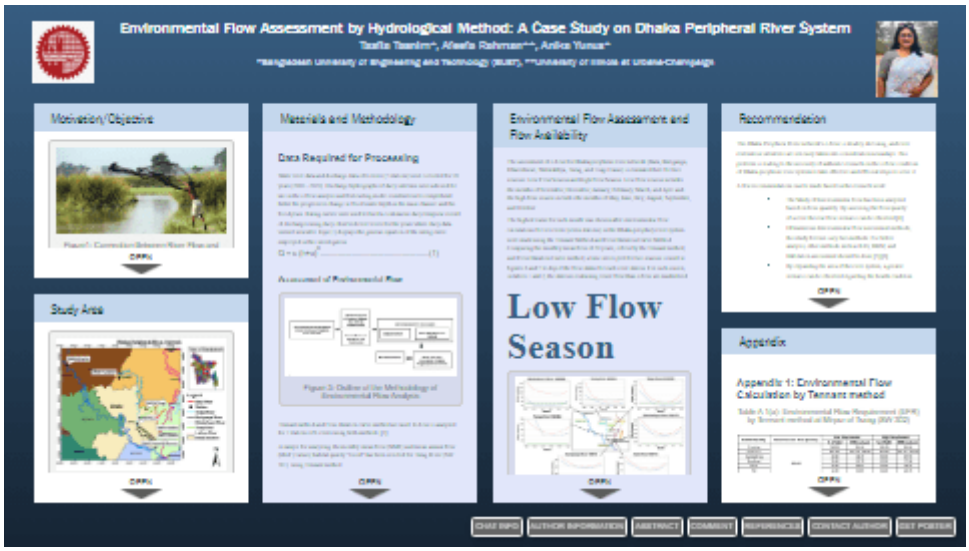
Environmental Flow Assessment by Hydrological Method: A Case Study on Dhaka Peripheral River System



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PRESENTED AT:

MOTIVATION

Figure1: Connection Between River Flow and Livelihood
Source: AFP Photo [1]

Environmental flow (e-flow) is the quantity of water that must flow to preserve freshwater resources, estuarine habitats, and human health. The river narrows and slows down as the flow drops below the e-flow, which is challenging for the environment and aquatic species. The rivers in Dhaka City have significantly less flow during dry seasons due to anthropogenic and natural activity. The change in the river system of a country has a considerable impact on the ecology of that country which leads to an alarming problem. To understand the entire situation and the ecology of the rivers, it is crucial to evaluate the e-flow need and compare it with the actual and expected river flow of the Dhaka peripheral rivers.

Objectives:

1. To determine the environmental flow requirements of the Dhaka peripheral river system.
2. To determine the flow scenario of the e-flow pattern of the river network.

STUDY AREA

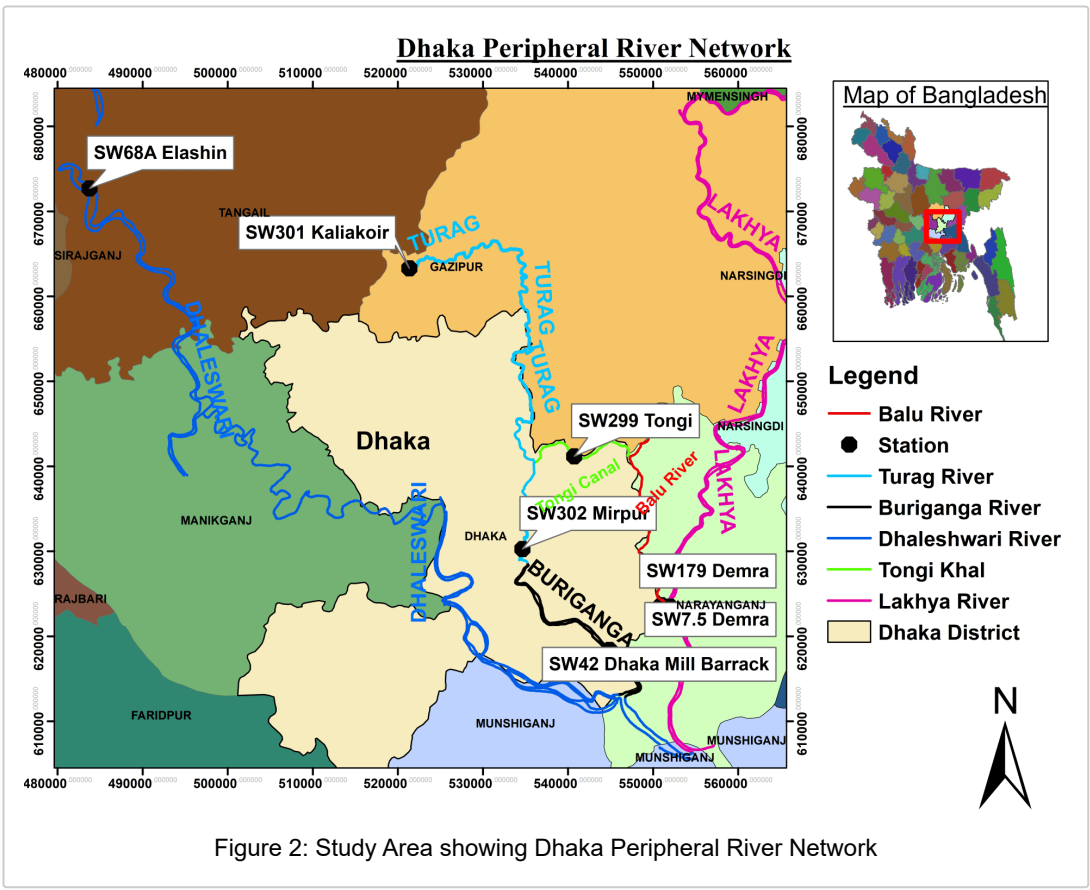


Figure 2: Study Area showing Dhaka Peripheral River Network

In this study, the research region includes Dhaka peripheral river network of 195 km consisting of the mid to lower reaches of the Balu river, 65 km of the Shitalakhya river, 35 km of the Turag river, 30 km of the Dhaleshwari river, and the whole run of the Buriganga river and 14 km of the Tongi Khal river.

MATERIALS AND METHODOLOGY

Data Required for Processing

Water level data and discharge data of 6 rivers (7 stations) were collected for 20 years (2000 - 2020). Discharge hydrographs of daily intervals were advised for use in the e-flow analysis and forecasting model construction to comprehend better the progressive change in flood water depth in the main channel and the flood plain. Rating curves were used to build a continuous daily temporal record of discharges using daily observed river levels for the years where daily data weren't available. Eqn (1) displays the general equation of the rating curve employed in this investigation.

$Q = c\,(h+a)^{n}$.....(1)

Assessment of Environmental Flow

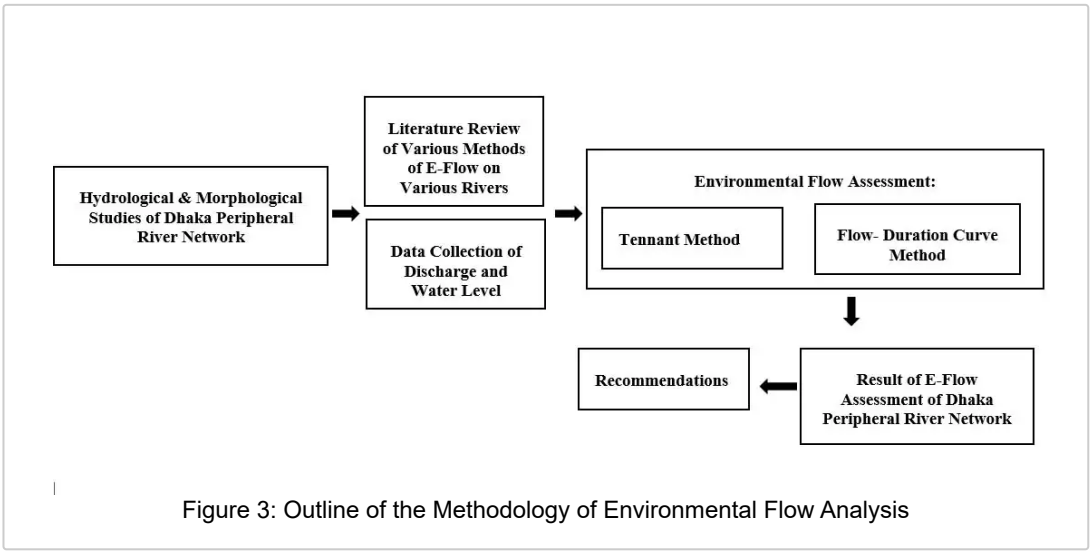


Figure 3: Outline of the Methodology of Environmental Flow Analysis

Tennant method and Flow duration curve method are used. E-flow is analyzed for 7 stations of 6 rivers using both methods. [2]

A sample for analyzing the monthly mean flow (MMF) and mean annual flow (MAF) values; habitat quality “Good” has been selected for Turag River (SW 301) using Tennant method.

Habitat Quality	Mean Annual Flow (cumec)	Low Flow Season		High Flow Season	
		% of MAF	EFR (cumec)	% of MAF	EFR (cumec)
Flushing	184.81	200.00	369.61	200.00	369.61
Optimum		60-100	110.88 - 184.81	60-100	110.88 - 184.81
Outstanding		40.00	73.92	60.00	110.88
Excellent		30.00	55.44	50.00	92.40
Good		20.00	36.96	40.00	73.92
Fair		10.00	18.48	30.00	55.44
Poor		10.00	18.48	10.00	18.48
Severe Degradation		<10	<18	<10	<18

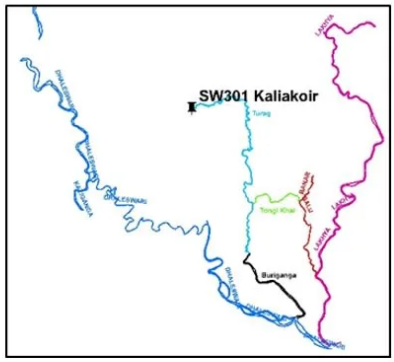


Figure 4: Environmental Flow Requirement (EFR) by Tennant method at Kaliakoir of Turag River (SW 301)

The suggestion on the environmental flow is set at the 50th percentile flow (Q50) for the high flow season and the 90th percentile flow (Q90) for the low flow season in order to evaluate the e-flow value using the flow duration curve method [3]. A sample analysis is shown for the same station (SW301) in figure 5.

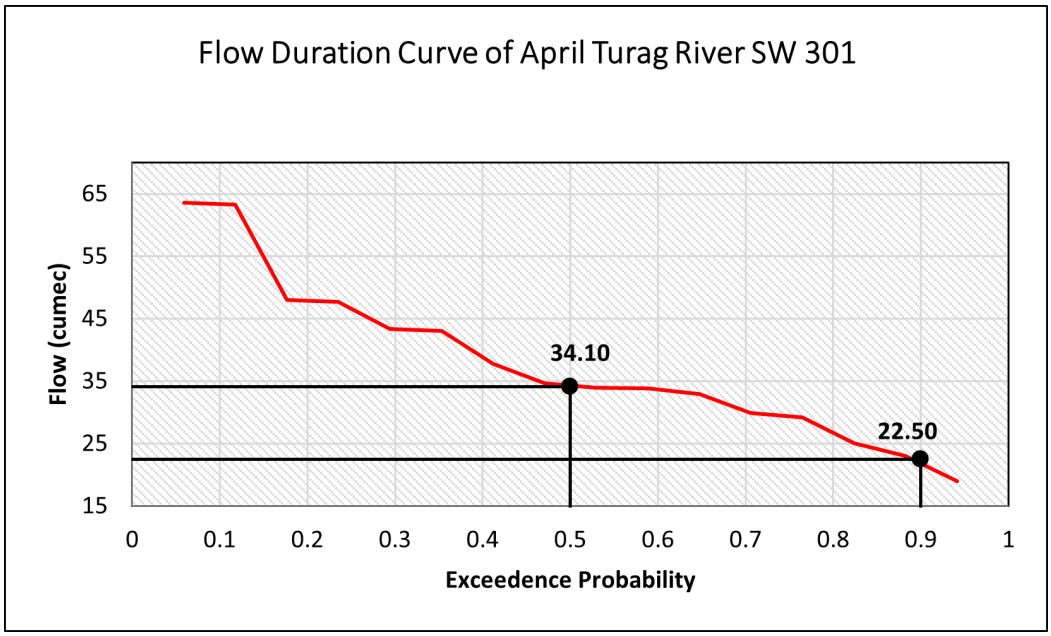


Figure 5: Environmental Flow Requirement (EFR) by Flow Duration Curve at Kaliakoir of Turag River (SW 301) for April.

The environmental flow of these two approaches has been compared for each month after 20 years of flow analysis, and the bigger value has been chosen as the e-flow and flow availability is assessed by comparing the calculated e-flow with the MMF.

ENVIRONMENTAL FLOW ASSESSMENT AND FLOW AVAILABILITY

The assessment of e-flow for Dhaka peripheral river network (Balu, Buriganga, Dhaleshwari, Shitalakhya, Turag, and Tongi Canal) is evaluated here for two seasons: Low Flow Season and High Flow Season. Low flow season includes the months of November, December, January, February, March, and April and the high flow season includes the months of May, June, July, August, September, and October.

The highest value for each month was chosen after environmental flow calculations for six rivers (seven stations) in the Dhaka periphery river system were made using the Tennant Method and Flow Duration Curve Method. Comparing the monthly mean flow of 20 years, e-flow by the Tennant method, and Flow Duration Curve method, a time series plot for two seasons is used in figures 6 and 7 to depict the flow status for each river station. For each season, in tables 1 and 2, the stations containing lower flow than e-flow are marked red.

Low Flow Season

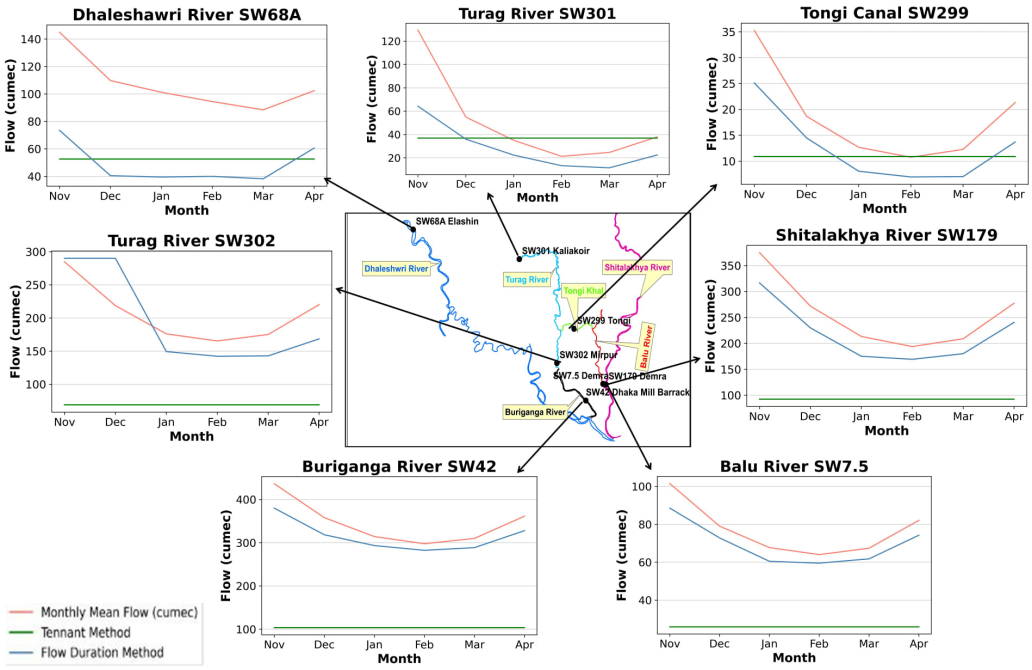


Figure 6 Comparison Hydrograph between Environmental Flow (Tennant Method and Flow Duration Curve Method) and Monthly Mean Flow for Low Flow Season of Dhaka Peripheral River Network (Seven Stations).

Table 1: Environmental Flow for Low Flow Season

River	Station ID/Name	Method	Environmental Flow Requirement (cumec)					
			Nov	Dec	Jan	Feb	Mar	Apr
Balu	SW 7.5/ Demra	Environmental Flow	88.55	72.83	60.50	59.52	61.80	74.24
		Mean Monthly Flow	101.49	79.03	67.72	64.04	67.40	82.09
		Flow Availability (%)	14.61	8.51	11.94	7.60	9.07	10.57
Buriganga	SW 42/Dhaka Mill Barrack	Environmental Flow	380.00	318.50	293.50	282.50	288.72	327.99
		Mean Monthly Flow	436.52	358.06	314.32	297.74	310.07	361.45
		Flow Availability (%)	14.87	12.42	7.09	5.39	7.39	10.20
Dhaleshwari	SW 68 A/Elashin	Environmental Flow	73.50	52.66	52.66	52.66	52.66	60.60
		Mean Monthly Flow	144.90	109.76	101.24	94.48	88.44	102.37
		Flow Availability (%)	97.14	108.44	92.26	79.42	67.95	68.93
Shitalakhya	SW 179/ Demra	Environmental Flow	316.64	229.86	175.21	169.31	180.15	240.53
		Mean Monthly Flow	375.11	271.78	213.40	193.86	208.96	277.53
		Flow Availability (%)	18.46	18.24	21.80	14.50	15.99	15.38
Turag	SW 301/Kaliakoir	Environmental Flow	64.30	36.96	36.96	36.96	36.96	36.96
		Mean Monthly Flow	129.47	55.01	35.09	21.36	24.68	38.02
		Flow Availability (%)	101.36	48.83	-5.06	-42.21	-33.24	2.85
Turag	SW 302/Mirpur	Environmental Flow	290.05	290.05	149.37	142.34	142.93	168.54
		Mean Monthly Flow	284.67	218.62	176.09	165.40	175.16	220.17
		Flow Availability (%)	-1.85	-24.63	17.89	16.20	22.55	30.64
Tongi Khal	SW 299/ Tongi	Environmental Flow	25.12	14.51	10.90	10.90	10.90	13.72
		Mean Monthly Flow	35.25	18.68	12.69	10.77	12.28	21.34
		Flow Availability (%)	40.33	28.76	16.43	-1.18	12.74	55.53

In the low flow season, water availability is not satisfactory most of the time in all Dhaka peripheral rivers except Dhaleshwari, Buriganga, and Shitalakhya.

The Turag River flows less than the necessary e-flow during the low flow season. In January, February, and March, station SW 301's flow availability is, respectively, 5.06%, 42.21%, and 33.24% less than the required e-flow. For SW 302, the river flow in November and December was 1.85% and 24.63% less than the e-flow, respectively. Additionally, the Tongi Canal flows 1.18% less than the e-flow in December.

High Flow Season

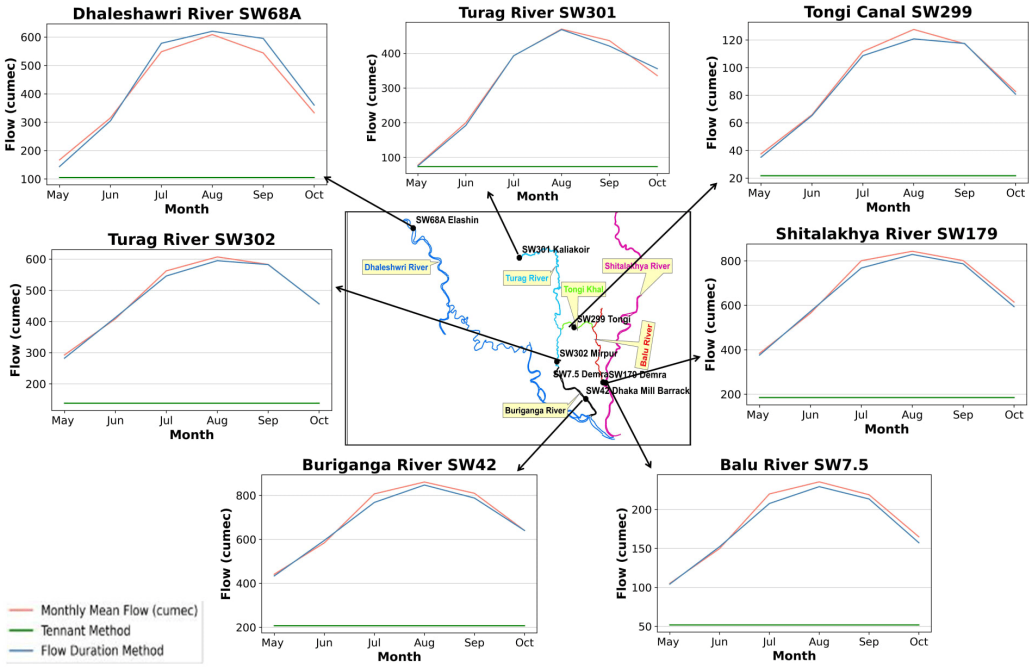


Figure 7 Comparison Hydrograph between Environmental Flow (Tennant Method and Flow Duration Curve Method) and Monthly Mean Flow for High Flow Season of Dhaka Peripheral River Network (Seven Stations).

Table 2: Environmental Flow for High Flow Season

River	Station ID/Name	Method	Environmental Flow Requirement (cumec)					
			May	Jun	Jul	Aug	Sep	Oct
Balu	SW 7.5/ Demra	Environmental Flow	104.30	152.34	207.78	229.44	213.60	157.41
		Mean Monthly Flow	105.21	149.92	220.08	235.56	219.00	164.98
		Flow Availability (%)	0.87	-1.59	5.92	2.67	2.53	4.81
Buriganga	SW 42/Dhaka Mill Barrack	Environmental Flow	434.00	595.50	768.21	847.30	788.00	640.50
		Mean Monthly Flow	441.54	584.21	807.13	861.01	809.75	640.63
		Flow Availability (%)	1.74	-1.90	5.07	1.62	2.76	0.02
Dhaleshwari	SW 68 A/Elashin	Environmental Flow	144.00	305.15	578.26	620.75	595.50	360.60
		Mean Monthly Flow	167.37	315.45	548.58	609.03	544.37	333.49
		Flow Availability (%)	16.23	3.38	-5.13	-1.89	-8.59	-7.52
Shitalakhya	SW 179/ Demra	Environmental Flow	376.27	572.77	768.21	829.31	787.05	594.10
		Mean Monthly Flow	384.11	564.35	801.05	843.56	801.59	614.78
		Flow Availability (%)	2.08	-1.47	4.27	1.72	1.85	3.48
Turag	SW 301/Kaliakoir	Environmental Flow	76.00	192.40	393.27	468.39	421.19	355.88
		Mean Monthly Flow	78.34	200.20	392.82	470.00	436.80	335.89
		Flow Availability (%)	3.08	4.05	-0.11	0.34	3.71	-5.62
Turag	SW 302/Mirpur	Environmental Flow	282.62	412.89	546.12	595.11	582.54	456.74
		Mean Monthly Flow	293.10	408.74	562.56	607.25	583.02	456.26
		Flow Availability (%)	3.71	-1.00	3.01	2.04	0.08	-0.11
Tongi Khal	SW 299/ Tongi	Environmental Flow	35.18	65.27	108.65	120.81	117.48	80.82
		Mean Monthly Flow	37.57	65.84	111.69	127.65	117.28	82.72
		Flow Availability (%)	6.79	0.88	2.80	5.66	-0.17	2.35

For the high-flow season, water availability of the peripheral rivers is satisfactory except Dhaleshwari and Turag Rivers.

