CHAPTER 3

STUDY AREA AND DATA USED

3.1 INTRODUCTION

In this research work, modelling of the sediment yield of the basin, sediment transport behaviour and pollutant transport dynamic of river Ganga near Varanasi is carried out. The overview of the study area and the methodology used is presented in the following sections.

3.2 STUDY AREA

There are twenty-two river basins in India, including small and large size, as per the Central Water Commission of India. Ganga river basin is the largest river basin in India. The holy river Ganga originates from the Gangotri glacier (travel 2,525 km) and crosses five states of India during their flow path Uttarakhand, Uttar Pradesh, Bihar, Jharkhand, and West Bengal. Major tributaries of river Ganga are Yamuna, Betwa, Chambal, Banas, Ramganga, Mahananda, Ghaghara, Son, Gandak Damodar, Kali Sindh, Dhasan , Parbati, Sind, Keri, Gomti and Sarda. Uttarakhand and Uttar Pradesh cover the highest Ganga basin drainage area of 294,364 km^2. Degradation of river basin due to soil erosion and these eroded soil transported by the river downstream of the river until the ocean's meeting. Developing an intelligent river management study on sediment yield from basin and river sediment transport is very important. Also, for proper management of the quality of water, understanding of pollutant transport dynamic is essential.

River Ganga carried lots of sediment from the upper part of the Himalayas and deposited it in the plain; this continuous process established the more significant Indo Gangetic plain.

The study area considered in this investigation lies between the co-ordinate 250 12’ 0” N to 250 26’ 00” N and 820 55’ 0” E to 830 12’ 0” E. It is near the Varanasi district of Uttar Pradesh. Varanasi is situated on the higher ground between the watercourses Assi river and

