Calibration and Validation of QUAL2E model on the Delhi stretch of river Yamuna, India

By

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BACKGROUND

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- **Rivers, especially in developing countries are getting polluted because of increased wasteloads and lack of appropriate water quality management plans.**

- **Although, many pollution abatement efforts have been taken up (GAP, YAP), no systematic and comprehensive effluent and stream regulation norms based on modeling using simulation models have been developed to effectively control the river pollution.**

A simulation model attempts to represent the physical functioning and consequent effects of causative factors (cause-effect) on the prototype system by a computerized algorithm (James and Lee 1971).

- **A simulation models indicate the values of water quality variables given the flow, the quantity and quality of the waste loadings, and the extent of measures designed to reduce waste discharges or to increase the waste assimilation capacity of the receiving river systems (Loucks 1976)**

- **However, the applicability of models for different climate conditions needs to be tested to have accurate prediction by the model.**

- **Thus a model needs to be calibrated and validated before being put into use for accurate water quality simulation.**

- At what stage does calibration and Validation comes in a modeling exercise?

STEPS IN MODELING (Chapra 2003; Somlyody 1989; McCutcheon 1989)

- a) Conceptualization
- b) Formulation of equations
- c) Coding / Programming
- d) Calibration (Confirmation)
- e) Validation (Verification / Corroboration)
- f) Simulation
- g) Sensitivity Analysis
- h) Scenario generation
- i) Post-audit

DATA REQUIRED IN MODELING (McCutcheon 1989)

- Initial Conditions
- Boundary Conditions
- Data for Calibration
- Data for Validation

CALIBRATION

- Calibration is one of the most important steps of modeling studies wherein the exact value of parameters to be used in a model is estimated using trail and error method so as to have accurate prediction by the model.

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CALIBRATION

Calibration is accomplished by adjustment of model coefficient during successive/ iterative model runs, until optimum goodness of fit between predicted and observed data is achieved.

VALIDATION (Verification / Corroboration)

- Validation is the process of verifying the simulation by the model.
- In this only the observed inputs are changed whereas the parameters are not.

Why to calibrate QUAL2E model, especially?

- QUAL2E is basically an indeterminate model.
- Indeterminate model means a model, which yields similar results under various combinations of model parameters.
- For example, if the simulated BOD compares well with the observed BOD under given set of value of model parameters, such as K1 and K3, the same simulation results can be obtained under different combinations of K1 and K3.

- When such indeterminately calibrated models are applied to the treatment and augmentation scenarios, the model results become very sensitive to the indeterminately determined “calibrated” parameters.
- This is because of the fact that such models use particular equations for finding the model parameters.

- These equations may not yield reliable results when applied to rivers different than the one for which they were developed.
- QUAL2E uses the O’Connor and Dobbins (1958) equation.
- This equation may not necessarily be the best to use for every river.

- What can be done to deal with such indeterminate models?

- Measure as many parameters as possible in the field.
- Develop some equations using the observed data for that particular river.
- Use this equation in the model.
- In this study, the original BOD and hydro-geometrical data of the study stretch has been obtained from various agencies (DJB 2005; CPCB 2000,2003,2005,2006).

QUAL2E Simulation Model

WATER QUALITY SIMULATION MODEL

- QUAL 2E (Brown and Barnwell, 1987)

- One dimensional steady state, Numerical model.

- one dimensional advective-dispersive mass transport and reaction equation.

• It can simulate 15 water quality parameters.

GOVERNING EQUATIONS OF QUAL2E

$$\frac{\partial C}{\partial t} = \frac{\partial\left(A_x D_l \dfrac{\partial C}{\partial x}\right)}{A_x \partial x} - \frac{\partial\left(A_x \bar{u} C\right)}{A_x \partial x} \frac{dC}{dt} + \frac{s}{V}$$

Where,

x= distance

t= time

C = concentration

A_x = cross sectional area

D_L =Dispersion coefficient

u = mean velocity

Water Quality Simulation using QUAL2E

- Conceptual Representation of a River System
- Hydraulic Routing of River Flow
- Initial and Boundary Conditions
- Rate constants
- Calibration and Validation
- Simulation under baseline (existing) condition
- WQ simulation under various scenarios

Hydraulic routing of river

- $V = a\,Q^{\,b}$ (3.1 a)
- $h = c\,Q^{d}$ (3.1 b)

Initial and Boundary Conditions

- IC: data specified to define the water quality condition at the beginning of the simulation period (McCutcheon 1989).

  BOD, DO, flow

- Set of data that describe the mass and energy that enters the model domain (subset of the stream segment being simulated).

  point loads and their quality, background flow, and concentration

Rate constants

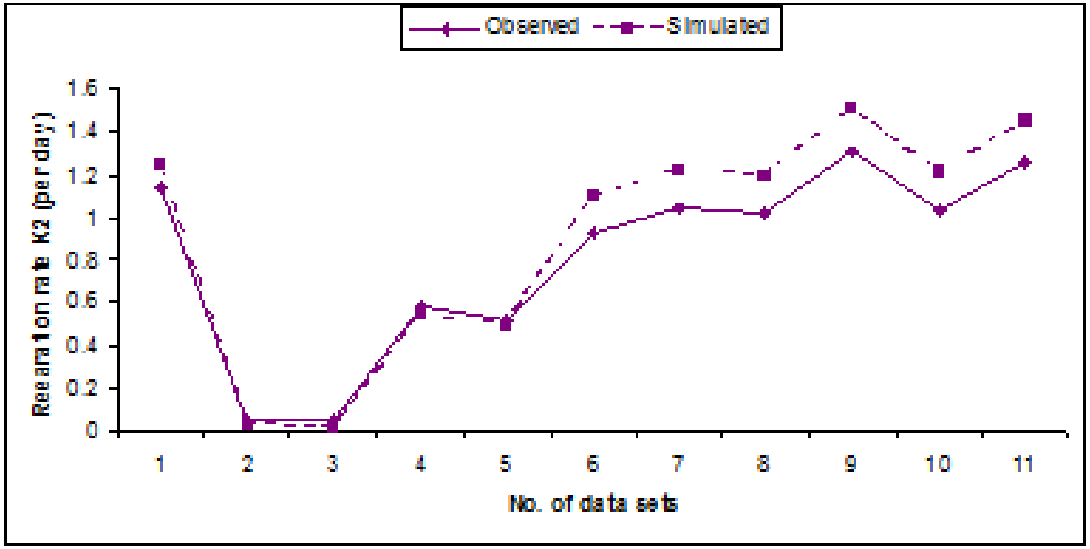
- a) Deoxygenation constant (K1)
- b) Reaeration constant (K2)
- c) BOD settling rate (K3)
- d) Sediment oxygen demand (K4)

- In this study a new equation for Reaeration coefficient K2 was developed using observed data (105 sets) (SPSS 10 was used)

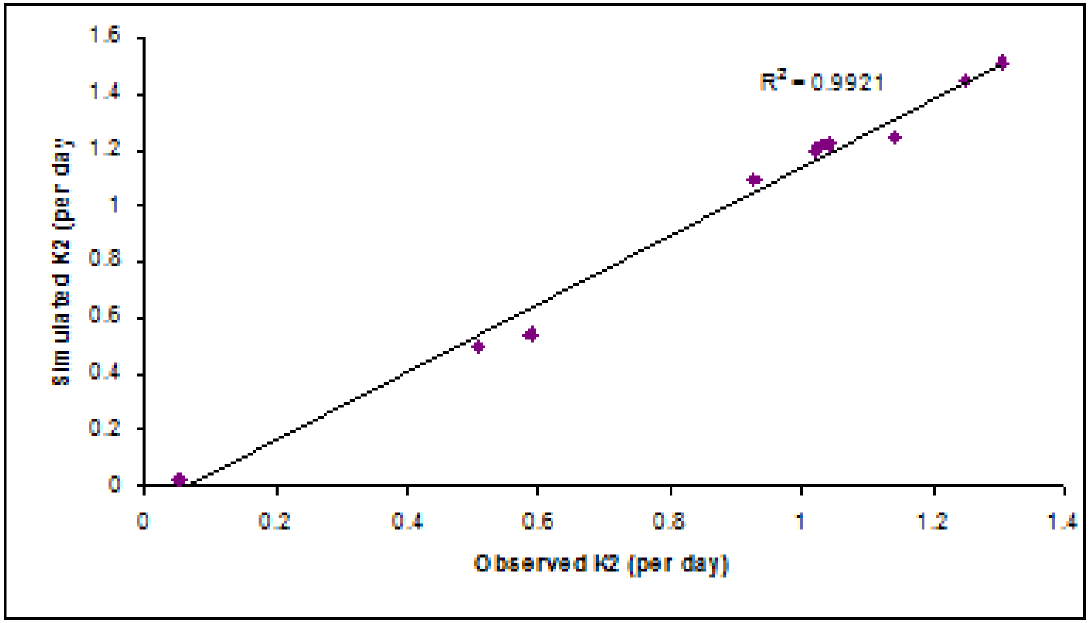
Estimation of rate constants

$$K_1 = \frac{1}{x} \ln \frac{L_0}{L} . V$$

$$K_2 = 4.27 \frac{(V)^{0.47}}{(H)^{2.09}}$$



Profile of observed and simulated K_2



Reaeration rate constant K_2-Measured and Simulated

Comparison with other Reaeration equations

Comparison with earlier K_2 predictive reaeration equation

Investigators	Coefficient of V (α_1)	Exponent of V (β_1)	Exponent of H (β_2)
O'Connor and Dobbins (1958)	3.9	0.5	1.5
Churchill et al. (1962)	5.01	0.969	1.673
Owens et al. (1964)	5.35	0.67	1.85
Langbein and Drum (1967)	5.14	1.0	1.33
Jha et al. (2000)	5.792	0.5	0.25
Present study	4.27	0.47	2.09

