Proceedings of the 5th International Conference on Civil Engineering for Sustainable Development (ICCESD2020), 7~9 February 2020, KUET, Khulna, Bangladesh (ISBN-978-984-34-8764-3)

SALINITY MODELING OF KOBADAK- SIBSA RIVER SYSTEM BY HEC-RAS

Akramul Haque*[1] and K.M. Ahtesham Hossain[2]

[1]M.Sc Engineering Student, Dept. of Water Resources Engineering, Bangladesh University of Engineering and Technology, Dhaka-1000, Bangladesh, Email: akramul109183@gmail.com
[2]Assistant professor, Dept. of Water Resources Engineering, Bangladesh University of Engineering and Technology, Dhaka-1000, Bangladesh, Email: ahtesham@wre.buet.ac.bd

***Corresponding Author**

ABSTRACT

Salinity intrusion is a major problem and is found increasing day-by-day in the south-western parts of Bangladesh. Due to the commission of Farakka Barrage on the Ganges river in 1975 and siltation of the Gorai River mouth, flow has been drastically reduced in the downstream of South-West region. Salinity intrusion on the areas near the tidal rivers create severe problem in agriculture and drinking water source. This study focuses on 1-D salinity modeling of the Kobadak-Sibsa River by HEC-RAS. Work is carried out in simulation of salinity concentration in different location which helps to identify which location exceed water drinking limit 1000 ppm and agricultural water limit 1500 ppm . The hydrodynamic model is calibrated using the data of June,2016 . Then this model is validated using the data of July, 2015.Model simulated tidal range showed good agreement with the observed values for Manning's roughness coefficient as 0.021.Once the hydrodynamic model is calibrated and validated, the salinity model is performed and calibrated for the year 2016 for different dispersion coefficient (D) for different reaches as tuning parameter. It has been found that for Kobadak upstream D=25 m^2/s, downstream D=780 m^2/s, Paikgacha D=2000 m^2/s, Sibsa upstream D=300 m^2/s and downstream D=9000 m^2/s which showed good agreement between simulated and observed salinity data. It has been found that from the month of December salinity gradually increases and reaches it's peak in April or May. Maximum salinity concentration is found in different location such as in Jhikargacha 130 ppm, Tala Magura 325 ppm ,Godaipur 4600 ppm, Paikgacha 7600 ppm ,Bishnipur 8600 ppm,Sutarkhali 12200 ppm, Nalian 12450 ppm. Also, this study focuses on statistical analysis of salinity and water level over the year of 2000-2017.

Keywords: *Hydro-dynamic modelling , Salinity, Kobadak-Sibsa, Statistical analysis, HEC-RAS.*

1. INTRODUCTION

Bangladesh is riverine country and was formed by deltaic deposits of the Ganges-Brahmaputra-Meghna. Due to the commission of Farakka Barrage on the Ganges river in 1975 and carrying large amount of silt and human intervention such as construction of bridge, abstractions for agriculture, drainage return flows, structures for flood control causes the natural flow of Kobadak-Sibsa river has been drastically reduced and altered (Azbina,2014).In at last twenty years, flow volume in the dry-season (December – April) has been declining. So, surface salinity in downstream of Kobadak and Sibsa river begin to increase rapidly from December and reaches the peak in late March or early April. It has a serious environmental impact: specially along the coastal areas around the sanctuary forests where the salty water has increasingly been intruding(saran,2017). In the recent years, groundwater based water supply in coastal area is suffering from a number of major problems mainly arsenic contamination, lowering of the water table, salinity and non-availability of suitable aquifers(PDO-ICZMP, 2004).The Mathabhanga River is one of the most important distributaries of the Ganges River. The Kobadak River originates from the Mathabangha at Alamdanga, Chuadanga and falls into the Sibsa at Paikgacha, Khulna. The morphology of the Kobadak is governed by sedimentation process and the human induced influences.Over times, the river has lost its drainage capacity.Now overbank spillage is a common phenomenon during each peak monsoon. Consequently, the entire catchment becomes water logged during the monsoon (Mehzabin, S., 2015). The recent 262-crore Kobadak River dredging project will allow to lead a comfortable life along the banks of the river as there will be no water-logging in their areas and more fresh water will flow through Kobadak-Sibsa river.

SWR is composed of 15 sections, occupying 17 % of the suburban areas of Bangladesh. The land's 62 % is farmland, its 15 % is covered with mangrove forests (Sundarbans), and its 13% is water areas (Mehzabin, S.,2015). Sundri top dying disease will occur if salinity exceeds 15000 ppm, water becomes less useful as salinity increases to 1000 ppm(WHO,2011), irrigation water becomes undoubtful if salinity exceeds 1500 ppm (Ayers &Westcot, 1985).So in upstream of the river there requires a minimum flow which prevents excess salinity intrusion.The specific objective of this study are-

1. To setup hydrodynamic model of Kobadak-Sibsa river system using HEC-RAS and its calibration, validation and simulation.
2. To setup of water quality model and performing a water quality calibration and simulation of Kobadak-Sibsa river system using HEC-RAS.
3. Simulation of salinity concentration at different locations of study area using HEC-RAS.
4. Trend analysis of salinity and water level over the year of 2000-2017.

