brahmaputra is particularly sensitive because the upper reaches of the river are located in a region of considerable geopolitical significance. As a result, information concerning hydrological conditions, infrastructure development and river management may acquire strategic importance beyond its purely scientific value.

The resulting trust deficit can affect the predictability and depth of information exchange. For this reason, hydrological cooperation should be insulated, as far as possible, from short-term political fluctuations. Establishing permanent technical channels and clearly defined data-sharing protocols would help maintain cooperation even during periods of diplomatic tension.

Lack of Common Data Standards and Interoperability

Another important challenge is the absence of a fully integrated system of common standards for the collection, formatting, validation and exchange of hydrological information. Effective transboundary water governance requires data generated by different national agencies to be comparable and interoperable. Differences in measurement procedures, temporal resolution, station specifications, quality-control protocols, metadata and digital formats can complicate the integration of datasets. This problem becomes particularly significant when hydrological information from different sources is combined with satellite imagery, rainfall forecasts and numerical flood models. Without common technical standards, differences between datasets may introduce uncertainty into forecasting systems.

Therefore, future India–China cooperation should include agreement on common data formats, metadata standards, quality-control procedures, measurement units and protocols for emergency data transmission**.**

Limited Transparency Regarding Major River Infrastructure

The development of large hydropower infrastructure in the upper reaches of the Yarlung Tsangpo has increased the importance of information transparency. From India's perspective, uncertainty regarding the location, scale, construction schedule and operational characteristics of major infrastructure can complicate long-term water-resource planning. It is important, however, to distinguish between infrastructure development and demonstrated downstream hydrological impact**.** The construction of a dam does not by itself establish that downstream water availability will decline. The actual consequences depend on reservoir characteristics, operational rules, seasonal flows, sediment processes, ecological conditions and other hydrological factors.

The governance problem therefore concerns predictability and transparency, rather than assuming a particular downstream impact in advance. Regular exchange of technical information concerning major infrastructure and its operation could reduce uncertainty and enable downstream institutions to incorporate potential changes into risk assessments.

Gap between Diplomatic Engagement and Scientific Cooperation

A further challenge is the relatively limited institutionalisation of direct scientific cooperation compared with diplomatic and government-to-government engagement. Transboundary river management increasingly requires specialised knowledge in hydrology, climatology, remote sensing, glaciology, sedimentology, and ecology and disaster-risk science. Government agencies alone cannot address all these dimensions without sustained scientific collaboration.

A stronger network involving universities, research institutions, hydrological agencies and technical experts from the riparian countries could generate independent scientific assessments and improve the reliability of policy decisions. Such cooperation could also reduce political misunderstandings by creating channels through which hydrological questions are examined through shared scientific methodologies rather than solely through diplomatic interpretation.

17. DISCUSSION

The evidence suggests that the Brahmaputra should not be understood through the simplistic binary of "cooperation versus conflict." The actual situation is more accurately characterised as limited functional cooperation within a broader environment of strategic mistrust and institutional fragmentation. The India–China data-sharing arrangements represent genuine cooperation. They have provided a mechanism through which hydrological information can support downstream flood management.

The most important issue is therefore not simply whether China shares information with India, but whether the existing information architecture is:

Timely + continuous + spatially representative + scientifically verifiable + institutionally predictable.

The implication is significant. India should avoid framing the issue exclusively as a geopolitical confrontation. Instead, it should develop a dual strategy:

Strategic vigilance + scientific cooperation.

Such an approach would allow India to protect its water and disaster-security interests without unnecessarily converting a complex hydrological problem into a binary political conflict.

18. Policy Recommendations

The preceding analysis demonstrates that the effectiveness of transboundary water governance in the Yarlung Tsangpo–Brahmaputra River system depends not only on the availability of hydrological information but also on its continuity, accuracy, spatial coverage, institutional reliability and timely transmission. The existing India–China arrangements provide an important foundation for cooperation; however, their predominantly bilateral and flood-season orientation is insufficient to address the increasingly complex challenges associated with climate variability, extreme hydrological events, infrastructure development and downstream water-security concerns. Accordingly, the following policy measures are proposed to strengthen hydrological data governance and improve India's capacity for flood management, disaster preparedness and long-term water-security planning.

Establishment of a Permanent and Predictable Hydrological Data-Sharing Protocol

India and China should move towards a permanent and clearly defined hydrological data-sharing protocol that remains operational irrespective of short-term fluctuations in bilateral political relations. Existing arrangements have provided an institutional foundation for the exchange of upstream hydrological information, but their effectiveness depends upon the continuity, predictability and timely transmission of such information.

A permanent protocol should clearly specify the categories of data to be exchanged, transmission frequency, responsible agencies, data formats, quality-control procedures and mechanisms for emergency communication. It should also include provisions for extraordinary hydrological events, such

as extreme rainfall, sudden changes in river discharge and other conditions that may generate downstream risks. Such institutionalisation would reduce uncertainty and transform hydrological data exchange from an ad hoc or politically contingent practice into a stable component of transboundary water governance.