The Balu River flows at 1.59% less than the necessary e-flow during high flow season, and the Buriganga River flows at 1.90% less than the needed e-flow in January. The Dhaleshwri river's flow availability is, successively, 5.13%, 1.89%, 8.59%, and 7.52% less than the necessary e-flow for the months of July to October. In the case of the Shitalakhya river, the available flow is 1.47% less than the necessary minimum flow for June, while the Tongi Canal has a flow of -0.17% during the month of September. For the Turag River, the level of flow deficit for station SW 301 is 0.11% and 5.62%, respectively, in July and October, while the level for station SW 302 is 1% and 0.11%, respectively, in June and October.

RECOMMENDATION

The Dhaka Peripheral River network's e-flow is steadily declining, and river restoration initiatives are seriously taken into consideration nowadays. This problem is leading to the necessity of authentic research on the e-flow condition of Dhaka peripheral river system to take effective and efficient steps to solve it.

A few recommendations can be made based on the research work:

- The Study of Environmental flow has been analyzed based on flow quantity. By assessing the flow quality of a river the real flow scenario can be observed [4].
- Of numerous Environmental flow assessment methods, this study follows only two methods. For better analysis, other methods such as RAV, BBM, and Habitation assessment should be done [5],[6].
- By expanding the area of the river system, a greater scenario can be observed regarding the health condition of the rivers of Dhaka which can lead to more effective and realistic solutions.

Studies like these ought to be highlighted and carefully analyzed so that the government can act in an effective manner.

APPENDIX

Appendix 1: Environmental Flow Calculation by Tennant method

Table A 1(a): Environmental Flow Requirement (EFR) by Tennant method at Mirpur of Turag (SW 302)

Habitat Quality	Mean Annual Flow (cumec)	Low Flow Season		High Flow Season	
		% of MAF	EFR (cumec)	% of MAF	EFR (cumec)
Flushing	345.92	200.00	691.84	200.00	691.84
Optimum		60-100	207.55 - 345.92	60-100	207.55 - 345.92
Outstanding		40.00	138.37	60.00	207.55
Excellent		30.00	103.78	50.00	172.96
Good		20.00	69.18	40.00	138.37
Fair		10.00	34.59	30.00	103.78
Poor		10.00	34.59	10.00	34.59
Severe Degradation		<10	< 34	<10	< 34

Table A .1(b): Environmental Flow Requirement (EFR) by Tennant method at Dhaka Mill Barrack of Buriganga (SW 42)

Habitat Quality	Mean Annual Flow (cumec)	Low Flow Season		High Flow Season	
		% of MAF	EFR (cumec)	% of MAF	EFR (cumec)
Flushing	518.54	200.00	1037.07	200.00	1037.07
Optimum		60-100	311.12 -518.54	60-100	311.12 -518.54
Outstanding		40.00	207.41	60.00	311.12
Excellent		30.00	155.56	50.00	259.27
Good		20.00	103.71	40.00	207.41
Fair		10.00	51.85	30.00	155.56
Poor		10.00	51.85	10.00	51.85
Severe Degradation		<10	< 51	<10	< 51

Table A. 1(c): Environmental Flow Requirement (EFR) by Tennant method at Elashin of Dhaleshwari (SW 68 A)

Habitat Quality	Mean Annual Flow (cumec)	Low Flow Season		High Flow Season	
		% of MAF	EFR (cumec)	% of MAF	EFR (cumec)
Flushing	263.29	200.00	526.58	200.00	526.58
Optimum		60-100	157.97 -263.29	60-100	157.97 - 263.29
Outstanding		40.00	105.32	60.00	157.97
Excellent		30.00	78.99	50.00	131.65
Good		20.00	52.66	40.00	105.32
Fair		10.00	26.33	30.00	78.99
Poor		10.00	26.33	10.00	26.33
Severe Degradation		<10	< 26	<10	< 26

Table A. 1(d): Environmental Flow Requirement (EFR) by Tennant method at Demra of Shitalakhya (SW 179)

Habitat Quality	Mean Annual Flow (cumec)	Low Flow Season		High Flow Season	
		% of MAF	EFR (cumec)	% of MAF	EFR (cumec)
Flushing	462.51	200.00	925.01	200.00	925.01
Optimum		60-100	277.50 - 462.51	60-100	277.50 - 462.51
Outstanding		40.00	185.00	60.00	277.50
Excellent		30.00	138.75	50.00	231.25
Good		20.00	92.50	40.00	185.00
Fair		10.00	46.25	30.00	138.75
Poor		10.00	46.25	10.00	46.25
Severe Degradation		<10	< 46	<10	< 46

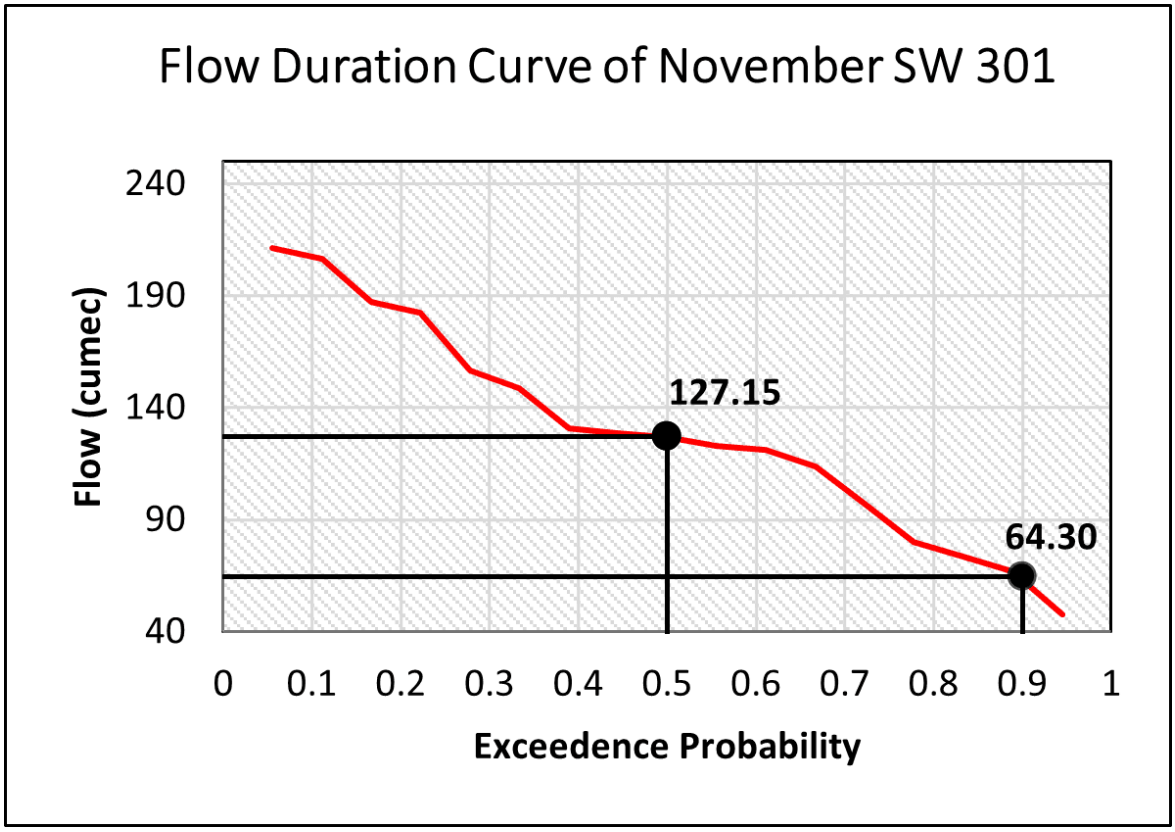
Table A. 1(e): Environmental Flow Requirement (EFR) by Tennant method at Demra of Balu River (SW 7.5)

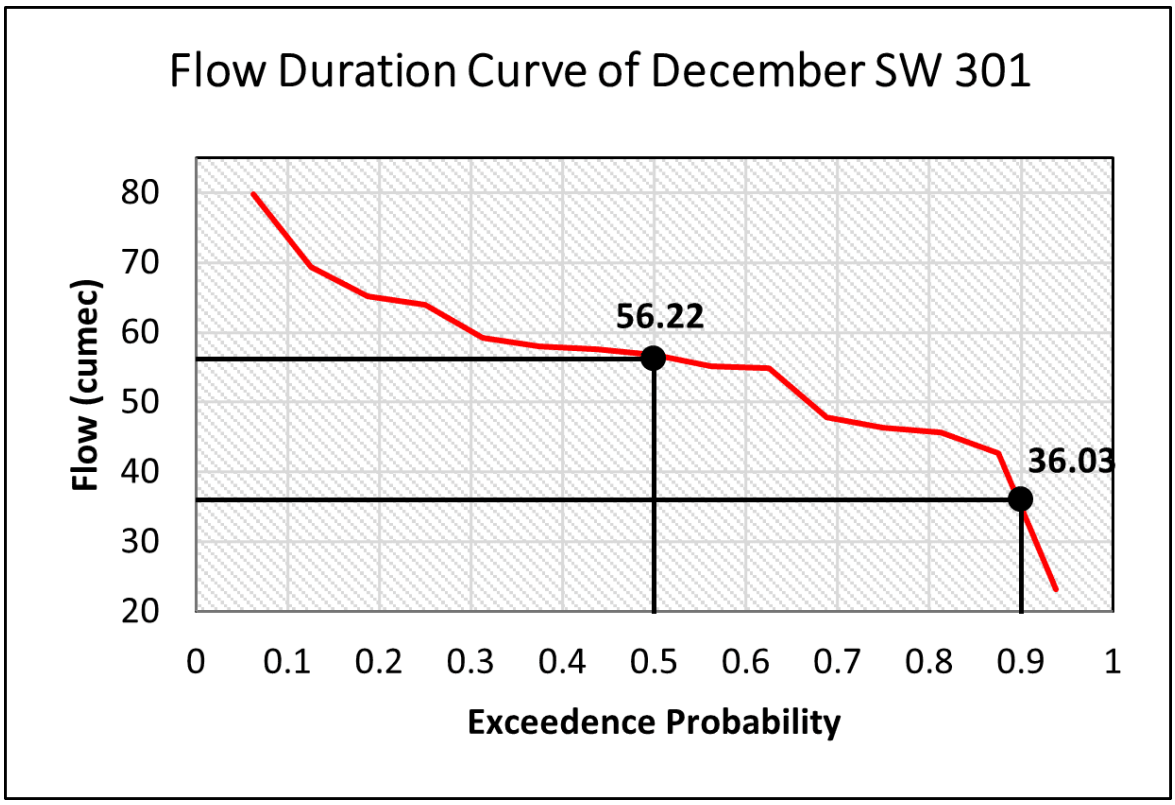
Habitat Quality	Mean Annual Flow (cumec)	Low Flow Season		High Flow Season	
		% of MAF	EFR (cumec)	% of MAF	EFR (cumec)
Flushing	129.7105451	200	259.4210901	200	259.4210901
Optimum		60-100	77.83 - 129.72	60-100	77.83 - 129.72
Outstanding		40	51.88421803	60	77.82632704
Excellent		30	38.91316352	50	64.85527253
Good		20	25.94210901	40	51.88421803
Fair		10	12.97105451	30	38.91316352
Poor		10	12.97105451	10	12.97105451
Severe Degradation		<10	< 12.50	<10	< 12.50

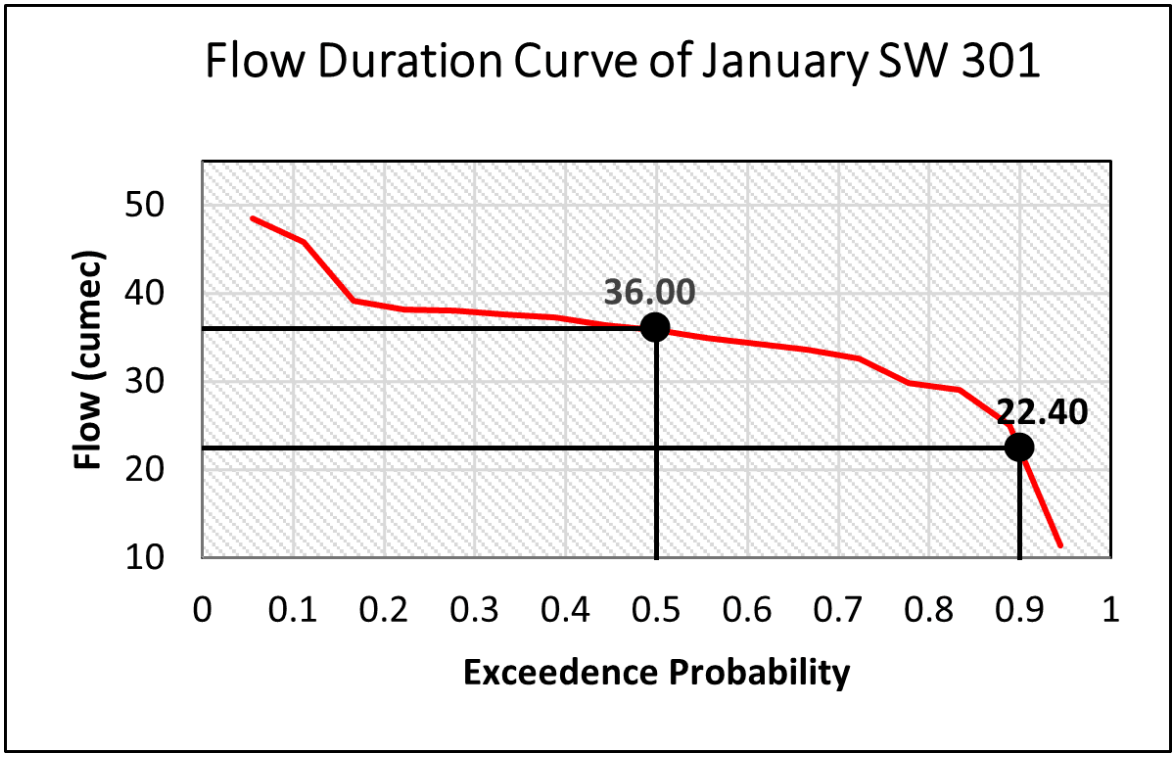
Table A .1 (F): Environmental Flow Requirement (EFR) by Tennant method at Tongi of Tongi Khal (SW 299)

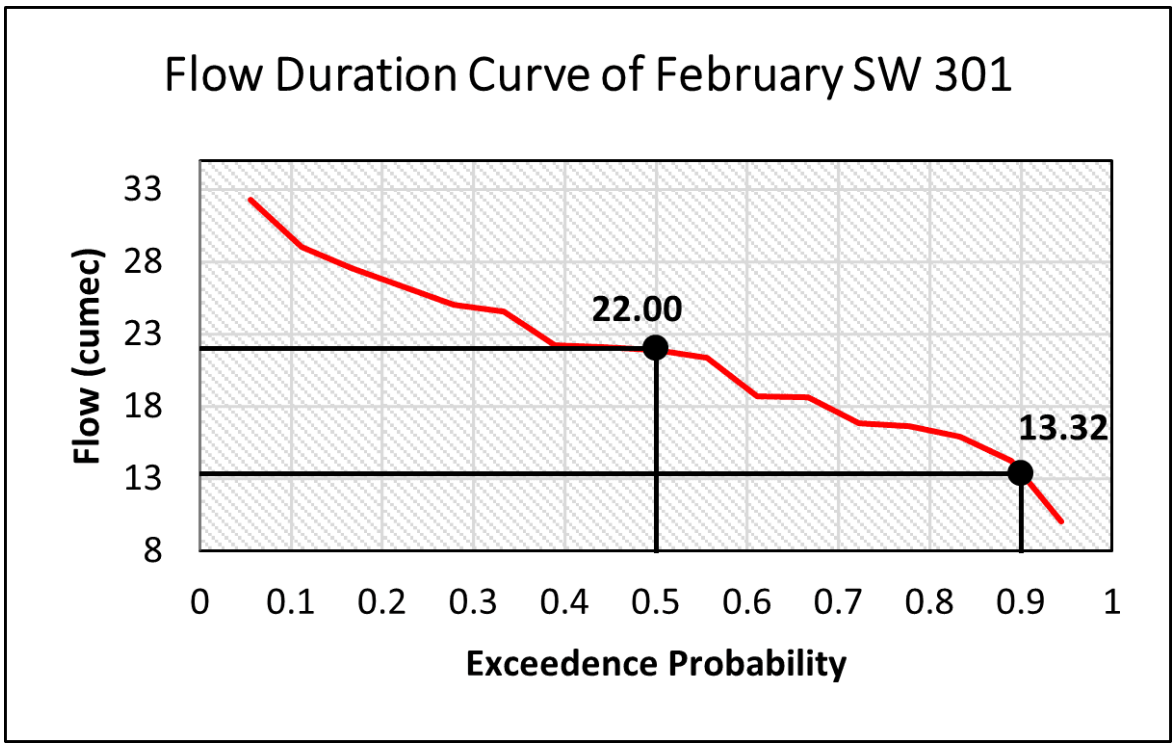
Habitat Quality	Mean Annual Flow (cumec)	Low Flow Season		High Flow Season	
		% of MAF	EFR (cumec)	% of MAF	EFR (cumec)
Flushing	54.48027807	200	108.9605561	200	108.9605561
Optimum		60-100	32.69 - 54.48	60-100	32.69 - 54.48
Outstanding		40	21.79211123	60	32.68816684
Excellent		30	16.34408342	50	27.24013903
Good		20	10.89605561	40	21.79211123
Fair		10	5.448027807	30	16.34408342
Poor		10	5.448027807	10	5.448027807
Severe Degradation		<10	< 5	<10	< 5

Appendix 2: Environmental Flow Calculation by Flow Duration Curve method




Flow Duration Curve of December SW 301
Flow (cumec)
80
70
60
50
40
30
20
56.22
36.03
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
Exceedence Probability


Flow Duration Curve of January SW 301
Flow (cumec)
50
40
30
20
10
36.00
22.40
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
Exceedence Probability



