## Research Note

# INLAND WATERWAYS AIDS TO NAVIGATION USING SEDIMENT PREDICITION

**Ayush Sharma*, Dr. (Cdr.) Arnab Das****

*BITS Pilani, **MRC Pune

## 1. INTRODUCTION

Inland water transport has a huge potential in India as it is a largely unexploited area. There are various advantages associated with this mode of transport, for example it has the least impact on environment and has least cost when compared to road and railways.[1]

Brahmaputra basin has flood issues that stem from the fact that it has the second highest sediment levels in the world, it gathers sediments from soft rocks and landslide-affected areas of the Himalayas. Dredging is important not only to reduce flooding by allowing more water to stay in the river but also because it makes the river navigable. [2]

Several methods have been developed to study sediment and model the sediment concentration in rivers. Channel geometry can be predicted using ANN as we cannot measure the dimension of a natural river at various point as they keep on changing. The Brahmaputra displays a wide range of morphological variations ranging between steep gorges and wide channels with gentle slopes, probably due to its tectonics driven gradient changes.[3]

Also, the width of the river is neither uniform along its course, nor invariable in the same place, except for a few short reaches. In fact, the mean width of the river has been increasing with time for about the last nine decades along its course in Assam. An abrupt increase in mean width is correlated to a tectonic event.[4]

Support Vector Regression are used to predict the Bed load material concentrations.[5] Hence, methods can be developed to estimate the bed load levels. Also, a warning generation algorithm should be developed to introduce the sediment aspects into the Aids to Navigation system.

## 2. SEDIMENT LOAD TRANSPORT IN BRAHMAPUTRA BASIN

The Brahmaputra River originates in the Tibetan plateau and runs on the northern side of the Himalaya before flowing into India. In India, the elevation drops drastically into an agricultural floodplain valley.[6]

A sediment budget is a quantitative statement of the transfer and storage of sediment as it is transported from its source to its eventual exit from the drainage basin. Due to heavy rainfall in the catchment, the Brahmaputra basin is subject to intense erosion processes.[3]

Both physical and chemical erosion rates are high in the Brahmaputra Basin compared with the world average.[7] The Namche Barwa or eastern syntaxis zone is the major source of sediments and supplies about 45% of the bulk sediment flux from only 20% of mountain area. This conclusion is based, however, on a limited number of samples and the possible variability of the system over short term makes it necessary to increase sampling to improve representativeness.[8]

Bed load represents the sediment rolling, sliding or jumping along the bed. The grains remain in contact with the bed for the majority of their transport.

Suspended load is the part of the total load which is not in continuous contact with the bed. This is due to turbulent fluctuations in the flow keeping the particles in suspension.

Wash load is made up of very fine particles and is generally not represented in the bed. For this reason, we do not have to include the wash load in the total mass of sediment transported and it can be neglected.

## 3. EXISTING MODELS

Some approaches, called indirect methods, include transport functions based on Einstein's bed-load function, in which the total sediment load can be obtained through the sum of bed load and suspended load functions.

Other approaches, called direct methods, determine the total sediment load directly, without making a distinction between the two modes of transport.

## 4. SUSPENDED LOAD TRANSPORT

Sediment particle size is the major factor in regulating the behavior of suspended material in aquatic environments (Nicholas & Walling, 1996). [9]

Inaccuracies in predicted suspended sediment concentrations related to the fitting procedure (statistical methods and scatter about the regression line) are discussed by Ferguson (1986, 1987) [10], Jansson (1985, 1997) [11], Singh and Durgunoglu (1989) [12] and Cohn et al. (1992) [13]. They concluded that the sediment load of a river is likely to be underestimated when concentrations are calculated from water discharge using least squares regression of log-transformed variables. [14]

Walling and Webb (1981) showed that when using mean loads in water discharge classes instead of rating curves, the order of magnitude of the load was correct. Jansson (1985) [15] suggested the use of mean loads in discharge classes to develop sediment rating curves, since by definition, a regression curve should go through the mean concentrations at every water discharges.

Sediment rating curves are used to predict Suspended load.[16] The most commonly used sediment rating curve is a power function (Walling 1978; Jansson 1997) [17] [18]

Suspended sediment load is being predicted using machine learning models based on river discharge rates. [19]

A lot of work has been done to implement ANN based models for suspended sediment concentration. [20,21,22] and sediment rating curves. [23,24]

## 5. BED LOAD TRANSPORT

When the flow conditions satisfy or exceed the criteria for incipient motion, sediment particles along the alluvial bed will start move. If the motion of sediment is “rolling”, “sliding” or “jumping” along the bed, it is called bed load transport. Generally, the bed load transport of a river is about 5-25% of that in suspension. However, for coarser material higher percentage of sediment may be transported as bed load.

