Chapter 6

Validation of models

6.1 Introduction

Three models have been formulated in this research:

1. Water Quality Index model.
2. Urbanization Index model.
3. Water Quality Urbanization Regression model (WQURM).

The models developed have been validated in this chapter. Thereafter, a hypothesis has been framed and the WQURM is tested for its statistical significance.

6.2 Validation of Water Quality Index model

6.2.1 Derivation of weightage of each parameter by experts opinion (Delphi technique)

In order to validate the methodology of development of Water Quality Index developed in this study, another approach of determining WQI has been adopted .i.e, WQI has also been calculated using Delphi Technique (A structured process for collecting knowledge from experts), (Linston and Turoff, 1975). A total of 6 water quality scientists/experts have been interviewed for various water quality parameters and asked them for relative ranking for six indicator water quality parameters under study. The weightage for each parameter [W_i] is calculated with the help of relative rank for its importance in water quality opined by water quality experts. Table 6.1 shows the Weightage obtained for water quality parameters using experts opinion.

Table 6.1 Computation of weightage of water quality parameters using experts opinion

Parameter	Relative rank						Sum	Normalized sum	Weightage (W_i)
	Expert-1	Expert-2	Expert-3	Expert-4	Expert-5	Expert-6			
pH	6	5	5	6	6	6	34	16.11	0.16
DO	9	9	9	9	8	9	53	25.12	0.25
BOD	8	8	8	8	8	8	48	22.75	0.23
Electrical conductivity	1	2	1	1	1	1	7	3.32	0.03
Nitrate nitrogen	3	3	3	2	2	3	16	7.58	0.08
Total coliform	9	9	9	8	9	9	53	25.12	0.25
Note: 9- most important, 1- least important						**Total**	211		

6.2.2. Water Quality Index (WQI) of the five stations by Delphi technique

Water Quality Index is equal to the sum of product of rating (Vr_i) and weightage (W_i) for all the parameters. According to the values of concentrations of various parameters from data base tables 4.5 to table 4.9, the rating (Vr_i) for each parameter i is obtained from table 3. The Weightage (Wi) for each parameter i is obtained from table 6.1. The WQI is computed using the following formula by this method.

$$WQI = \sum_{i=1}^{n} (W_i \text{ x } Vr_i) \qquad (6.1)$$

Table 6.2 shows the results obtained for Water Quality Index using experts' opinion by Delphi technique.

Table 6.2 Water Quality Index for the stations computed using Delphi technique

Water Quality Index							
	Station- S_1						
	2005	2006	2007	2008	2009	2010	2011
Jan	47.8	24.0	62.8	63.8	47.8	57.0	37.8
Apr	30.0	33.2	25.8	47.8	34.0	33.2	43.2
July	37.8	57.8	72.8	37.8	62.8	33.2	47.8
Oct	72.4	67.8	72.8	67.0	73.8	67.8	83.2
	Station- S_2						
	2005	2006	2007	2008	2009	2010	2011
Jan	62.4	82.0	82.4	87.0	87.4	87.4	92.0
Apr	62.8	77.4	82.4	87.4	52.8	57.8	84.2
July	68.8	52.8	62.8	67.8	92.0	77.8	71.4
Oct	64.2	82.0	77.4	77.8	87.0	92.0	82.4
	Station- S_3						
	2005	2006	2007	2008	2009	2010	2011
Jan	87.0	87.4	92.0	82.8	72.8	78.6	88.8
Apr	87.0	71.4	92.0	87.0	77.8	47.8	79.8
July	73.6	72.8	39.0	82.8	67.8	62.0	84.8
Oct	87.0	92.0	92.0	92.0	82.4	87.0	87.0
	Station- S_4						
	2005	2006	2007	2008	2009	2010	2011
Jan	37.8	37.8	43.2	34.6	37.8	47.8	37.8
Apr	33.2	33.2	37.8	47.8	33.2	33.2	33.2
July	37.8	43.2	47.8	47.8	47.8	47.8	43.2
Oct	37.8	43.2	52.8	37.8	52.4	52.4	53.6
	Station- S_5						
	2005	2006	2007	2008	2009	2010	2011
Jan	77.4	87.0	84.2	78.6	82.4	82.0	82.4
Apr	72.4	72.4	77.4	72.4	72.8	82.0	77.4
July	73.8	87.0	77.4	77.4	74.6	87.0	79.2
Oct	82.4	93.8	89.4	87.0	83.2	82.0	87.0

6.3. Validation of Water Quality Index model developed in the study by comparison with Delphi technique

The WQI obtained by the Water Quality Index model developed in the present study is compared with the WQI computed by using experts' opinion i.e, Delphi technique as shown in Figure 6.1. From the graph showing the comparison of WQI obtained by both the methods for the five stations, it can be seen that the values by both methods are very close (R^2 = 0.999) with trend line slope near to 45^0.Hence, the Water Quality Index model developed in the present study is validated.

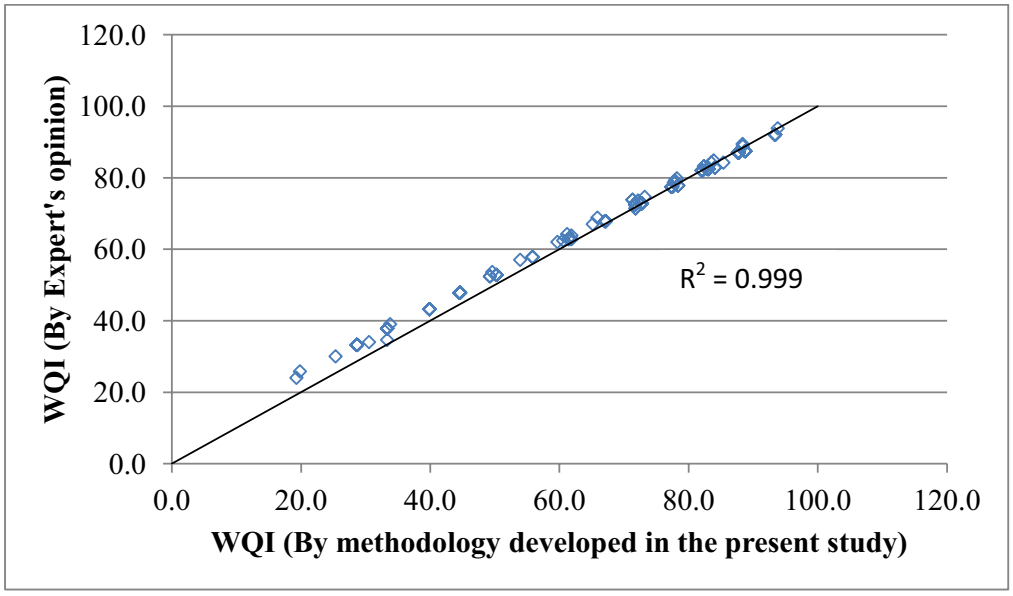

Figure 6.1 Validation of Water Quality Index Model by Comparison of WQI by two methods

6.4 Validation of Urbanization Index model

For the purpose of validation of the Urbanization Index developed in this study, the Urbanization level for the districts given by Census of India, 2011 is considered. Census of India, 2011 categorises the level of Urbanization based on % of urban population to total population as shown in Table 6.3. There is a scope of comparison because the Census, 2011 has also divided urbanization level into 5 classes as is done in the present study. There is a scope of comparison between urbanization level from Census and the Ui model developed

here because the Census, 2011 has also divided urbanization level into 5 classes as is done in the present study. According to Census of India, 2011 the level of Urbanization as a % of urban population to total population is 84.06%, 22.76% and 14.96 % for Ahmedabad district, Kheda district and Sabarkantha district respectively.

From Table 6.3, according to Census of India, 2011, Ahmedabad district falls under category - highly urban, Kheda and Sabarkantha district fall under category -moderately rural. Also, five classes are formed in this study, based on the Urbanicity of the district are shown in Table 3.13 in section **3.2.2.7**. From the Urbanization Index model developed in this study, the Urbanization Index for Ahmedabad district, Kheda district and Sabarkantha district are 84.44, 40 and 36.67 respectively. Hence from Table 3.13 in section 3.2.2.7, Ahmedabad falls under category very highly Urban, Kheda and Sabarkantha district fall under category -moderately rural. The validation of Urbanization Index is shown in Table 6.4. From Table 6.4, it can be noted that the Urbanization Index model gives the same results of Urbanization levels of the districts according to Census of India, 2011. Hence the Urbanization Index model is validated.