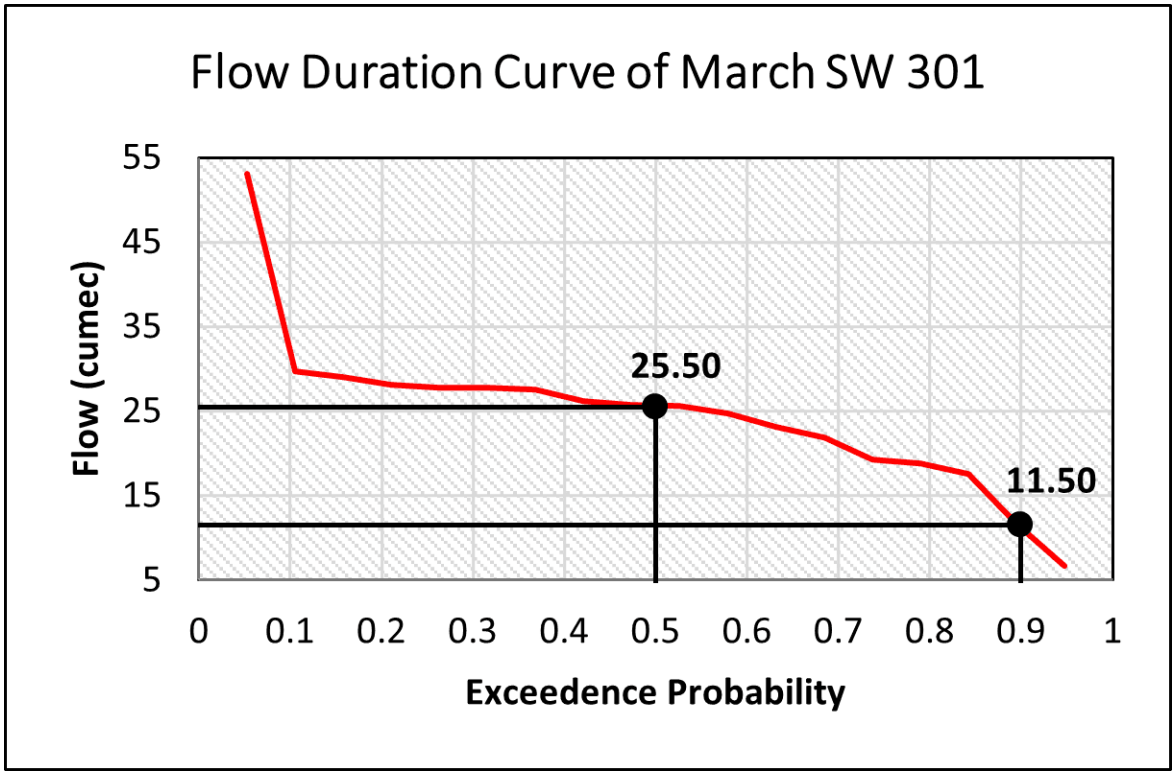
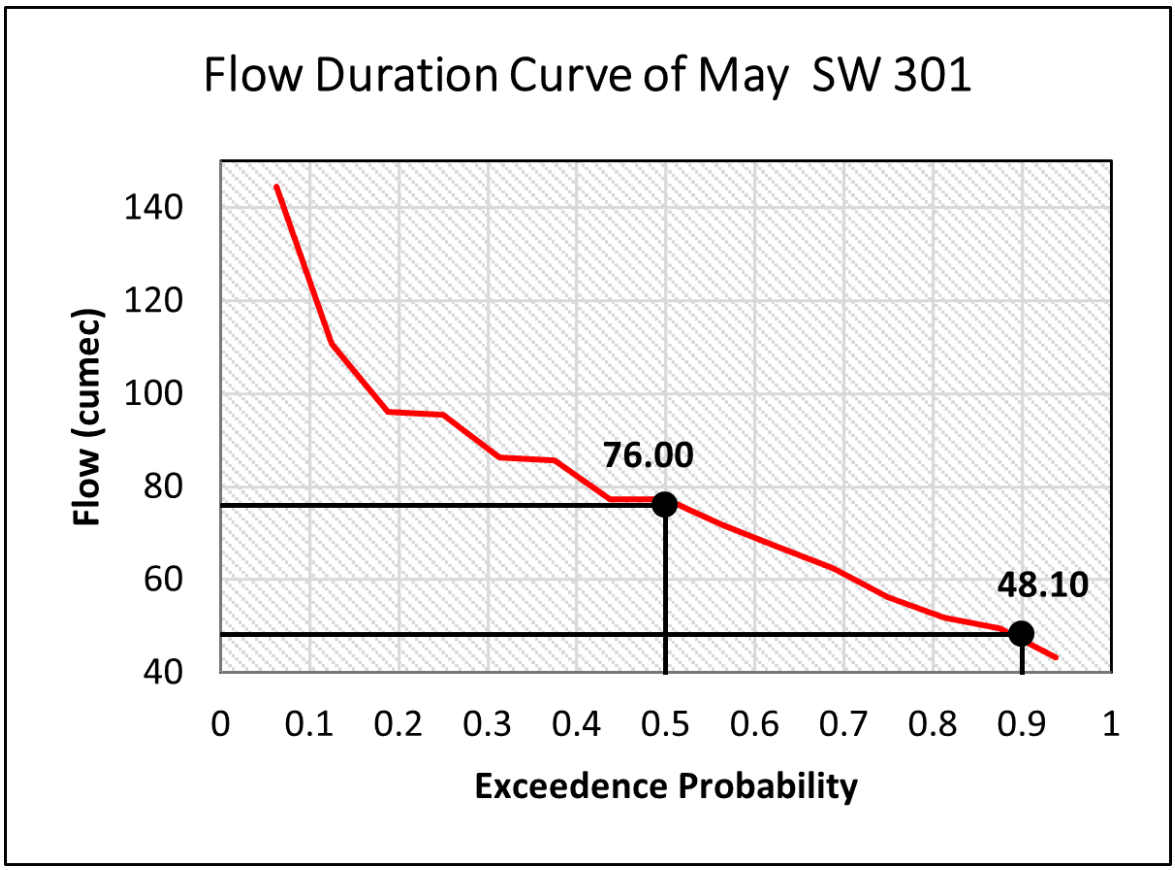
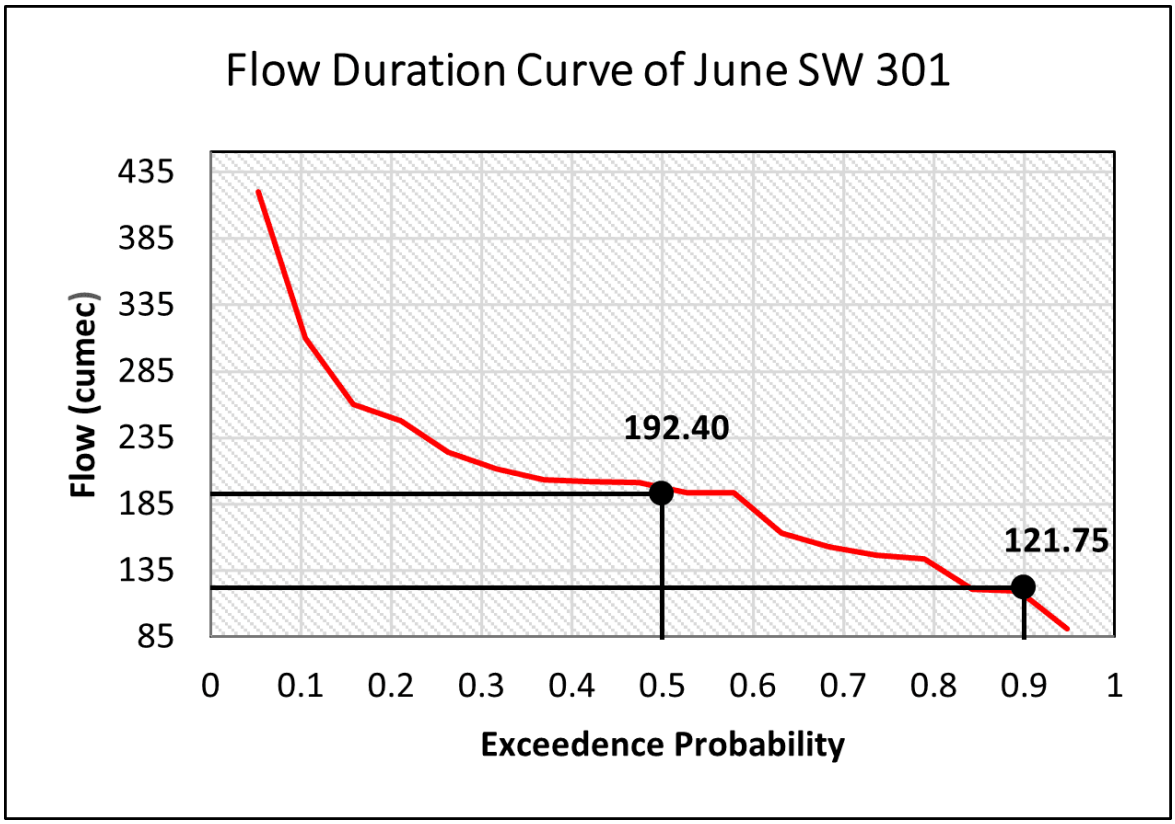
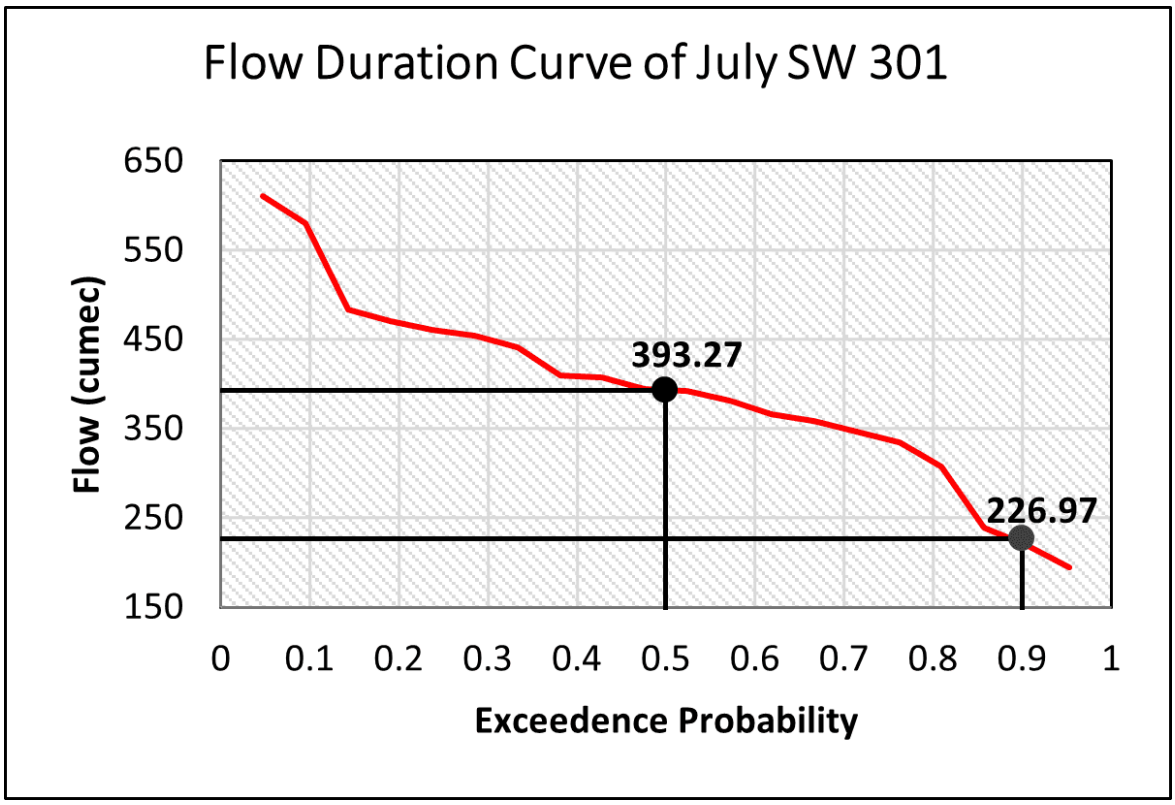
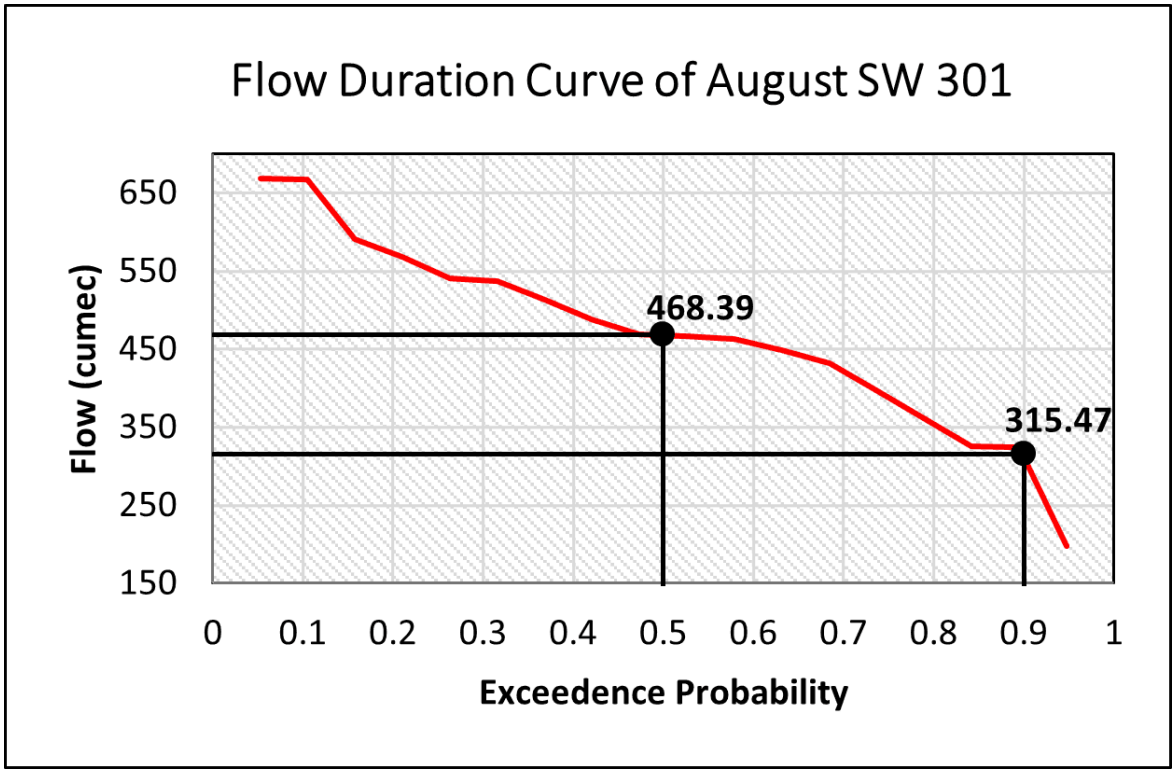


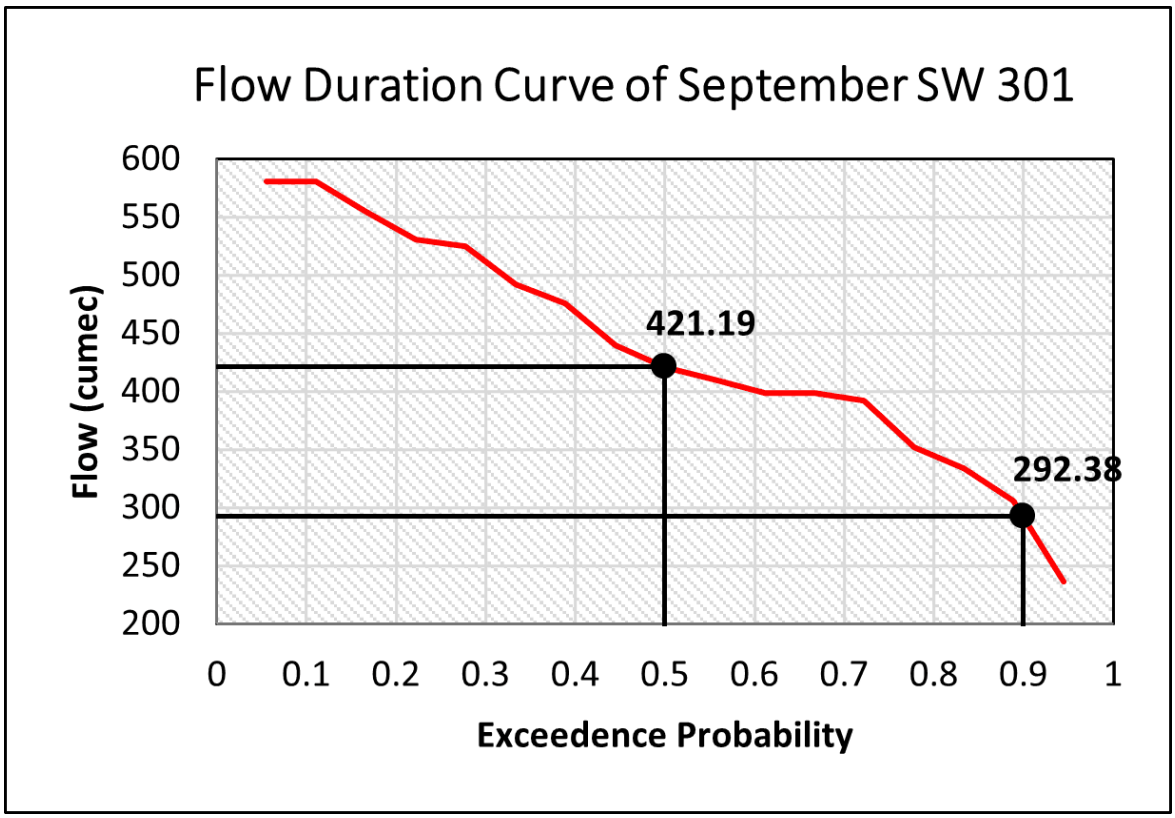
Figure 2 (a): Flow Duration Curve at Kaliakoir of Turag (SW 301)for Low Flow Season


Flow Duration Curve of May SW 301
140
120
100
80
60
40
Flow (cumec)
76.00
48.10
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
Exceedence Probability


Flow Duration Curve of June SW 301
435
385
335
285
235
185
135
85
Flow (cumec)
192.40
121.75
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
Exceedence Probability


Flow Duration Curve of July SW 301
650
550
450
350
250
150
Flow (cumec)
393.27
226.97
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
Exceedence Probability


Flow Duration Curve of August SW 301
650
550
450
350
250
150
Flow (cumec)
468.39
315.47
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
Exceedence Probability



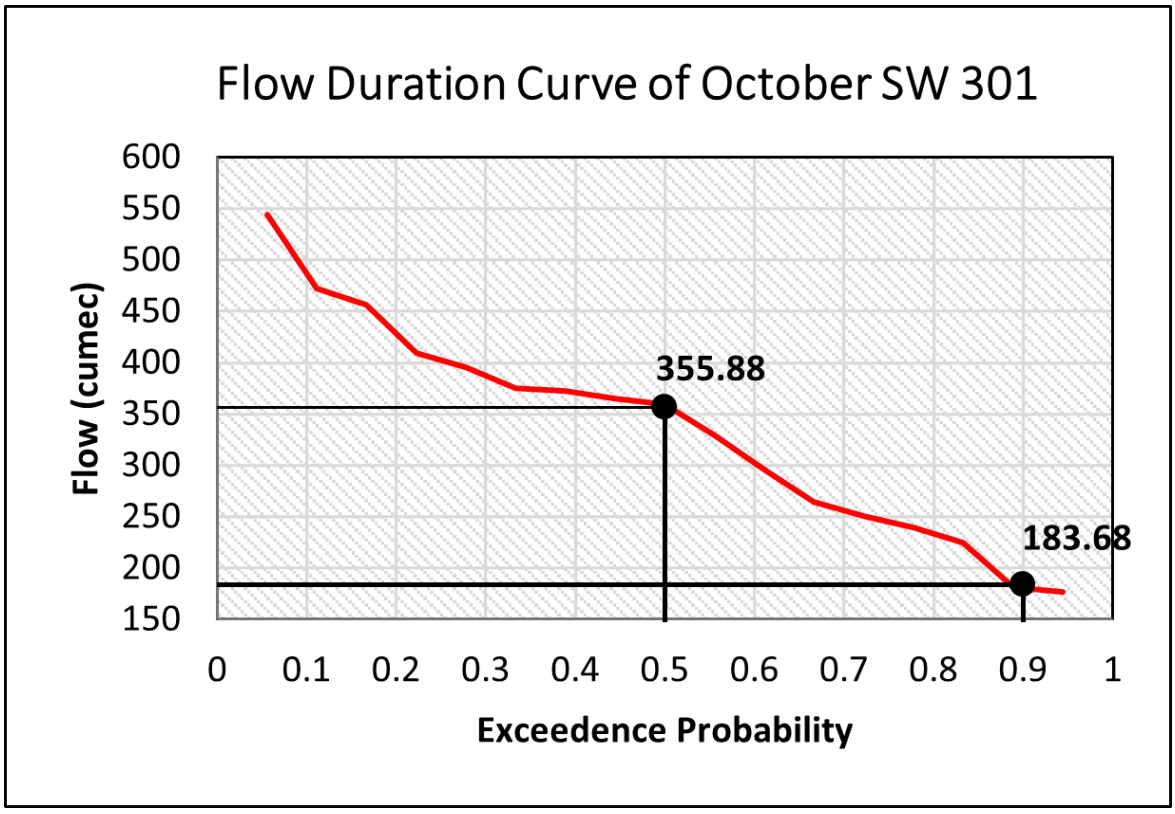
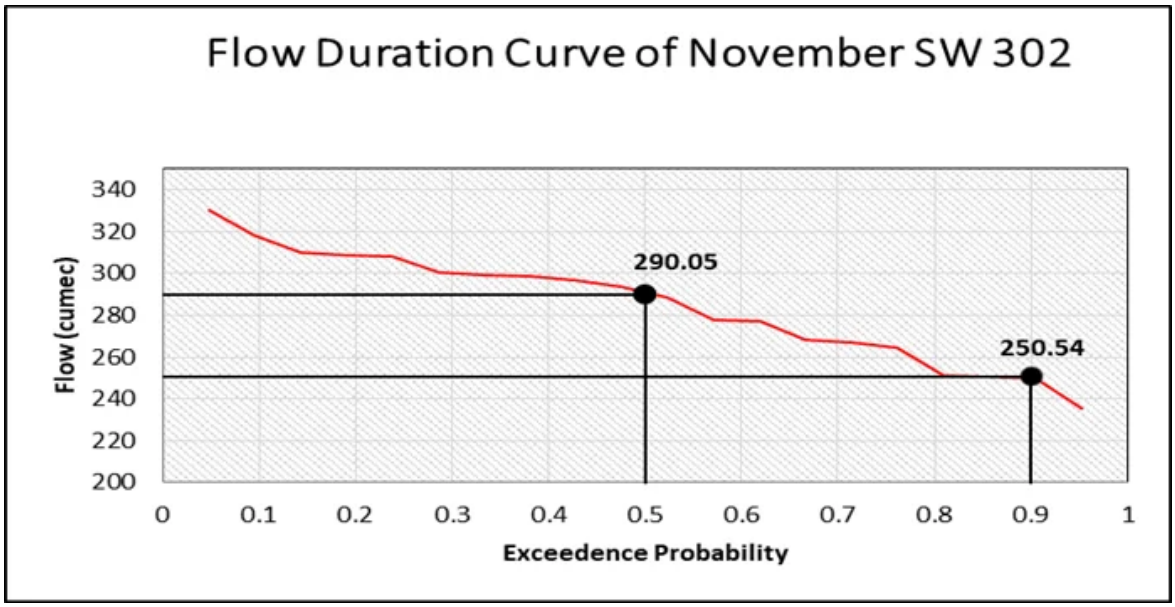
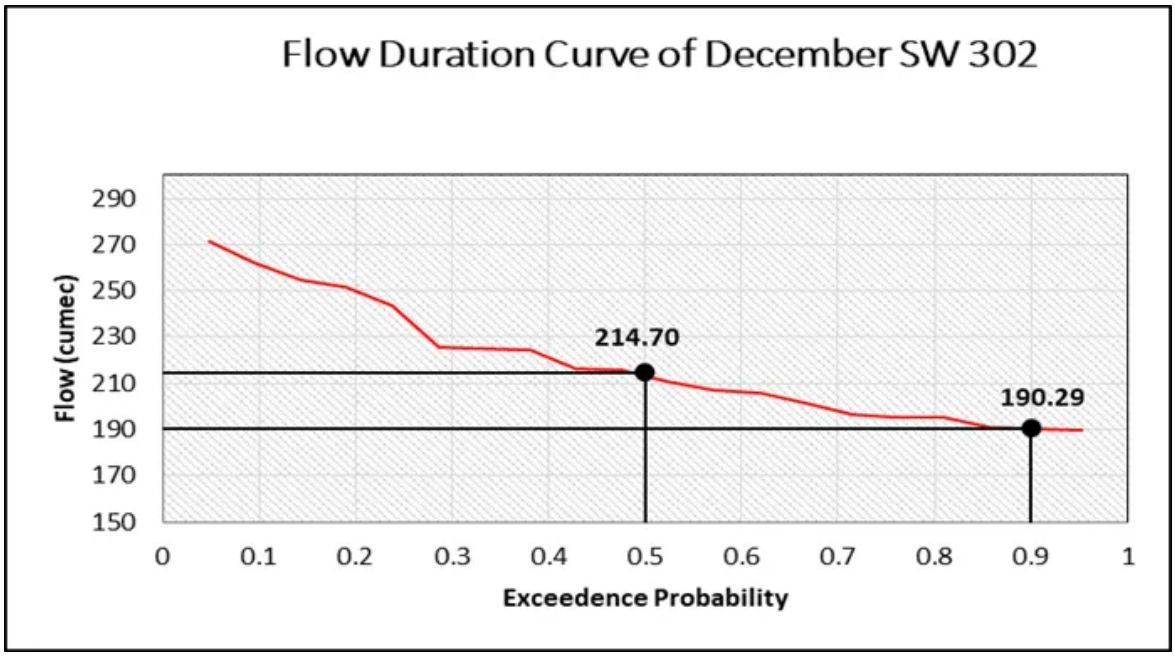


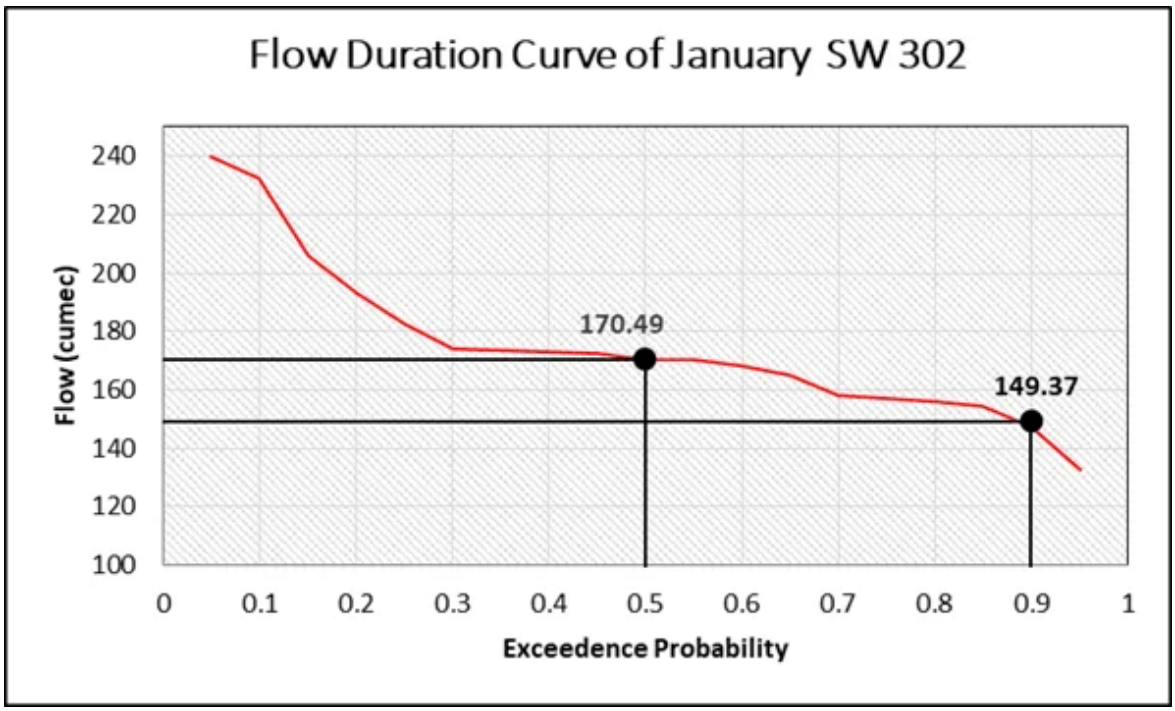
Figure 2(a) (continued): Flow Duration Curve at Kaliakoir of Turag (SW 301) for High Flow Season

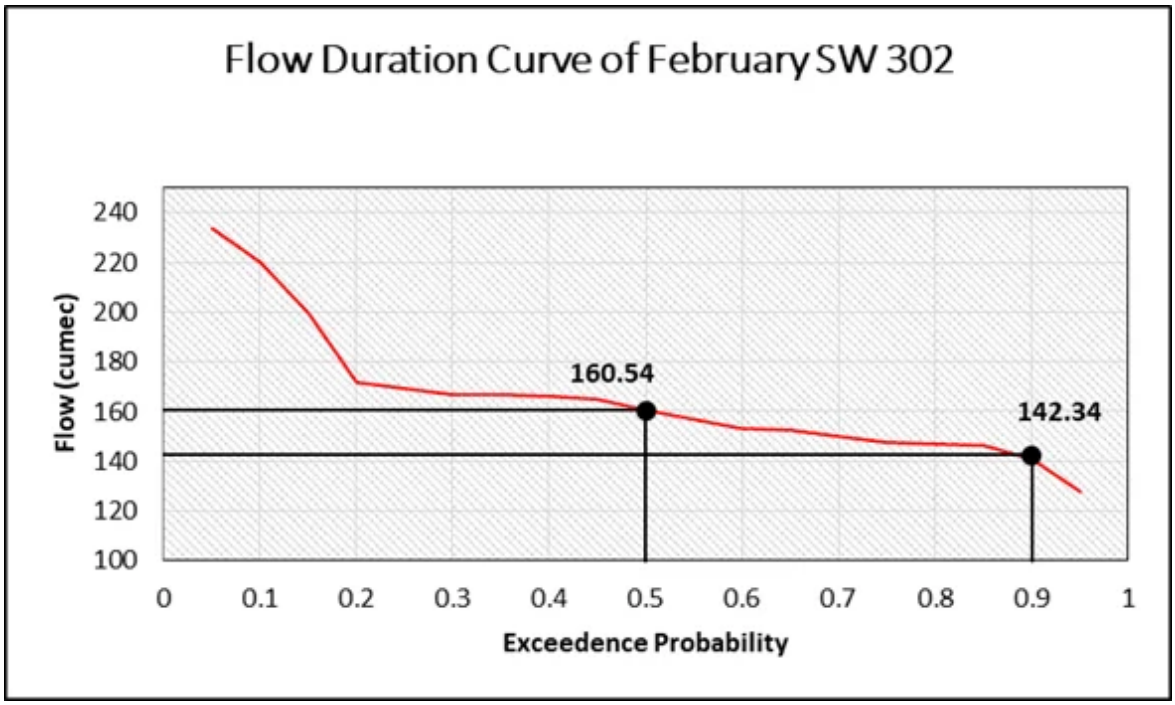
Table 2 (a): Environmental flow requirement (EFR) using Flow duration curve method at Kaliakoir of Turag River SW 301.