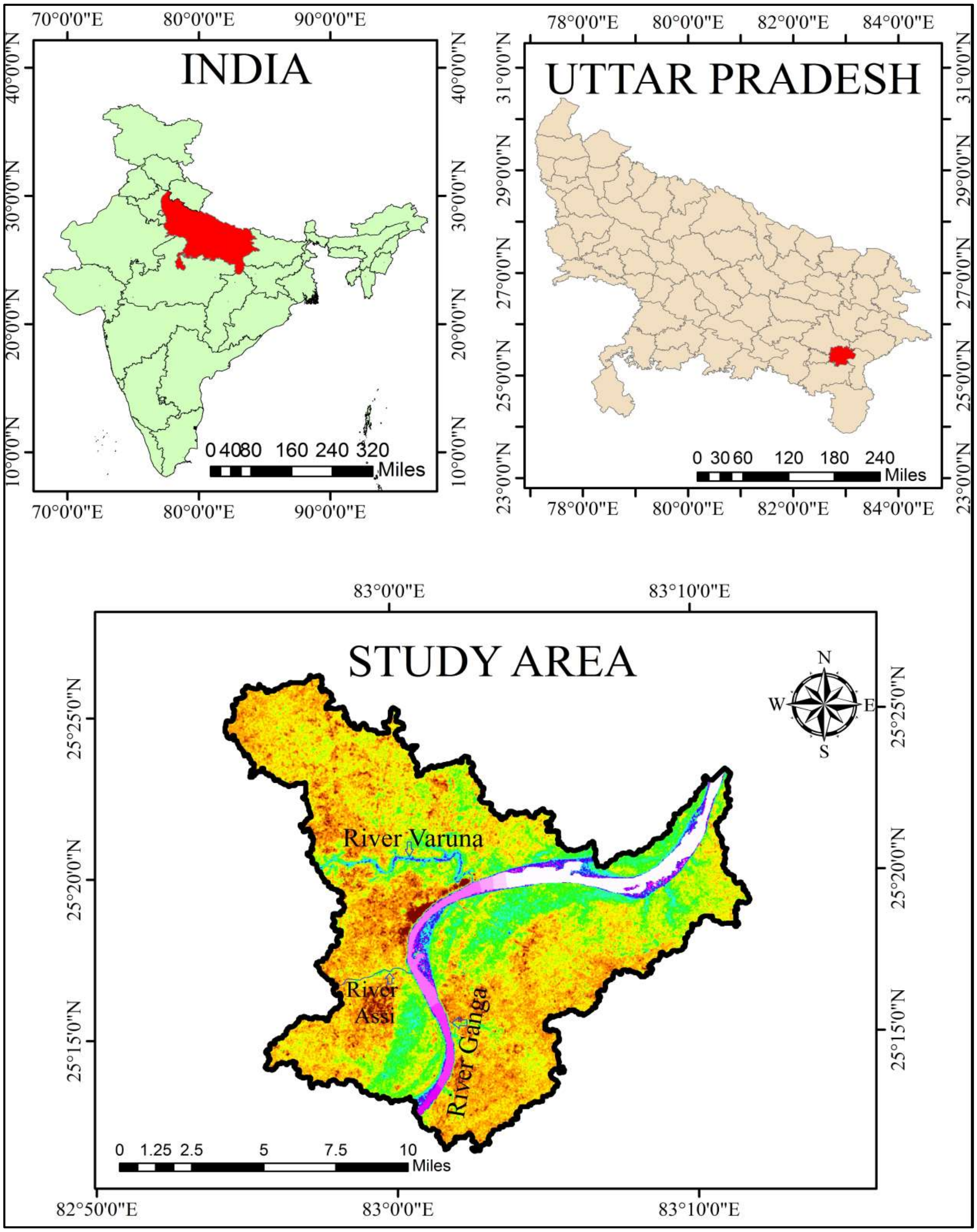


Figure 3.1 Study area

Varuna river, as shown in Figure 3.1. The study area covers 366 square kilometres with 35 kilometres flow length of river Ganga. The mean elevation of the study area is 80.71 m, and the lowest elevation is 58 m near the river Ganga. The study area is located near the tropic of cancer and receives the highest rainfall in July, where the lowest rainfall was received in November. The temperature was also very high during summer (April to May) and the lowest temperature during winter (December to January). The detailed monthly variation of temperature and rainfall from January 2011 to December 2020 is given in Table 3.1. Varanasi city is located at higher ground level but not protected from the flood. The city faced severe flooding in 1978, 2013 and 2016. The highest danger level for Varanasi is 71.26 m, fixed by the Central Water Commission (CWC), but the flood level reaches up to 73.90 m in 1978, which is 2.64 m above the danger level. Again after 35 years, flood reaches 1.36 m and 1.29 m above the danger line in 2013 and 2016, respectively. The frequency of flood become more prominent in recent years. According to the objective of the investigation specific area and stretch of the river is selected.

Table 3.1 Details of monthly average rainfall and temperature of the study area

Sl. No.	**Month (2011 to 2020)**	**Rainfall (*mm*)**	**Max Temp. (^0C)**	**Min. Temp. (^0C)**
1	January	16.09	20.80	9.30
2	February	14.35	26.60	12.26
3	March	13.12	33.95	17.23
4	April	13.72	40.02	22.36
5	May	10.40	41.03	26.09
6	June	102.08	39.68	28.23
7	July	278.04	34.67	26.98
8	August	233.29	33.90	26.54
9	September	166.49	34.14	25.62
10	October	32.21	33.09	21.24
11	November	0.89	29.92	15.31
12	December	4.46	24.03	10.32

3.2.1 STUDY AREA FOR SEDIMENT MODELING

The selected study area covers the Varanasi watershed, and it is part of eastern Uttar Pradesh. The watershed is formed by the sentiment brought by the river Ganga. This Varanasi watershed has three major rivers, Ganga, Varuna and Assi. The river Ganga is one of the largest rivers of this watershed, which flows approximately 35 kilometres. The total area of the Varanasi watershed is 366 square kilometres. Figure 3.2, as given below, describes the study area for sediment yield modelling.