Table 6.3 Urbanization level given by Census of India, 2011

Urbanization Scale (% of urban population to total population)	**Level of urbanization**
< 12.50	Highly rural
12.51 - 27.5	Moderately rural
27.51 - 42.5	Moderately urban
42.51 - 57.5	Urban
> 57.51	Highly urban

Table 6.4 Category of Urbanization level according to Census of India, 2011 and Urbanization Index model developed in the present study

District		**Category of Urbanization level according to Census of India, 2011**	**Urbanization level according to UI model developed in the present study**	**Category of Urbanization level according to UI model developed in the present study**
Ahmedabad	84.06 %	Highly urban	84.44	Highly urban
Kheda	22.76 %	Moderately rural	40	Moderately rural
Sabarkantha	14.96 %	Moderately rural	36.67	Moderately rural

6.5 Validation of Water Quality - Urbanization Regression model (WQURM)

For the purpose of validation, the Water Quality- Urbanization Regression model (WQURM) developed in the present study is applied on Mahi river basin.

6.5.1 The Mahi river basin

The Mahi basin extends over states of Madhya Pradesh, Rajasthan and Gujarat having total area of 34,842 Sq.km with a maximum length and width of about 330 km and 250 km. It lies between 72°21’ to 75°19’ east longitudes and 21°46’ to 24°30’ north latitudes. It is bounded by Aravalli hills on the north and the north-west, by Malwa Plateau on the east, by the Vindhyas on the south and by the Gulf of Khambhat on the west. Mahi is one of the major interstate west flowing rivers of India. It originates from the northern slopes of Vindhyas at an altitude of 500 m near village Bhopawar, Sardarpur tehsil in Dhar district of Madhya Pradesh. The total length of Mahi is 583 km. The Mahi flows northwards initially entering into Banswara district and then turning southward flowing through Udaipur and Dungarpur districts before entering into Gujarat. In Gujarat, it flows through Panchmahal, Kheda, Vadodara and Bharuch districts before draining into the Gulf. The principal tributaries of the river are the Som from the west and the Anas and the Panam from the east. It drains into the

Arabian Sea through the Gulf of Khambhat. The major part of basin is covered with agricultural land accounting to 63.63% of the total area and 4.34% of the basin is covered by water bodies.. The Salient Features of Mahi Basin are shown in Table 6.5.

Table 6.5 Salient Features of Mahi Basin

Basin Extent Longitude Latitude	 72° 21’ to 75° 19’ E 21° 46’ to 24° 30’ N
Length of Mahi river (Km)	583
Catchment Area (Sq.km.)	34842
Average Water Resource Potential (MCM)	11020

The state wise distribution of the drainage area is shown in the following Table.6.6.

Table 6.6 State wise distribution of the drainage area of Mahi river

State	**Drainage area (Sq. Km.)**
Rajasthan	16453
Gujarat	11694
Madhya Pradesh	6695
Total	34842

The map of Mahi basin is shown in Figure 6.2.

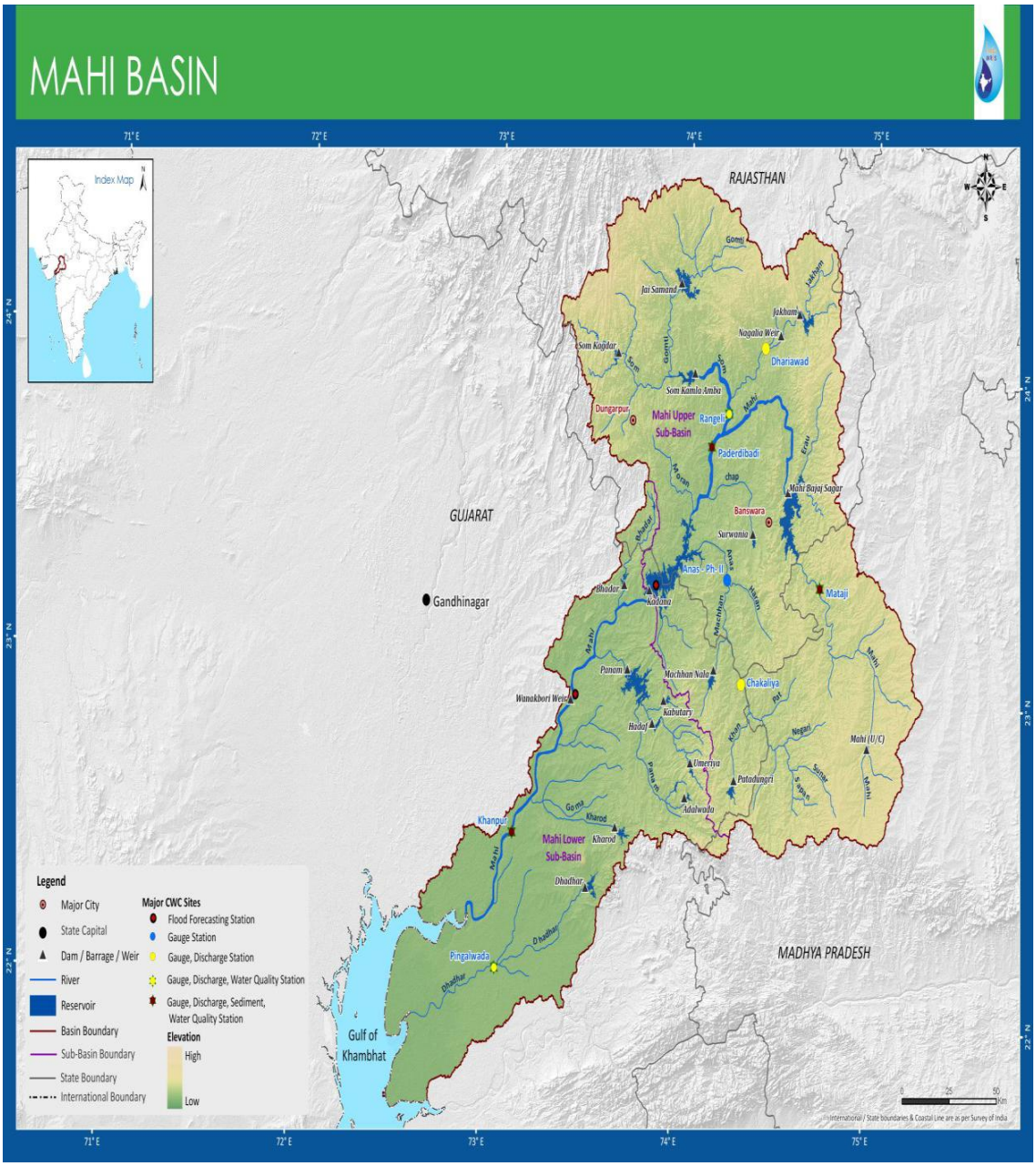

Figure 6.2 Map of Mahi River Basin

(Source: www.india-wris.nrsc.gov.in)

Four stations are selected on the Mahi river basin for the validation of WQURM model developed in this study.

1.Station 1 (M_1) - Mahi river at d/s of Kadana dam located in Kadana taluka, Panchmahal district, Gujarat, latitude 23.2895° N, longitude 73.8382° E.

2.Station 2 (M_2) - Mahi river at Sevalia, located in Taluka Thasra, Kheda district, Gujarat, latitude 22.8250° N, longitude 73.3421° E.

3.Station 3 (M_3) - Mahi river at Umeta located in Taluka Anklav, Anand district, Gujarat, latitude 22.3912°N, longitude 72.9945° E.

4. Station 4 (M_4) - Mahi river at Mujpur located in Vadodara district, Taluka Padra, Gujarat, latitude 22.2374° N , longitude 73.0903° E.