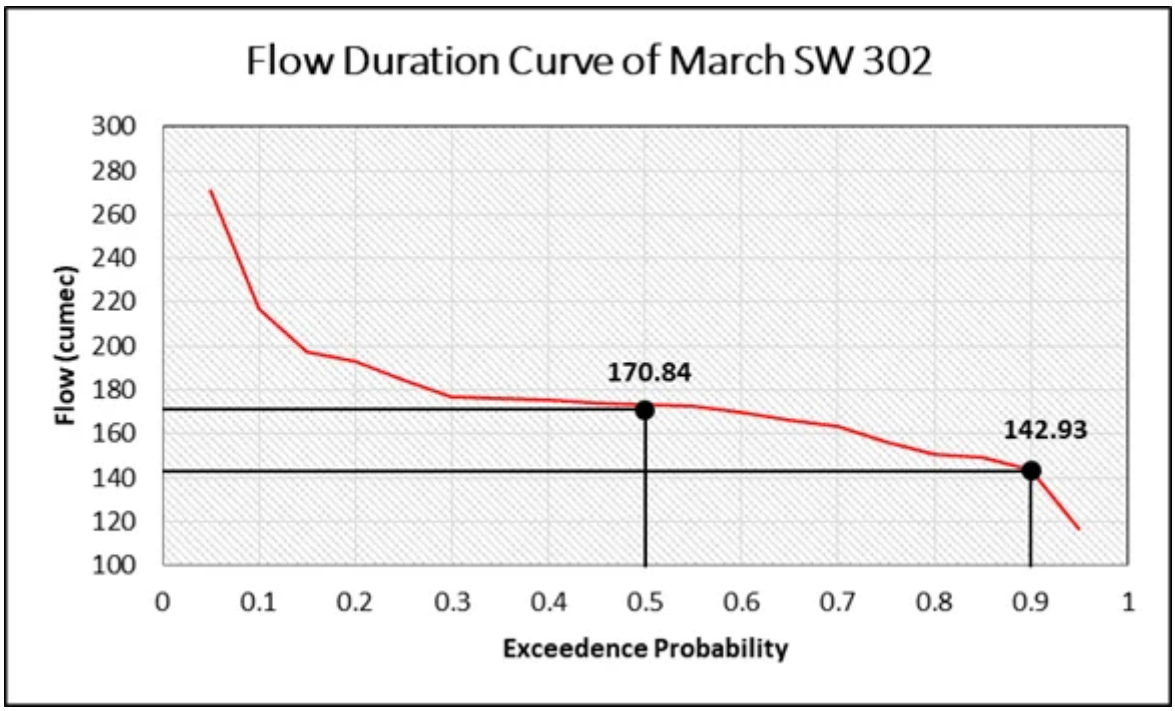
Month	Jan	Febr	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Flow Season	Low	Low	Low	Low	High	High	High	High	High	High	Low	Low
50th Percentile Flow (cumec)	36.00	22.00	25.50	34.10	76.00	192.40	393.27	468.39	421.19	355.88	127.15	56.22
90th Percentile Flow (cumec)	22.40	13.32	11.50	22.50	48.10	121.75	226.97	315.47	292.38	183.68	64.30	36.03
ERF (cumec)	22.40	13.32	11.50	22.50	76.00	192.40	393.27	468.39	421.19	355.88	64.30	36.03






Flow Duration Curve of January SW 302
Flow (cumec)
240
220
200
180
160
140
120
100
170.49
149.37
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
Exceedence Probability


Flow Duration Curve of February SW 302
Flow (cumec)
240
220
200
180
160
140
120
100
160.54
142.34
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
Exceedence Probability



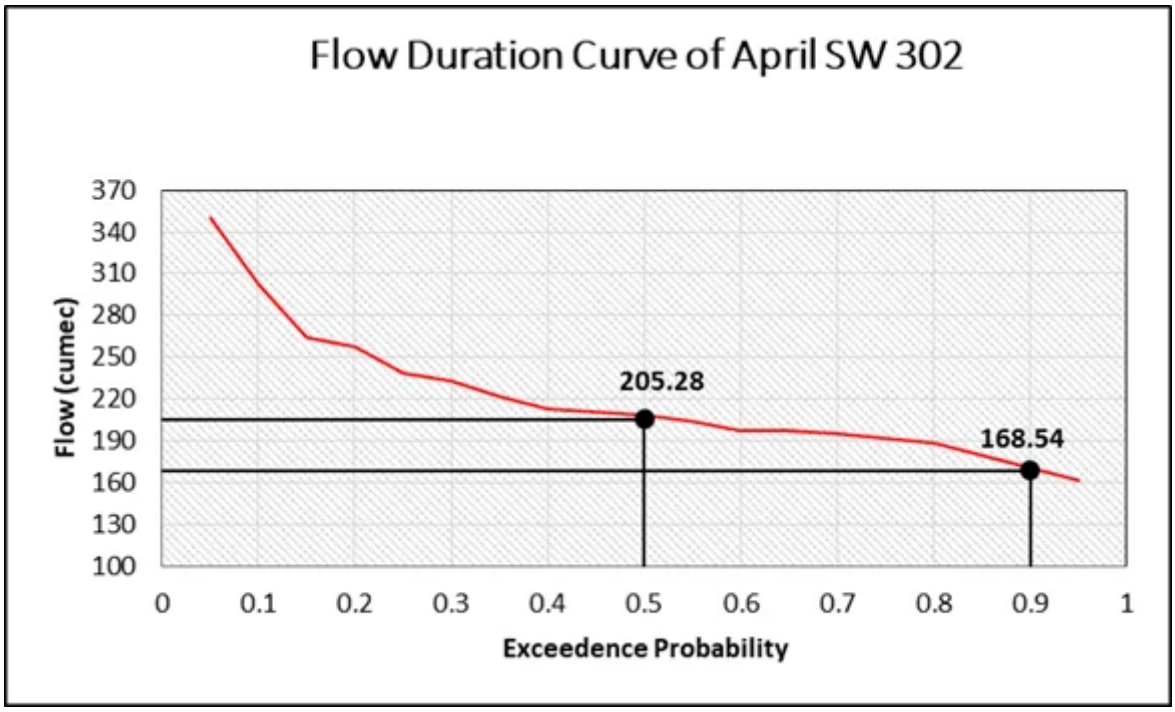
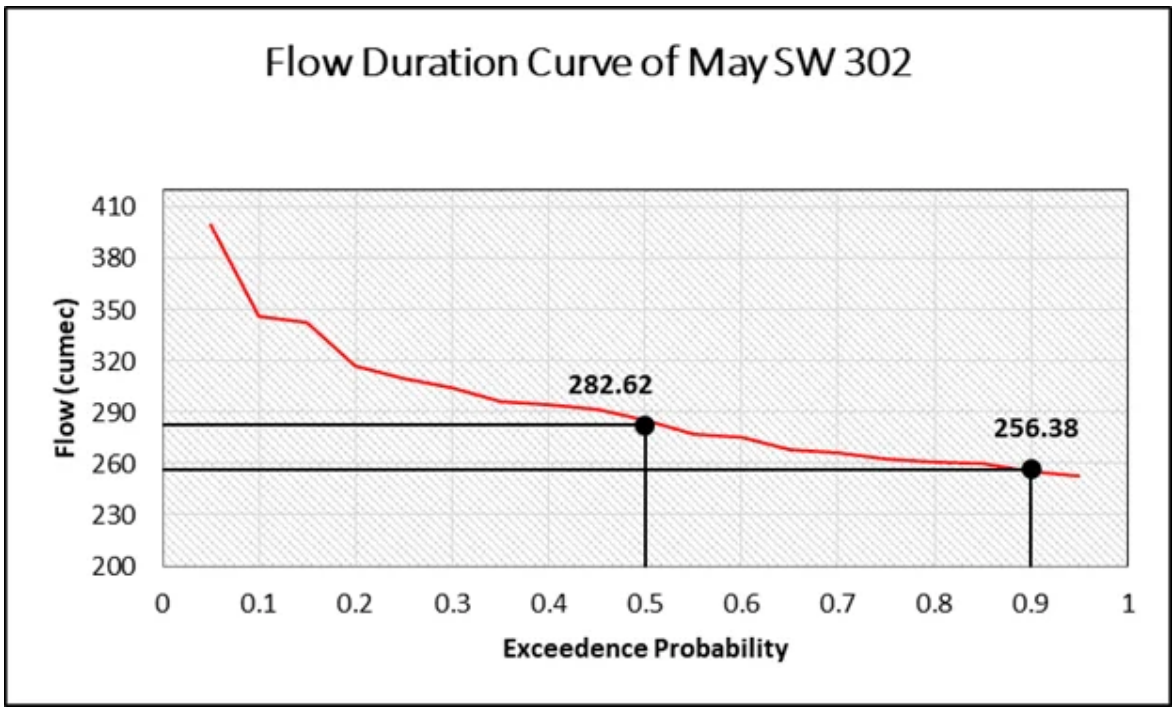
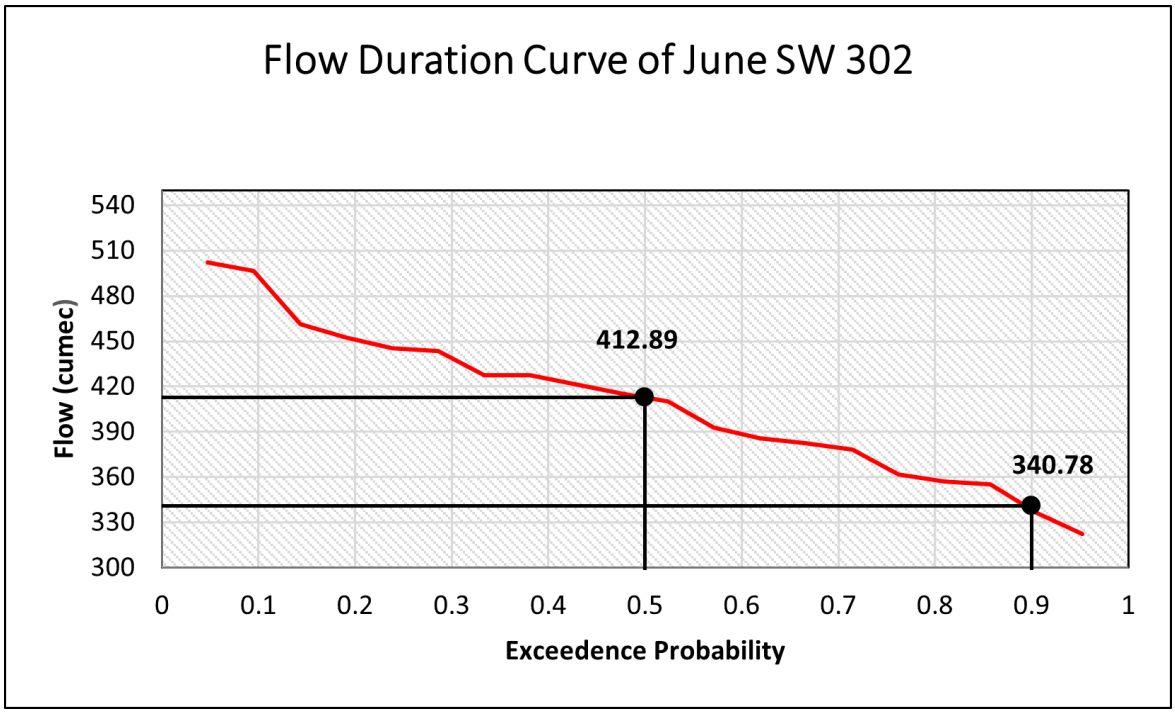
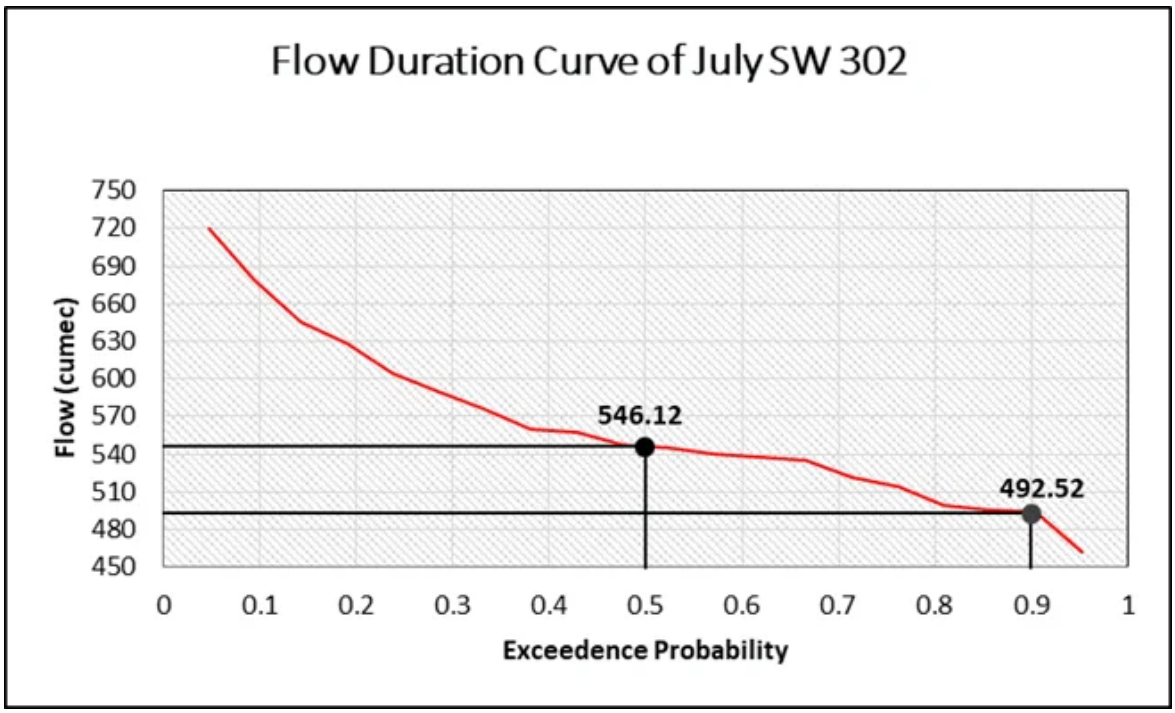
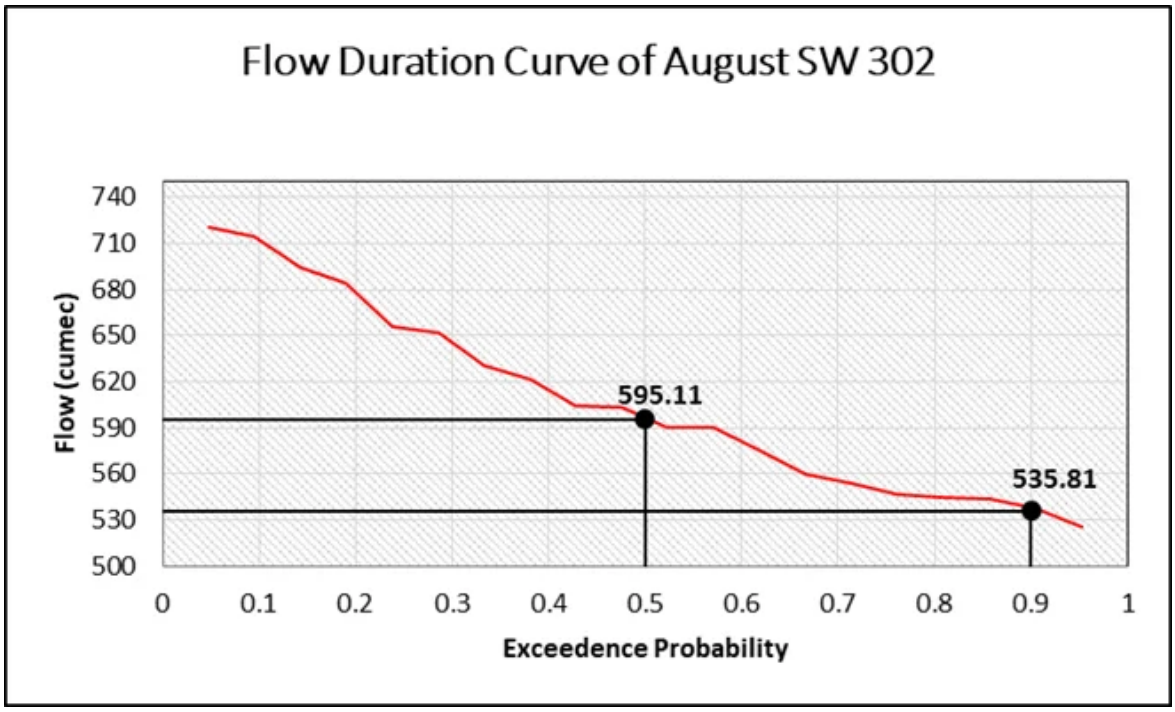


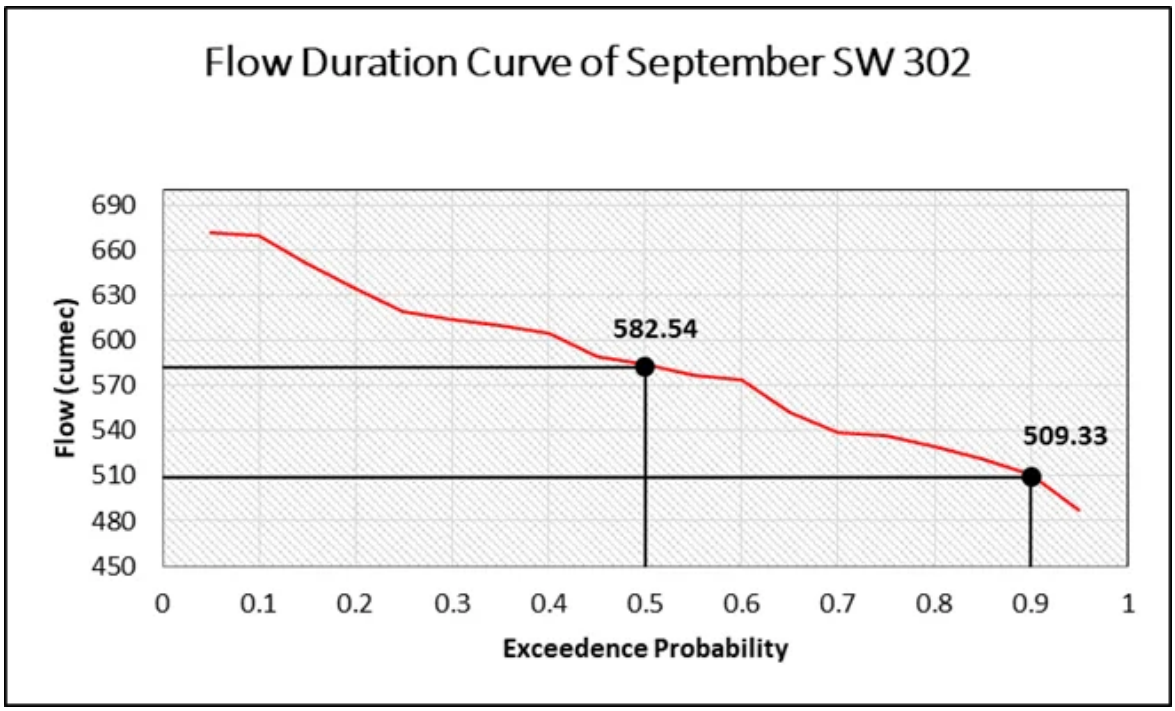
Figure 2(b): Flow duration curve at Mirpur of Turag (SW 302) for Low Flow Season.