MODEL PARAMETERS

RATE CONSTANTS

K1 (Deoxygenation constant)

K2 (Reaeration constant)

K3 (Sediment oxygen demand)

K4 (Settling)

Hydraulic coefficients and Exponents.

$$V = a\,Q^{b}$$

$$H = cQ^{d}$$

$$W = eQ^{f}$$

$$a.c.e = 1$$

$$b + d + f = 1$$

STUDY AREA

- **Delhi stretch of river Yamuna**

River Water Quality Simulation in India

- Bhargava (1983) (S-P equation)- Delhi
- Bhargava (1986) (S-P equation) – Delhi
- Ghosh (1996) (QUAL2E)
- Abbasi et al. (1999) (QUAL2E)
- Priyadarshini and Reddy (2000)
- Dikshit et al. (2000)
- Sharma et al. (2000) (QUAL2E)
- Hussain and Jha (2003) (QUAL2E)
- Gupta et al. (2004)
- Kazmi and Hansen (1997) (MIKE 11) -Yamuna
- Kazmi and Agrawal (2005) (MIKE 11) - Yamuna
- Dhage et al. (2006)
- Paliwal et al. (2007) (QUAL2E) –Delhi
- Sharma and Singh (STREAM ?) - Delhi

Limitations of studies on Delhi stretch

- Probably, only 3-4 studies on water quality modeling (using simulation models) in the Delhi stretch of the river Yamuna. (Bhargawa 1983, 1986; Kazmi and Hansen 1997; Kazmi 2000; Kazmi 2005; Paliwal et al. 2007).

- Although, these have been contributed to the existing knowledge, only 3-5 reaches only were considered. (between Wazirabad barrage and Okhla barrage).- (otherwise it should be 16)

DESCRIPTION OF THE STUDY AREA

- Delhi Stretch of River Yamuna.

- 22 Kms stretch from Wazirabad barrage to Okhla barrage.

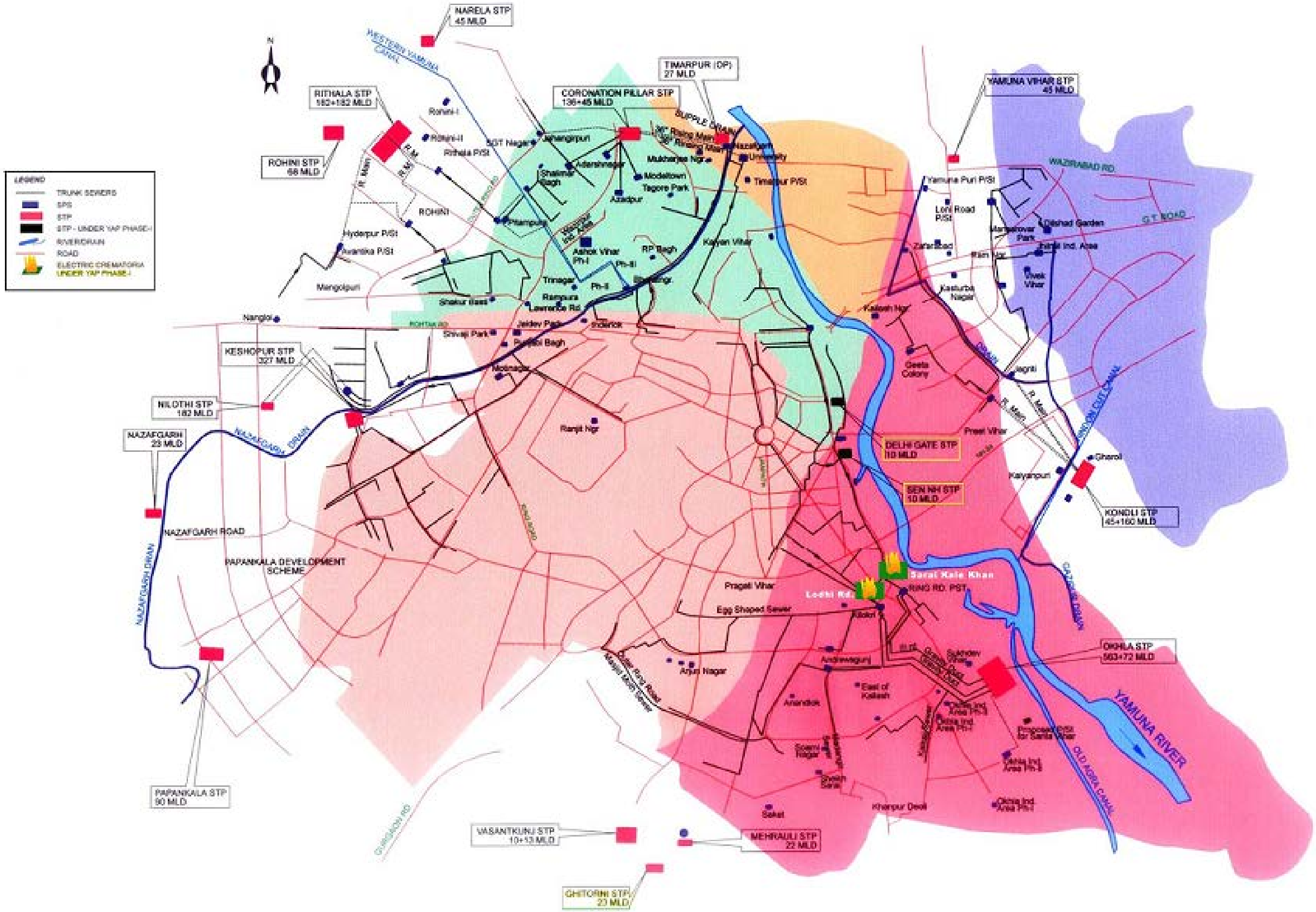
- All 15 drains discharging into this stretch considered.

- This 2% long stretch (22 kms) contributes 80% of the total pollution load in the whole river. (total length of 1374 kms)

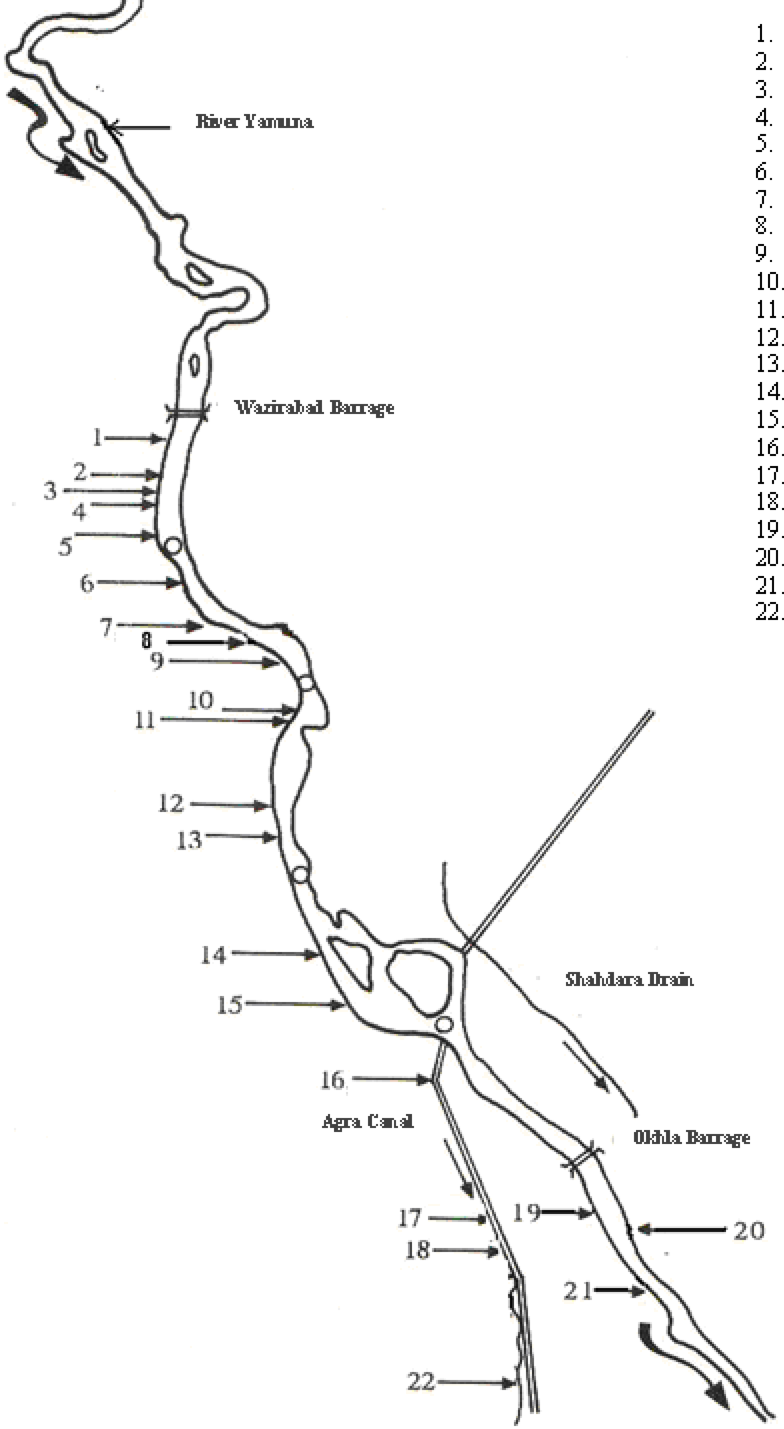
SCOPE/LIMITATIONS OF THE STUDY

- Stretch Wazirabad barrage and Okhla barrage having fifteen drains (point sources) only has been considered.
- Only point sources have been considered.
- Only domestic effluents (and not industrial effluents) have been considered.
- Only BOD and DO have been considered because of lack of data of other parameters for all 16 reaches in Delhi.