The Map of Mahi River Basin with the location of the stations is shown in Figure 6.3

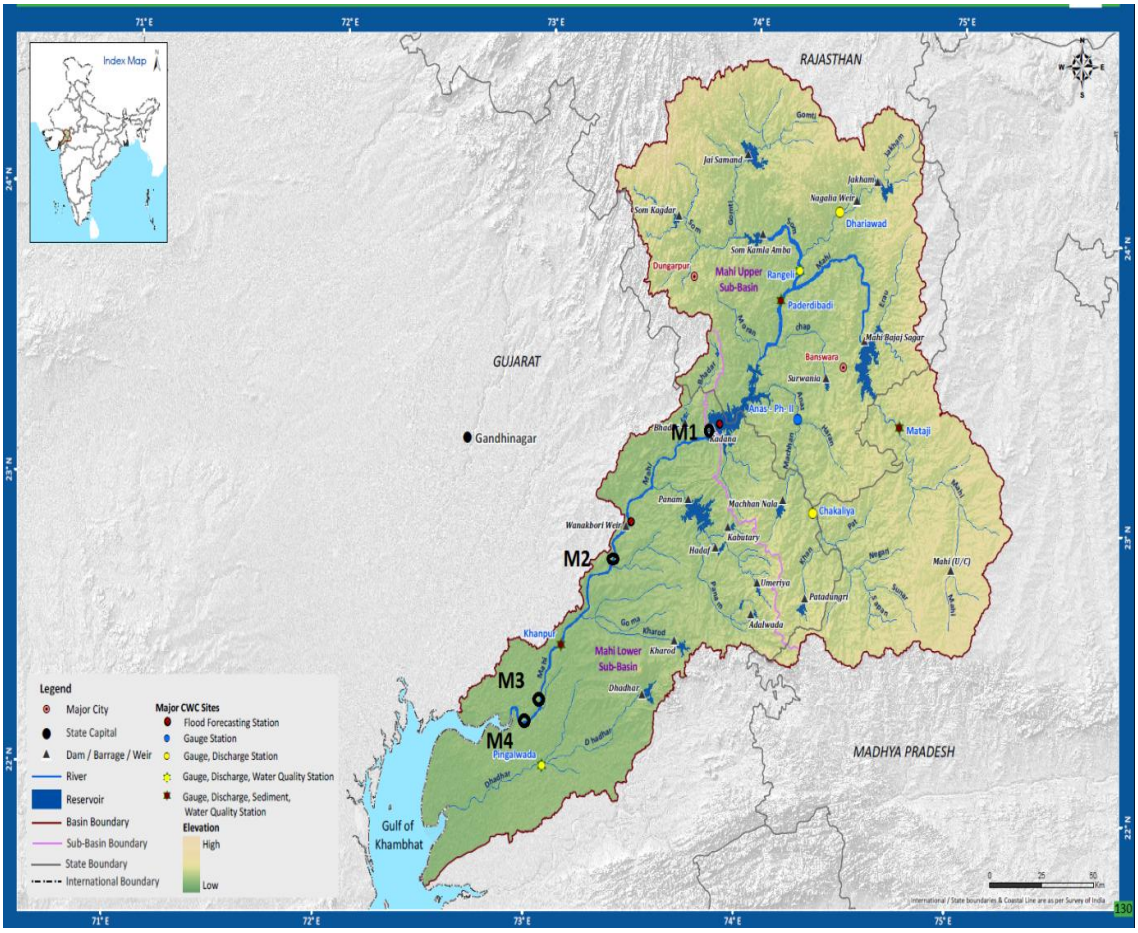

Figure 6.3 Map of Mahi River Basin with stations under study

6.5.2 Data base for Water Quality at Mahi River Basin

Water quality quarterly concentration for the parameters, pH, Dissolved oxygen, BOD, Electrical Conductivity, Nitrate nitrogen and Total Coliform for the stations M_1, M_2, M_3 and M_4 has been collected for the present study for a four year period between 2005 to 2011 in which data are available from Gujarat Pollution Control Board (GPCB),Gandhinagar. The data base of urbanization parameters obtained from the Census of India was available for a decade 2001-2011 while the data base of the water quality for Mahi river was available on a quarterly period in span between years 2001-2011. Hence year-wise correlation between water quality and urbanization is not carried out. Correlation is done by taking average of water quality index in a span lying in decade 2001-2011. The data available were considered for the correlation for accurate results.

The data for the parameter concentration for the stations M_1, M_2, M_3 & M_4 is shown in Table 6.7 to 6.10.

Table 6.7 Data of station M_1 (Kadana Dam)

	Station- M_1 Kadana Dam						
Year	Month	pH	DO	BOD	EC	Nitrate Nitrogen	Total Coliform
			(mg/l)	(mg/l)	(μ mhos/cm)	(mg/l)	(MPN/100 ml)
2005	Jan	8.3	7	1.8	342	0.35	11
	Apr	8.4	8.1	2.1	317	0.1	4
	July	7.9	6.3	1.5	352	0.21	7
	Oct	8.3	10	6	300	0.21	6
	average	8.2	7.9	2.9	327.8	0.2	7.0
2006	Jan	8.5	10.4	1.1	344	0.1	9
	Apr	8	8.3	2.2	334	0.1	7
	July	8	8.3	2	260	0.1	7
	Oct	8.1	7.8	1.2	383	0.1	9
	average	8.2	8.7	1.6	330.3	0.1	8.0

2010	Jan	8.2	10	0.8	318	0.3	3
	Apr	8.2	7.9	0.2	224	0.3	14
	July	8	6.2	0.4	322	0.2	11
	Oct	8	7.2	0.9	322	0.2	9
	average	8.1	7.8	0.6	296.5	0.3	9.3
2011	Jan	7.2	7.8	1.4	348	0.1	15
	Apr	8	7.7	2.7	385	0.1	14
	July	8.5	7.3	3.3	404	0.1	9
	Oct	8.6	7.8	2.4	380	0.1	14
	average	8.1	7.7	2.5	379.3	0.1	13.0

Table 6.8 Data of station M_2 (Sevalia)

Station -M_2 Sevalia							
Year	Month	pH	DO (mg/l)	BOD (mg/l)	EC (μ mhos/cm)	Nitrate Nitrogen (mg/l)	Total Coliform (MPN/100 ml)
2005	Apr	8.7	8.1	4.1	372	0.3	14
	July	8.3	8.5	1.8	288	0.2	15
	Oct	8.7	9.9	2.7	356	0.2	7
	average	8.6	8.8	2.9	338.7	0.2	12.0
2006	Jan	8.4	11.5	3.3	364	0.1	15
	Apr	8.7	10.8	2.7	354	0.1	11
	July	8.2	9	2.8	341	0.1	4
	Oct	8.1	9.3	3.1	354	0.2	11
	average	8.4	10.2	3.0	353.3	0.1	10.3
2007	Jan	8.2	10.5	1.9	430	0.1	7
	Apr	8.5	8.8	3.2	375	NA	20
	July	7.9	7.8	1.4	228	NA	11

	Oct	8.5	9.8	3.6	334	NA	4
	average	8.3	9.2	2.5	341.8	0.1	10.5
2008	Jan	8.4	8.2	0.6	386	NA	NA
	Apr	8.6	6	0.6	401	0.3	NA
	July	8.1	9	3	401	0.1	4
	Oct	8.8	9.4	1.6	264	NA	4
	average	8.5	8.2	1.5	363.0	0.2	4.0

Table 6.9 Data of station M_3 (Umeta Bridge)

Station -M_3 Umeta Bridge							
Year	Month	pH	DO (mg/l)	BOD (mg/l)	EC (μ mhos/cm)	Nitrate Nitrogen (mg/l)	Total Coliform (MPN/100 ml)
2005	Jan	8.6	8.1	1	409	0.3	15
	Apr	7.8	7.6	3.2	379	0.4	15
	July	8.8	11	4.7	283	0.2	20
	Oct	8.6	8.6	2.5	463	0.3	11
	average	8.5	8.8	2.9	383.5	0.3	15.3
2006	Jan	8.5	8.3	2.8	407	0.2	5
	Apr	7.7	10.4	3.3	435	0.1	11
	Oct	7.8	6.9	2.7	621	0.2	7
	average	8	8.5	2.9	487.7	0.2	7.7
2007	Jan	8.1	8.2	1.3	590	0.2	4
	Apr	8.4	7.5	3.7	524	0.1	21
	July	7.4	7.5	2.6	186	0.2	14
	Oct	8.2	7.2	1.6	330	0.1	7
	average	8.0	7.6	2.3	407.5	0.2	11.5
2008	Jan	8.4	9.9	3.3	403	0.3	11

	Apr	8.6	8.2	2.8	435	0.1	7
	July	8.5	7.8	1.6	462	0.2	4
	Oct	8.9	10.6	4.4	460	0.2	3
	average	8.6	9.1	3.0	440.0	0.2	6.3

Table 6.10 Data of station M_4 (Mujpur)

Station- M_4 Mujpur							
Year	Month	pH	DO (mg/l)	BOD (mg/l)	EC (μ mhos/cm)	Nitrate Nitrogen (mg/l)	Total Coliform (MPN/100 ml)
2005	Jan	8.2	8.8	2.4	7080	0.3	11
	Apr	8.8	8.9	1.7	378	0.4	28
	July	8.8	9.2	5.9	389	0.2	14
	average	8.6	9.0	3.3	2615.7	0.3	17.7
2006	Jan	8.5	8.9	3	539	0.2	4
	Apr	8.8	10.9	3.3	436	0.1	28
	Oct	8	9.1	2.3	426	0.1	15
	average	8.4	9.6	2.9	467.0	0.1	15.7
2007	Jan	8.3	10.4	5.7	3720	0.3	14
	Apr	8.3	7.9	3.8	559	0.3	15
	July	7.6	8	2	199	0.2	15
	Oct	8.1	8	1.6	328	0.1	11
	average	8.1	8.6	3.3	1201.5	0.2	13.8
2008	Jan	8.3	10.2	2.1	692	0.3	11
	Apr	8.3	9.2	4.2	485	0.4	11
	July	7.6	6.6	5	6110	0.2	3
	Oct	8.9	9.6	3.6	462	0.1	3
	average	8.3	8.9	3.7	1937.3	0.3	7.0

6.5.3 Data base for Urbanization level of districts on Mahi river basin

District-wise data of households by main source of lighting, number of households having specified assets, census houses by predominant material of roof, population size and population density for Mahi river basin are collected from Census of India, 2011. District-wise data base of number of industries, educational facilities and health services are collected from Ministry of Micro Medium and Small Enterprise (MSME) 2011, Government of India.(website: dsmsme.gov.in). Land Use, land cover pattern, district-wise data is collected from National Remote Sensing Centre (NRSC) 2011, Hyderabad. The data-base for the urbanization parameters collected for districts: Anand, Dahod, Panchmahals (Gujarat); Banswara, Dungarpur, Udaipur, Pratapgarh (Rajasthan); Jhabua, Dhar , Ratlam (Madhya Pradesh) are shown in Table.6.11

Table 6.11 Data for Parameters for measurement of Urbanization level of districts located on Mahi river basin.