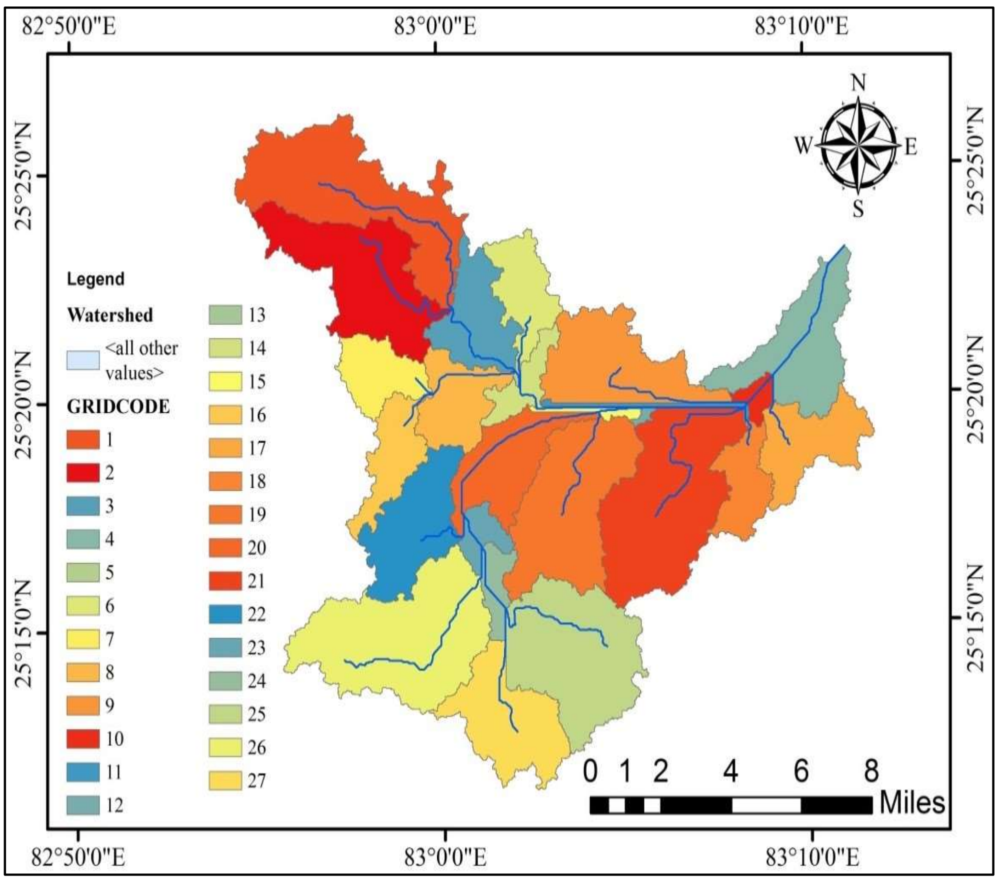


Figure 3.2 Study area for watershed sediment modelling

A total of twenty-seven subwatershed has been considered for the study of sediment yield modelling. The detailed description of this sub-watershed is mentioned in .

Table 3.2 Details of Sub Watershed

Sub - Watershed no.	**Co-ordinate (*Decimal*)**	**Area (m^2)**	**Manning's n**	**Sub-Watershed no.**	**Co-ordinate (*Decimal*)**	**Area (m^2)**	**Manning's n**
1	25.40727 82.962551	3268.14	0.041	15	25.32739 83.072202	129.76	0.034
2	25.378356 82.964635	2595.83	0.037	16	25.311976 82.977836	941.58	0.031
3	25.362404 83.017038	1260.08	0.038	17	25.314972 83.167583	1304.18	0.032
4	25.349619 83.164274	1923.68	0.029	18	25.299968 83.137438	830.99	0.029
5	25.341289 83.035242	21.73	0.031	19	25.293583 83.058932	2751.08	0.030
6	25.371922 83.038648	986.09	0.035	20	25.308891 83.029774	1473.42	0.035
7	25.342604 82.972517	889.48	0.029	21	25.294428 83.102426	3427.71	0.037
8	25.332036 83.007555	1105.94	0.027	22	25.286717 82.987317	1668.54	0.041
9	25.344161 83.079555	2009.17	0.036	23	25.283025 83.018521	373.70	0.040
10	25.331473 83.143919	212.94	0.025	24	25.264203 83.024522	399.51	0.042
11	25.329623 83.093631	147.10	0.025	25	25.239085 83.059418	2964.74	0.021
12	25.328624 83.099292	54.01	0.027	26	25.246505 82.981428	3588.79	0.034
13	25.328978 83.092279	30.36	0.031	27	25.215648 83.029143	1802.54	0.035
14	25.338065 83.038795	526.24	0.034				

3.2.2 STUDY AREA FOR IDENTIFICATION OF SEDIMENT TRANSPORT

In this study, a stretch of about 10 km in length near Varanasi was selected for the sediment transport behaviour. The stretch selected was started near Samane Ghat Bridge (25°09’24.8” N 82°31’32.0” E) in the upstream side to Raj Ghat (25°20'02.5"N 83°03'35.5"E) on the downstream side of the river. Differential Global Positioning System (DGPS) and ADCP were used to collect data related to this stretch. Fifteen Cross-sections were selected in this stretch to monitor the suspended sediment concentration (SSC). The help of DGPS measured the elevation and position of the cross-sections. At the same time, the use of ADCP measured river cross-section profile, discharge, velocity and suspended sediments. Figure 3.3 shows the different cross-section of the stretch selected for the study.