SEWERAGE NETWORK OF DELHI CITY



(Source: Yamuna Action Plan Website)



1. Najafgarh Drain
2. Magazine Road
3. Sweeper Colony Drain
4. Kyber Pass Drain
5. Metcalf House Drain
6. Morigate Drain
7. Tonga Stand Drain
8. Moat Drain
9. Civil Mill Drain
10. Delhi Gate Drain
11. Sen Nursing Home Drain
12. Drain No-12A
13. Drain No-14A
14. Barapulla Drain
15. Maharani Bagh Drain
16. Kalkaji Drain
17. Sarita Vihar Bridge Drain
18. Sarita Vihar Drain
19. LPG Bottling Plant Drain
20. Shahdara Drain
21. Tuglakabad Drain
22. Tehkhand Drain

Total BOD load contribution to the river Yamuna and Agra Canal in the Delhi stretch.

Year	BOD load (tones/day)	Year	BOD load (tones/day)
1982	117.3	1995	178.4
1983	132.3	1996	216.19
1984	119.4	1997	206.85
1985	123.2	1998	211.0
1986	165.1	1999	192.94
1987	148.5	2000	240.0
1988	159.6	2002	231.2
1989	163.4	2003	244.73
1990	167.5	2004	240.37
1991	179.8	2005	255.75

Water Quality Simulation

Conceptual Representation of a River System

- 16 reaches system (uniform hydraulic characteristics)

- Each reach sub divided into equal computational element of 0.3 km.

- Headwater element; Standard element; Element just upstream of a junction; Junction element; Last element in system; Input element; and Withdrawal element.

Details of stream reach configuration

Reac h No.	Name of the reach	Reach chainage		Total element s
		Begin (km)	End (km)	
1	Wazirabad Barrage to Najafgarh Drain	0.0	0.3	1
2	Najafgarh Drain to Magazine Road Drain	0.3	1.5	4
3	Magazine Road Drain to Sweeper Colony	1.5	1.8	1
4	Sweeper Colony Drain to Khyber Pass Drain	1.8	3.6	6
5	Khyber Pass Drain to Metcalf House Drain	3.6	4.2	2
6	Metcalf House Drain to Morigate Drain	4.2	5.7	5
7	Morigate Drain to Tonga Stand Drain	5.7	6.3	2
8	Tonga Stand Drain to Moat Drain	6.3	6.6	1
9	Moat Drain to Civil Mill Drain	6.6	7.2	2
10	Civil Mill Drain to Delhi Gate Drain	7.2	9.0	6
11	Delhi Gate Drain to Sen Nursing Home Drain	9.0	12.0	10
12	Sen Nursing Home Drain to Drain No.12A	12.0	13.5	5
13	Drain No. 12A to Drain No. 14A	13.5	14.1	2
14	Drain No. 14A to Barapulla Drain	14.1	15.6	5
15	Barapulla Drain to Maharani Bagh Drain	15.6	18.0	8
16	Maharani Bagh drain to Okhla Barrage	18.0	21.9	13

Wazirabad Barrage
0.0 Km
Qin = 1.5 m3/sec, BOD = 3 mg/l, DO = 5.5 mg/l
Najafgarh Drain (D1)
(20.68)
0.3 Km
Magazine Road Drain (D2)
(0.07)
1.5 Km
Sweeper Colony Drain (D3)
(0.13)
1.8 Km
Khyber Pass Drain (D4)
(0.13)
3.6 Km
Metcalf House Drain (D5)
(0.09)
4.2 Km
Qudsia Bagh Drain (D6)
(0.39)
5.7 Km
Tonga Stand Drain (D7)
(0.09)
6.3 Km
Moat Drain (D8)
(0.001)
6.6 Km
Civil Mill Drain (D9)
(0.52)
7.2 Km
Delhi Gate Drain (D10)
(0.56)
9.0 Km
S.N. Home Drain (D11)
(1.01)
12.0 Km
Drain No-12A (D12)
(0.04)
13.5 Km
Drain No-14 (D13)
(0.37)
14.1 Km
Barapulla Drain (D14A)
(1.35)
15.6 Km
Maharani Bagh Drain (D15)
(0.74)
Hindon cut
(30)
Agra Canal
18.0 Km
Qout=55.671 m3/sec, BOD=17.8, DO=1.4 mg/l
Okhla Barrage
22.00 Km

DATA REQUIREMENT FOR WQSM

i. Water quality data of various reaches and drains of the river

ii. Hydraulic (flow, velocity) and geometrical data (width, depth) of the 22 Km river stretch

iii. Elevation, latitude, longitude of the basin

iv. Rate constants

Geometric and hydraulic data of the Delhi stretch of the river Yamuna

Name of reach	Length (Km)	Width (m)	Depth (m)	Flow (Q in m^3/sec.)	Velocity (m/sec.)
R1	0.3	60	0.4	1.0	0.032
R2	1.2	83	1.1	22.97	0.25
R3	0.3	110	1.1	23.027	0.19
R4	1.8	110	1.1	23.131	0.21
R5	0.6	110	1.3	23.245	0.178
R6	1.5	100	1.3	24.187	0.186
R7	0.6	130	1.4	24.682	0.13
R8	0.3	120	1.3	24.759	0.158
R9	0.6	125	1.2	24.7591	0.165
R10	1.8	185	1.2	25.436	0.13
R11	3.0	170	1.2	27.335	0.14
R12	1.5	115	6.0	28.329	0.1
R13	0.6	120	1.8	28.519	0.132
R14	1.5	130	2.1	28.709	0.105
R15	2.4	272	3.0	30.585	0.075
R16	3.9	200	2.5	30.80	0.117

Reach No.	Velocity-discharge relation	Depth-discharge relation
1	$V = 0.0396Q^{0.5138}$	$h = 0.4411Q^{0.3374}$
2	$V = 0.0758Q^{0.3961}$	$h = 0.2852Q^{0.4215}$
3	$V = 0.0584Q^{0.3714}$	$h = 0.3096Q^{0.4083}$
4	$V = 0.2108Q^{0.029}$	$h = 0.1085Q^{0.7411}$
5	$V = 0.232Q^{0.0686}$	$h = 0.0996Q^{0.778}$
6	$V = 0.3081Q^{0.1571}$	$h = 0.0736Q^{0.6727}$
7	$V = 0.2215Q^{0.0622}$	$h = 0.0782Q^{0.8538}$
8	$V = 0.2475Q^{0.0931}$	$h = 0.0679Q^{0.796}$
9	$V = 0.25Q^{0.0955}$	$h = 0.06Q^{0.7308}$
10	$V = 0.0169Q^{0.6028}$	$h = 0.4271Q^{0.3146}$
11	$V = 0.4554Q^{0.3677}$	$h = 0.0498Q^{0.6146}$
12	$V = 0.0321Q^{0.1096}$	$h = 03732Q^{0.3784}$
13	$V = 0.0396Q^{0.5138}$	$h = 0.4411Q^{0.3374}$
14	$V = 0.0396Q^{0.5138}$	$h = 0.4411Q^{0.3374}$
15	$V = 0.0396Q^{0.5138}$	$h = 0.4411Q^{0.3374}$
16	$V = 0.0396Q^{0.5138}$	$h = 0.4411Q^{0.3374}$

Values of hydraulic parameters of the stream

Reach No.	Hydraulic Coefficients/Exponents for the Delhi reach			
	Velocity discharge relationship		Depth discharge relationship	
	coefficient	exponent	coefficient	Exponent
1	0.0396	0.5138	0.4411	0.3374
2	0.0758	0.3961	0.2852	0.4215
3	0.0584	0.3714	0.3096	0.4083
4	0.2108	0.029	0.1085	0.4411
5	0.232	0.0686	0.0996	0.378
6	0.3081	0.1571	0.07362	0.6727
7	0.2215	0.0622	0.0782	0.8538
8	0.2475	0.0931	0.0679	0.796
9	0.25	0.0955	0.06	0.7308
10	0.0169	0.6028	0.4271	0.3146
11	0.4554	0.3677	0.0498	0.6146
12	0.0321	0.1096	0.3732	0.3784
13	0.0396	0.5138	0.4411	0.3374
14	0.0396	0.5138	0.4411	0.3374
15	0.0396	0.5138	0.4411	0.3374
16	0.0396	0.5138	0.4411	0.3374