(1) Shear Stress Approach

Duboys (1879) assume that sediment particles move in layers along the bed and presented following relationship.

Shields’ Approach: In his study of incipient motion, Shield obtain semi empirical equation for bed-load.

(2) Energy Slope Approach

Meyer-Peter et al. (1934) conducted extensive laboratory studies on sediment transport.

After 14 years of research and analysis, Meyer-Peter and Muller (1948) transformed the Meyer-Peter formula into Meyer-Peter and Mullers’ Formula.[25]

(3) Discharge Approach

Schoklistch (1934,1943) pioneered the use of discharge for determination of bed load.[26]

(4) Regression Approach

Rottner (1959) applied a regression analysis on laboratory data and developed dimensionally homogenous formula.[27]

## 6. TOTAL LOAD TRANSPORT

(1) Engelund & Hansen’s Approach: They applied Bagnold’s stream power concept and similarity principle to obtain a sediment transport function.[28]

(2) Ackers and White’s Approach: Based on Bagnold’s stream power concept they applied dimensional analysis and obtain the following relationship.[29]

(3) Yang Approach: He used concept of unit stream power (velocity slope product) and obtained following expression by running regression analysis for 463 sets of laboratory data.[30]

(4) Shen and Hung’s Approach: They recommended a regression equation based on 587 sets of laboratory data in the sand size range.[31]

## 7. DATA REQUIERMENT

Current data of river characteristics and discharges of the Brahmaputra are not freely accessible. To overcome this lack of data, recent studies have focused on extracting basin data from satellite imagery,[32] including river data but these methods still cannot fully replace in situ measurements.[33]

For example, data can be obtained by using advanced instruments-ADCP, GPS enabled Echo sounder.[34]

## 8. POSSIBILITIES

Channel geometry can be predicted using neural networks that require grain size and discharge rate using data pre-processing and tuning of the hyperparameters of the architecture.

Determining bed load transport using machine learning approach [5] is another aspect, the bed load material (kg/s) is plotted against discharge (m3/s) for a particular location on the river. A curve can be plotted using support vector regressions which can then be used to predict the bed load transport rate at that point for any given discharge rate. This model will need to updated with newer data for better predictions.

## 9. AIDS TO NAVIGATION

In maritime, AIS is also used to provide information for emphasizing classical aids to navigation for the marking of buoys, wrecks, wind farms, etc. Special AIS Aids to Navigation Report message (AIS AtoN) transfers the position and the meaning of the aids to navigation as well as information if the buoy is on the required position or not (off position).

Using the AIS AtoN report message it can represent a real buoy lying in the water or it may represent a position where no real buoy is present. This doing so as if there would be a buoy is called a virtual AtoN. [35]

Navigable rivers should be monitored by installing sensor networks along waterways. These would make it possible to obtain real-time data on tides, currents, salinity, wind, etc., and to study the behaviour of these variables. Visual aids to navigation cannot yield further improvements to navigation efficiency, but it is necessary to ensure that all kind of visual AtoN mark the deepest areas of the channel.[36]

## 10. CHALLENGES

Ground reality of Inland water transport in India needs to be improved by developing a well-defined framework, that guarantees a sustainable growth.[1] Automating data collection methods is a primary step which can lead to development of a more accurate real time sediment predictions. [36]

Every year during the south-west monsoon the main stream and the tributaries of the Brahmaputra spill over their banks causing devastating floods in the Assam Plains associated with huge loss and damage to human lives, property, and infrastructure.[3] Transport of soil and sediment associated nutrients in the runoff and its deposition in various sinks is also a matter of concern.[2]

Providing AtoN devices to every vessel is also a challenge and must be administered for security purposes.

Another major challenge is the variable river channel geometry which has led to researchers looking into methods like remote sensing [32] to model the channel geometry. The primary channel of the Brahmaputra occasionally branches-off into smaller primary channels and a number of secondary channels during the low flow period.[33]

## 11. OPPORTUNITIES

Multi modal systems would make IWT cheaper and more environment friendly means of transport, especially for cargo movement. India has recently developed its fir multi modal terminal at Varanasi. [37]

Another opportunity lies in making our waters more navigable, this holds true for majority of Indian rivers.

## 12. WAY AHEAD

The way forward for India in terms of inland water transport will require understanding our resources by gathering data and performing mathematical modelling. Collins et al. (2017) [18] proposes a decision-tree representing the current state of knowledge in sediment source tracing.

Sediment levels prediction is a promising technique to make our water more navigable as dredging can be performed when sediments levels could rise above safe limits in near future.

Mapping of the River channel geometry on a Real time basis for Indian rivers would help in increasing the efficiency of the Inland water transport system. Creech et al. (2014) [38] and Fischer et al. (2017) [6] discuss HEC-RAS sediment transport model.

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