Urbanization Parameters	DISTRICT									
	Anand (Guj.)	**Dahod (Guj.)**	**Panchmahals (Guj.)**	**Banswara (Raj.)**	**Dungarpur (Raj.)**	**Udaipur (Raj.)**	**Pratapgarh (Raj.)**	**Jhabua (M.P)**	**Dhar (M.P)**	**Ratlam (M.P)**
Population size	2090276	2126558	2388267	1797485	1388552	3068420	867848	1025048	2185793	1455069
Population density (persons/sq.Km)	653	582	458	397	368	262	195	285	268	299
Industries	950	3637	200	3958	3400	4021	1885	7144	7292	8302
% of Built up area to total area	2.34	0.29	1.10	1.02	1.12	1.08	0.20	0.4	1.31	1.45
Roofing (%)	10.54	2.65	5.66	1.47	1.10	3.16	0.95	1.54	3.42	3.21
Electricity Facility (%)	18.09	11.33	16.70	6.7	10.17	11.66	8.25	12.23	15.99	14.69
Educational facilities	25	1	12	12	15	34	2	5	8	6
Health services (major Hospitals)	4	2	7	7	2	21	0	1	1	1
Assets(%)	0.97	0.19	1.47	0.27	0.23	0.90	0.16	0.16	0.26	0.53

6.5.4 Water Quality Index of stations on Mahi river

The equation (3.2) developed in this study is reproduced below:

$WQI = \sum_{i=1}^{n}(W_i \; x \; \mathrm{Vr}_i)$

The above equation is used to compute the Water Quality Index of the stations, M_1, M_2, M_3, and M_4 for four years and is shown in Table 6.12.

Table 6.12 Water Quality Index for the stations on Mahi river

Station	Year	Water Quality Index	Average Water Quality Index
M_1	**2005**	93.44	95.17
	2006	93.44	
	2010	94.75	
	2011	99.06	
M_2	**2005**	86.82	93.19
	2006	93.44	
	2007	93.44	
	2008	99.06	
M_3	**2005**	90.13	89.78
	2006	93.44	
	2007	93.44	
	2008	82.13	
M_4	**2005**	85.44	86.28
	2006	93.44	
	2007	88.75	
	2008	77.5	

6.5.5 Urbanization Index of districts located on Mahi river basin

The points for each of the urbanization parameter for the districts, Anand, Dahod, Panchmahals (Gujarat); Banswara, Dungarpur, Udaipur, Pratapgarh (Rajasthan); Jhabua, Dhar , Ratlam (Madhya Pradesh) falling in the Mahi river basin are obtained using the urbanization scale developed in the present study. The points are aggregated and the normalized Urbanization Index for each district is obtained, shown in Table 6.13.

Table 6.13 Urbanization Index computation for the districts under study

Urbanization Parameters	POINTS FOR DISTRICTS									
	Anand	**Dahod**	**Panchmahals**	**Banswara**	**Dungarpur**	**Udaipur**	**Pratapgarh**	**Jhabua**	**Dhar**	**Ratlam**
Population size	4	4	4	4	3	5	3	3	4	3
Population density	4	3	3	2	2	2	1	2	2	2
Industries	3	4	2	4	4	4	3	5	5	5
% of Built up area to total area	8	1	3	4	4	4	1	2	5	5
Roofing	4	1	2	1	1	1	1	1	1	1
Electricity Facility	4	3	4	2	3	3	2	3	4	3
Educational Facilities	4	4	4	4	4	4	3	4	4	4
Health services	5	5	5	5	5	9	5	5	5	5
Assets	5	1	2	2	2	5	1	1	2	3
Total Points	**41**	**26**	**29**	**28**	**28**	**37**	**20**	**26**	**32**	**31**
Urbanization Index	**45.6**	**28.9**	**32.2**	**31.1**	**31.1**	**41.1**	**22.2**	**28.9**	**35.6**	**34.4**

6.5.6 Computation of the Urbanization Index of the catchment of the stations on Mahi river

The watershed map with districts of the Mahi river basin is shown in Figure 6.4

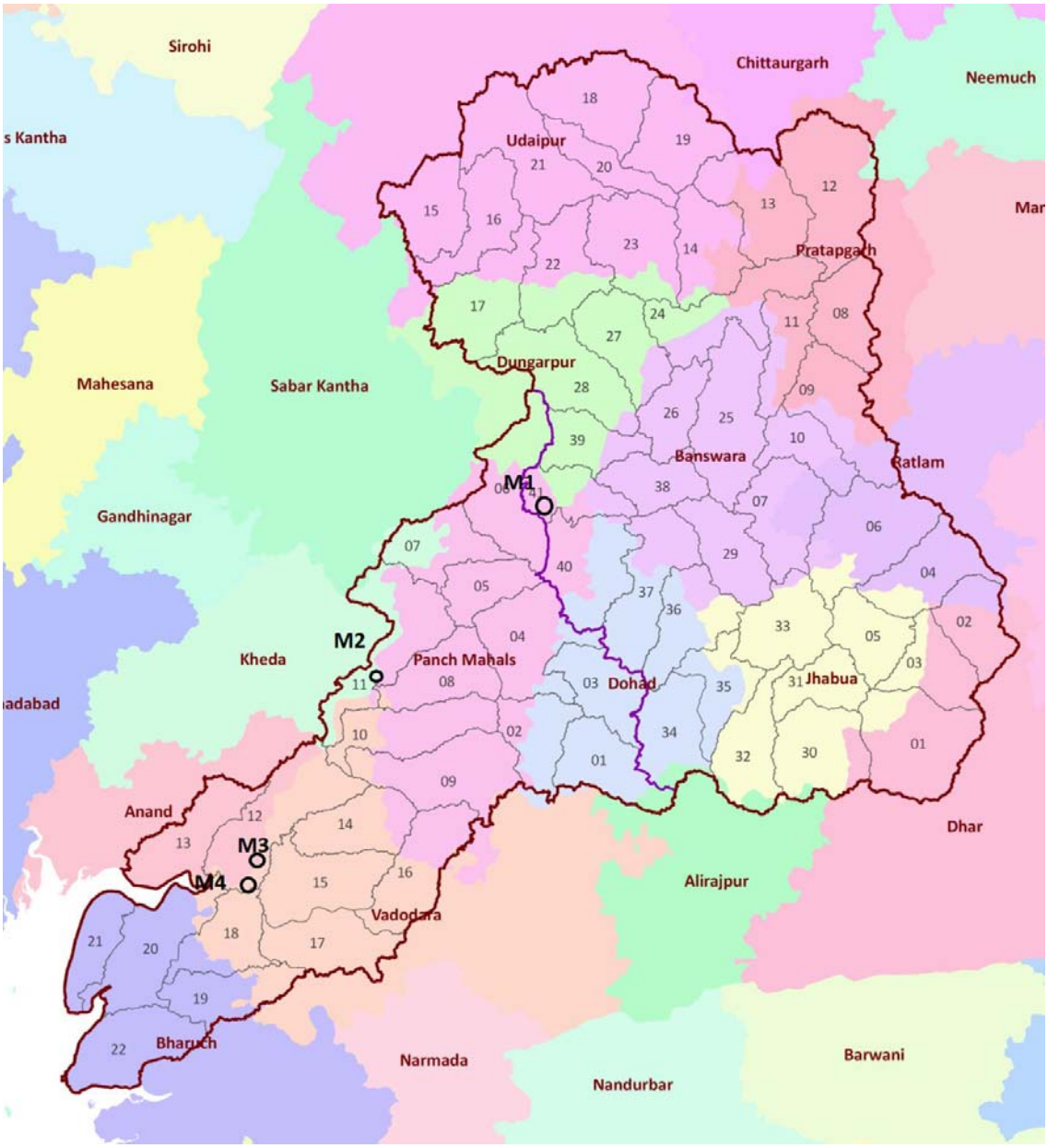

Figure 6.4 Watershed map of Mahi river basin with districts and stations

From the watershed map of the Mahi river basin, the area of the watershed falling in the catchment of the station is measured and shown in Table 6.14.