Values of reaction coefficients

Reach No.	BOD decay (K_1 per day)	BOD settling (K_3 per day)	SOD rate (K_4 per day)	Reaeration coefficient (K_2 per day)
1	0.31	0.9	0.5	5.75
2	0.42	0.9	0.5	1.824
3	0.23	0.9	0.5	1.603
4	0.43	0.9	0.5	1.68
5	0.55	0.9	0.5	1.0967
6	0.31	0.9	0.5	1.2
7	0.33	0.9	0.5	0.81
8	0.45	0.9	0.5	1.037
9	0.44	0.9	0.5	1.25
10	0.32	0.9	0.5	1.12
11	0.314	0.9	0.5	1.034
12	0.295	0.9	0.5	0.0342
13	0.39	0.9	0.5	0.4826
14	0.26	0.9	0.5	0.314
15	0.24	0.9	0.5	0.272
16	0.38	0.9	0.5	0.23

- It has been reported in the literature (Bhargawa 1983; Kazmi and Agrawal 2005) that in the Delhi stretch of the river Yamuna, BOD removal takes place mainly because of settling of organic matter.
- Thus, the value of K3, the rate of BOD removal by sedimentation/settling has been adopted as 0.9 per day (Kazmi and Agrawal 2005).
- Benthic oxygen demand (K4), does not affect the Delhi stretch, this value has been adopted as 0.5 per day from the same literature.

CALIBRATION (March 15-June 15, 2002)

- The survey data of the March 15-June 15, 2002 period (Mean monthly) were used for the calibration.

Point loads and withdrawals-Calibration

Name of drain	Flow (m^3/sec)	BOD (mg/l)	DO (mg/l)	Temperature (°C)	Percentage treatment
Najafgarh drain	21.97	58	0.0	28	0.0
Magazine Road drain	0.057	448	0.0	28	0.0
Sweeper Colony drain	0.104	286	0.0	28	0.0
Khyber Pass drain	0.114	92	0.0	28	0.0
Metcalf House drain	0.942	84	0.0	28	0.0
Mori Gate drain	0.495	174	0.0	28	0.0
Tonga Stand drain	0.077	84	0.0	28	0.0
Moat drain	0.0001	78	0.0	28	0.0
Civil Mill drain	0.677	134	0.0	28	0.0
Delhi Gate drain	1.899	88	0.0	28	0.0
Sen Nursing Home drain	0.994	74	0.0	31	0.0
Drain No. 12A	0.19	92	0.0	31	0.0
Drain No. 14	0.19	170	0.0	31	0.0
Barapulla drain	1.871	92	0.0	32	0.0
Maharani Bagh drain	0.224+28.00*	46	0.0	32	0.0