Flow Duration Curve of May SW 302
Flow (cumec)
410
380
350
320
290
260
230
200
282.62
256.38
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
Exceedence Probability


Flow Duration Curve of June SW 302
Flow (cumec)
540
510
480
450
420
390
360
330
300
412.89
340.78
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
Exceedence Probability


Flow Duration Curve of July SW 302
750
720
690
660
630
600
570
540
510
480
450
Flow (cumec)
546.12
492.52
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
Exceedence Probability


Flow Duration Curve of August SW 302
740
710
680
650
620
590
560
530
500
Flow (cumec)
595.11
535.81
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
Exceedence Probability



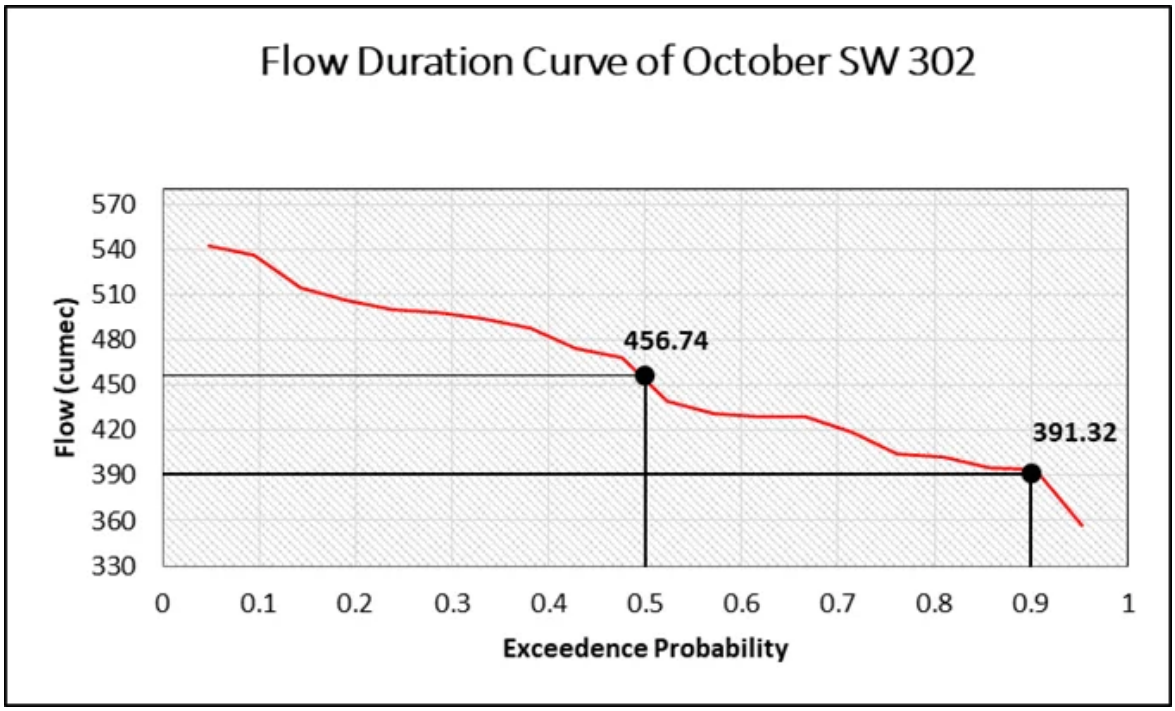
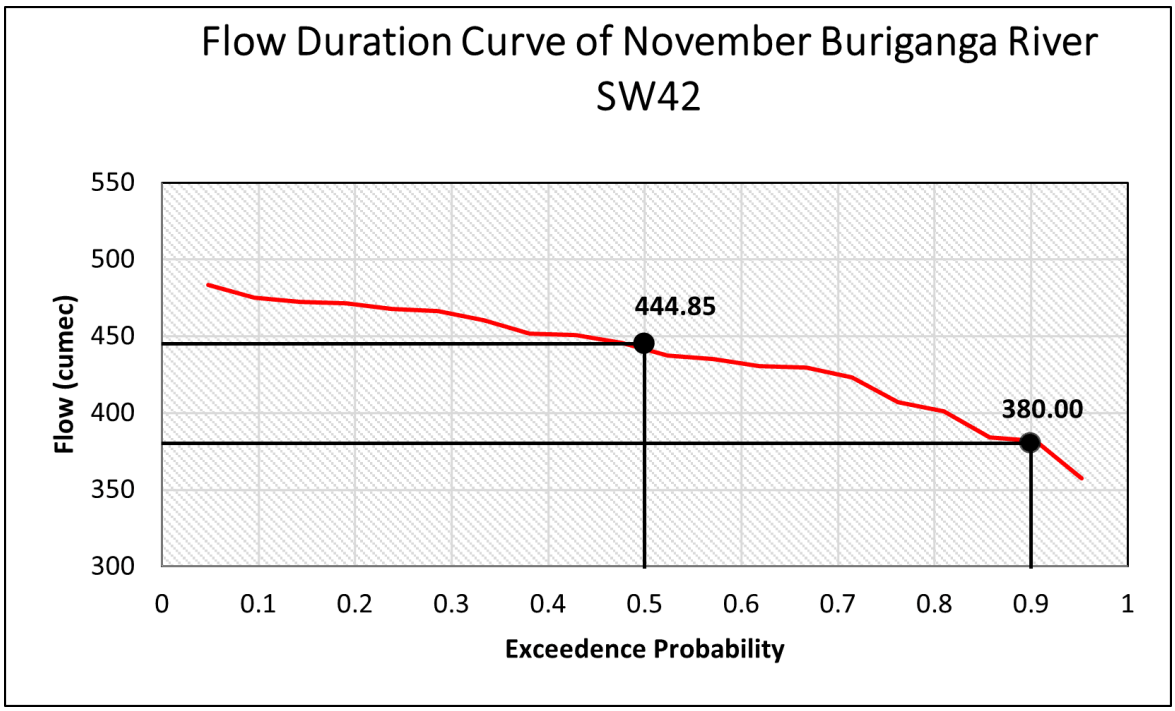
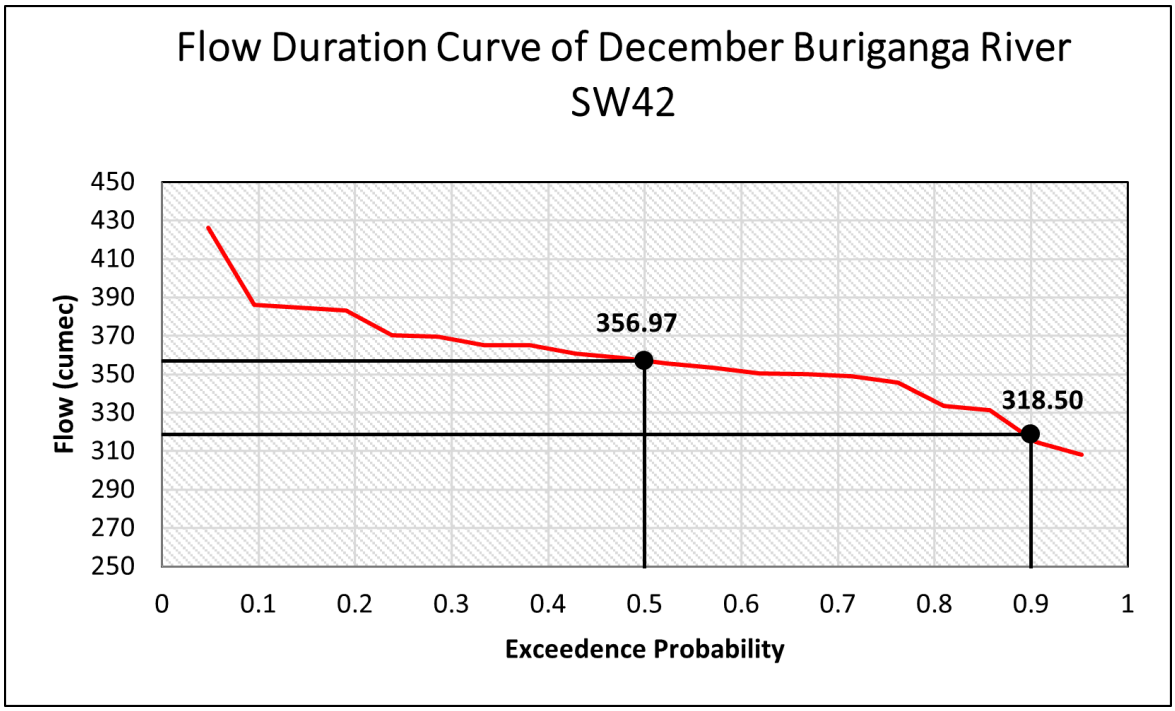


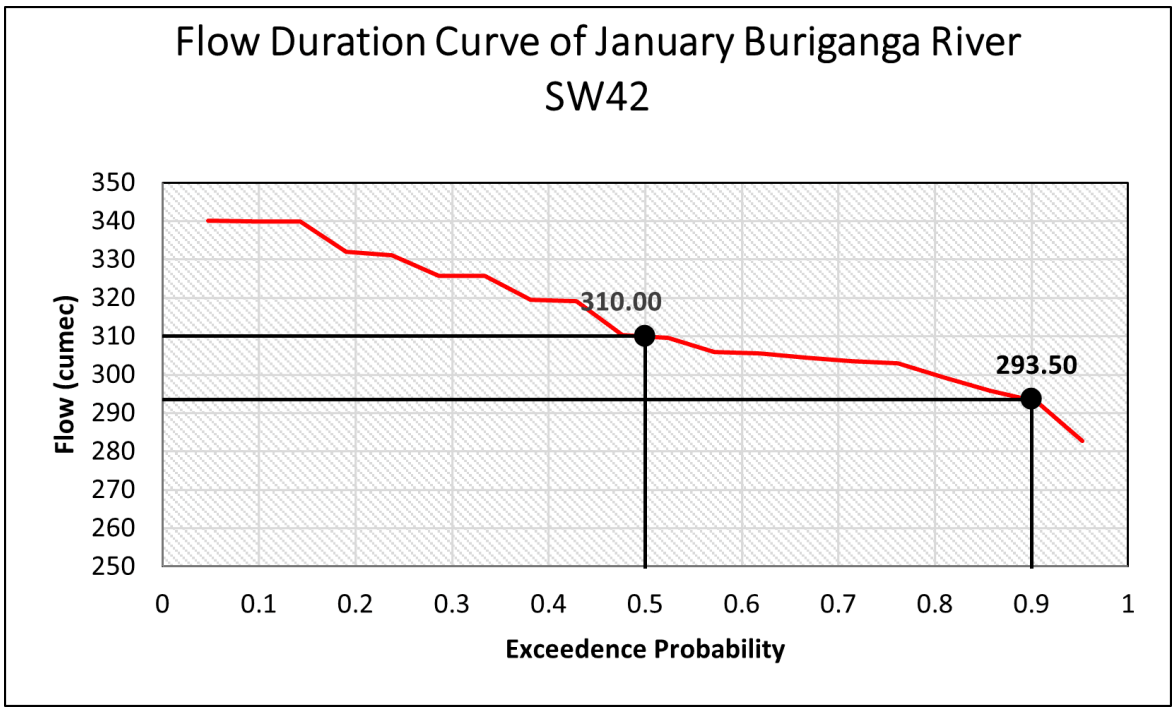
Figure 2(b) (continued): Flow duration curve at Mirpur of Turag (SW 302) for High Flow Season.

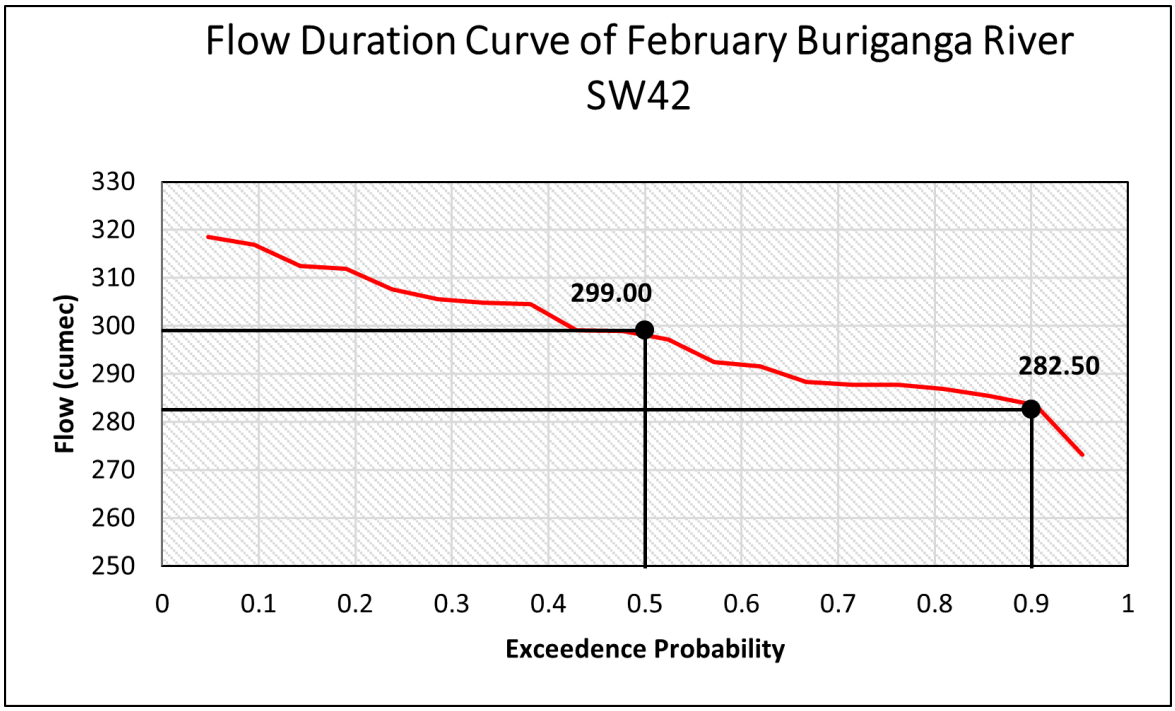
Table 2(b): Environmental flow requirement (EFR) using the Flow duration curve method at Mirpur of Turag River (SW 302).

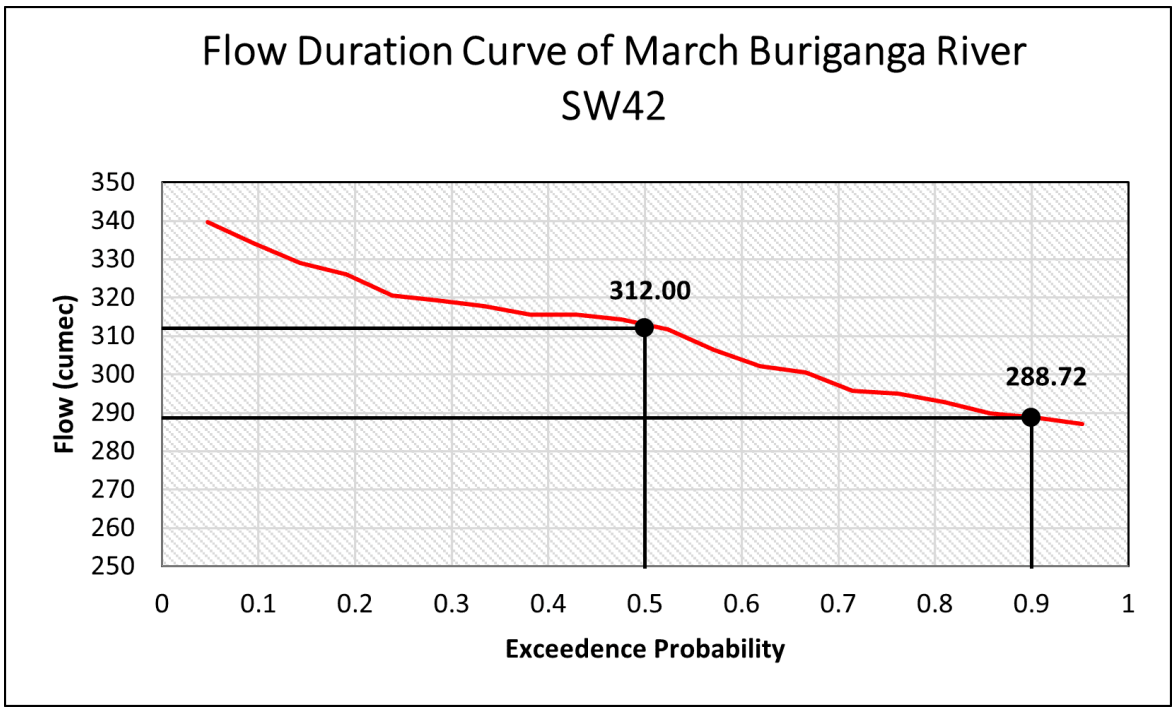
Month	January	February	March	April	May	June	July	August	September	October	November	December
Flow Season	Low	Low	Low	Low	High	High	High	High	High	High	Low	Low
50th Percentile Flow (cumec)	170.49	160.54	170.84	205.28	282.62	412.89	546.12	595.11	582.54	456.74	290.05	290.05
90th Percentile Flow (cumec)	149.37	142.34	142.93	168.54	256.38	340.78	492.52	535.81	509.33	391.32	250.54	250.54
EFF (cumec)	149.37	142.34	142.93	168.54	282.62	412.89	546.12	595.11	582.54	456.74	290.05	290.05


Flow Duration Curve of November Buriganga River SW42
550
500
450
400
350
300
Flow (cumec)
444.85
380.00
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
Exceedence Probability


Flow Duration Curve of December Buriganga River SW42
450
430
410
390
370
350
330
310
290
270
250
Flow (cumec)
356.97
318.50
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
Exceedence Probability


Flow Duration Curve of January Buriganga River SW42
Flow (cumec)
350
340
330
320
310
300
290
280
270
260
250
310.00
293.50
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
Exceedence Probability


Flow Duration Curve of February Buriganga River SW42
Flow (cumec)
330
320
310
300
290
280
270
260
250
299.00
282.50
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
Exceedence Probability