Transition from Seasonal Data Sharing to Year-Round and Near-Real-Time Exchange

The existing emphasis on flood-season information should gradually be expanded towards year-round hydrological data exchange. Seasonal information remains important for flood forecasting, but contemporary river-basin management requires continuous information concerning both high-flow and low-flow conditions. The proposed system should operate on a differentiated basis. Routine hydrological observations could be transmitted at regular intervals throughout the year, while the frequency of transmission could increase during periods of extreme rainfall, rapid changes in river levels or other hydrological emergencies.

Near-real-time information would be particularly valuable for improving downstream flood-warning lead time. It would also support long-term assessment of seasonal variability, drought conditions, climate-induced changes and ecological processes. Therefore, the objective should be to shift from a seasonal flood-information mechanism to an integrated year-round hydrological information system.

Expansion of the Scope of Hydrological and Environmental Parameters

The effectiveness of data sharing depends not only on the frequency of transmission but also on the range of parameters included in the information exchange. Future cooperation should therefore progressively expand beyond basic river-stage and discharge information.

The data-sharing framework should, where technically and institutionally feasible, incorporate:

- precipitation and rainfall intensity;
- river water level;
- river discharge;
- sediment concentration and sediment transport;
- water temperature;
- snow and glacier-related indicators;
- information on extreme hydrological events;
- relevant meteorological observations; and
- Emergency hydrological alerts.

A broader dataset would enable Indian agencies and scientific institutions to develop more sophisticated hydrological models. It would also facilitate analysis of the relationship between climatic variability, upstream hydrological processes and downstream river behaviour. The emphasis should consequently be placed on integrated hydrological information rather than isolated measurements.

Development of a Satellite-Based Independent Verification System

India should strengthen the use of satellite remote sensing and geospatial technologies as an independent layer of hydrological observation. Satellite-based monitoring cannot replace ground-based hydrological measurements, but it can complement them and provide valuable information across areas where conventional monitoring is geographically difficult. Satellite observations can contribute to the assessment of river extent, surface-water changes, precipitation patterns, snow and glacier conditions, flood inundation and other environmental indicators. When combined with ground observations from the Central Water Commission and other agencies, these datasets can provide a more comprehensive picture of basin conditions.

An independent satellite-based information layer would also improve the scientific verification of exchanged hydrological information and reduce India's dependence on any single source of upstream observations. The proposed approach should therefore be based on data integration rather than data substitution, combining:

Ground observations + satellite observations + meteorological data + hydrological modelling.

Establishment of a Joint Transboundary Flood Early-Warning Mechanism

Given the recurrent flood vulnerability of the Brahmaputra basin, India and China should consider establishing a dedicated technical mechanism for transboundary flood early warning. Such a mechanism could establish common protocols for identifying extreme hydrological events and communicating warnings to downstream authorities. The system should specify thresholds for emergency alerts, responsible agencies, communication channels and procedures for rapid transmission of information.

For India, such a mechanism would be particularly significant for Arunachal Pradesh and Assam, where the arrival of flood waves can have substantial implications for settlements, agriculture, transportation and infrastructure. A joint early-warning mechanism would also represent a practical area of cooperation where scientific and humanitarian objectives are less politically contentious than broader questions of water allocation.

Creation of a Brahmaputra Scientific Cooperation Network

Transboundary water governance requires sustained scientific cooperation extending beyond government agencies. India, China, Bhutan and Bangladesh should therefore work towards establishing a Brahmaputra Scientific Cooperation Network involving universities, research institutions, hydrological agencies, climate scientists and disaster-management organisations.

The network could focus on collaborative research in areas such as:

- hydrological and flood modelling;
- climate-change impacts;
- sediment transport and river morphology;
- glacier and snow dynamics;
- ecological flows;
- flood and disaster-risk assessment;

- remote sensing and geospatial monitoring; and
- Long-term changes in river behaviour.

Such a network would create an institutional space in which scientific questions could be examined through shared methodologies and evidence. It could also reduce dependence on politically framed interpretations of hydrological developments. Importantly, scientific cooperation should not be limited to the exchange of research publications. It should include joint datasets, methodological workshops, collaborative modelling exercises, researcher exchanges and periodic scientific assessments of the basin.

Development of a Multilateral Brahmaputra Basin Dialogue

The long-term objective should be to complement existing bilateral India–China arrangements with a broader multilateral dialogue involving China, India, Bhutan and Bangladesh. The Brahmaputra is a shared river system, and its hydrological, ecological and socioeconomic processes extend beyond bilateral political boundaries. A multilateral platform could therefore provide an institutional framework for discussing issues that cannot be effectively addressed through bilateral arrangements alone.

The proposed Brahmaputra Basin Dialogue could initially focus on relatively non-contentious areas, including:

1. flood forecasting and disaster management;
2. hydrological and meteorological data exchange;
3. climate-change adaptation;
4. scientific research;
5. sediment and river morphology;
6. ecosystem conservation; and
7. Capacity building.

Over time, the scope could be expanded to include broader questions concerning infrastructure development, environmental impacts and sustainable basin management. A gradual, issue-based approach would be more realistic than attempting to establish an extensive water-sharing treaty immediately. The objective should be to build institutional trust through functional cooperation.