* - Flow through Hindon Cut

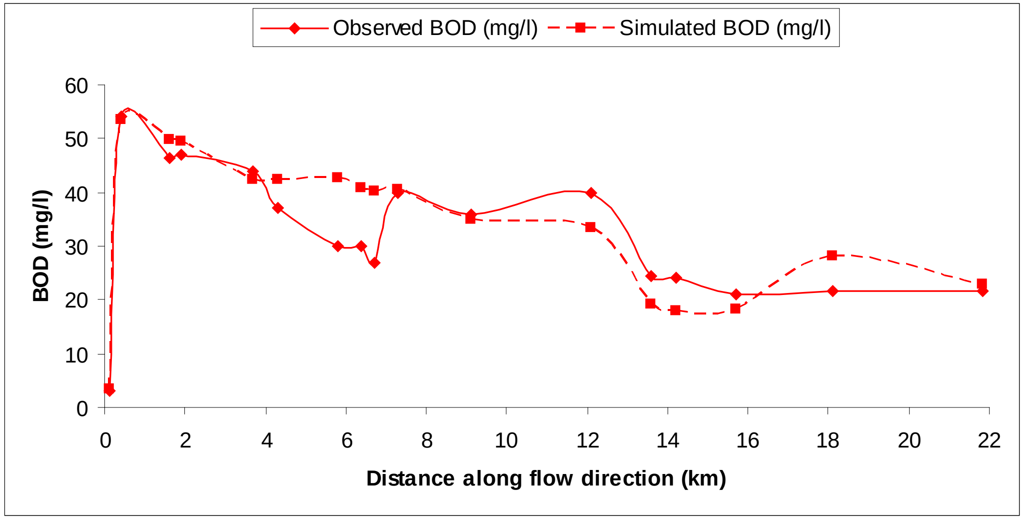


Fig 4.4a Calibration-Profiles of observed and simulated BOD

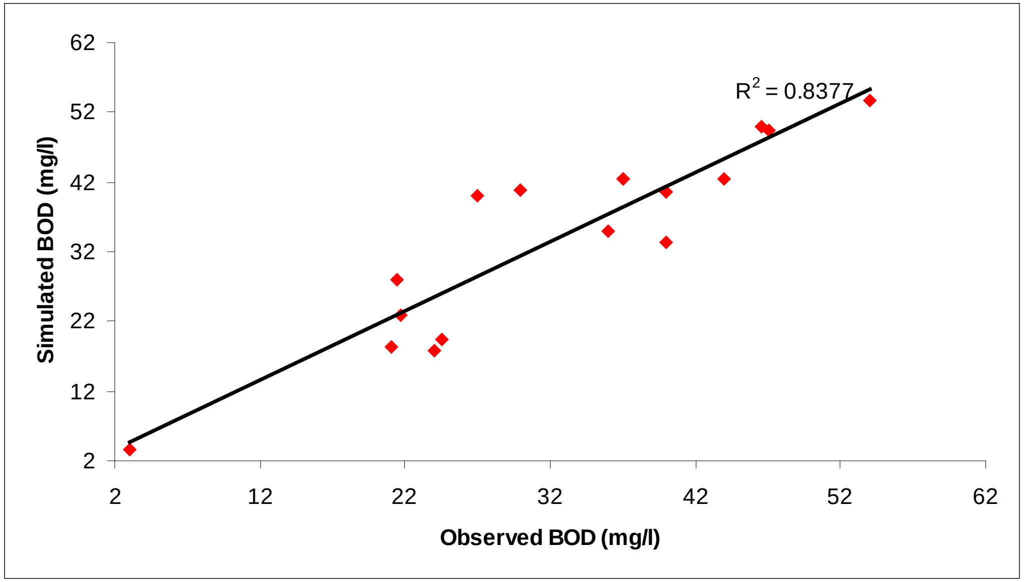


Fig 4.4b Calibration-Correlation between observed and simulated BOD

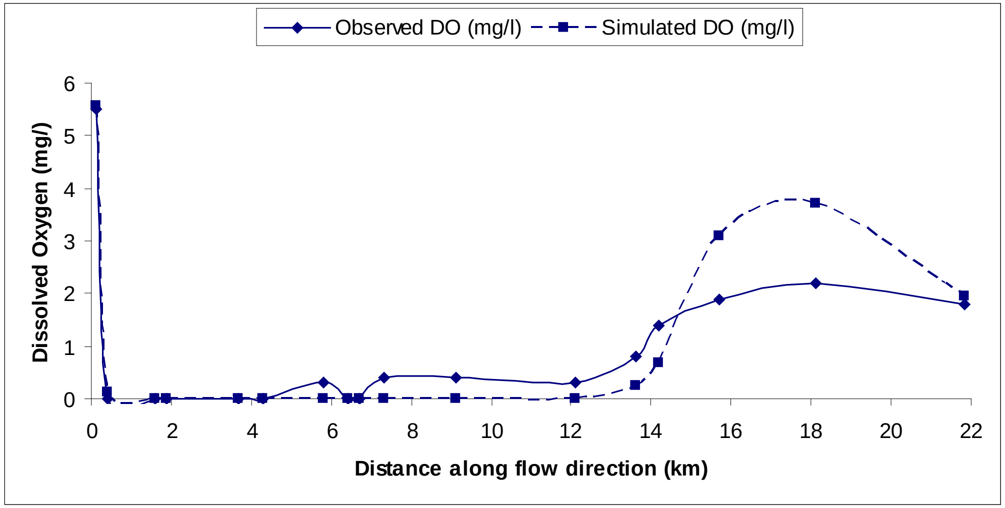


Fig 4.5a Calibration-Profile of observed and simulated DO

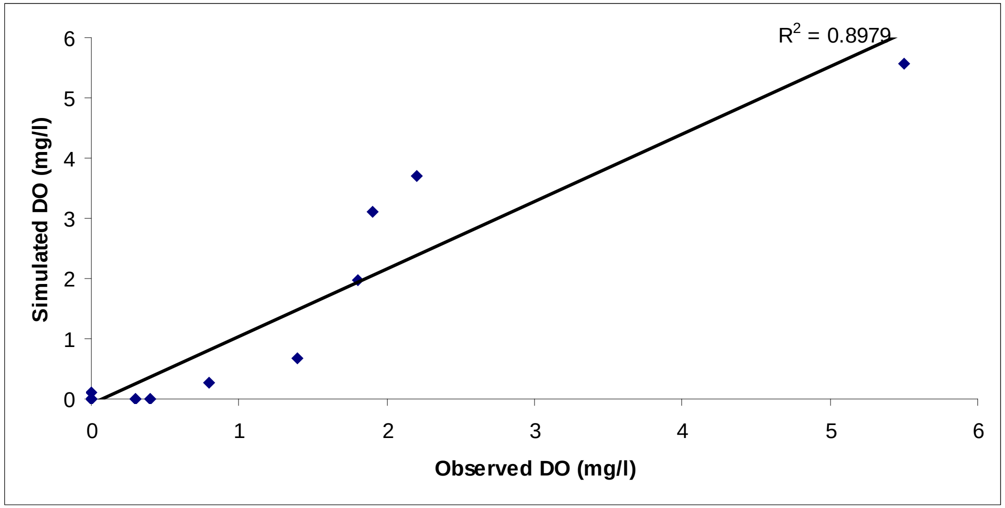


Fig 4.5b Calibration-Correlation between observed and simulated DO

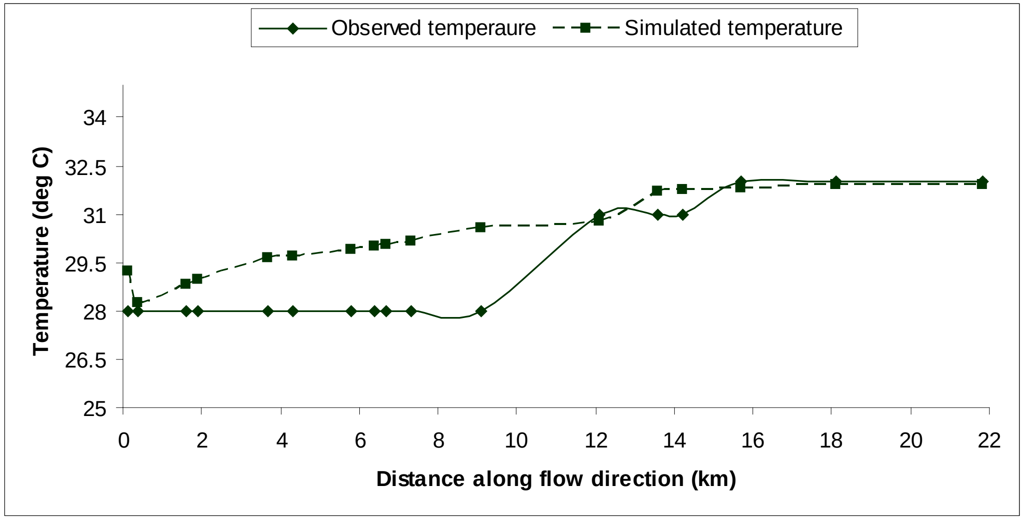


Fig 4.6a Calibration-Profile of observed and simulated temperature

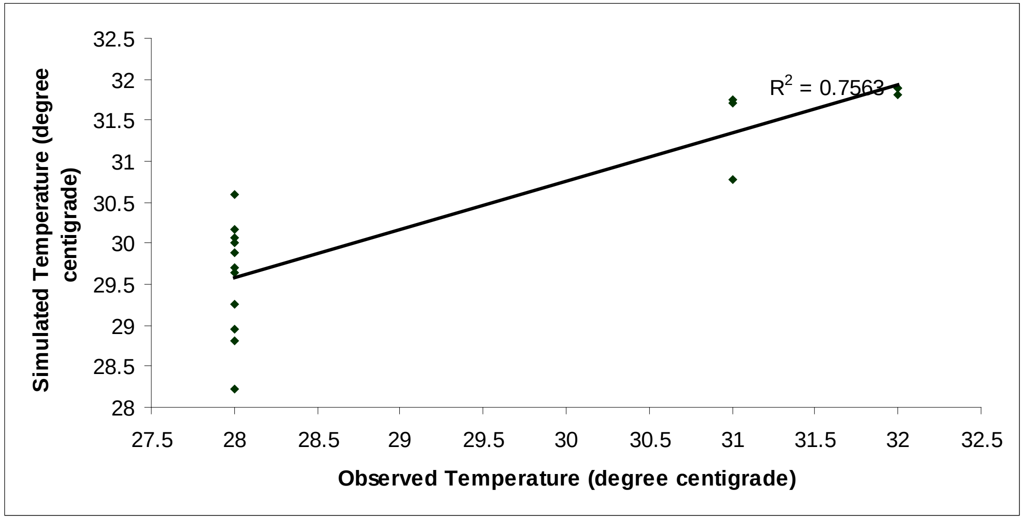


Fig 4.6b Calibration-Correlation between observed and simulated temperature

VALIDATION (Feb 2003)

Table 4.10 Point load and withdrawals for validation

Name of drain	Flow (m^3/sec)	BOD (mg/l)	DO (mg/l)	Temperature (C)	Percentage treatment
Najafgarh drain	25.709	40	0.0	28	0.0
Magazine Road drain	0.035	220	0.0	28	0.0
Sweeper Colony drain	0.053	180	0.0	28	0.0
Khber Pass drain	0.15	100	0.0	28	0.0
Metcalf House drain	0.287	60	0.0	28	0.0
Mori Gate drain	0.387	60	0.0	28	0.0
Tonga Stand drain	0.143	40	0.0	28	0.0
Moat drain	0.058	50	0.0	28	0.0
Civil Mill drain	0.557	190	0.0	28	0.0
Delhi Gate drain	1.328	100	0.0	28	0.0
Sen Nursing Home drain	1.765	300	0.0	31	0.0
Drain No. 12Ar	0.044	60	0.0	31	0.0
Drain No. 14	0.34	40	0.0	31	0.0
Barapulla drain	0.541	60	0.0	32	0.0
Maharani Bagh drain	0.176+28.00*	40	1.5	32	0.0