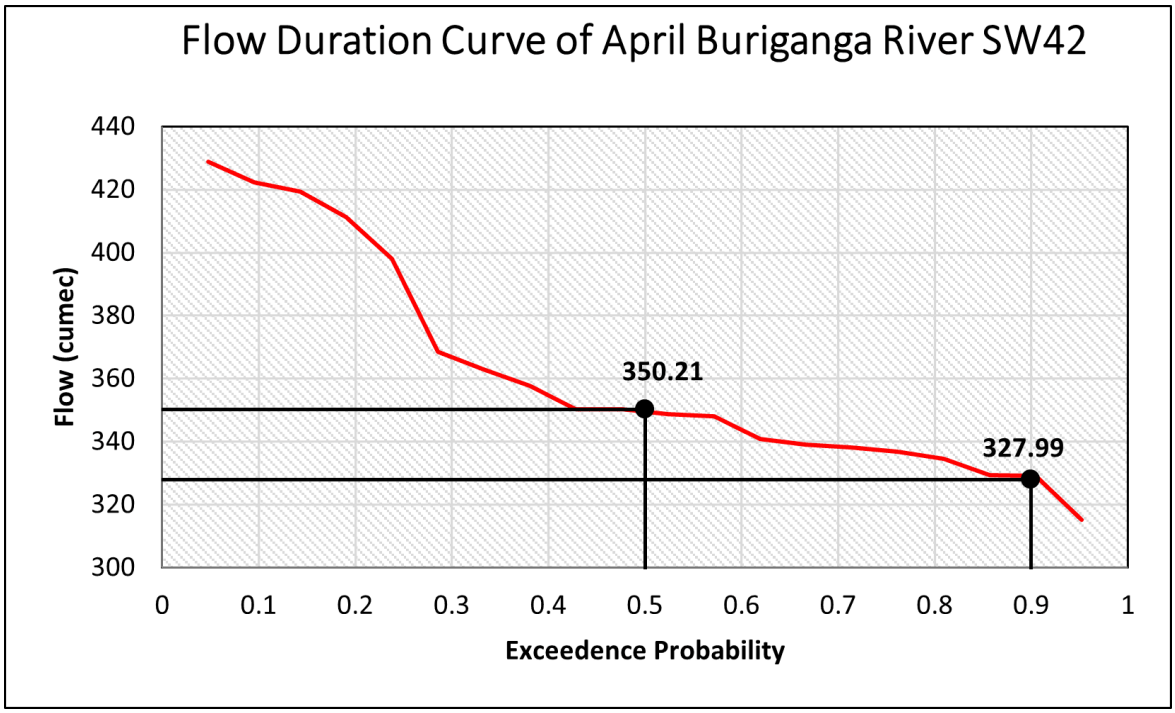
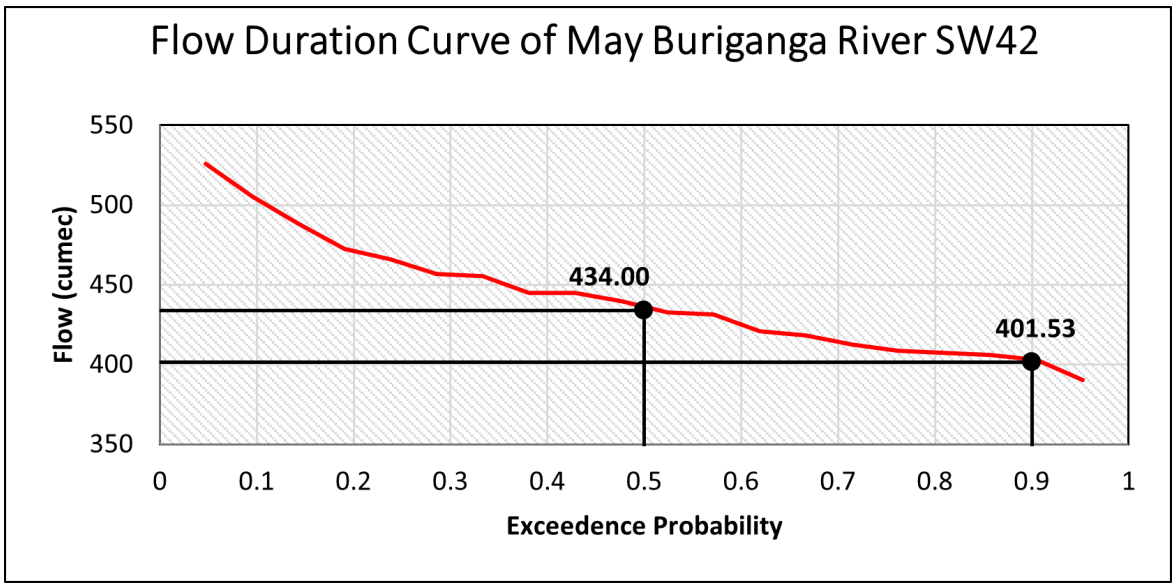
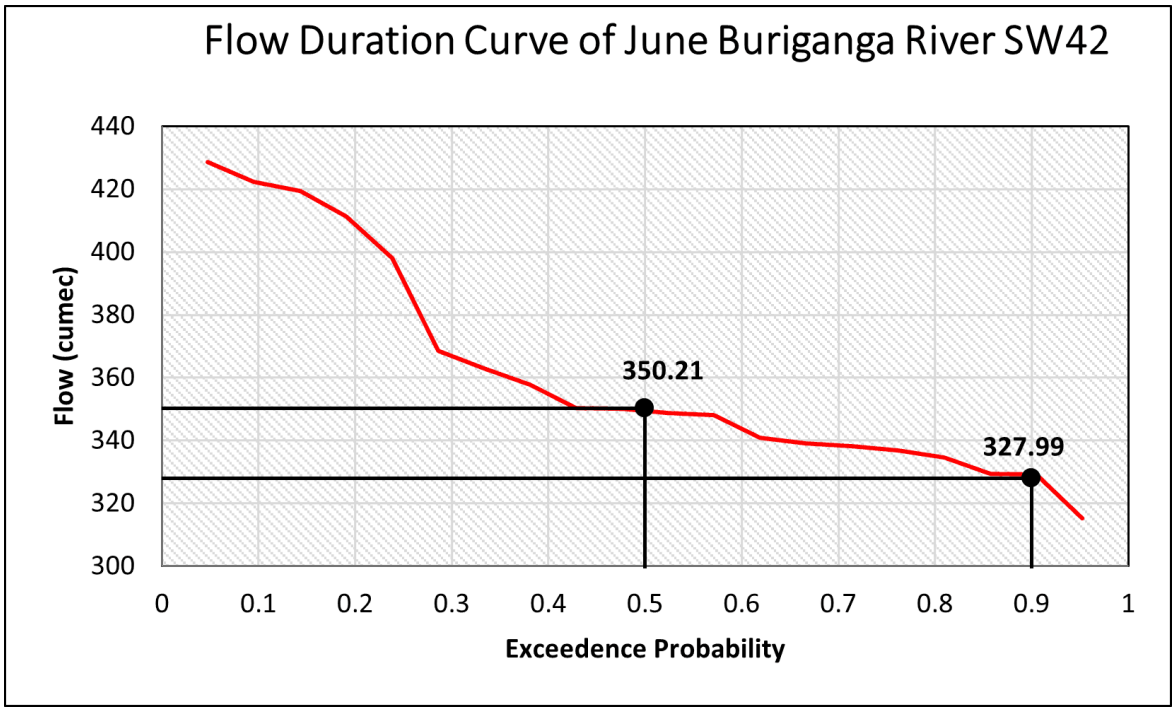
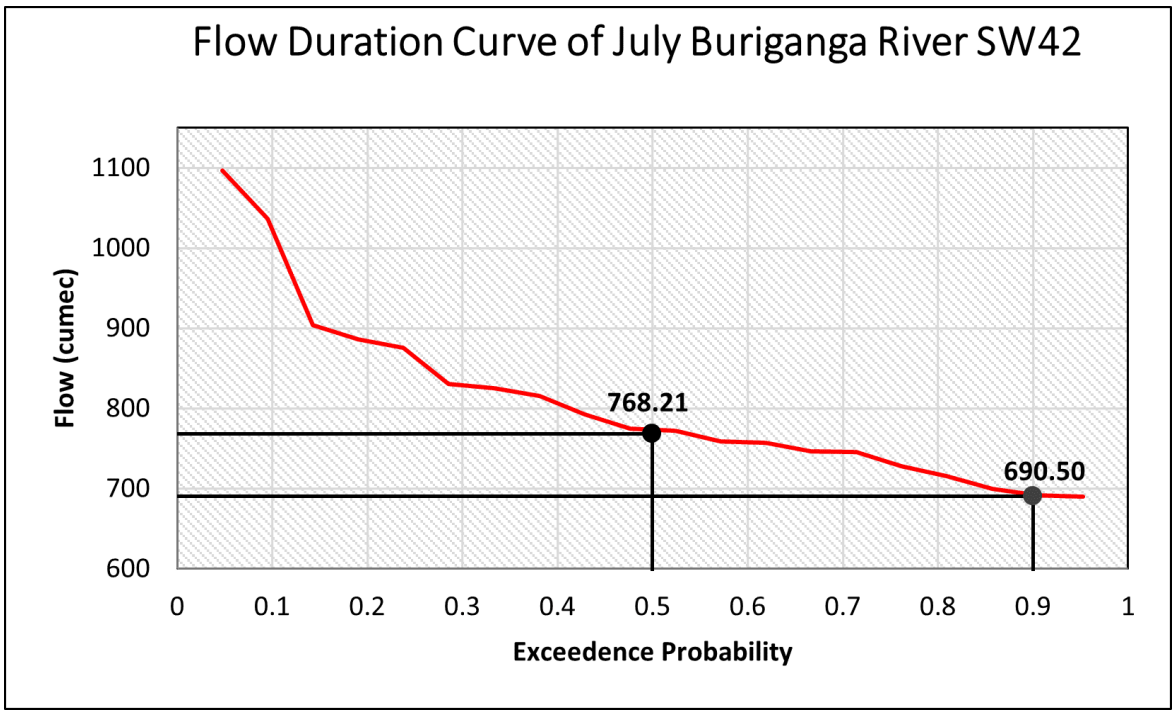
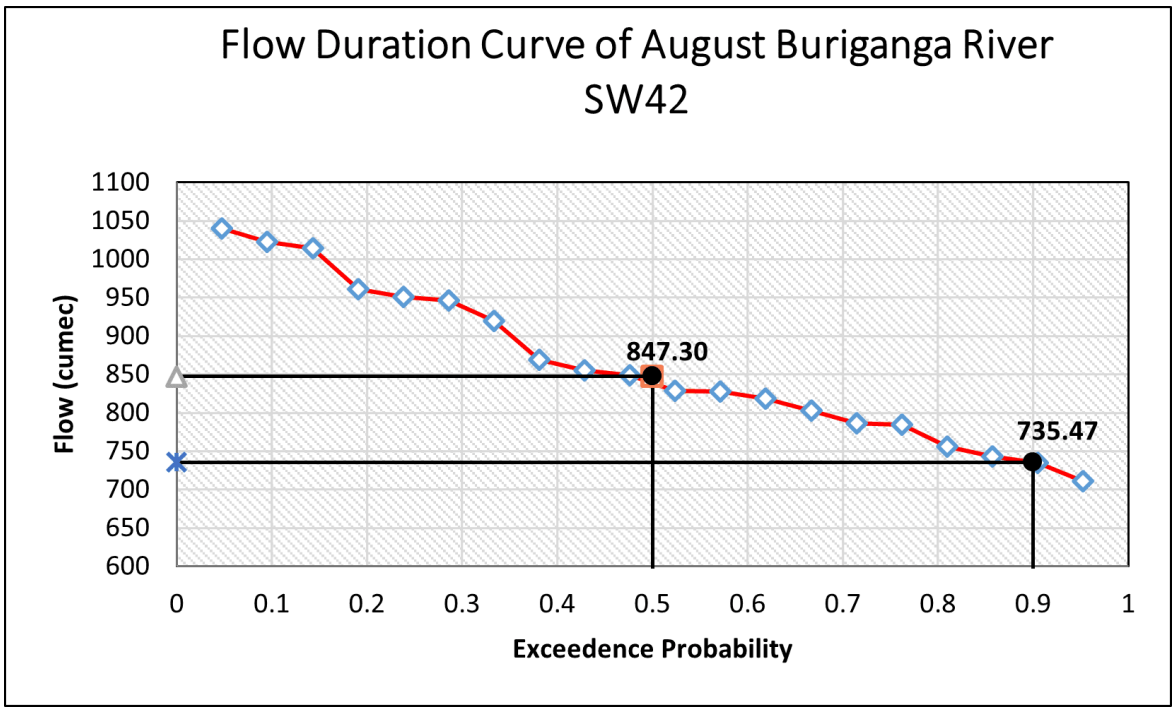


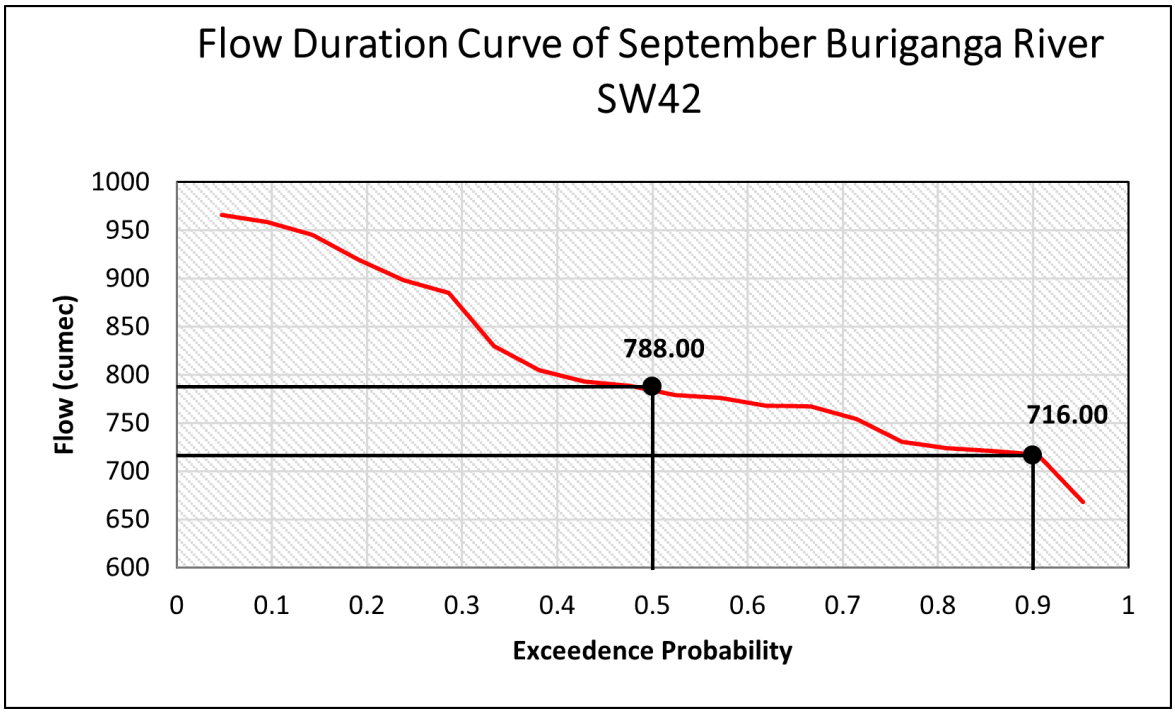
Figure 2(c): Flow duration curve at Dhaka Mill Barrack of Buriganga (SW 42) for Low Flow Season.


Flow Duration Curve of May Buriganga River SW42
Flow (cumec)
550
500
450
400
350
434.00
401.53
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
Exceedence Probability


Flow Duration Curve of June Buriganga River SW42
Flow (cumec)
440
420
400
380
360
340
320
300
350.21
327.99
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
Exceedence Probability


Flow Duration Curve of July Buriganga River SW42
Flow (cumec)
1100
1000
900
800
700
600
768.21
690.50
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
Exceedence Probability


Flow Duration Curve of August Buriganga River SW42
Flow (cumec)
1100
1050
1000
950
900
850
800
750
700
650
600
847.30
735.47
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
Exceedence Probability


Flow Duration Curve of September Buriganga River SW42
Flow (cumec)
1000
950
900
850
800
750
700
650
600
788.00
716.00
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
Exceedence Probability

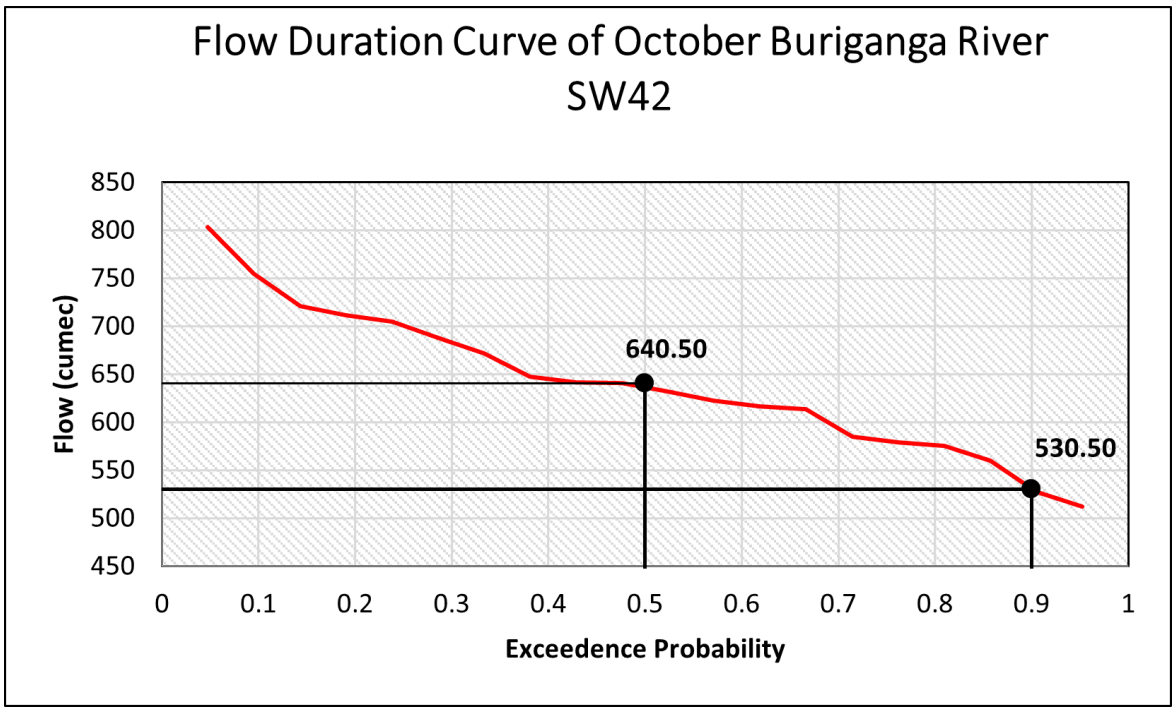
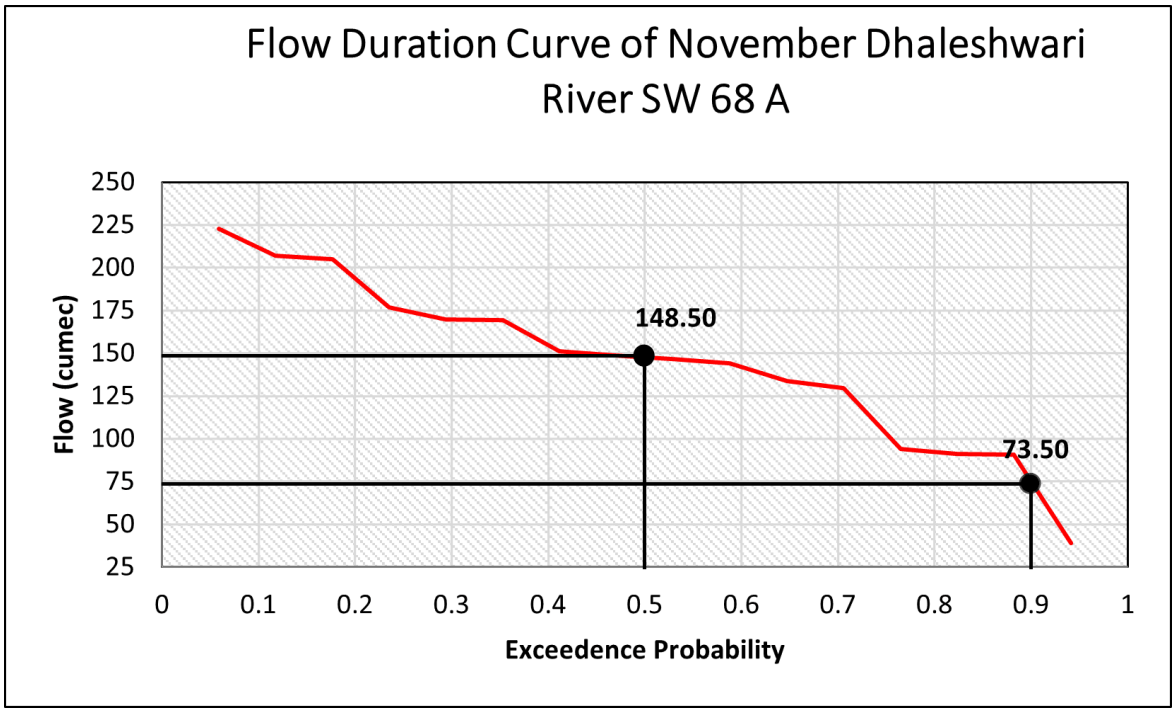
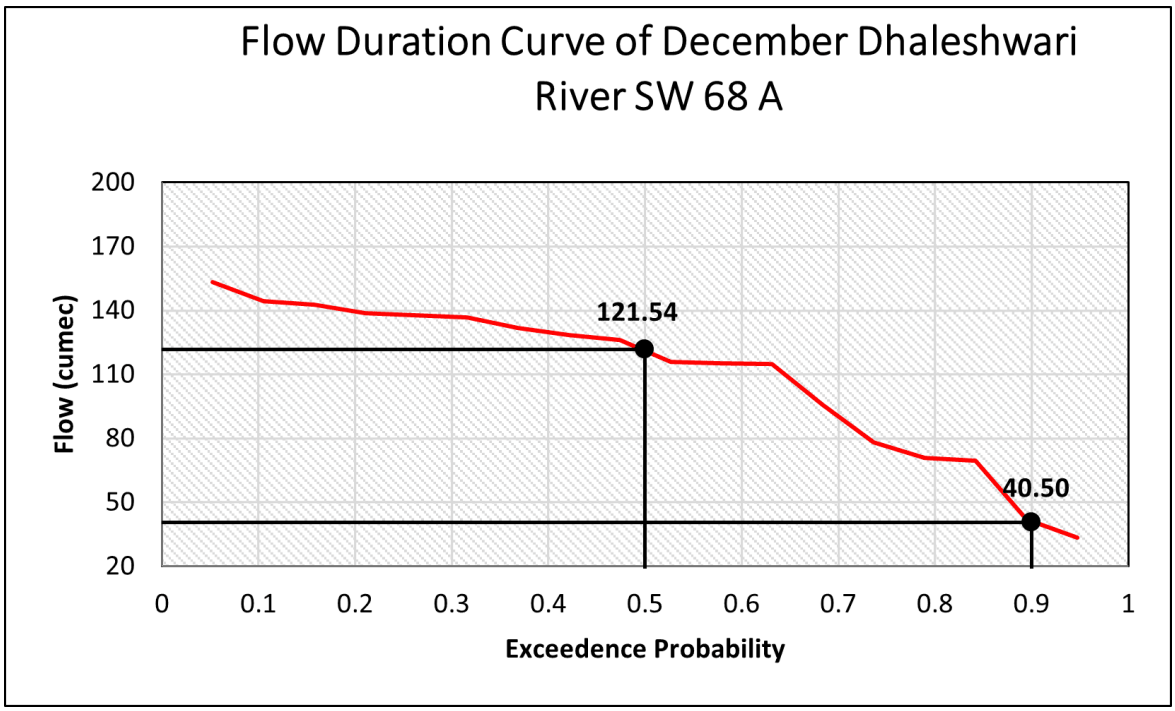


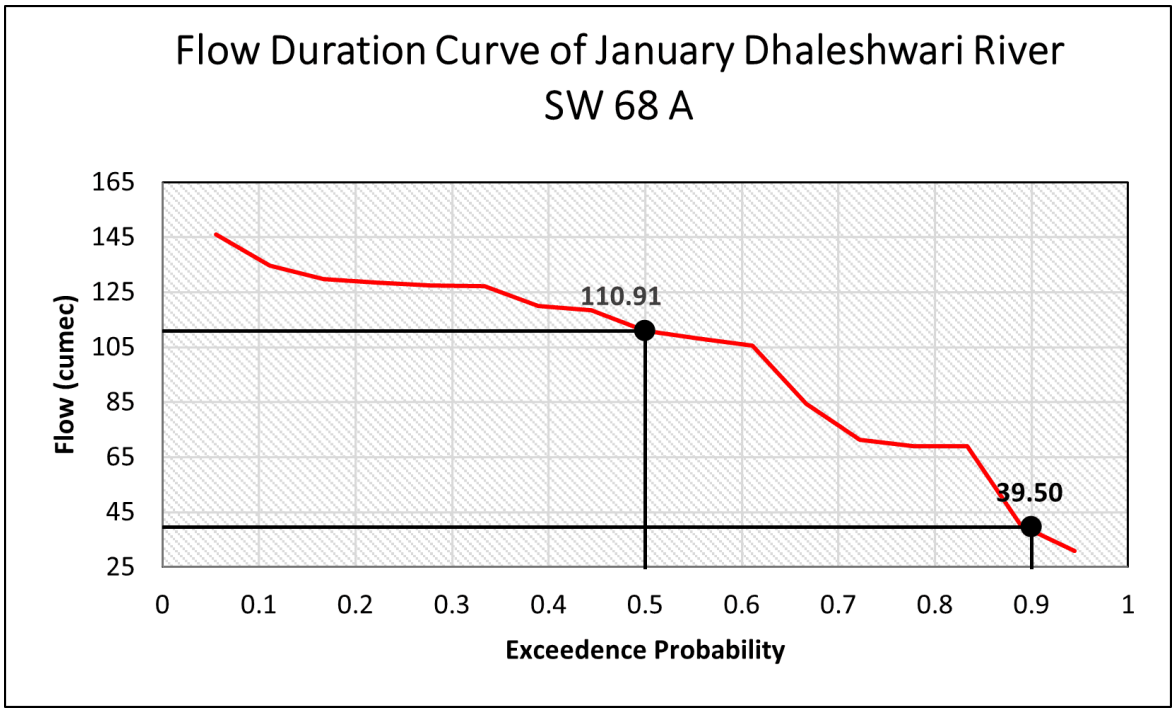
Figure 2(c) (continued): Flow duration curve at Dhaka Mill Barrack of Buriganga (SW 42) for High Flow Season.