Strengthening India's Domestic Hydrological Information Infrastructure

International data sharing should be complemented by continued strengthening of India's own hydrological monitoring capabilities. India should expand the integration of river gauges, automatic weather stations, satellite observations, radar rainfall data, digital elevation models and numerical flood-forecasting systems. The Central Water Commission, India Meteorological Department, National Remote Sensing institutions, state water-resource departments and disaster-management agencies should develop interoperable information systems capable of producing integrated basin-level assessments. This would ensure that India does not depend exclusively upon upstream data for flood preparedness. Instead, upstream information would become one component of a broader and scientifically robust national forecasting system.

Development of Common Data Standards and Interoperable Platforms

Future cooperation should also address the technical problem of data compatibility. India and China should work towards common standards concerning units of measurement, temporal resolution, metadata, quality control and digital formats. An interoperable platform could facilitate the integration of hydrological information from multiple sources and reduce technical inconsistencies. The long-term objective should be the creation of a Brahmaputra Hydrological Information Architecture in which information from government agencies, satellite systems and scientific institutions can be integrated within a common analytical framework.

Institutionalisation of Emergency Communication Channels

A dedicated emergency communication mechanism should be developed for exceptional hydrological situations. Normal diplomatic channels may not always be sufficiently rapid for disaster management. A technical emergency channel connecting designated hydrological and disaster-management authorities could facilitate rapid communication during extreme rainfall, sudden river-level changes, landslides, glacial or other high-risk events. Such a mechanism would strengthen mutual confidence because its primary purpose would be humanitarian and disaster-related rather than geopolitical.

Towards an Integrated Model of Brahmaputra Water Governance

The recommendations proposed above can be integrated into a three-level governance framework:

Governance Level	Proposed Mechanism	Principal Function
Technical	Permanent Hydrological Data Exchange Mechanism	Continuous data sharing, standardisation, and flood alerts
Scientific	Brahmaputra Scientific Cooperation Network	Joint research, modelling, and environmental assessment
Diplomatic	Multilateral Brahmaputra Basin Dialogue	Long-term cooperation among China, India, Bhutan, and Bangladesh

The three levels should operate in coordination rather than isolation. Technical cooperation can generate reliable information; scientific cooperation can interpret that information; and diplomatic institutions can translate scientific findings into durable policy arrangements. This approach would help transform the existing fragmented system into a more integrated form of transboundary water governance.

Strategic Priority for India

From India's perspective, the immediate policy priority should not be to frame the Brahmaputra exclusively as a geopolitical contest over water. Such an approach risks obscuring the technically complex nature of the basin. Instead, India's strategy should combine domestic hydrological capacity, technological independence, and scientific diplomacy and institutionalised international cooperation.

The most effective approach would therefore rest on four complementary principles:
Information sufficiency → scientific verification → institutional predictability → cooperative governance.
Such a strategy would enable India to manage downstream risks more effectively while maintaining channels for constructive engagement with upstream and other riparian states.

20. MAJOR FINDINGS

The study produces six principal findings.
First, India and China already possess an institutional basis for hydrological data sharing; therefore, describing the relationship simply as "absence of cooperation" is inaccurate.
Second, existing cooperation is predominantly designed around flood forecasting rather than integrated basin governance.
Third, the problem is better conceptualised as information asymmetry than as an empirically established "data monopoly."
Fourth, India's substantial downstream monitoring network cannot completely substitute for timely upstream information because upstream observations may provide additional forecasting lead time.
Fifth, the spatial representativeness of the existing upstream monitoring stations is an important issue and requires further scientific assessment.
Sixth, future water-security planning should focus not only on total water availability but also on uncertainty concerning timing, variability, extreme events, sediment and ecological change.

21. CONCLUSION

The Yarlung Tsangpo–Brahmaputra is simultaneously a river system, an ecological corridor, an economic resource and a geopolitical space. Its governance cannot therefore be reduced to the question of how much water flows from China to India. The evidence examined in this paper demonstrates that hydrological information represents an essential but insufficiently institutionalised component of transboundary water governance. India and China have established mechanisms for exchanging upstream hydrological information, and these mechanisms constitute an important foundation for cooperation. However, their predominantly bilateral and seasonal character, limited spatial coverage and absence of a comprehensive basin-wide framework restrict their effectiveness.
For India, the central challenge is therefore not simply Chinese control over the upper river, but the uncertainty produced when downstream planning operates with incomplete or delayed information about upstream hydrological conditions. This distinction has important policy implications. The objective of Indian water diplomacy should not be limited to demanding more data; it should be to create a predictable, continuous, verifiable and scientifically meaningful information architecture.
A resilient Brahmaputra governance system should integrate upstream and downstream observations, satellite technology, flood forecasting, and climate modelling and institutional cooperation. Bilateral India–China mechanisms should be strengthened, but they should also be complemented by a broader basin dialogue involving Bhutan and Bangladesh.
Ultimately, the future of Brahmaputra water security will depend not merely on physical control over water, but on the capacity of riparian states to share knowledge, reduce uncertainty and institutionalise cooperation.

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