1.1 Study area

For the present study, Kobadak-Sibsa river is chosen due to it is the most important source of fresh water supply in the downstream in South West region and recently completion of Kobadak dredging project will allow the researchers to contribute to restore the environmental flow and prevent salinity intrusion.Figure 1-1(https://www.google.com/earth/) shows study area which was conducted on the 130km of Kobadak-Sibsa River stretching between the Jhikargacha river station in the upstream and the Sibsa River in the downstream named Nalianala Hadda river station.The average width of Kobadak river is 400 m including its floodplain. Kobadak River flows in the southern periphery and meets Sibsa near Jhikargacha and important source of Sibsa river. The average width of Sibsariver is 1250 km and is about 100 km long.The river forms much of the boundary between Paikgachha and Dacopeupazila. Inside the Sundarbans Reserve Forest, it meets the Passur River, then separates again near Mongla, before reaching the Bay of Bengal (Wikipedia).

`

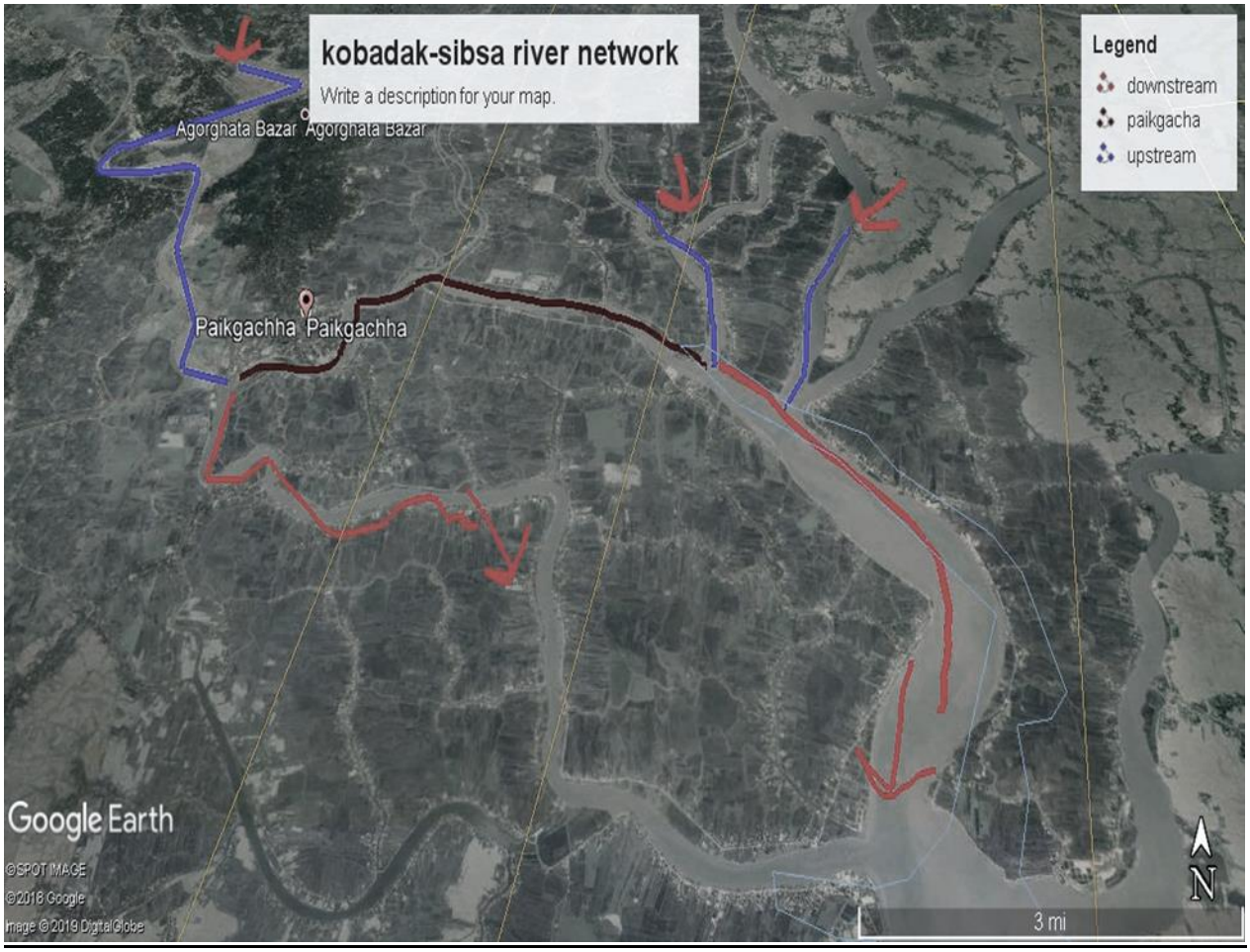

Figure 1-1: Kobadak-sibsa full network

2. METHODOLOGY

2.1 Data collection

For the development of hydrodynamic and salinity model of Kobadak-Sibsa River, data of bathymetry,discharge,stage hydrograph and salinity concentration at different stations have been collected from relevant sources which are shown in Table 1-1.30 cross section data (19 of Kobadak,6 of Passur river and other 5 are interpolated) of Rupsha-Passur river were collected.

Table 1-1: Data collection

Data type	Source	Data location	Period
Bathymetry	BWDB	Kobadak-Sibsa	2000-2017
Discharge	BWDB	Jhikargacha	2015,2016
Water level	BWDB	SW-162-164,258-259	2000-2017
Salinity	BWDB	SW-162,258,259	2000-2017

2.2 Model setup

Two steps are involved in HEC-RAS modelling:

- Hydrodynamic modelling
- Water quality analysis

`

In hydro-dynamic model setup, flow hydrograph of Jhikargacha SW-162 and stage hydrographSW-258, 242 for another upstream branch have been inserted as upstream boundary condition. For downstream branch, two stage hydrograph SW-259,164 have been inserted as downstream boundary condition. Data for January 2016 to December 2016 are used. SW-29 stage hydrograph is used for calibration and validation for the month of June, 2016 and July, 2015 respectively.

In water quality analysis, arbitrary constituent was selected as Water Quality constituents. Tracer was mentioned as conservative. Minimum cell Length was given 200. Salinity concentration data for upstream branch and downstream branch river have been inserted as boundary condition. No branch is neglected asupstream flow is very important for salinity analysis. Paikgacha station is used for calibration of salinity graph for January 2016 to December 2016.