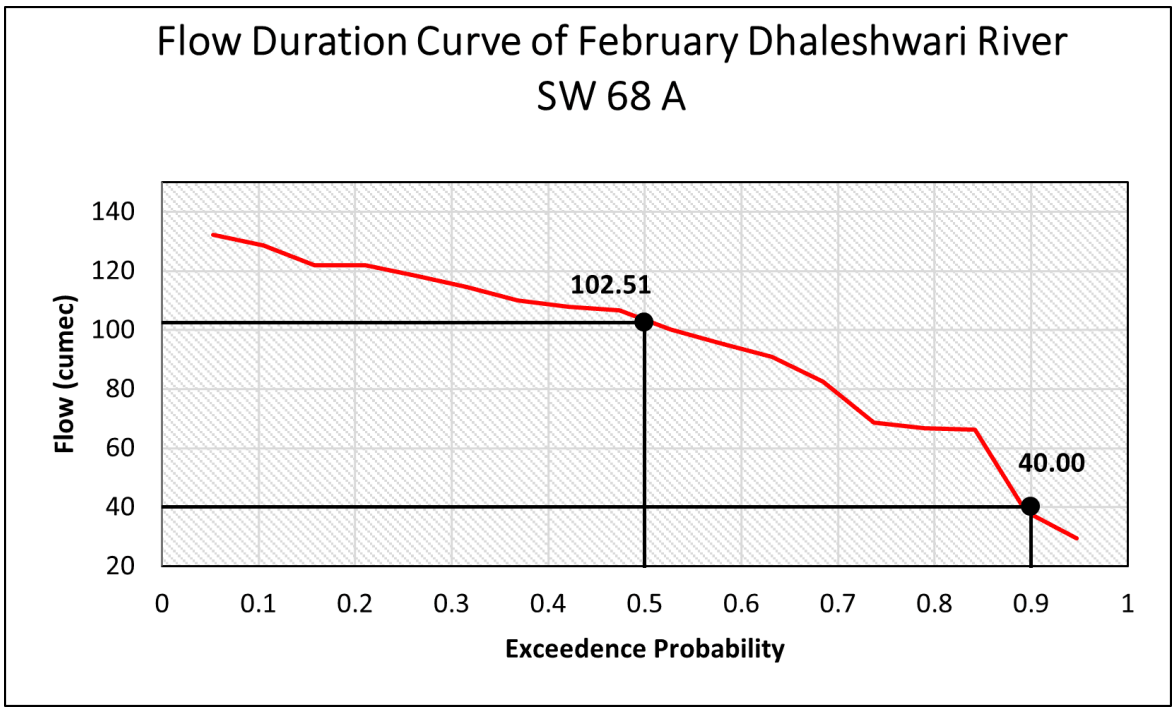
Table 2(c): Environmental flow requirement (EFR) using Flow duration curve method at Dhaka Mill Barack of Buriganga River (SW 42)

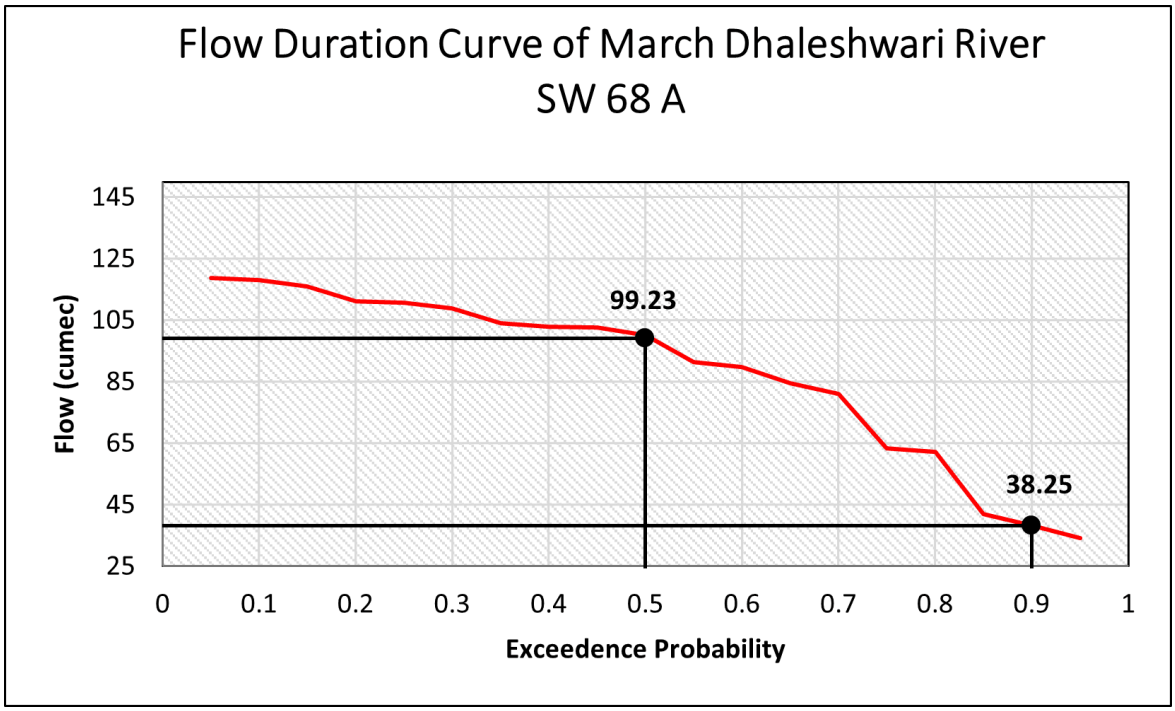
Month	January	February	March	April	May	June	July	August	September	October	November	December
Flow Season	Low	Low	Low	Low	High	High	High	High	High	High	Low	Low
50th Percentile Flow (cumec)	310.00	299.00	312.00	350.21	434.00	595.50	768.21	847.30	788.00	640.50	444.85	356.97
90th Percentile Flow (cumec)	293.50	282.50	288.72	327.99	401.53	509.48	690.50	735.47	716.00	530.50	380.00	318.50
ERF (cumec)	293.50	282.50	288.72	327.99	434.00	595.50	768.21	847.30	788.00	640.50	380.00	318.50




Flow Duration Curve of December Dhaleshwari River SW 68 A
Flow (cumec)
200
170
140
110
80
50
20
121.54
40.50
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
Exceedence Probability


Flow Duration Curve of January Dhaleshwari River SW 68 A
Flow (cumec)
165
145
125
105
85
65
45
25
110.91
39.50
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
Exceedence Probability


Flow Duration Curve of February Dhaleshwari River
SW 68 A
Flow (cumec)
140
120
100
80
60
40
20
102.51
40.00
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
Exceedence Probability


Flow Duration Curve of March Dhaleshwari River
SW 68 A
Flow (cumec)
145
125
105
85
65
45
25
99.23
38.25
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
Exceedence Probability

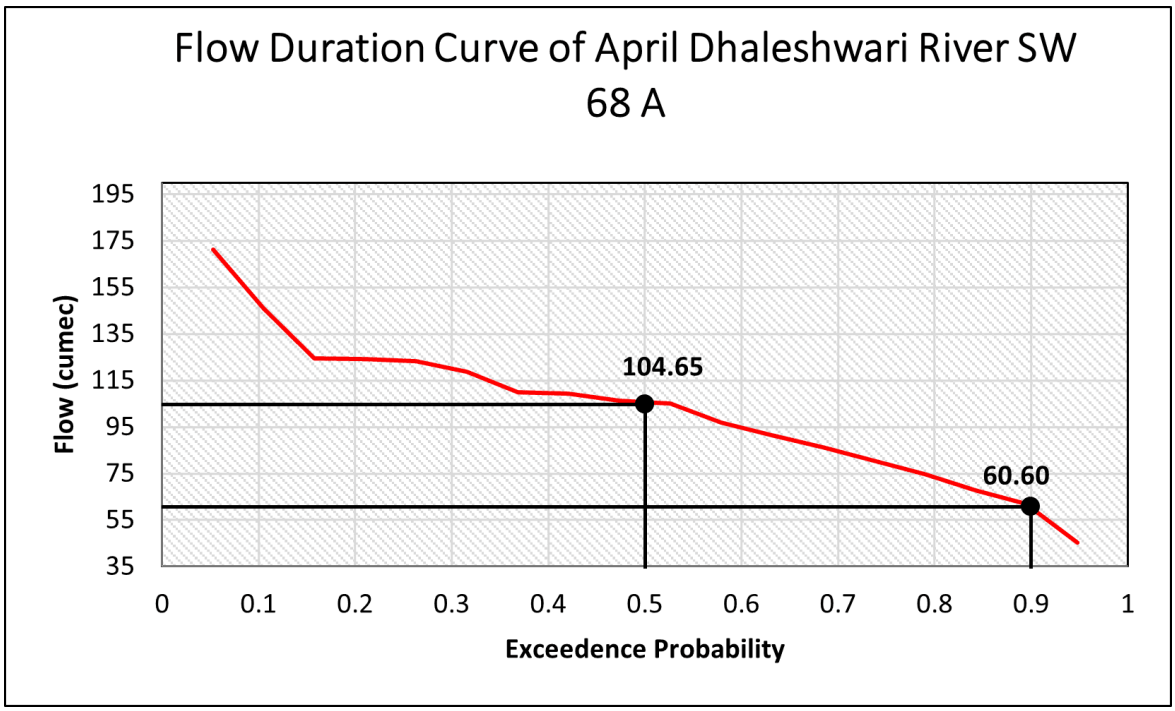
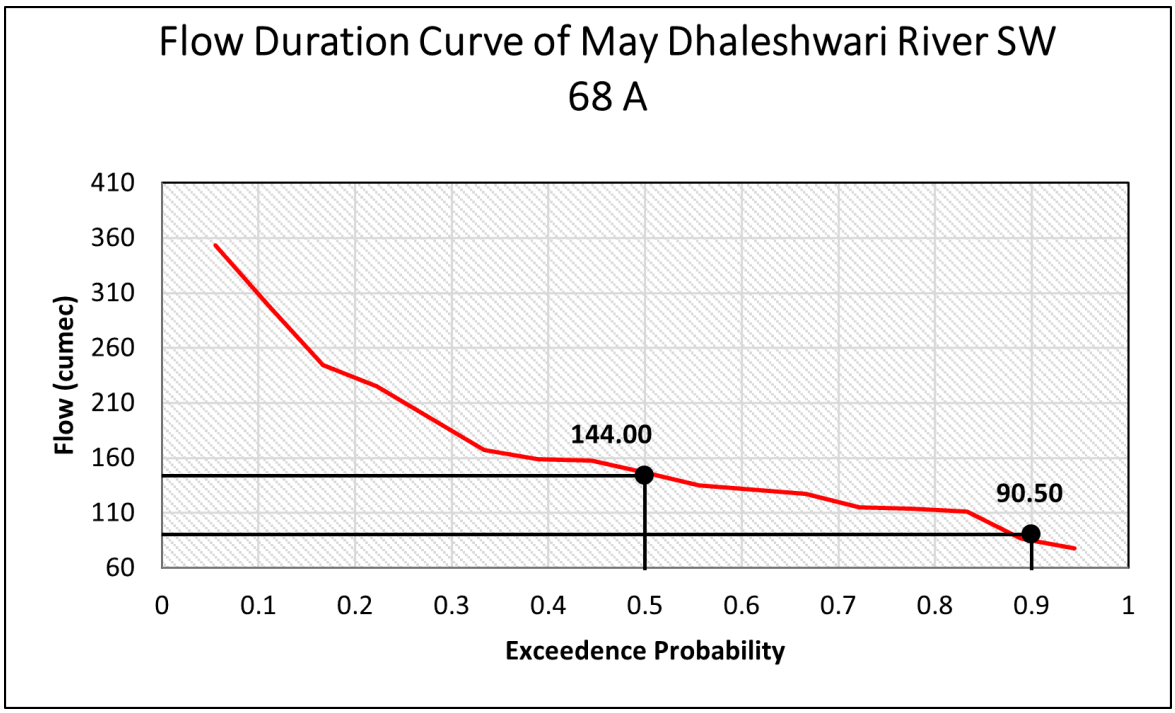
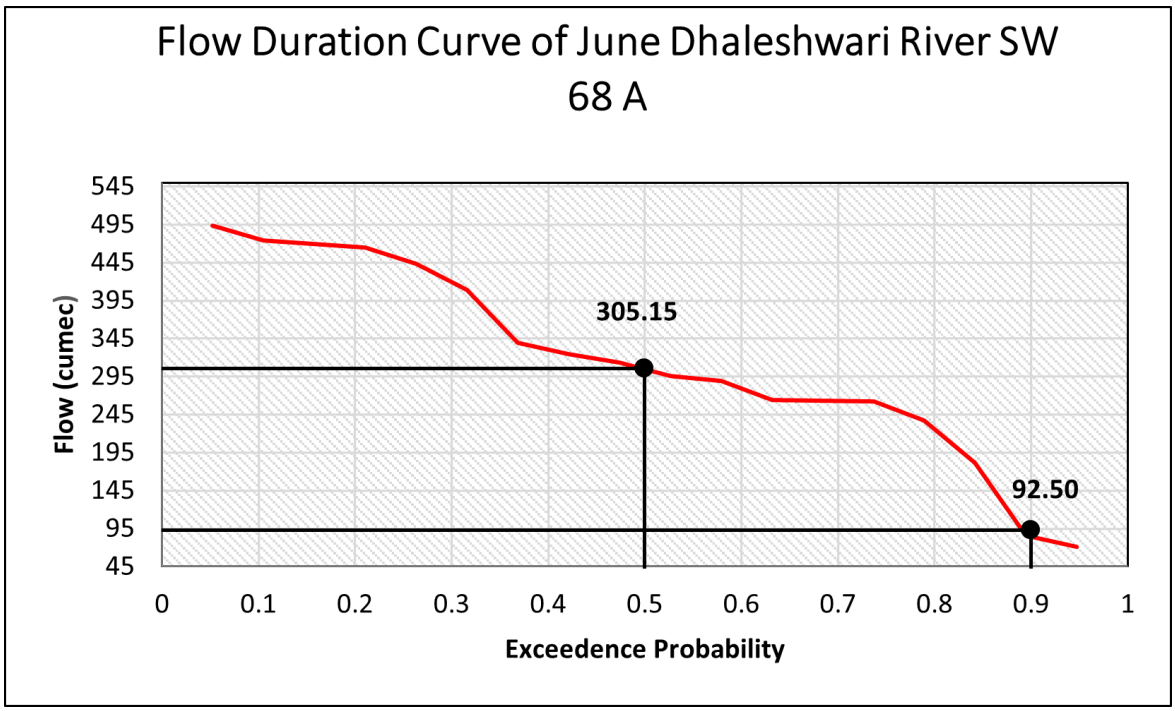
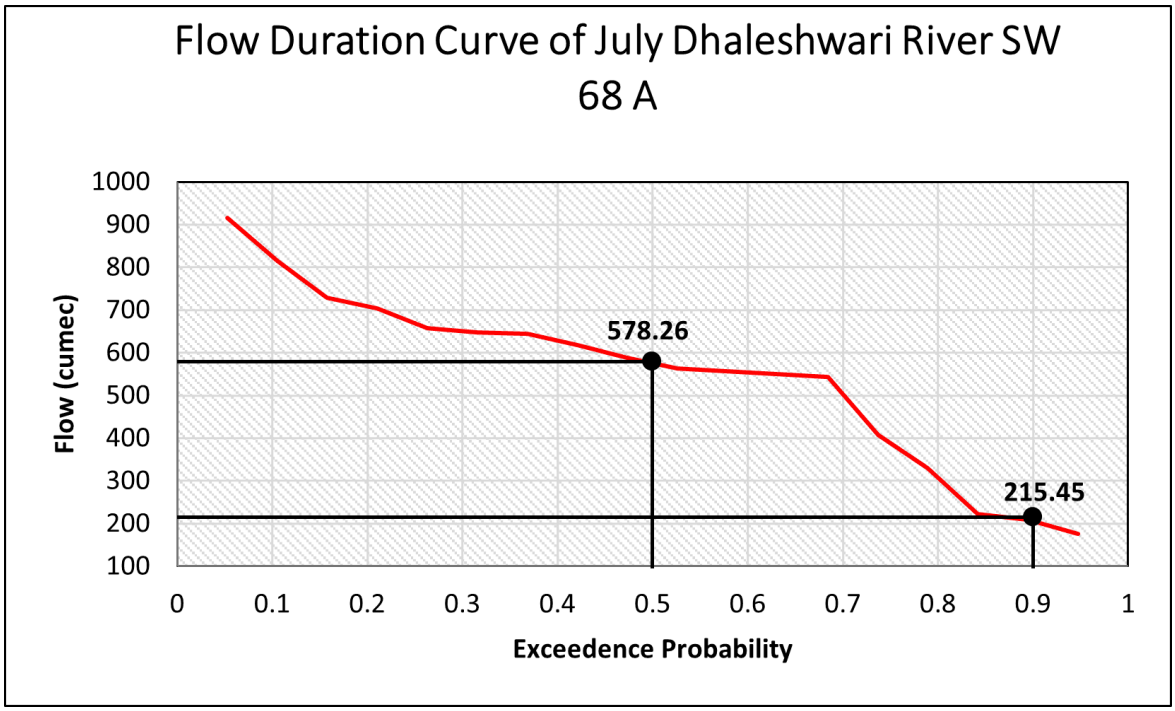
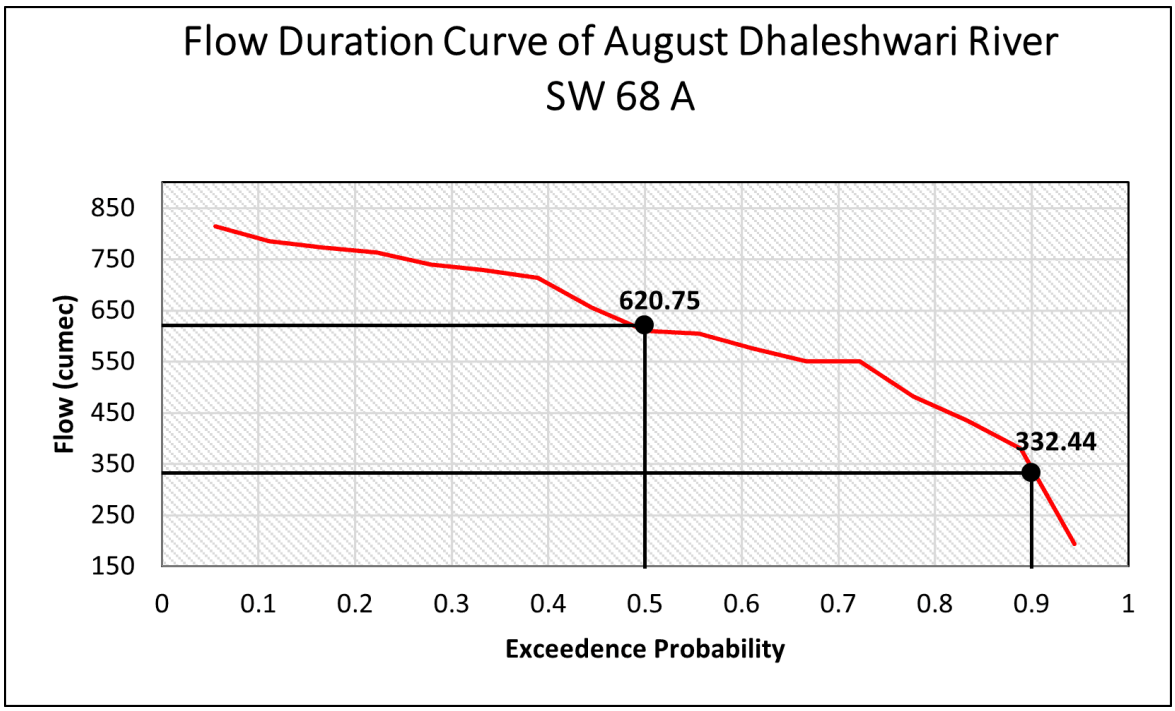


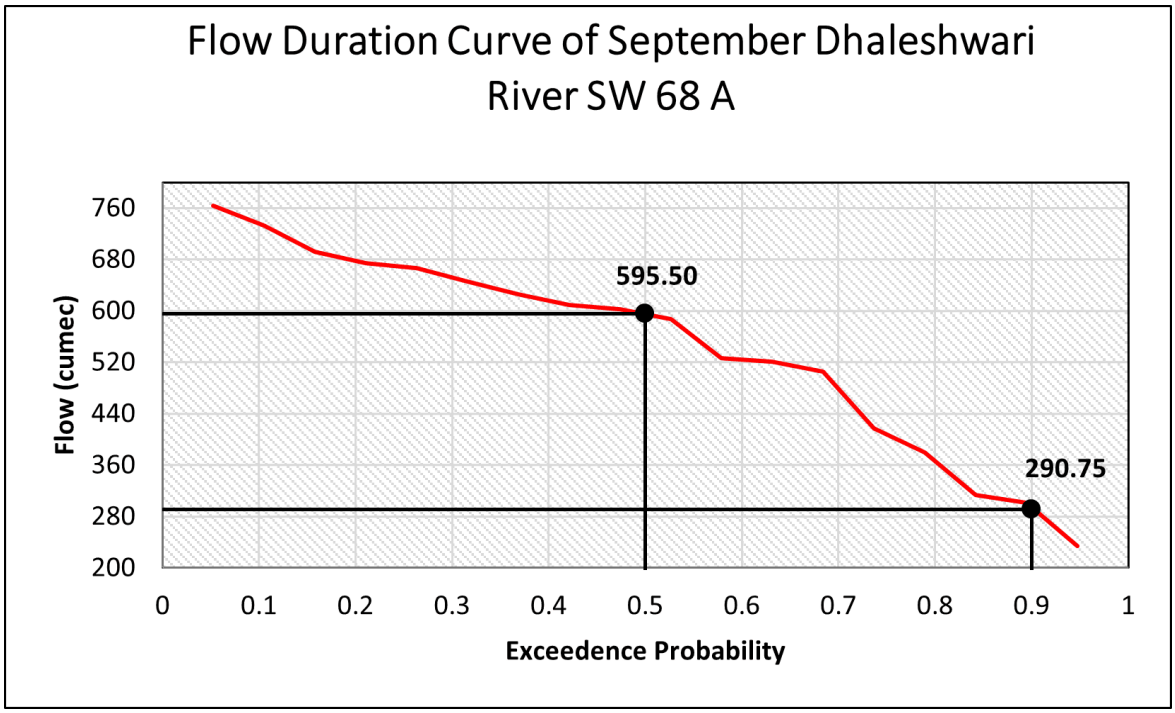
Figure 2(d): Flow duration curve at Elashin of Dhaleshwari (SW 68 A) for Low Flow Season.