*- Flow through Hindon Cut Canal

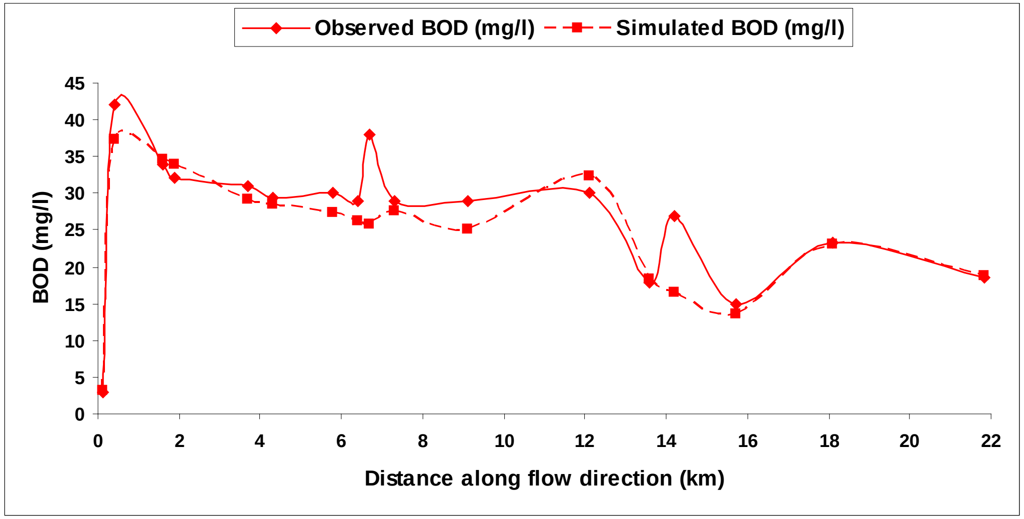


Fig 4.7a Validation–Profile of observed and simulated BOD

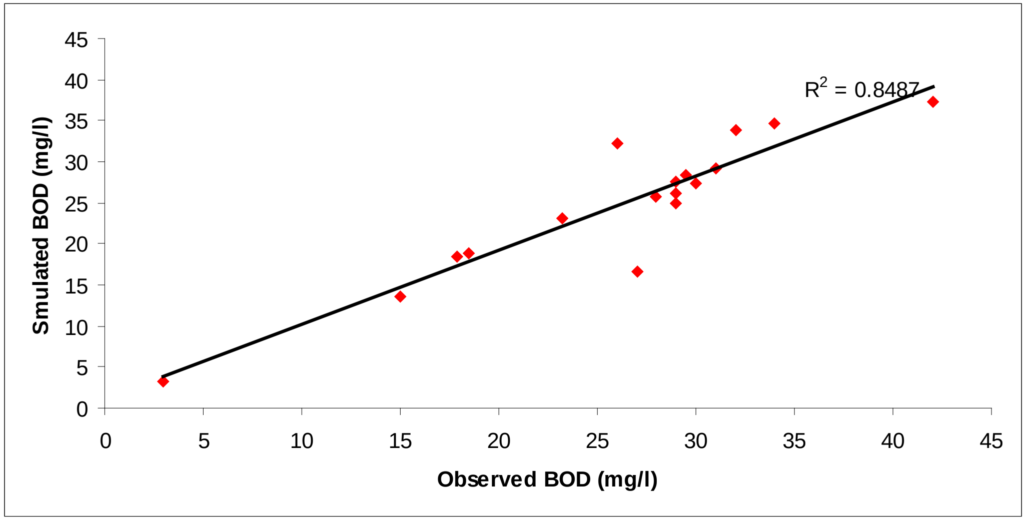


Fig 4.7b Validation–Correlation between observed vs. simulated BOD

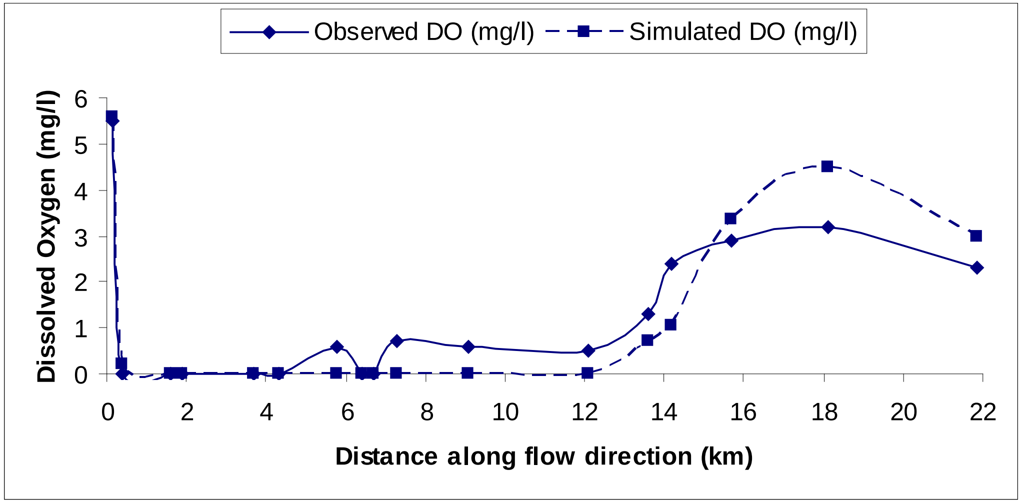


Fig 4.8a Validation–Profile of observed and simulated DO

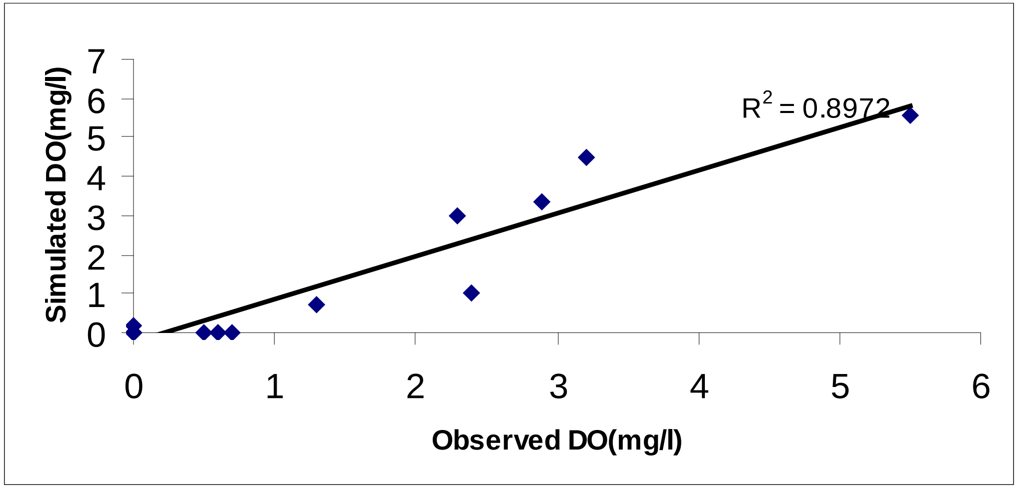


Fig 4.8b Validation–Correlation between observed vs. simulated DO

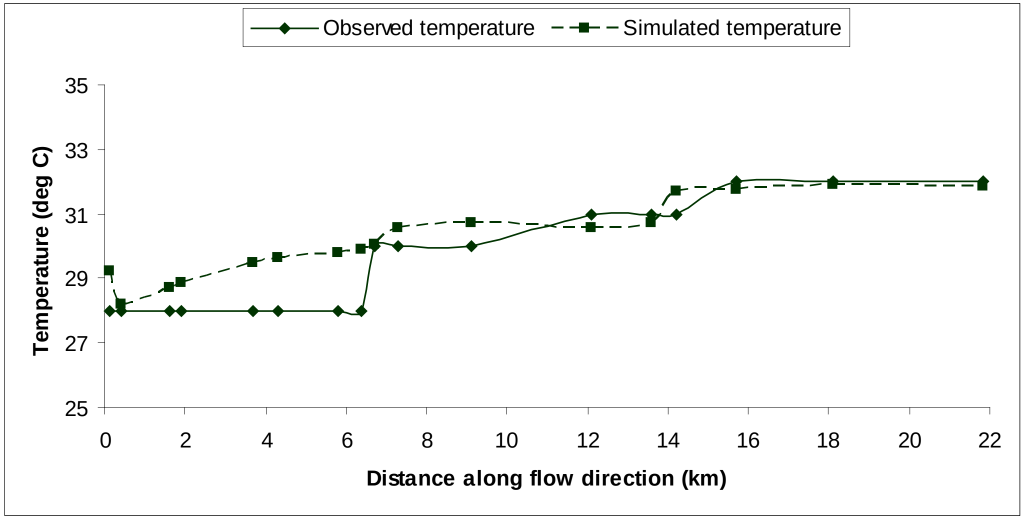


Fig 4.9a Validation–Profile of observed and simulated temperature

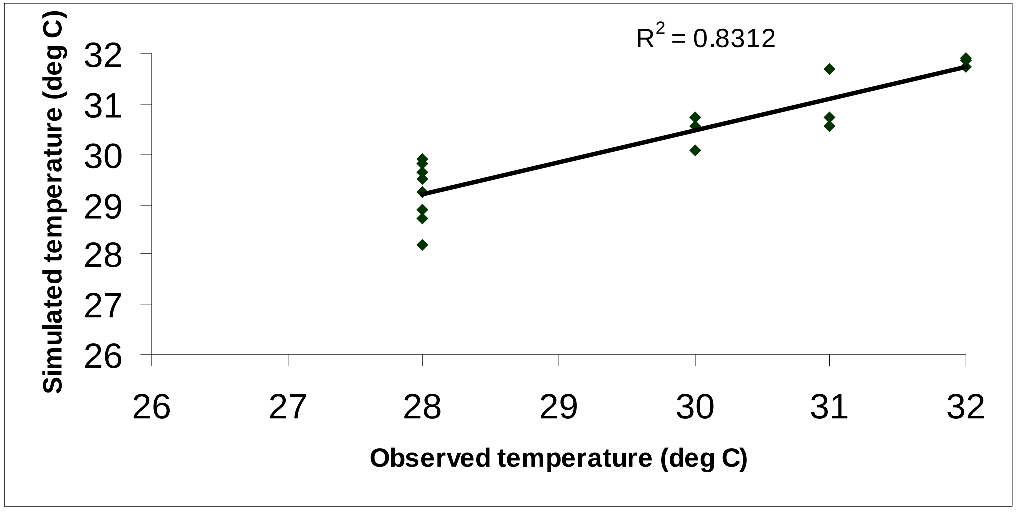


Fig 4.9b Validation–Correlation between observed and simulated temperature

Index of Agreement (Nunnari 2004)

$$\mathrm{IOA} = 1 - \frac{\sum_{i=1}^{N} (P_i - O_i)^2}{\sum_{i=1}^{N} \left(\left| P_i - \overline{O_i} \right| + \left| O_i - \overline{O} \right| \right)}$$

where,

P_i = predicted value of output variable

O_i = Observed value of variable

$\overline{P}$ = Average value of predicted output

$\overline{O}$ = Average value of observed variable

Summary of performance indices

Parameters	Calibration		Validation	
	Coefficient of correlation	Index of agreement	Coefficient of Correlation	Index of agreement
BOD	0.8377	0.8428	0.8487	0.7123
DO	0.8979	0.9761	0.8972	0.9544
Temperature	0.7463	0.818	0.8312	0.9352