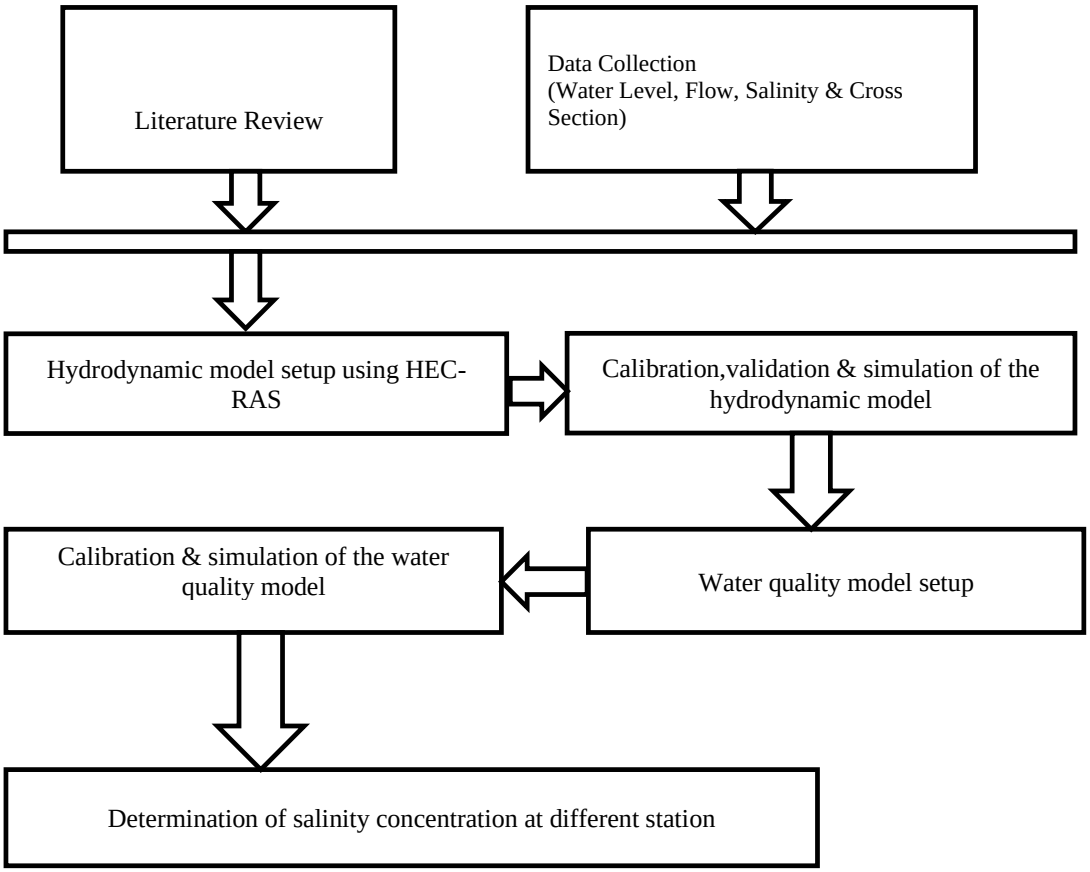

Figure 2-1: Diagram of methodology

3. DATA ANALYSIS AND RESULTS

3.1 Calibration and Validation of Hydrodynamic and Salinity Model

The hydrodynamic model is calibrated using the data of June,2016 (Figure 3-1). Then this model is validated using the data of July, 2015(Figure 3-2).Model simulated tidal range showed good agreement with the observed values for Manning's roughness coefficient as 0.021.Once the hydrodynamic model is calibrated and validated, the salinity model is performed and calibrated for the year 2016 for different dispersion,the coefficient (D) for different reaches as tuning parameter. It has been found that for Kobadak upstream dispersion co-efficient D=25 m^2/s,Kobadak river downstream D=780 m^2/s, Paikgacha D=2000 m^2/s, Sibsa upstream D=300 m^2/s and downstream D=9000 m^2/s which are shown in Table 3-1.

`

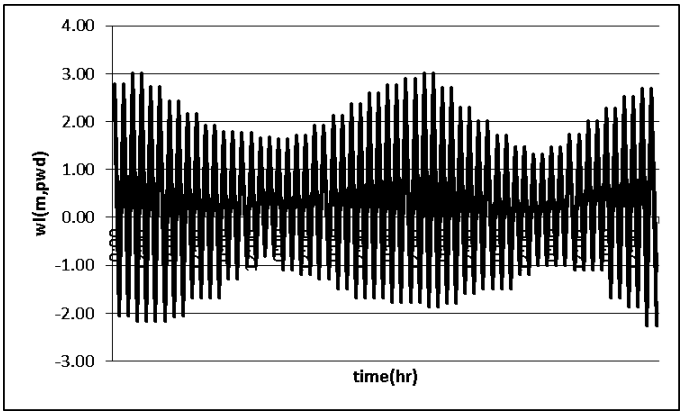