6.5.6.1 Urbanization Index for catchment area of station M_1

From the watershed map of Mahi river basin, the area of the watershed falling in the catchment of the station is measured and shown in Table. The catchment area of station M_1 is shown in Figure 6.5.

Figure 6.5 Watersheds contributing to the station M_1

For the stations whose catchment area consists of watershed portions of more than one district, the Urbanization Index of the catchment of the station is the weighted average of the Urbanization Index of the portions of the multiple districts (Case A2 B2, section 3.2.2.6). This case is applicable to stations M_1. The equation 3.7 for Urbanization Index of the

catchment of the station developed in chapter 3 is used for computing the UI of district portions.

As discussed in section 3.2.2.6, where there are number of (multiple) whole district lying in the catchment (under case A1 B2), then Urbanization Index of the catchment is the average of the Urbanization Index of the districts. This case is also applicable to stations M_1 as the districts Jhabua, Banswara, Dahod and Panchmahal are almost entirely lying in the catchment area of M_1. Hence, to evaluate the UI of M_1, first the UI of the portions of the multiple districts (considering Case A2 B2) is computed and then the average of the UI of the whole districts is incorporated (considering Case A1 B2) as shown in Table 6.15.

6.5.6.2 Urbanization Index computation for catchment area of station M_2, M_3 and M_4

The catchment area of station M_2, M_3 and M_4 is shown in Figure 6.6, 6.7 and 6.8 respectively.

Figure 6.6 Watersheds contributing to the station M_2

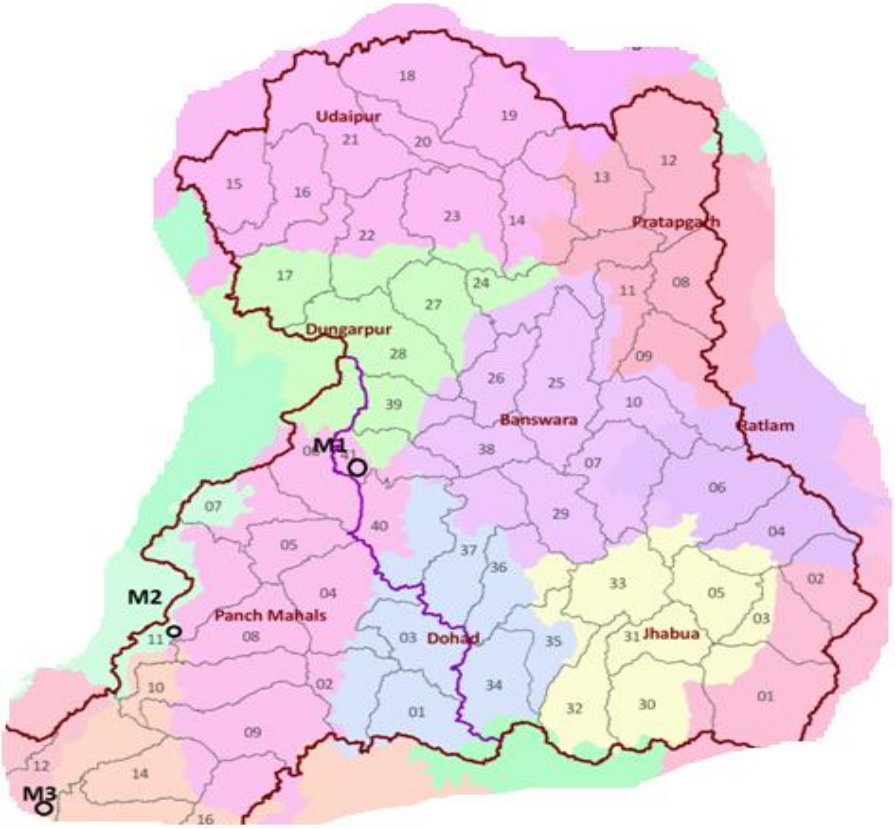

Figure 6.7 Watersheds contributing to the station M_3

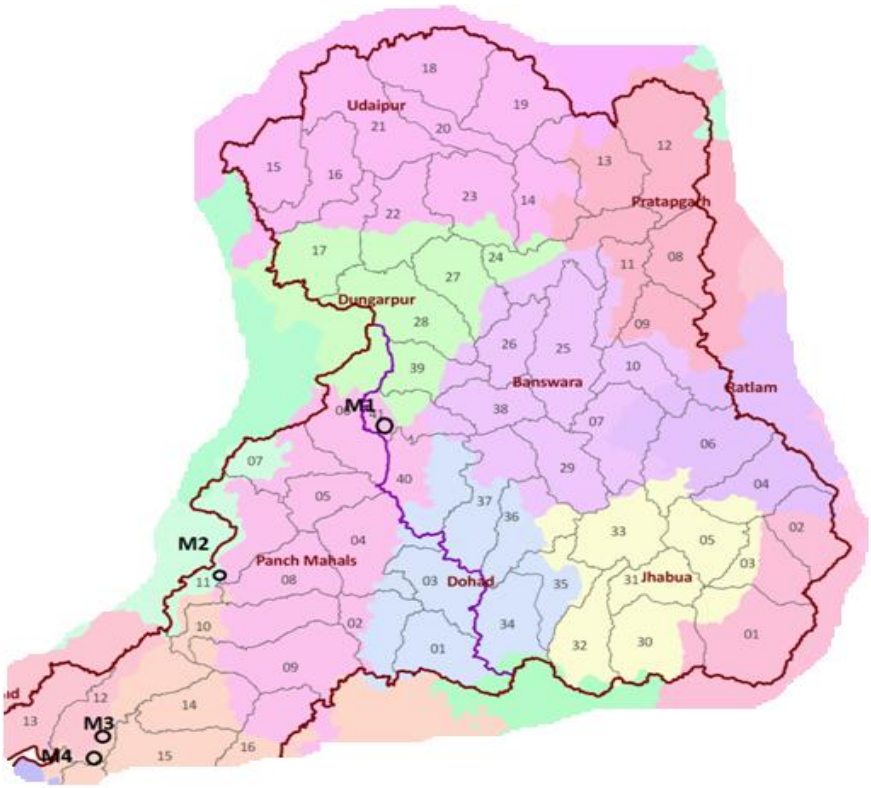

Figure 6.8 Watersheds contributing to the station M_4

For the stations M_2, M_3 and M_4, the catchment area consists of multiple district portions. Hence Case A2 B2 is applicable. Again as the catchment area of M_1 is also contributing the inflow to station M_2, M_3 and M_4 ,the same methodology as M_1 is followed i.e, first the UI of the portions of the multiple districts (considering Case A2 B2) is computed and then the average of the UI of the whole districts is incorporated (considering Case A1 B2) as shown in Table 6.16, 6.17 and 6.18 respectively.

Table 6.14 Area Measurements for Catchment of the stations on Mahi river

Station	**Watershed No. contributing to the station**	**District in which watershed falls**	**Watershed area of the district falling in the catchment (Km^2)**	**Area of the district (Km^2)**	**Ratio of watershed area to the total area of the district**
M_1	1,2,3 (upper basin)	Dhar	1874.5	8150	0.23
	4,6 (upper basin)	Ratlam	1215.25	4861	0.25
	5,30,31,32,33 (upper basin)	Jhabua	6293	6793	1
	7,10,25,26,38 (upper basin)	Banswara	5037	5037	1
	34,35,36,37,40 (upper basin)	Dahod	3397.03	3733	0.91
	6,40,41(upper basin)	Panchmahal	1067.43	5083	0.21
	6,17,22,23,24,27,28,39 (upper basin)	Dungarpur	3420	3800	0.90
	14,15,16,17,18,19,20,21,22,23(upper basin)	Udaipur	4029	13430	0.30
	8,9,11,12,13,24 (upper basin)	Pratapgarh	3947.52	4112	0.96