Water quality simulation under baseline condition

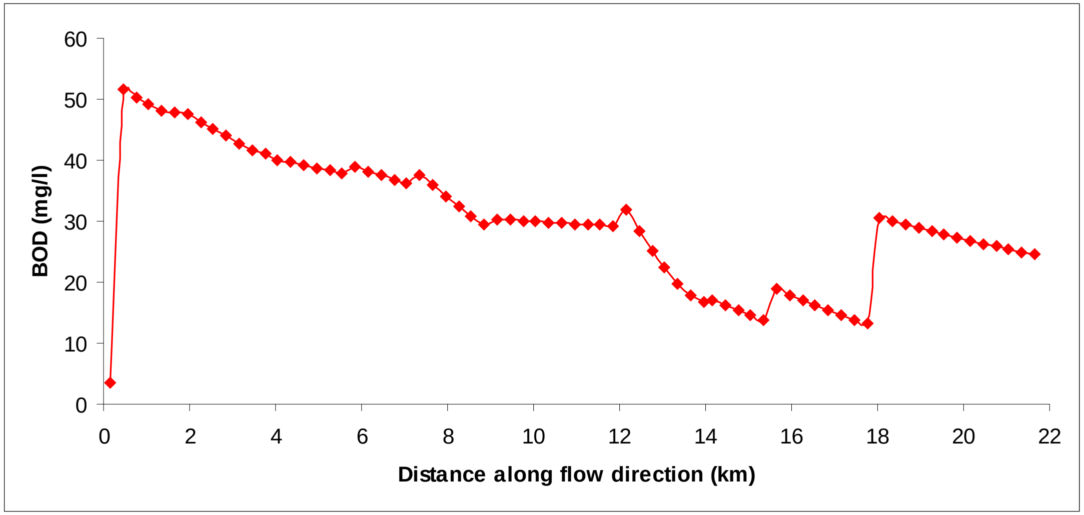


Fig 4.10a Variation of BOD under baseline condition

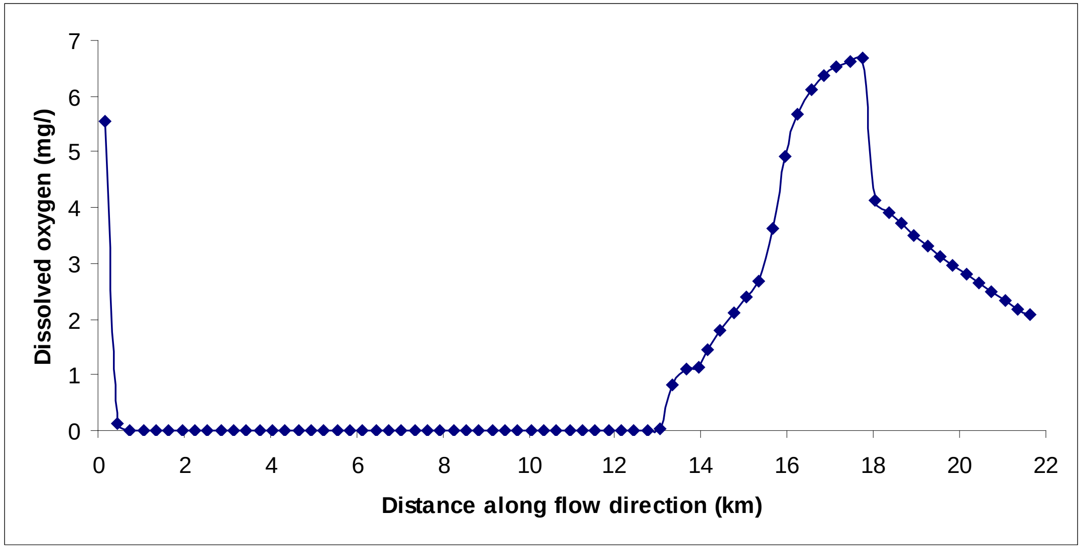


Fig 4.10b Variation of DO under baseline condition

Water quality under baseline conditions

Reach No.	BOD Range (mg/l)	DO Range (mg/l)	Reach No.	BOD Range (mg/l)	DO Range (mg/l)
R-1	3.45	5.56	R-9	36.15-36.76	0.0-0.0
R-2	48.12-51.51	0.0-0.14	R-10	29.45-37.7	0.0-0.0
R-3	47.89	0.0-0.0	R-11	29.32-30.29	0.0-0.0
R-4	41.65-47.54	0.0-0.0	R-12	19.8-31.95	0.0-0.83
R-5	40.12-41.07	0.0-0.0	R-13	16.68-17.96	1.09-1.15
R-6	37.95-39.63	0.0-0.0	R-14	13.84-17.04	1.45-2.69
R-7	38.06-38.87	0.0-0.0	R-15	13.28-18.83	3.63-6.67
R-8	37.47	0.0-0.0	R-16	24.58-30.41	2.07-4.13

Water quality management scenarios as applied to the Delhi stretch

S. No.	Description	Case A (Existing)	Case B	Case C
1	Absence of Pollution abatement measures	Baseline	Diversion of Najafgarh Drain and no treatment to other drains.	Just diversion of the fourteen drains other than the Najafgarh Drain and no treatment to the Najafgarh Drain.
2	Wastewater treatment	PT, ST, TT, AT	PT, ST, TT, AT	PT, ST, TT, AT
3	Flow augmentation	S, R	S, R	S, R
4	Wastewater treatment plus flow augmentation (S)	(PT+S) (ST+S) (TT+S) (AT+S)	- - - -	- - - -
5	Wastewater treatment plus flow augmentation (R)	(PT+R) (ST+R) (TT+R) (AT+R)	- - - -	(PT+R) (ST+R) - -
	Total	19 Nos.	07 Nos.	09 Nos.

Point loads and withdrawals-Case A

Name of drain	Flow (m^3/sec)	BOD (mg/l)	DO (mg/l)	Temperature (C)	Percentage treatment
Najafgarh Drain	20.68	56	0.0	28	0.0
Magazine Road Drain	0.07	333	0.0	28	0.0
Sweeper Colony Drain	0.13	236	0.0	28	0.0
Khber Pass Drain	0.13	136	0.0	28	0.0
Metcalf House Drain	0.09	73	0.2	28	0.0
Mori Gate Drain	0.39	134	0.2	28	0.0
Tonga Stand Drain	0.09	96	0.4	28	0.0
Moat Drain	0.001	62	0.3	28	0.0
Civil Mill Drain	0.52	171	0.0	28	0.0
Delhi Gate Drain	0.56	103	0.0	28	0.0
Sen Nursing Home Drain	1.01	183	0.0	31	0.0
Drain No. 12A	0.04	105	0.2	31	0.0
Drain No. 14A	0.37	116	0.3	31	0.0
Barapulla Drain	1.35	135	0.0	32	0.0
Maharani Bagh Drain	0.74+28.0*	48	1.5	32	0.0

*-Flow through Hindon Cut

Characteristics of dischargers

Drain No.	Name of drain	Milestone from Wazirabad barrage (km)	Average flow (cumecs)	BOD (mg/l)	BOD load (kg/day)
D1	Najafgarh Drain	0.3	20.68	56	100058
D2	Magazine Road Drain	1.5	0.07	333	2014
D3	Sweeper Colony Drain	1.8	0.13	236	2651
D4	Khber Pass Drain	3.6	0.13	136	1528
D5	Metcalf House Drain	4.2	0.09	73	568
D6	Mori Gate Drain	5.7	0.39	134	4515
D7	Tonga Stand Drain	6.3	0.09	96	746
D8	Moat Drain	6.6	0.001	62	5.36
D9	Civil Mill Drain	7.2	0.52	171	7683
D10	Delhi Gate Drain	9.0	0.56	103	4984
D11	Sen Nursing Home Drain	12.0	1.01	183	15969.3
D12	Drain No. 12A	13.5	0.04	105	363
D13	Drain No. 14A	14.1	0.37	116	3708.29
D14	Barapulla Drain	15.6	1.35	135	15746.4
D15	Maharani Bagh Drain	18.0	0.74	48	3515.48
			28.4526		164055.83

RESULTS OF WATER QUALITY SIMULATION UNDER SCENARIOS

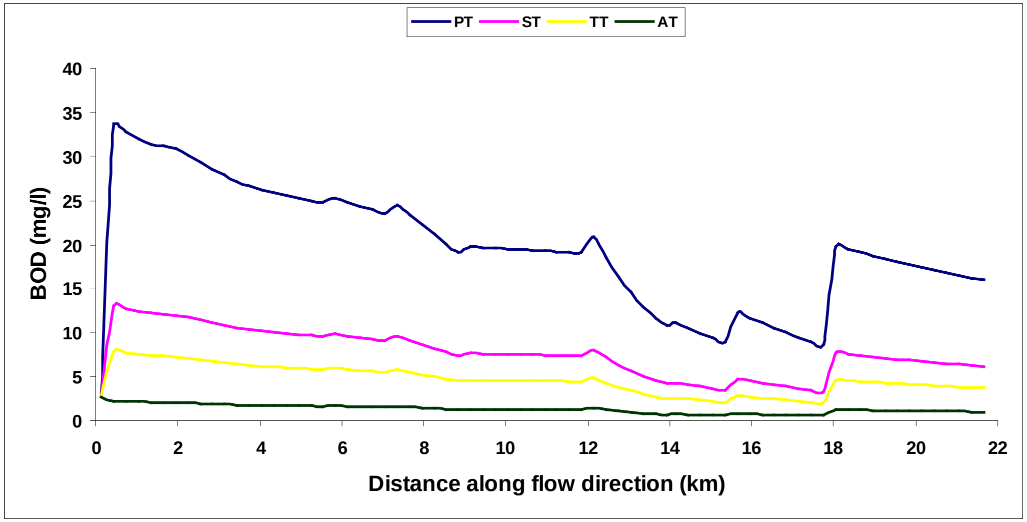


Fig. 5.1a Variation of BOD with varying treatment levels (Case A)