Figure 3-1: Calibration graph for n=0.021 (June 2016, SW-29, Sutarkhali Forest Office)

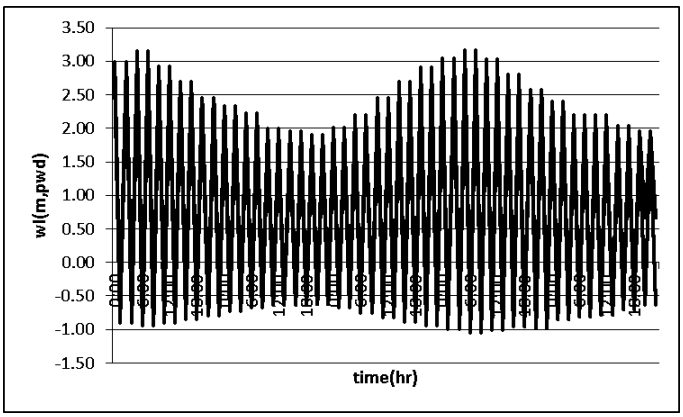

Fig 3-2: Validation stage hydrograph for n=0.021 (July,2015, Sutarkhali Forest Office)

The salinity concentration value of the River is determined by Water Quality Analysis through HEC-RAS. The salinity concentration differs with the advection dispersion coefficient used in the model. For the reach Paikgacha (station no:39), the salinity concentration value determined from model is compared to the original salinity concentration value of the Paikgacha SW-258.

Salinity concentration is given and computed in mg/L. Unit of the dispersion coefficient is in m^2/s. Calibration is done for January 2016 to December 2016 which is shown in Figure 3-3. The maximum possible value of dispersion coefficient is determined through analysis.

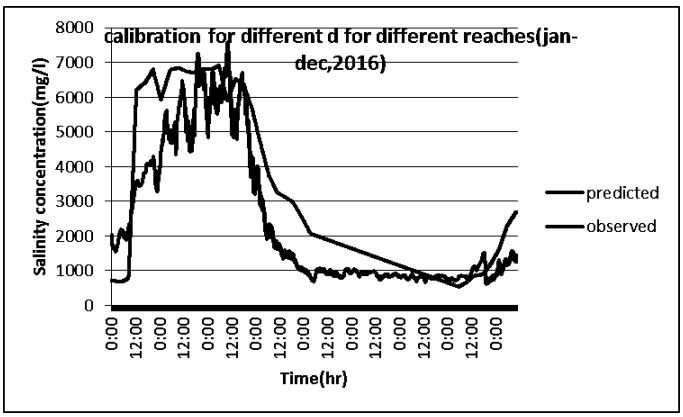

Figure 3-3: Salinity concentration graph for different d at SW-258(paikgacha)