	1,2,3 (upper basin)	Dhar	1874.5	8150	0.23
	4,6 (upper basin)	Ratlam	1215.25	4861	0.25
	5,30,31,32,33 (upper basin)	Jhabua	6293	6793	1
	7,10,25,26,38 (upper basin)	Banswara	5037	5037	1
	34,35,36,37,40 (upper basin)	Dahod	3397.03	3733	0.91
M_2	6,40,41(upper basin)	Panchmahal	1067.43	5083	0.21
	6,17,22,23,24,27,28,39 (upper basin)	Dungarpur	3420	3800	0.90
	14,15,16,17,18,19,20,21,22,23(upper basin)	Udaipur	4029	13430	0.30
	8,9,11,12,13,24 (upper basin)	Pratapgarh	3947.52	4112	0.96
	1,3	Dahod	1996.38	7394	0.27
	2	Dahod	484	4401	0.11
		Panchmahal	147.88	7394	0.02
	4,5,11	Panchmahal	1880.71	5083	0.37
M_3	1,2,3 (upper basin)	Dhar	1874.5	8150	0.23
	4,6 (upper basin)	Ratlam	1215.25	4861	0.25
	5,30,31,32,33 (upper basin)	Jhabua	6293	6793	1
	7,10,25,26,38 (upper basin)	Banswara	5037	5037	1
	34,35,36,37,40	Dahod	3397.03	3733	0.91

	(upper basin)				
	6,40,41(upper basin)	Panchmahal	1067.43	5083	0.21
	6,17,22,23,24,27,28,39 (upper basin)	Dungarpur	3420	3800	0.90
	14,15,16,17,18,19,20,21,22,23(upper basin)	Udaipur	4029	13430	0.30
	8,9,11,12,13,24 (upper basin)	Pratapgarh	3947.52	4112	0.96
	1,3	Dahod	1996.38	7394	0.27
	2	Dahod	484	4401	0.11
		Panchmahal	147.88	7394	0.02
	4,5,11	Panchmahal	1880.71	5083	0.37
	8,9	Panchmahal	1270.75	5083	0.25
	10	Panchmahal	965.7	5083	0.19
	12	Anand	206.57	2951	0.07
		Vadodara	389.7	7794	0.05
M_4	1,2,3 (upper basin)	Dhar	1874.5	8150	0.23
	4,6 (upper basin)	Ratlam	1215.25	4861	0.25
	5,30,31,32,33 (upper basin)	Jhabua	6293	6793	1
	7,10,25,26,38 (upper basin)	Banswara	5037	5037	1
	34,35,36,37,40 (upper basin)	Dahod	3397.03	3733	0.91
	6,40,41(upper basin)	Panchmahal	1067.43	5083	0.21
	6,17,22,23,24,27,28,39 (upper	Dungarpur	3420	3800	0.90

	basin)				
	14,15,16,17,18, 19,20,21,22,23(upper basin)	Udaipur	4029	13430	0.30
	8,9,11,12,13,24 (upper basin)	Pratapgarh	3947.52	4112	0.96
	1,3	Dahod	1996.38	7394	0.27
	2	Dahod	484	4401	0.11
		Panchmahal	147.88	7394	0.02
	4,5,11	Panchmahal	1880.71	5083	0.37
	8,9	Panchmahal	1270.75	5083	0.25
	10	Panchmahal	965.7	5083	0.19
	12	Anand	295.1	2951	0.10
		Vadodara	701.46	7794	0.09

Table.6.15 Urbanization Index computation for station M_1

Water-shed No.	**District**	**Watershed area of the district falling in the catchment (Km^2)**	**Total area of the district (Km^2)**	**Ratio of watershed area to the total area of the district**	**UI of the district**	**UI of the portions of districts**	$\frac{a_{i,j,k} \times UI_j \times a_{i,j,k}}{A_j \times A_k}$
(1)	**(2)**	**(3)**	**(4)**	**(5) = (3)/(4)**	**(6)**	**(7)= (5)x(6)**	**(8)=$\frac{(7)x(3)}{\sum(3)}$**
1,2,3 (upper basin)	Dhar	1874.5	8150	0.23	35.6	8.18	0.53
4,6 (upper basin)	Ratlam	1215.25	4861	0.25	34.4	8.6	0.36
5,30,31,32,33 (upper basin)	Jhabua	6293	6793	0.93	28.9	---	---
7,10,25,26,38 (upper basin)	Banswara	5037	5037	1	31.1	---	---
34,35,36,37,40 (upper basin)	Dahod	1880	3733	0.50	28.9	14.6	0.95
6,40,41(upper basin)	Panchmahal	1067.43	5083	0.21	32.2	6.76	0.25
6,17,22,23,24,27,28,39 (upper basin)	Dungarpur	3420	3800	0.90	31.1	---	---
14,15,16,17,18,19,20,21,22,23(upper basin)	Udaipur	4029	13430	0.30	41.1	12.3	1.73
8,9,11,12,13,24(upper basin)	Pratapgarh	3947.52	4112	0.96	22.2	---	---
Total		**28763.7**					**3.83**
Average Urbanization Index of watershed i.e, $(\sum(8) \times 5)$							**19.13**
Urbanization Index of the catchment of the station M_1 = (avg of UI of watershed, UI of Jhabua, Banswara, Dungarpur, Pratapgarh) i.e, (avg. of 19.13,28.9, 31.1, 31.1,22.2)							**26.49**

Table.6.16 Urbanization Index computation for station M_2

Water-shed No.	**District**	**Watershed area of the district falling in the catchment (Km^2)**	**Total area of the district (Km^2)**	**Ratio of watershed area to the total area of the district**	**UI of the district**	**UI of the portions of districts**	$\frac{a_{i,j,k} \times UI_j \times a_{i,j,k}}{A_j \times A_k}$
(1)	**(2)**	**(3)**	**(4)**	**(5) = (3)/(4)**	**(6)**	**(7)= (5)x(6)**	**(8)=$\frac{(7)x(3)}{\sum(3)}$**
1,2,3 (upper basin)	Dhar	1874.5	8150	0.23	35.6	8.19	0.46
4,6 (upper basin)	Ratlam	1215.25	4861	0.25	34.4	8.6	0.31
5,30,31,32,33 (upper basin)	Jhabua	6293	6793	0.93	28.9	---	---
7,10,25,26,38 (upper basin)	Banswara	5037	5037	1	31.1	---	---
34,35,36,37,40 (upper basin)	Dahod	1880	3733	0.50	28.9	14.55	0.82
6,40,41(upper basin)	Panchmahal	1067.43	5083	0.21	32.2	6.76	0.22
6,17,22,23,24,27,28,39 (upper basin)	Dungarpur	3420	3800	0.90	31.1	---	---
14,15,16,17,18,19,20,21,22,23(upper basin)	Udaipur	4029	13430	0.30	41.1	12.33	1.49
8,9,11,12,13,24(upper basin)	Pratapgarh	3947.52	4112	0.96	22.2	---	---
1,3	Dahod	1996.38	7394	0.27	28.9	7.8	0.47
2	Dahod	484.11	4401	0.11	28.9	3.18	0.05
	Panchmahal	147.88	7394	0.02	32.2	0.64	0.003

4,5,11	Panchmahal	1880.71	5083	0.37	32.2	11.91	0.67
Total		**4509.08**					4.50
						Average Urbanization Index of watershed (∑(8) x 9)	40.48
						Urbanization Index of M_2 = (avg of UI of watershed, UI of Jhabua, Banswara, Dungarpur, Pratapgarh) **Average (40.48, 28.9,31.1,28.9,31.1,22.2)**	**30.75**

Table.6.17 Urbanization Index computation for station M_3

Water-shed No.	**District**	**Watershed area of the district falling in the catchment (Km^2)**	**Total area of the district (Km^2)**	**Ratio of watershed area to the total area of the district**	**UI of the district**	**UI of the portions of districts**	$\frac{a_{i,j,k} \times UI_j \times a_{i,j,k}}{A_j \times A_k}$
(1)	**(2)**	**(3)**	**(4)**	**(5) = (3)/(4)**	**(6)**	**(7)= (5)x(6)**	**(8)=$\frac{(7)x(3)}{\sum(3)}$**
1,2,3 (upper basin)	Dhar	1874.5	8150	0.23	35.6	8.19	0.42
4,6 (upper basin)	Ratlam	1215.25	4861	0.25	34.4	8.6	0.29
5,30,31,32,33 (upper basin)	Jhabua	6293	6793	0.93	28.9	---	---
7,10,25,26,38 (upper basin)	Banswara	5037	5037	1	31.1	---	---
34,35,36,37,40 (upper basin)	Dahod	1880	3733	0.50	28.9	14.55	0.76