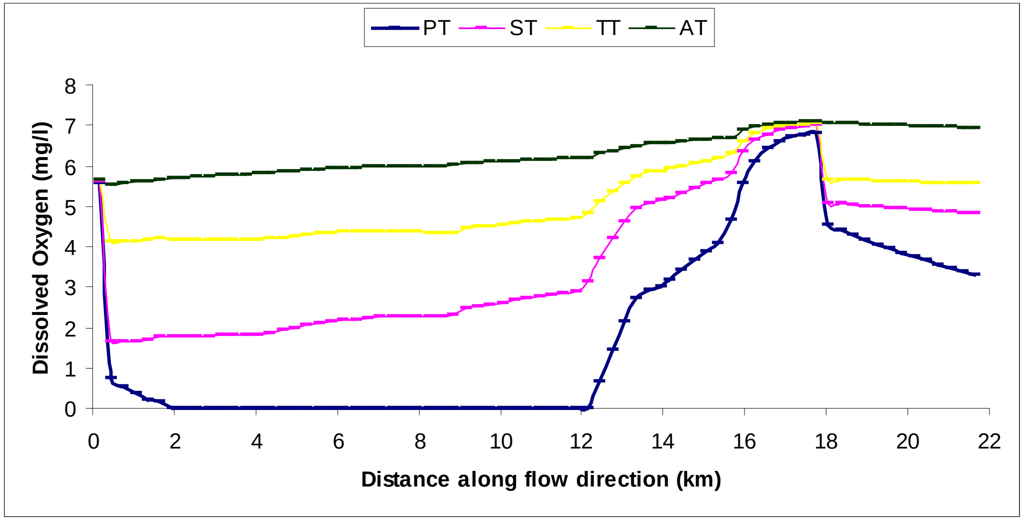


Fig. 5.1b Variation of DO with varying treatment levels (Case A)

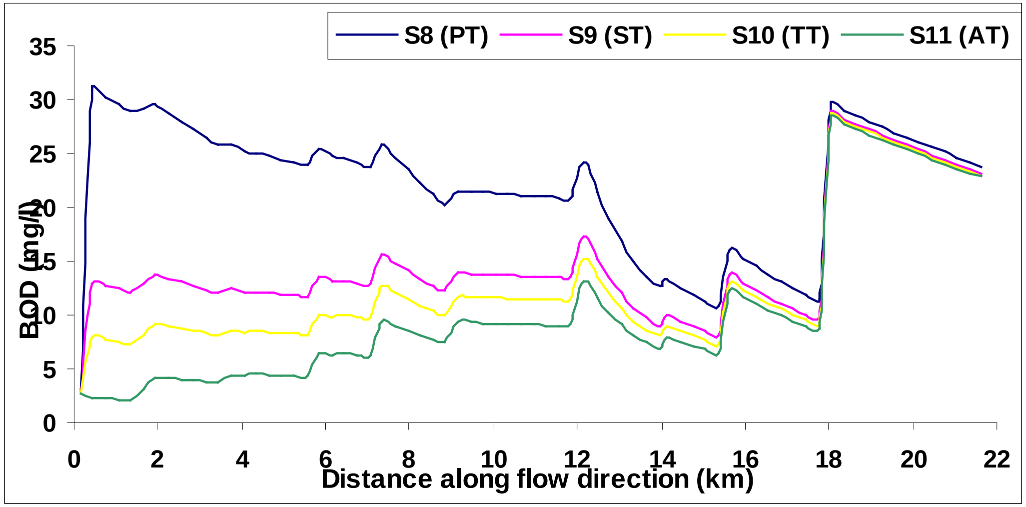


Fig 5.3a Variation of BOD with varying treatment to Najafgarh drain

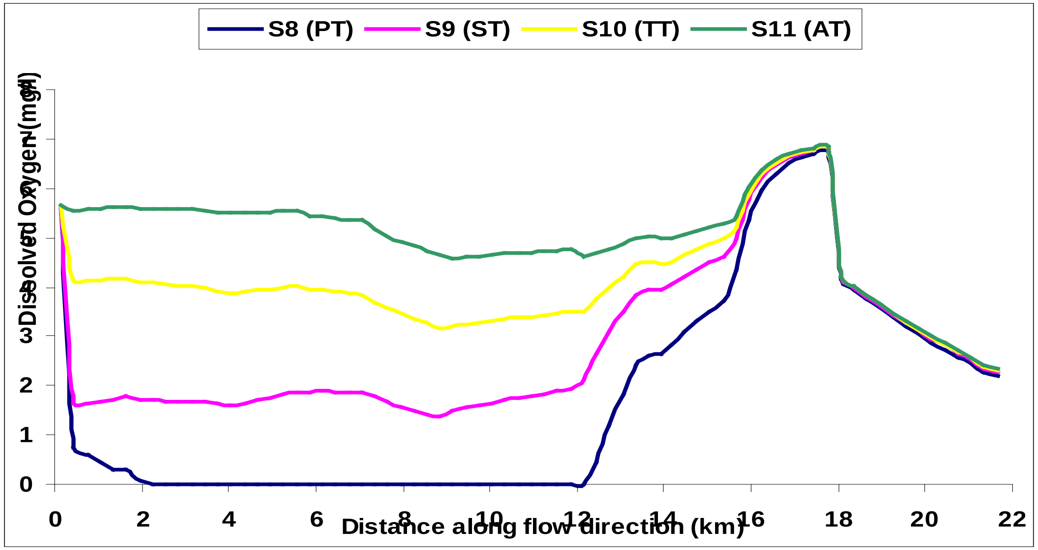


Fig 5.3b Variation of DO with varying treatment to Najafgarh drain

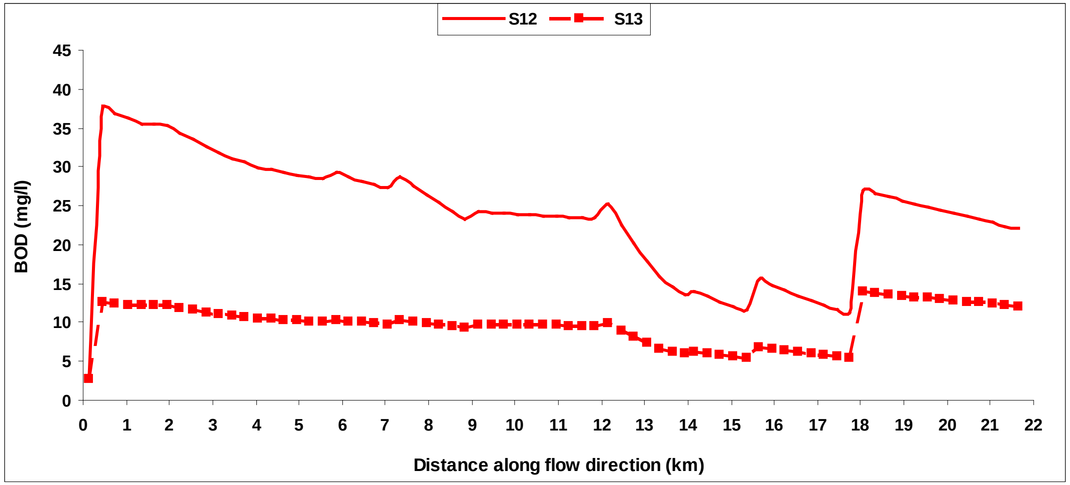


Fig 5.4a Variation of BOD with varying flow augmentation (Case A)

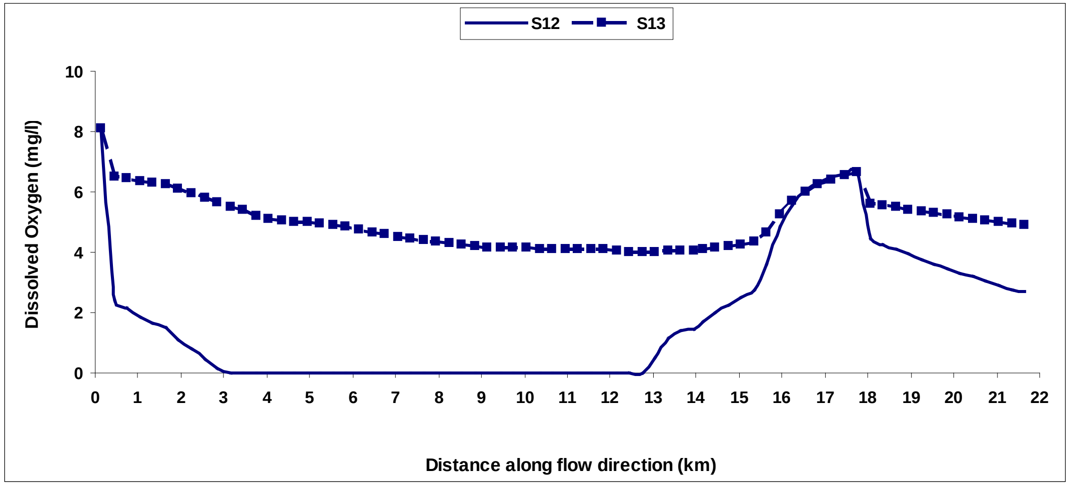


Fig 5.4b Variation of DO with varying Flow augmentation (Case A)

CONCLUSIONS

- The presentation has highlighted the importance of calibration and validation in a modeling study.
- It has attempted to give an insight into the methodology for calibration and validation.
- It has attempted calibration of QUAL2E model for Delhi stretch of river.
-
- It has attempted to shed some myths, the beginners / students / fresh researchers have, about modeling.

It has offered some caveats, the present day engineers/decision makers become enamored with software /newly discovered tools without realizing their limitations.

- Lastly, it has emphasized the need for good quality/quantity data, technical expertise, research facility and academia-industry interaction, interdisciplinary approach, if mathematical models are to be accepted as tools for future to solve real life problems for the benefit of mankind.

CONCLUSIONS

- Results obtained will be very useful to the decision makers in implementing policies and solutions for improving the water quality in the river Yamuna up to the desired level.

THANK YOU VERY MUCH!