`

Table 3-1: Fixed dispersion at different reaches

River	Reach	RS	Fixed dispersion(m^2/s)
Kobadak-Sibsa	Paikgacha	40	2000
Kobadak	Upstream	60	25
Kobadak	Downstream	30	780
Sibsa	Upstream	52.5	300
Sibsa	Intermediate	39	548
Sibsa	Upstream	70	105
Sibsa	Downstream	5	9000

Table 3-1 provides the dispersion co-efficient used for different reaches.So when considering main channel with branches it will be better to use different co-efficient value for different reach because dispersion co-efficient depends on velocity,top width,frictional slope,shear velocity,depth of the channel.

3.2 simulation of salinity concentration at different locations

It has been found that from the month of December salinity gradually increases and reaches its peak in April or May.Maximum salinity concentration is found in different location such as in Jhikargacha 130 ppm,TalaMagura 325 ppm,Godaipur 4600 ppm, Paikgacha 7600 ppm ,Bishnipur 8600 ppm,Sutarkhali 12200 ppm, Nalian 12450 ppm.

Figure 3-4 is for Agorghata where salinity concentration does not measure.It indicates that the maximum salinity is 1700 mg/l which occurs in the month of mid- April.As this location locates far upstream of Paikgacha the salinity concentration is in satisfactory range for agricultural and water drinking use.

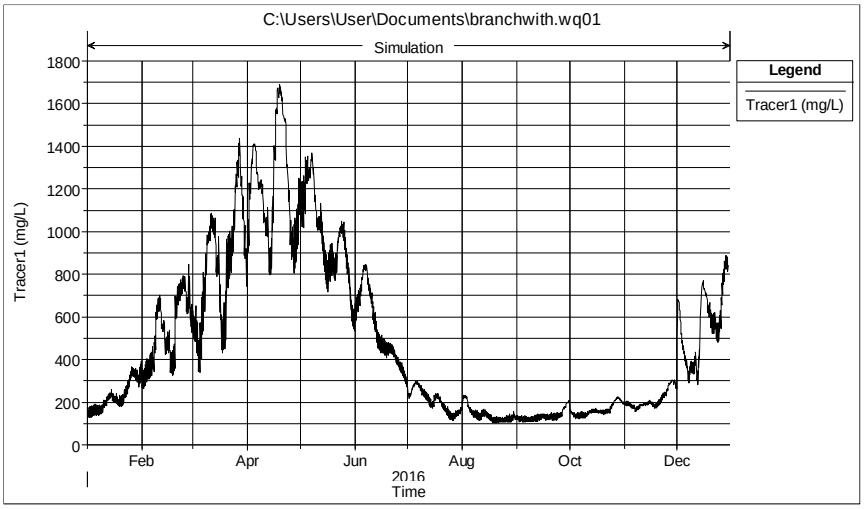

Figure 3-4: Salinity graph at Agorghata

At Godaipur, in figure 3-5, It indicates that the maximum salinity is 4600 mg/l which occurs in the month of mid-April. As this location locates near upstream of Paikgachaand low flow from upstream, the salinity concentration is not in good range for agricultural and water drinking use. The fluctuation of concentration is also very high.

`

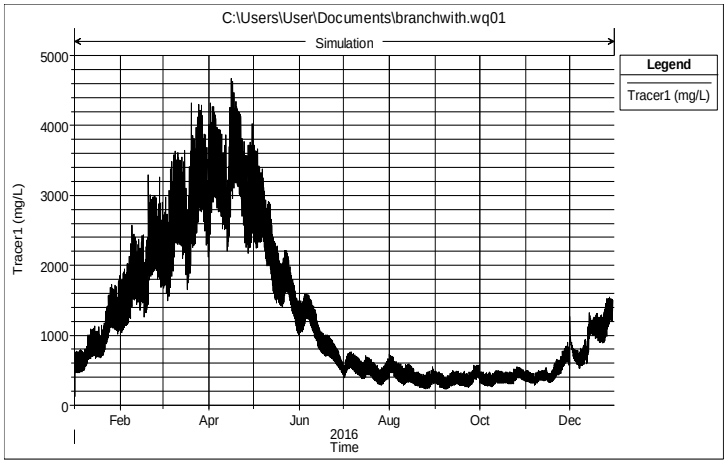

Figure 3-5 : Salinity graph at Godaipur

The figure 3-6 is for Paikgacha. It shows that the maximum salinity is 7600 mg/l which occurs in the month of mid -April.As this location locates near the tidal river name Sibsa the salinity concentration is very high .