6,40,41(upper basin)	Panchmahal	1067.43	5083	0.21	32.2	6.76	0.20
6,17,22,23,24,27,28,39 (upper basin)	Dungarpur	3420	3800	0.90	31.1	---	---
14,15,16,17,18,19,20,21,22,23(upper basin)	Udaipur	4029	13430	0.30	41.1	12.33	1.37
8,9,11,12,13,24(upper basin)	Pratapgarh	3947.52	4112	0.96	22.2	---	---
1,3	Dahod	1996.38	7394	0.27	28.9	7.8	0.43
2	Dahod	484.11	4401	0.11	28.9	3.18	0.04
	Panchmahal	147.88	7394	0.02	32.2	0.64	0.003
4,5,11	Panchmahal	1880.71	5083	0.37	32.2	11.91	0.62
8,9	Panchmahal	1270.75	5083	0.25	32.2	8.05	0.28
10	Panchmahal	965.7	5083	0.19	32.2	6.12	0.16
	Anand	230	2951	0.07	45.6	3.19	0.02
12	Vadodara	450	7794	0.05	66.7	3.34	0.04
Total		**36189.23**					7.861
							4.64
Average Urbanization Index of watershed (∑(8) x 13)							60.36
Urbanization Index of M_3 = (avg of UI of watershed, UI of Jhabua, Banswara, Dungarpur, Pratapgarh) **i.e, Average of (60.36,28.9,31.1,28.9,31.1,22.2)**							**34.73**

Table.6.18 Urbanization Index computation for station M_4

Water-shed No.	**District**	**Watershed area of the district falling in the catchment (Km^2)**	**Total area of the district (Km^2)**	**Ratio of watershed area to the total area of the district**	**UI of the district**	**UI of the portions of districts**	$\frac{a_{i,j,k} \times UI_j \times a_{i,j,k}}{A_j \times A_k}$
(1)	**(2)**	**(3)**	**(4)**	**(5) = (3)/(4)**	**(6)**	**(7)= (5)x(6)**	**(8)=$\frac{(7)x(3)}{\sum(3)}$**
1,2,3 (upper basin)	Dhar	1874.5	8150	0.23	35.6	8.19	0.42
4,6 (upper basin)	Ratlam	1215.25	4861	0.25	34.4	8.6	0.29
5,30,31,32,33 (upper basin)	Jhabua	6293	6793	0.93	28.9	---	---
7,10,25,26,38 (upper basin)	Banswara	5037	5037	1	31.1	---	---
34,35,36,37,40 (upper basin)	Dahod	1880	3733	0.50	28.9	14.55	0.75
6,40,41(upper basin)	Panchmahal	1067.43	5083	0.21	32.2	6.76	0.20
6,17,22,23,24,27,28,39 (upper basin)	Dungarpur	3420	3800	0.90	31.1	---	---
14,15,16,17,18,19,20,21,22,23(upper basin)	Udaipur	4029	13430	0.30	41.1	12.33	1.37
8,9,11,12,13,24(upper basin)	Pratapgarh	3947.52	4112	0.96	22.2	---	---
1,3	Dahod	1996.38	7394	0.27	28.9	7.8	0.43
2	Dahod	484.11	4401	0.11	28.9	3.18	0.04
	Panchmahal	147.88	7394	0.02	32.2	0.64	0.003

4,5,11	Panchmahal	1880.71	5083	0.37	32.2	11.91	0.62
8,9	Panchmahal	1270.75	5083	0.25	32.2	8.05	0.28
10	Panchmahal	965.7	5083	0.19	32.2	6.12	0.16
	Anand	265.59	2951	0.09	45.6	4.10	0.03
12	Vadodara	531	7794	0.07	66.7	4.54	0.07
Total		**36305.82**					4.66
Average Urbanization Index of watershed (∑(8) x 13)							60.62
Urbanization Index of M_4 = (avg of UI of watershed, UI of Jhabua, Banswara, Dungarpur, Pratapgarh) i.e, **Average of (60.62, 28.9,31.1,28.9,31.1,22.2)**							**34.78**

6.5.7 Results of Water Quality Index and Urbanization Index of the stations on Mahi river

Results of Water Quality Index and Urbanization Index of the stations on Mahi river are shown in Table 6.19

Table 6.19 Results of Water Quality Index and Urbanization Index of the stations on Mahi river

Station	Water Quality Index	Urbanization Index
M_1	95.17	26.49
M_2	93.19	30.75
M_3	89.78	34.73
M_4	86.28	34.78

6.5.8 Water Quality- Urbanization Regression model (WQURM) validation on Mahi river

In the present study, to develop the Water Quality- Urbanization Regression Model for Mahi river, various regression types are considered for fitting from the results of Water Quality Index and Urbanization Index of Mahi river (Table 6.19). The trend of various regression types are shown in figure 6.9 to figure 6.11. The best fit curve/line is determined from all the above regression types by computing the sum of square of error. The regression showing the least sum of square of errors is selected as the best fit curve and the corresponding equation defines the Water Quality - Urbanization Regression Model (WQURM) for Mahi river. Table 6.20 shows sum of square of error obtained for the different regression types.

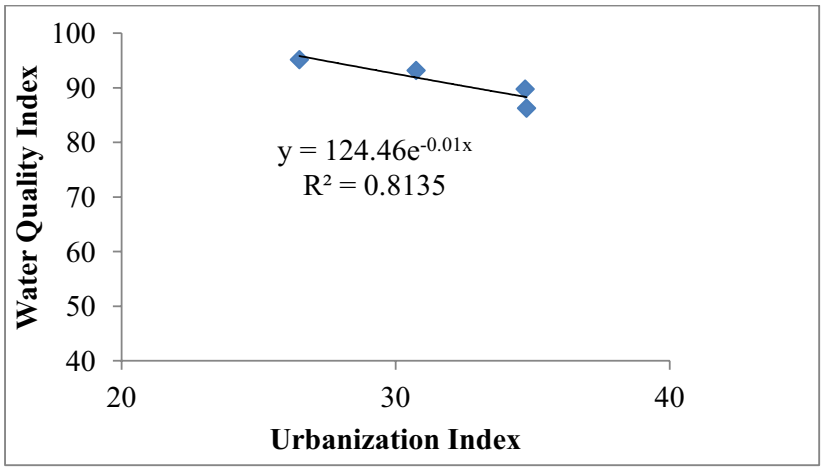

Figure 6.9 Exponential Regression plot for Mahi river

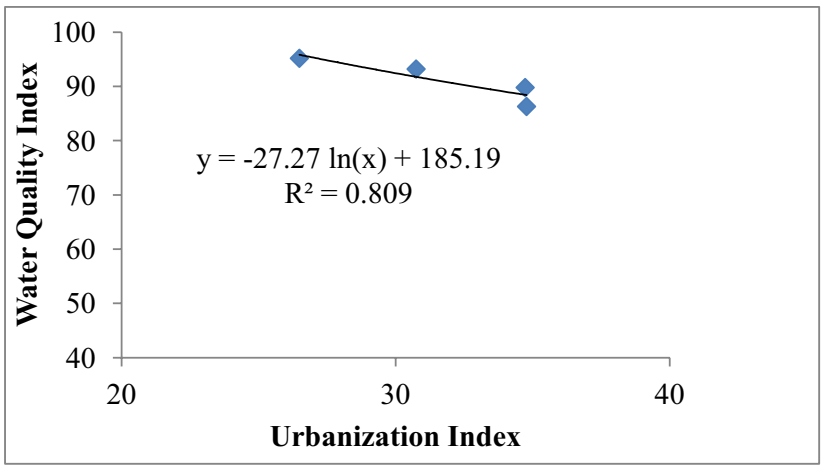

Figure 6.10 Logarithmic Regression plot for Mahi river

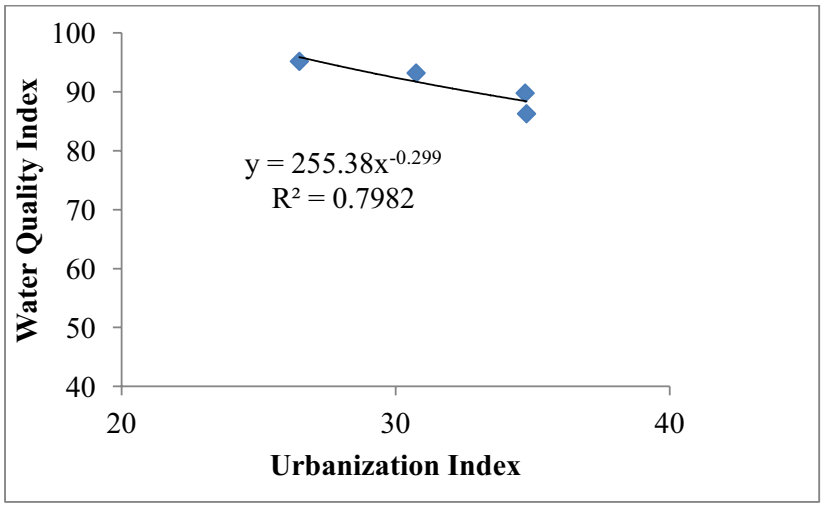

Figure 6.11 Power Regression plot for Mahi river

Table 6.20 Sum of Square of Error for different types of Regression

Sr. No.	Type of Regression	Regression Equation	R^2	Sum of Square of Error
1.	Exponential	$y = 124.46\ e^{-0.01x}$	0.81	8.91
2.	Logarithmic	$y = -27.27\ \ln(x) + 185.19$	0.76	8.77
3.	Power	$y = 225.38\ x^{-0.299}$	0.72	9.00
4.	Linear	$y = -0.8999x + 119.62$	0.82	8.08

From Table 6.20, it is observed that the linear regression shows the least sum of square of error and $R^2 = 0.82$. The graph of Water Quality Index and Urbanization Index is plotted for the Water Quality - Urbanization Regression Model (WQURM) using the results of Water Quality Index and Urbanization Index of stations (Table 6.20) and is shown in figure 6.12. The Figure 6.12 shows the Water - Quality Urbanization Regression Model (WQURM) developed for Mahi river in the present study for a linear regression.