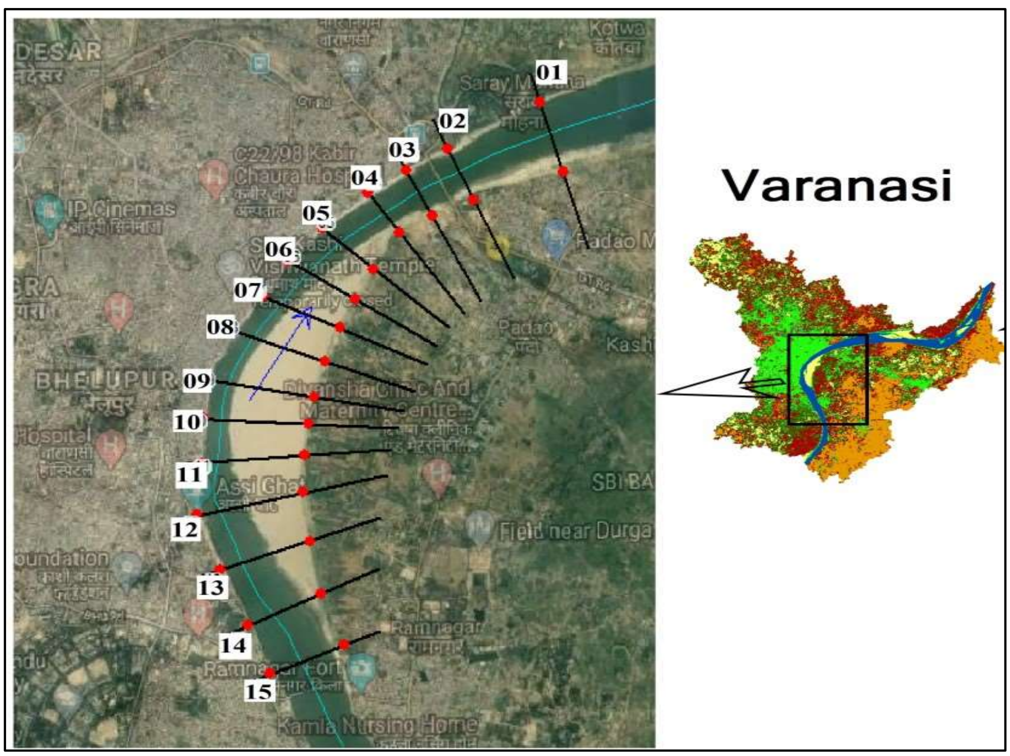


Figure 3.3 The plan view of the study area with 15 cross-sections

The coordinates of the fifteen cross-sections selected are presented in Table 3.3. The name of the chosen cross-sections is presented in Table 3.4. These names were based upon the locality and the name of Ghat of Varanasi. The distance between two cross-sections is s hown in Table 3.5.

Table 3.3 location of each cross-section with coordinates

Cross-section No. (*U/S to D/S*)	**N-Reading (*Concave Bank*)**	**E-Reading (*Concave Bank*)**	**N-Reading (*Convex Bank)***	**E-Reading (*Convex Bank*)**
CS 15	25° 16' 22"	83° 00' 54"	25° 16' 33"	83° 0'1 19"
CS 14	25° 16' 42"	83° 00' 44"	25° 16' 48"	83° 01' 10"
CS 13	25° 17' 1"	83° 00' 34"	25° 17' 3"	83° 0' 56"
CS 12	25° 17' 19"	83° 00' 25"	25° 17' 22"	83° 00' 40"
CS 11	25° 17' 38"	83° 00' 25"	25° 17' 36"	83° 0' 46"
CS 10	25° 17' 54"	83° 00' 26"	25° 17' 50"	83° 0' 45"
CS 09	25° 18' 10"	83° 00' 29"	25° 18' 6"	83° 0' 45"
CS 08	25° 18' 25"	83° 00' 38"	25° 18' 20"	83° 0' 51"
CS 07	25° 18' 38"	83° 00' 50"	25° 18' 32"	83° 01' 3"
CS 06	25° 18' 52"	83° 01' 1"	25° 18' 43"	83° 01' 16"
CS 05	25° 19' 4"	83° 0'1 17"	25° 18' 53"	83° 01' 30"
CS 04	25° 19' 15"	83° 01' 33"	25° 19' 1"	83° 01' 46"
CS 03	25° 19' 25"	83° 0'1 51"	25° 19' 9"	83° 02' 3"
CS 02	25° 19' 32"	83° 02' 11"	25° 19' 17"	83° 02' 18"
CS 01	25°19'46.9"	83°02'43.3"	25°19'26.0"	83°02'52.6"