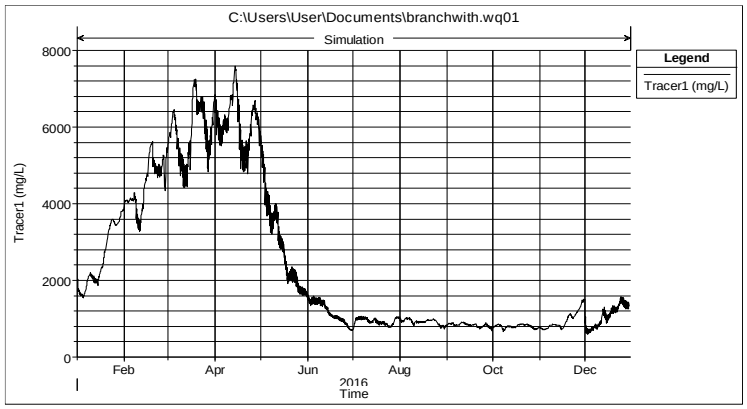

Figure 3-6 : Salinity graph at Paikgacha

The figure 3-7 and 3-8 is for Bishnipur and Sutarkhali respectively. That shows that the maximum salinity is 8600 mg/l and 12400 mg/l which occurs in the month of March.As those location locate in the tidal river the salinity concentration is usually very high.

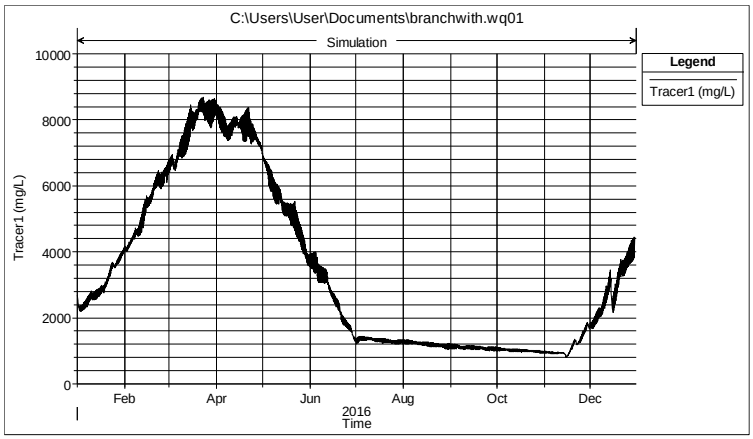

Figure 3-7 :Salinity graph at Bishnipur

`

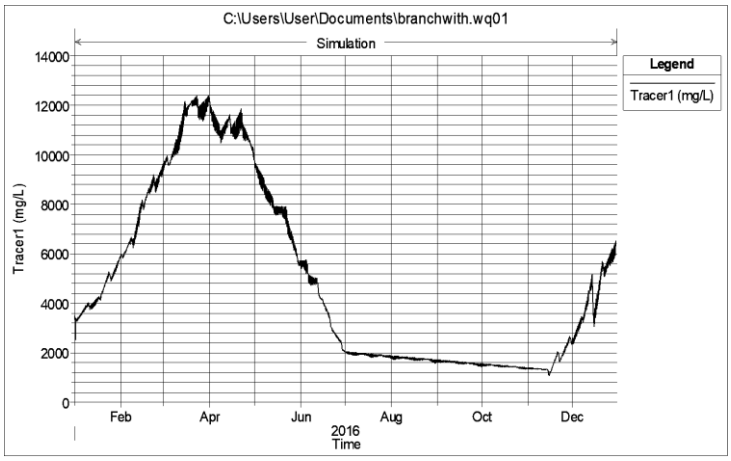

Figure 3-8 : Salinity graph at Sutarkhali

3.3 Statistical analysis

Salinity: graphs showing the variation of salinity and water level over the last 18 years:

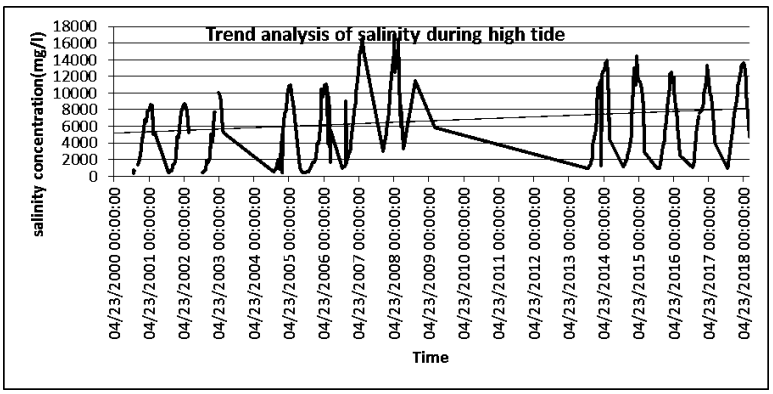

Figure 3-9 : Salinity variation during high tide at Nailina Hadda(SW-259)