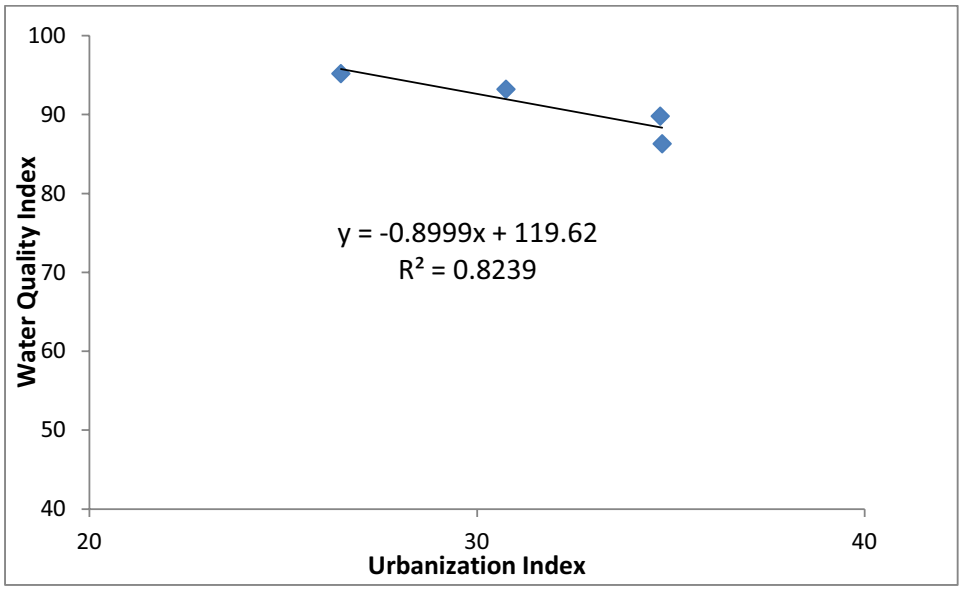

Figure 6.12 Graph for Water Quality- Urbanization Regression Model (WQURM) plot for Mahi river

From Figure 6.12, The WQURM linear mathematical model for Mahi river is

$y = - 0.8999 x + 119.62.$

Where, y = Water Quality Index of the station and x = Urbanization Index of the catchment of the station.

R^2 = 0.8239 shows a high degree of correlation between the Water Quality Index and Urbanization Index for the Mahi river. The trend of the line shows a negative correlation between the two parameters which shows that as urbanization of an area increases, the water quality deteriorates.

The trend of the WQURM model for Mahi river confirms with the linear trend of the WQURM model of Sabarmati river. Hence WQURM model developed in this study is validated.

Figure 6.13 shows the WQURM models developed for Sabarmati river and Mahi river.

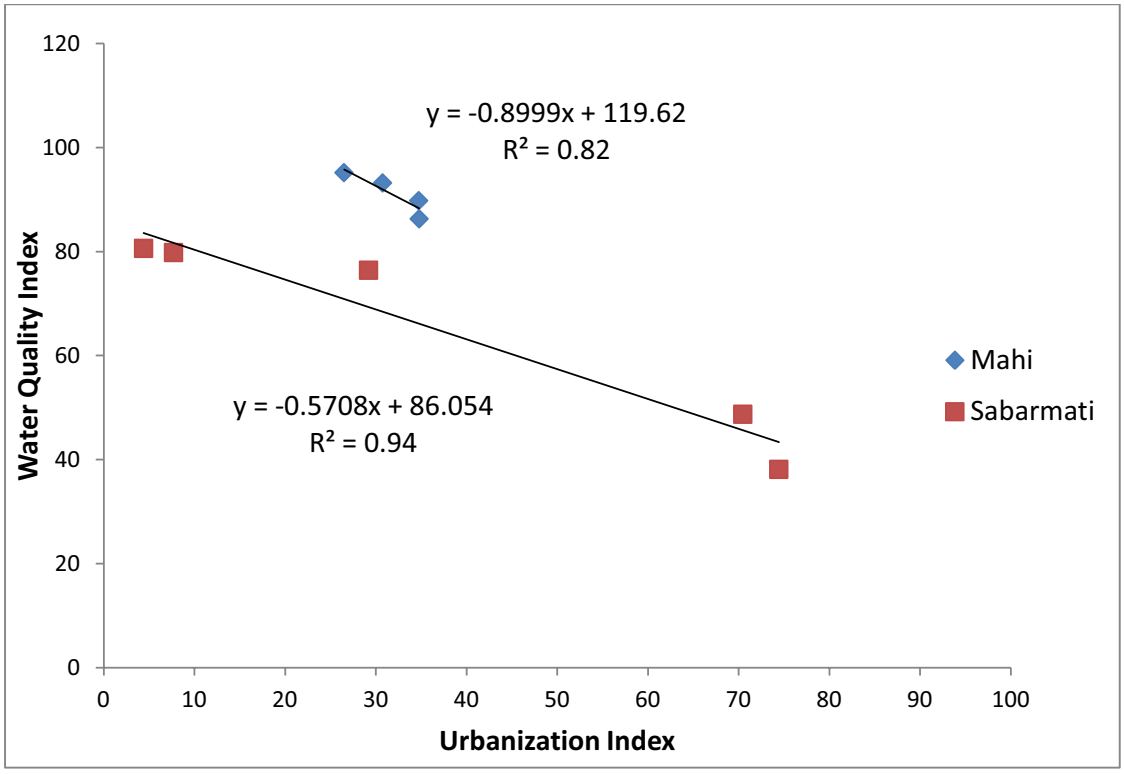

Figure 6.13 WQURM models for Sabarmati river and Mahi river

6.6 Framing hypothesis and adopting the test of statistical significance of the WQURM model applied on Sabarmati river

Regression analysis was carried out between the Water Quality Index and the Urbanization Index obtained for the stations on Sabarmati river. The Urbanization Index is taken as an independent variable and Water Quality Index as a dependent variable. To check the statistical significance of the WQURM model, the test of significance is carried out.

To test H_0: $\beta_1 = 0$ against $\beta_1 \neq 0$ at a significance level $\alpha = 0.05$.

The regression statistics is shown in Table 6.21. The Analysis of Variance (ANOVA) is shown in Table 6.22. The Regression coefficients are shown in Table 6.22.

Using p- value approach:

From the output shown in Table 6.23, p-value = 0.00681 which is less than 0.025.

Hence from above, we reject the null hypothesis that the two variables Water Quality Index and Urbanization Index are unrelated at $\alpha = 0.05$. In other words there is a relationship existing between the two variables.

From the ANOVA Table, significance f – value = 0.0068 which is < 0.025.Therefore, the results are reliable .i.e, statistically significant at 5% level of significance.

Table 6.21 Regression Statistics

Regression Statistics	
Multiple R	0.968084
R Square	0.937187
Adjusted R Square	0.91625
Standard Error	5.753953
Observations	5

Table 6.22 ANOVA

	df	SS	MS	F	Significance F
Regression	1	1481.944	1481.944	44.760	0.0068
Residual	3	99.32394	33.10798		
Total	4	1581.268			

Table 6.23 Regression coefficients

	Coefficients	Standard Error	t Stat	P-value	Lower 95%	Upper 95%	Lower 95.0%	Upper 95.0%
Intercept	86.083	4.1009	20.9909	0.00023	73.032	99.134	73.0324	99.1348
X Variable 1	-0.573	0.0857	-6.6903	0.00681	-0.846	-0.300	-0.8465	-0.3008