

**MODELLING OF SEDIMENT TRANSPORT AND  
POLLUTANT DYNAMICS OF RIVER GANGA AT  
VARANASI**



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for the Award of Degree**

***Doctor of Philosophy***

**by**

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## **CHAPTER 8**

### **SUMMARY AND CONCLUSION**

#### **8.1 SUMMARY**

Rivers are the major source of drinking water and lifeline for humans. Major cities like; Delhi, Varanasi, Kanpur, Patna, etc., developed at the bank or rivers due to the dependency of human activities on the rivers. A river like Ganga is not the only source of drinking water or water for irrigation purpose; it is also important for social, cultural and religious purposes. To fulfill all these needs, the water of the river should be available in good condition in terms of qualitatively and quantitatively. Due to natural causes and sometimes due to human activities flow of river gets affected. The sedimentation process is a natural process that occurs in the river, and river flow gets affected by this very significantly. Also, the pollutant discharged by human activities affects the quality of river water.

#### **8.2 CONCLUSION**

The following major conclusions are drawn from the study and modelling done on the sediment and pollutant transport near Varanasi.

1. The output of model done by ArcSWAT have shown that the precipitation of the watershed was high (1444 mm) in year 2016 and runoff in this year was high. Due to increase in the urbanization near Varanasi from 2010 to 2016. The urbanization increases the impervious strata which increase the runoff.
2. The sediment yield data obtained from the SWAT analysis have shown that agricultural land is greater prone to the erosion. While land covered by the vegetation is relatively lesser prone to the erosion.

3. Sediment yield found in year 2016 was greater as compared to the other years due to the higher runoff on that year. It shows that the sediment yield is proportional to the runoff.
4. Rainfall data shows that maximum rainfall in the region of the Varanasi receives in month of July to September. Results have shown that the short interval precipitation creates more surface runoff. Results have also shown that urban area of sub-watershed also creates high surface runoff.
5. The help of SUFI-2 did calibration and validation of SWAT modeling. The performance is measured with the help of coefficient of determination, percent prediction uncertainty (95PPU) and Nash–Sutcliffe efficiency. It shows that modeling by SWAT; perform well for sediment yield prediction of basin.
6. A study on sediment analysis from the year 2012 to 2017 has shown that from the upstream side i.e from Aghoreshwar Ghat to the downstream side i.e. near the Raj Ghat, the cross-section depth of the bed of river increases. It shows that the due to erosion in downstream side depth of the river has increased
7. Raj ghat cross-section was found to be the most critical than other cross-section selected. Raj ghat cross-section shows that depression in the bed of the river is increasing with time due to continuous erosion. In recent years double depression is observed at this cross-section due to the erosion process.
8. Bed cross-section analyses have also confirmed that river bank having concave side shows erosion and convex side of river shows sedimentation. Slope in concave side found steeper due to erosion, while slope in convex side shows relatively mild slope.

9. Significant variation of the bed depth was found mainly in some part of the cross-section. In other part of cross-section, no significant variation was found. It happens because water flows throughout the year only in that part of cross-section.
10. The results obtained from the analysis of sediment concentration shows that peak in the concentration occurs during the month of August and September. In the month of August and September peak flow condition in river occurs. Due to the peak flow in river high erosion process get accelerated; due to this sediment concentration get increased.
11. Output from the HEC-RAS found to be satisfactory when compared with the result obtained from the direct measurement at river. So, the modeling technique used for sediment transport dynamic can be utilized satisfactorily for different related purposes.
12. Overall, the river bed cross-section obtained from outcome of the HEC-RAS shows the continuous erosion process. Because of this depression in overall cross-section of river is taking place with time.
13. The variation of the sediment concentration for all the cross-sections considered for the study is of similar nature. Not much difference in the magnitude of the sediment concentration was observed. This shows that in longitudinal direction for a short stretch significant change in the sediment concentration doesn't takes place.
14. The results obtained from the modeling of the pollutant transport dynamics shows that the side of point of discharge affects the diffusion process. The pollutants from Assi Nallah remain in the side of concave. Due the centrifugal force on the pollutant flow of pollutant remains in the concave side of the river.

15. CFD Modeling of the pollutant transport by the help of ANSYS show satisfactory result, when compared with the result of laboratory test. It confirms that the modeling process adopted for pollutant transport dynamics is suitable for the modeling.
16. Due to the higher velocity, accumulation of pollutant near the meeting point of Assi Nallah doesn't take place. While at some distance, velocity becomes less and accumulation of pollutant increases, due to this concentration of the pollutant increases. But at considerable distance due to dilution concentration of the pollutant decreases.

### **8.3 SCOPE FOR FURTHER RESEARCH**

The scope of further study is suggested as follows:

- The impact of major construction like; Dams, hydropower projects, etc. on the sediment transport behaviour and flow characteristics of the river like Ganga can be considered.
- The impact of the structures like bridges or activities like sand mining on the local scouring and its effect on the sediment transport behaviour can be considered for further study.
- The impact of the sediment characteristics of the river on pollutant transport modelling can be further investigated.
- The development of different tools and techniques for the proper and continuous monitoring of the sediment transport behaviour of the river can be investigated.

- This study's impact of single inlet point of pollutant for the study of pollutant transport dynamic in the river is considered. In further investigation, the effect of the multiple source point on the pollutant transport dynamic can be considered.