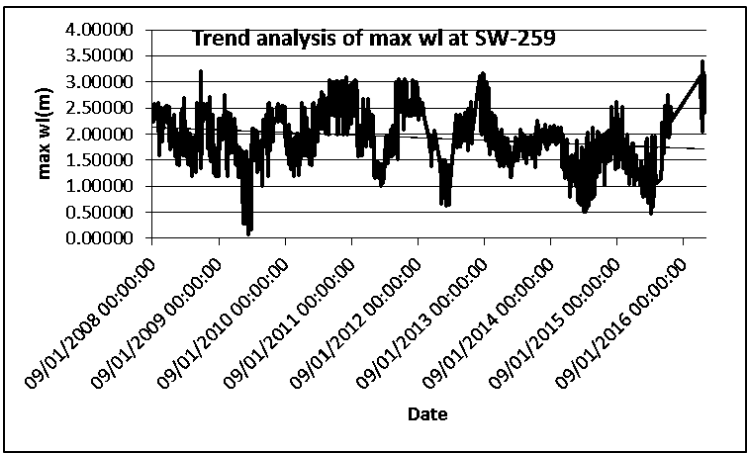

Figure 3-10: Max wl (m) variation over the year at Nailina Hadda (SW-259)

From above, we can say that there is relationship between water level and salinity. With decreasing water level salinity increases and vice-versa.

`

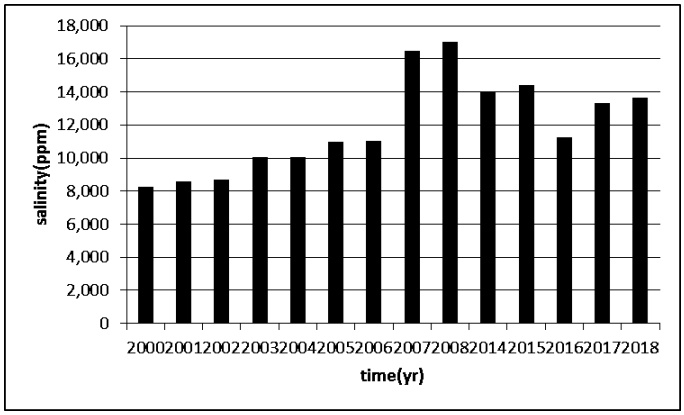

Figure 3-11:Maximum yearly salinity variation at Nailina_hadda(SW-259)

From above bar chart (Figure 3-11), we conclude that with the time salinity is increasing.But we see that in 2007 and 2008 the salinity is so high compare to other year.This is because 2007 tropical cyclone SIDR.

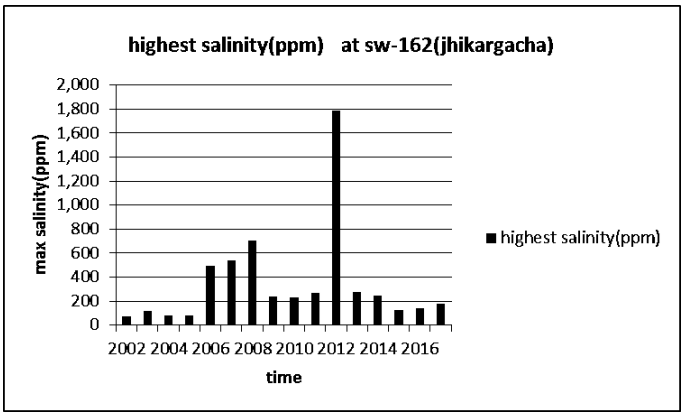

Figure 3-12:Maximum yearly salinity variation over at Jhikargacha (SW-258)

At Jhikargacha though salinity increases in 2007 at the time of SIDR but in 2012 the salinity concentration is higher than any other year because of low upstream flow in that year which is shown in Figure 3-12.

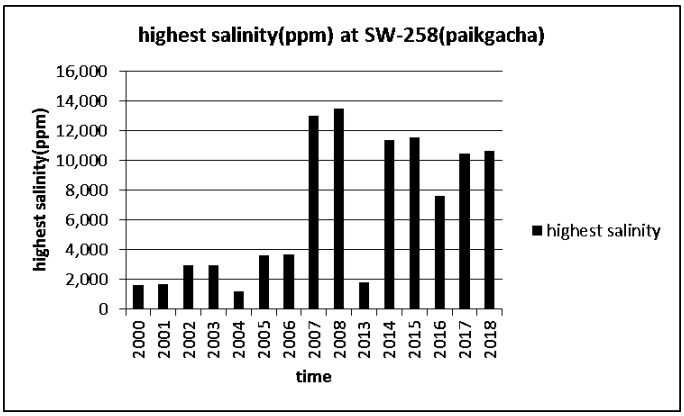

Figure 3-13: Yearly maximum salinity variation at Paikgacha(SW-258) from the year 2000 to 2016

At Paikgacha, in figure 3-13, the highest salinity occur at the time 2007-2008 because of SIDR.But we see that after 2013 the salinity was drastically increased compare to 2000-2006.