Table 3.4 Location name near the cross-Sections

Cross-section No.(*U/S to D/S*)	**Location Name Near The Cross-Sections**
CS 15	Near Samne Ghat Bridge
CS 14	Near Ravidas Ghat

CS 13	Ravidas Ghat
CS 12	AssiGhat
CS 11	Shrinishad Raj Ghat
CS 10	HarishchandraGhat
CS 09	MansarowarGhat
CS 08	DashaswamedhGhat
CS 07	ManikarnikaGhat
CS 06	Ramghat and JatarGhat
CS 05	HanumangarhiGhat
CS 04	TeliyanaGhat
CS 03	Guru Ravidas Temple
CS 02	Near Rajghat
CS 01	Near river Varuna

Table 3.5 Details of the distance between the cross-sections

Cross-sections	**Distance B/W two Sections (*m*)**	**Cross-sections**	**Distance B/W two Sections (*m*)**
CS 15-CS 14	612.8	CS8-CS7	496.9
CS14-CS13	685.5	CS7-CS6	471.6
CS13-CS12	640.7	CS6-CS5	491.9
CS12-CS11	557	CS5-CS4	601.8
CS11-CS10	475.2	CS4-CS3	462.6
CS10-CS9	418.5	CS3-CS2	524
CS9-CS8	576.6	CS2-CS1	1120.5

3.2.3 STUDY AREA FOR SEDIMENT TRANSPORT MODELING

For modelling the sediment transport of river Ganga near Varanasi, a stretch of about 35 km was selected. The selection of stretch under consideration was based upon the existence of a gauge station for the collection of the hydraulic parameter by the Central

Water Commission, Government of India. The selected stretch starts from Mirzapur to near Raj Ghat, Varanasi. Mirzapur is situated on the upstream side of the Varanasi. Both places are in the eastern part of Uttar Pradesh, India. The stretch selected lies in the middle reach part of the river Ganga. Fifteen cross-sections were considered for the determination of sediment load and cross-section. Figure 3.4 shows the study area and selected fifteen cross-sections. Cross-section 15 (CS15) is the first cross-section in upstream side and cross-section 1 (CS1) is last cross-section in downstream side. The cross-section details all the fifteen sections selected and tabulated in Table 3.3 to Table 3.5 in the preceding sub section.

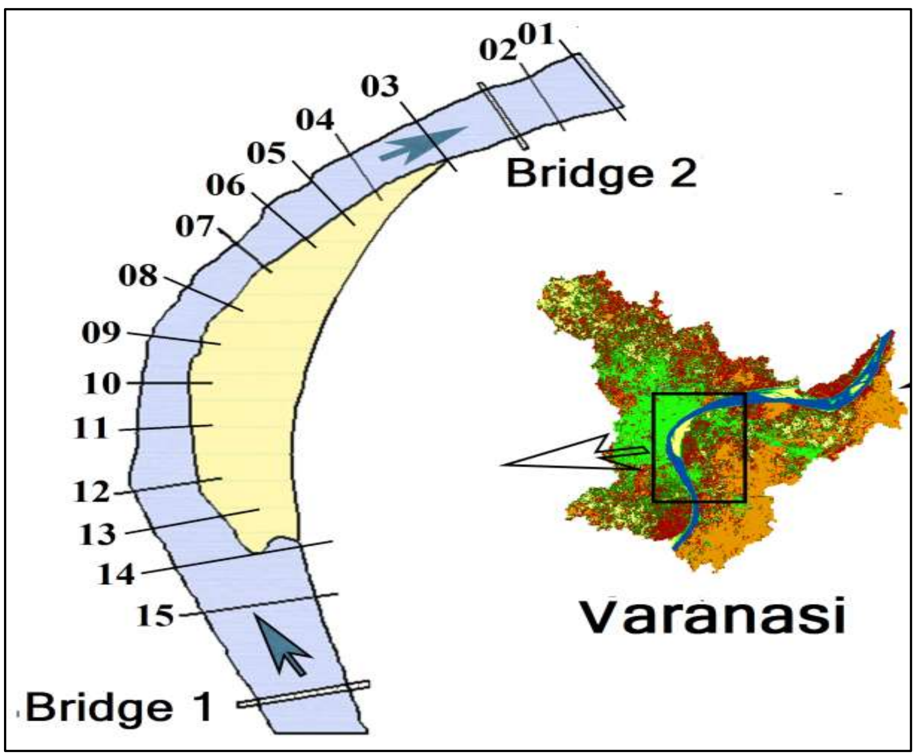
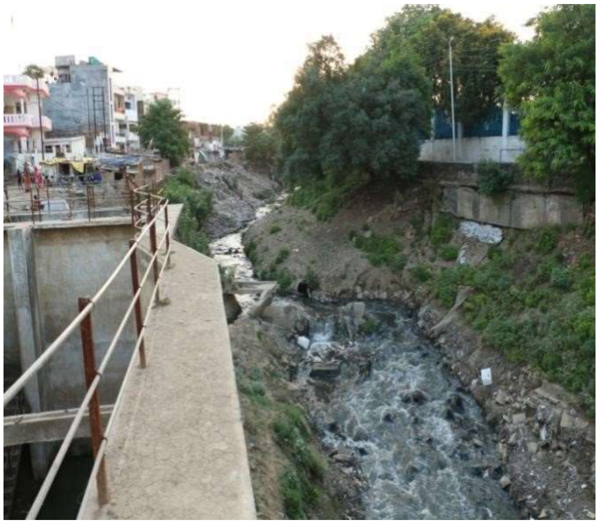