`

4.CONCLUSIONS

In this study, an attempt was made to analyze salanity concentration at different location and statistical analysis of variables:

- The hydrodynamic model is calibrated using the data of June , 2016 . Regression analysis is carried out and co-relation (R^2) is found 0.956. Then this model is validated using the data of July, 2015.Model simulated tidal range showed good agreement with the observed values for Manning's roughness coefficient as 0.021 and R^2 is found 0.9652 .Once the hydrodynamic model is calibrated and validated, the salinity model is performed and calibrated for the year 2016 for different dispersion coefficient (D) for different reaches as tuning parameter. It has been found that for Kobadak upstream D=25 m^2/s, downstream D=780 m^2/s, Paikgacha D=2000 m^2/s, Sibsa upstream D=300 m^2/s and downstream D=9000 m^2/s which showed good agreement between simulated and observed salinity data and R^2 is found 0.856 .

- Usually the maximum salinity occurs in April and May, at the end of dry season, During December to May.Water is neither usable as a source of drinking water nor for irrigation nearly paikgacha and it's downstream as salinity concentration exceeds water drinking limit 1000 ppm and agricultural water limit 1500 ppm (WHO,2011).The salinity intrusion zone has increased and is more than any previous years. Salinity in Jhikargacha, Hazirbaagh, Ujjalpur, Bankra, Deara, Digdana, Mathshia, Chakla, Nowali remain in safe limit throughout the year.But it has been found that found that maximum salinity in Agorghata is 1600 ppm, in Godaipur is 4000ppm,in Paikgacha is 6500ppm and downstream of Paikgacha such as in Bishnipur is 8000ppm,in Sutarkhali is 12000ppm,in Nalian is 12500ppm for the year of 2016.
- From statistical analysis it is seen that salinity is increasing with decreasing water level.The maximum salinity occur in Paikgacha and Naliana are 12500 ppm and 16500 ppm in 2007-2008 due to SIDR.

REFERENCES

BWDB. (2011). Rivers of Bangladesh. Bangladesh Water Development Board,Ministry of Water Resources.

Boa,E.R, & Rahman,M.A. (2015). Sundri top dying symptoms and cause. Bangladesh Forest Research Institute.

Google Earth Engine. (n.d.). Retrieved April 20, 2019, from https://www.google.com/earth/

Jahid, S. (2016). Assessing environmental flow for the Kobadak River and developing a framework for its maintenance. M.Sc. Thesis,Institute of Water and Flood Mangement, Bangladesh University Engineering and Technology,Dhaka,Bangladesh.

Mehzabin, S. (2015). Trend Analysis of variables and Modeling of Flow and Salinity of the Gorai River using HEC-RAS model. B.Sc Thesis,Department of Water Resources Engineering,Bangldesh University Of Engineering and Technology,Dhaka,Bangladesh.

Pal1, A., Hossain1, M. Z., Hasan2, M. A., Molla1, S. R., & Asif3*, A. A. (2016). Disaster(SIDR) causes salinity intrusion in the south-western parts of Bangladesh. Asian-Australasian Journal of Bioscience and Biotechnology, 301-302.

PDO-ICZMP. (2004). Areas with special status in Coastal Zone. warpo.portal.gov.bd.

Rahman, M. A., & Dipa, S. J. (2016). A study on river system, hydrology and surface water salinity of sundarbans rivers. Proceedings of 3rd International Conference on Advances in Civil Engineering, 21-23 December 2016, CUET, Chittagong, Bangladesh , (pp. 824-825).

Rahman, M. Z. (2015). Modeling of the Surface Water Salinity in the Southwest Region of Bangladesh. M.Sc Thesis,Department Of Water Resources Engineering, Bangladesh University Engineering and Technology,Dhaka,Bangladesh.

saran, S. H. (2017). Modeling of Flow and salinity characteristics of the rupsha-passur river system. B.Sc Thesis,Department Of Water Resources Engineering, Bangladesh University Engineering and Technology,Dhaka,Bangladesh.

`

Westcot, & Ayers. (1985). Guidelines for interpretation of mater quality for irrigation. The Food and Agriculture Organization of the United Nations.

WHO. (2011). Guidelines for Drinking-water Quality. Retrieved February 2019, from https://apublica.org/wp-content/uploads/2014/03/Guidelines-OMS-2011.pdf

Wikipedia. (n.d.). Retrieved 2019, from https://en.wikipedia.org/wiki/Shibsa_River

`