Figure 3.4 Study area considered sediment transport modelling

3.2.4 STUDY AREA FOR CFD MODELING OF POLLUTANT FLOW DYNAMICS

For modelling of the pollutant dynamics, a 10 km stretch near Varanasi was considered for the investigation. The waste water which is coming from 'Assi Nallah' is near to the Varanasi. Assi Nallah meeting to the river Ganga at coordinate 25°16'58.8"N 83°00'35.1"E. Figure 3.5 shows the satellite view of the stretch of river Ganga considered in this study. Also, the point where Assi Nallah meets the river Ganga is indicated. The photographic picture of the Assi Nallah is shown in Figure 3.5. Figure 3.6 (a), Assi Nallah flowing near to river Ganga is shown, while Figure 3.6 (b) shows the photographic view of the meeting of Nallah with the river.

Figure 3.5 Study area with Assi Nallah



(a)

(b)

Figure 3.6 (a) Assi Nallah flowing near river Ganga and (b) Assi Nallah meeting to river Ganga

3.3 DATA USED

Two types of data were used in this research work. The first type of data was used as input data for modelling for sediment yield of the basin, sediment transport modelling and pollutant transport dynamic. The second type of data was used for validation of the modelling. Depending upon the objective, suitable input data and validation data were used. For sediment yield modelling, DEM data, hydrological data and metrological data were used as input. At the same time, the monthly runoff was used for validation purposes. For Sediment transport modelling, DEM data, sediment data, hydrological data and metrological data were used as input data. Direct measurement of the sediment concentration and bed cross-section were used for validation of the model. For measurement of the bed cross-section and sediment concentration was done with the help of ADCP. For calibration of ADCP data, direct measurement of the sediment concentration was done with the use of the water sampler. Figure 3.7 shows the photographic view of the sampling process at the river site, and Figure 3.8 shows the calculation of suspended sediment load from the laboratory method. For modelling the pollutant transport dynamic as input data, DEM, Flow data, pollutant characteristic data were used. For validation flow pattern from the channel was used. Details of all these input data and data for validation are presented in Chapter 4 to Chapter 7.

Figure 3.7 Photographic view of water sampling taken for sediment concentration

Figure 3.8 Estimation of suspended sediment load in lab

3.4 SOFTWARE USED

Different software packages were used for obtaining various objectives. The Soil & Water Assessment Tool (SWAT) was used for the sediment yield modelling of the basin with the help of ArcSWAT. Also, for image processing, ArcGIS was used to get the geospatial data. Acoustic Doppler Current Profiler (ADCP) with supporting software WinRiver II used for identification of sediment transport process in the different cross-section. For sediment transport modelling. Hydrological Engineering Centre – River Analysis System (HEC-RAS) is used as open-source software. For pollutant transport modelling, ANSYS software was used. Under this, the fluent tool is used for the Computation Fluid Dynamic modelling (CFD).