Flow Duration Curve of June Dhaleshwari River SW 68 A
545
495
445
395
345
295
245
195
145
95
45
Flow (cumec)
305.15
92.50
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
Exceedence Probability


Flow Duration Curve of July Dhaleshwari River SW 68 A
1000
900
800
700
600
500
400
300
200
100
Flow (cumec)
578.26
215.45
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
Exceedence Probability


Flow Duration Curve of August Dhaleshwari River SW 68 A
850
750
650
550
450
350
250
150
Flow (cumec)
620.75
332.44
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
Exceedence Probability


Flow Duration Curve of September Dhaleshwari River SW 68 A
760
680
600
520
440
360
280
200
Flow (cumec)
595.50
290.75
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
Exceedence Probability

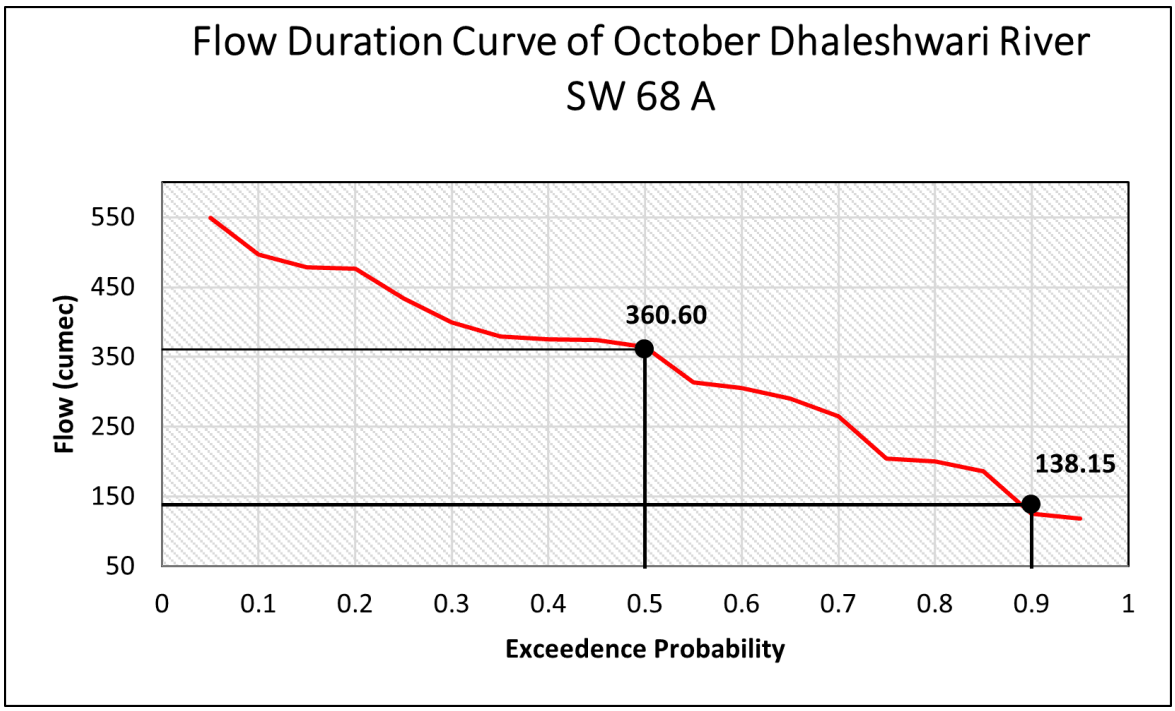
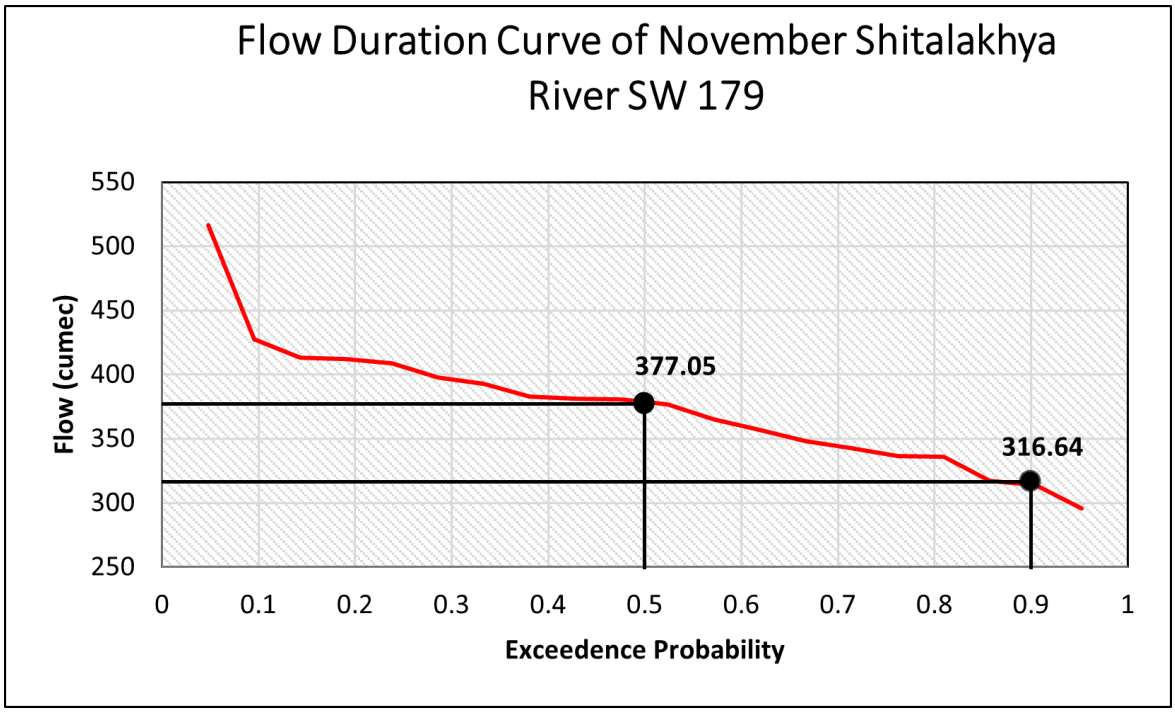
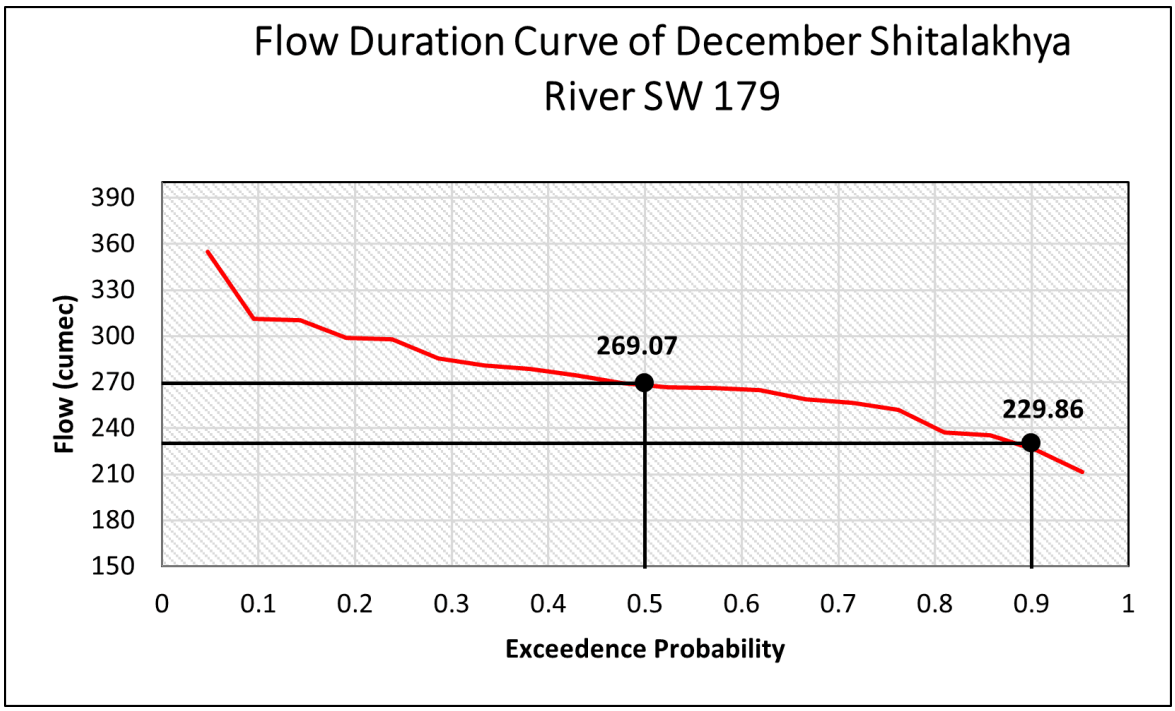


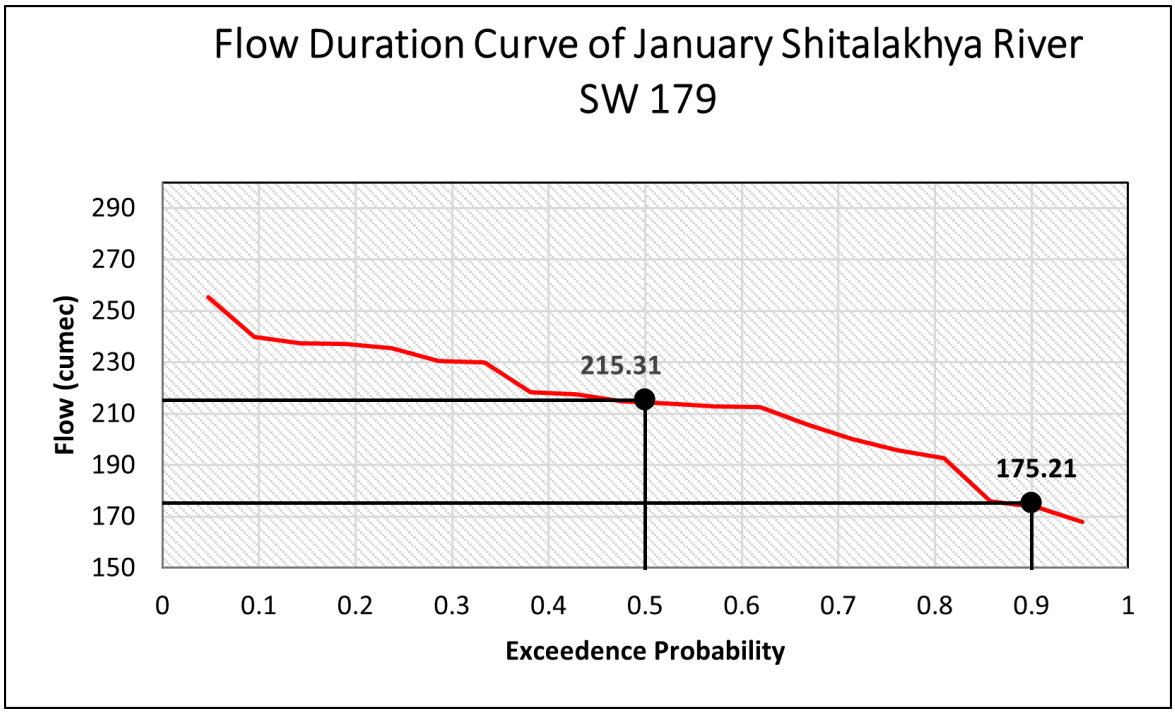
Figure 2(d) (continued): Flow duration curve at Elashin of Dhaleshwari (SW 68 A) for Low Flow Season.

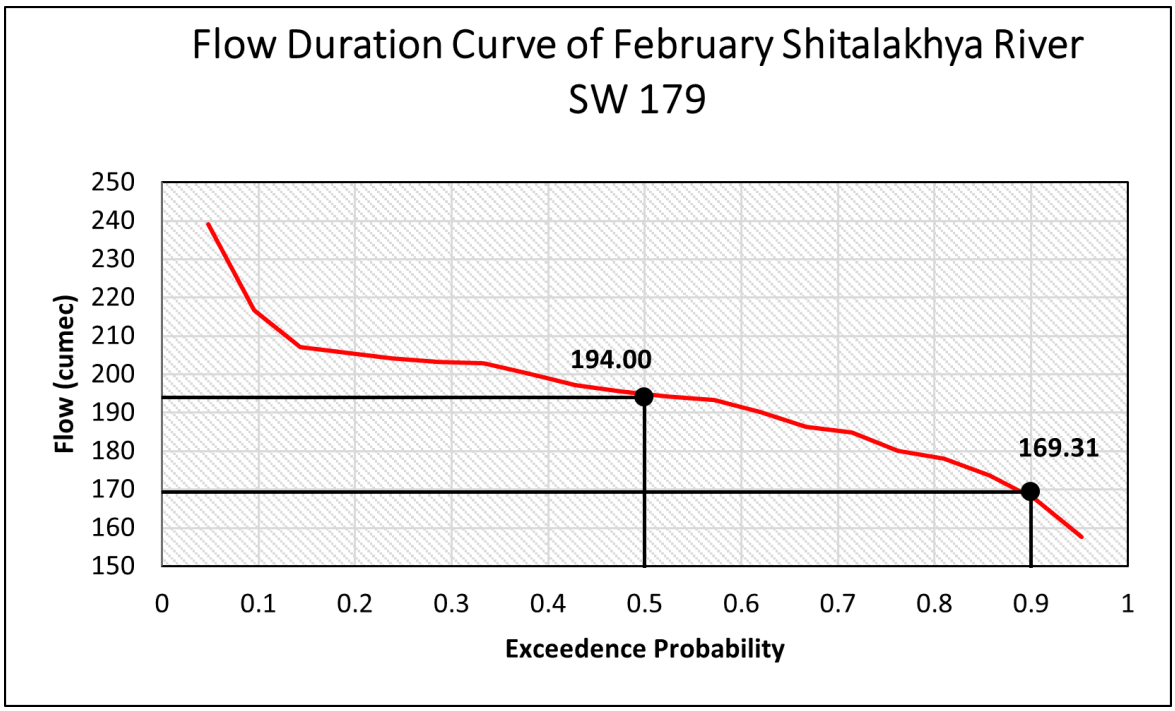
Table 2(d): Environmental flow requirement (EFR) using Flow duration curve method at Elashin of Dhaleshwari River (SW 68A)

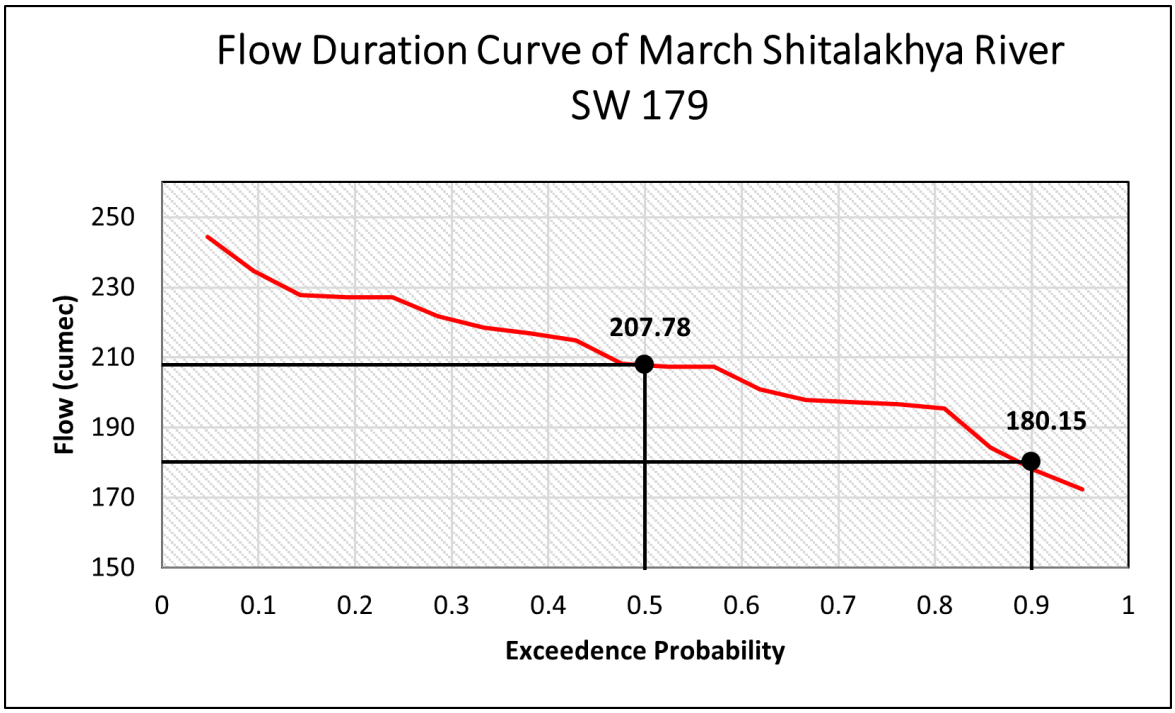
Month	January	February	March	April	May	June	July	August	September	October	November	December
Flow Season	Low	Low	Low	Low	High	High	High	High	High	High	Low	Low
50th Percentile Flow (cumec)	110.91	102.51	99.23	104.65	144.00	305.15	578.26	620.75	595.50	360.60	148.50	121.54
90th Percentile Flow (cumec)	39.50	40.00	38.25	60.60	90.50	92.50	215.45	332.44	290.75	138.15	73.50	40.50
ERF (cumec)	39.50	40.00	38.25	60.60	144.00	305.15	578.26	620.75	595.50	360.60	73.50	40.50




Flow Duration Curve of December Shitalakhya River SW 179
Flow (cumec)
390
360
330
300
270
240
210
180
150
269.07
229.86
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
Exceedence Probability


Flow Duration Curve of January Shitalakhya River SW 179
Flow (cumec)
290
270
250
230
210
190
170
150
215.31
175.21
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
Exceedence Probability


Flow Duration Curve of February Shitalakhya River
SW 179
250
240
230
220
210
200
190
180
170
160
150
Flow (cumec)
194.00
169.31
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
Exceedence Probability


Flow Duration Curve of March Shitalakhya River
SW 179
250
230
210
190
170
150
Flow (cumec)
207.78
180.15
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
Exceedence Probability

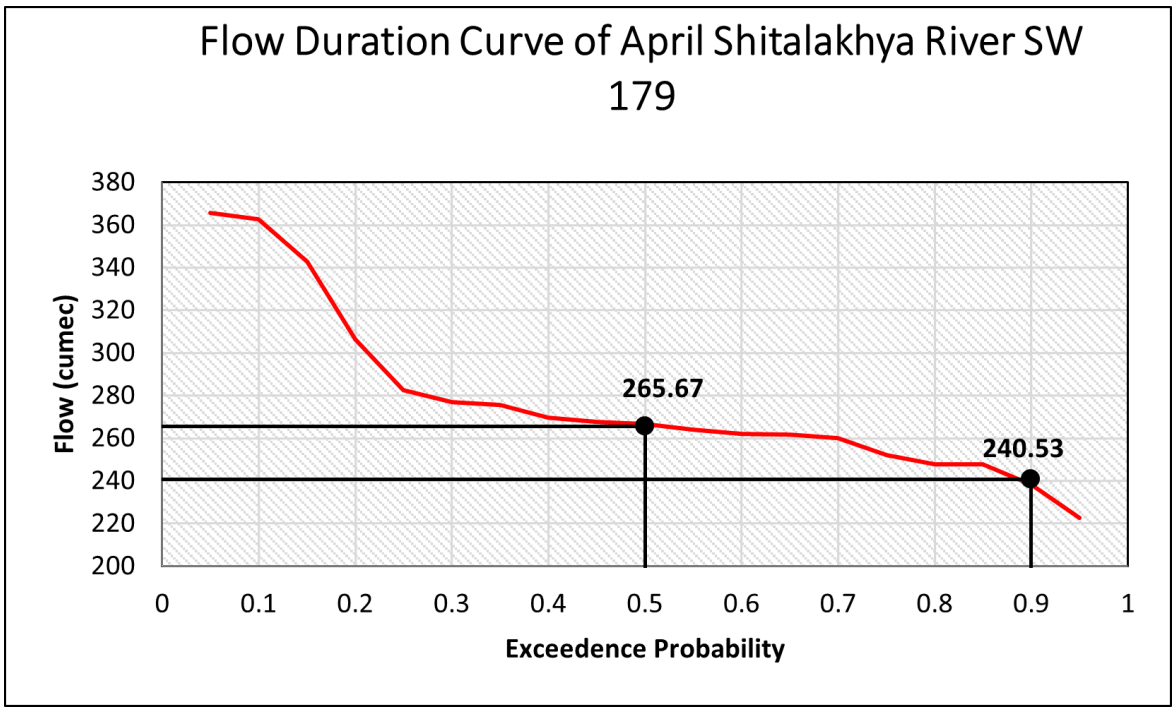
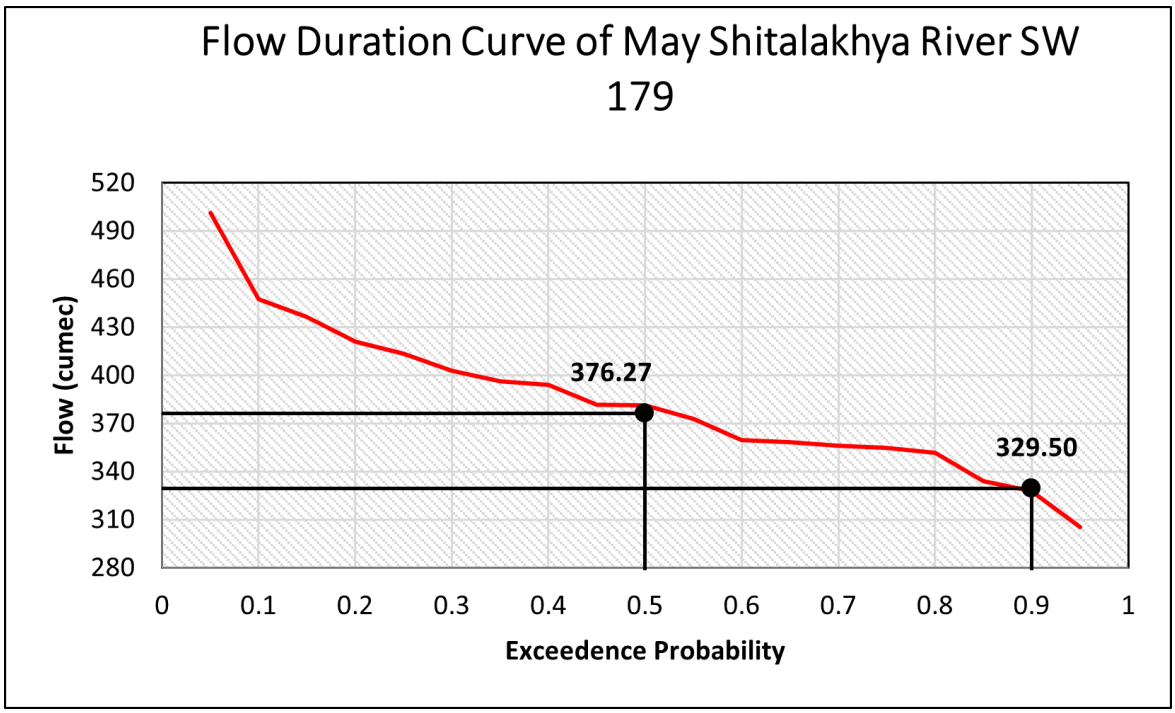
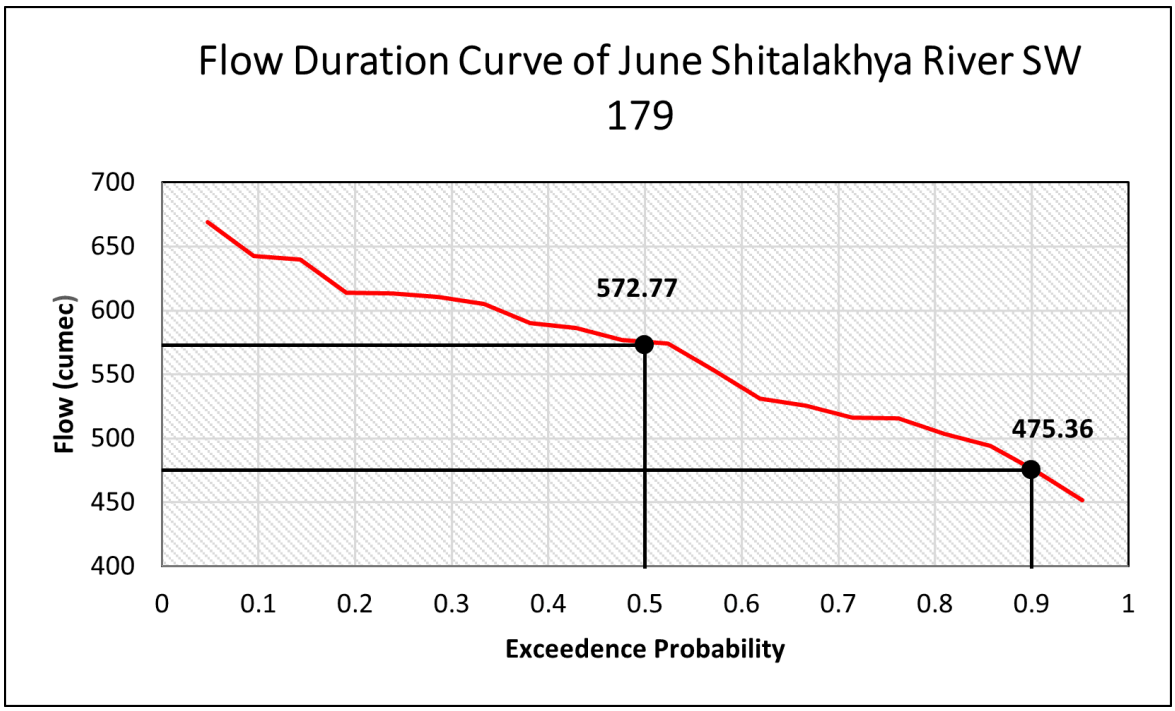
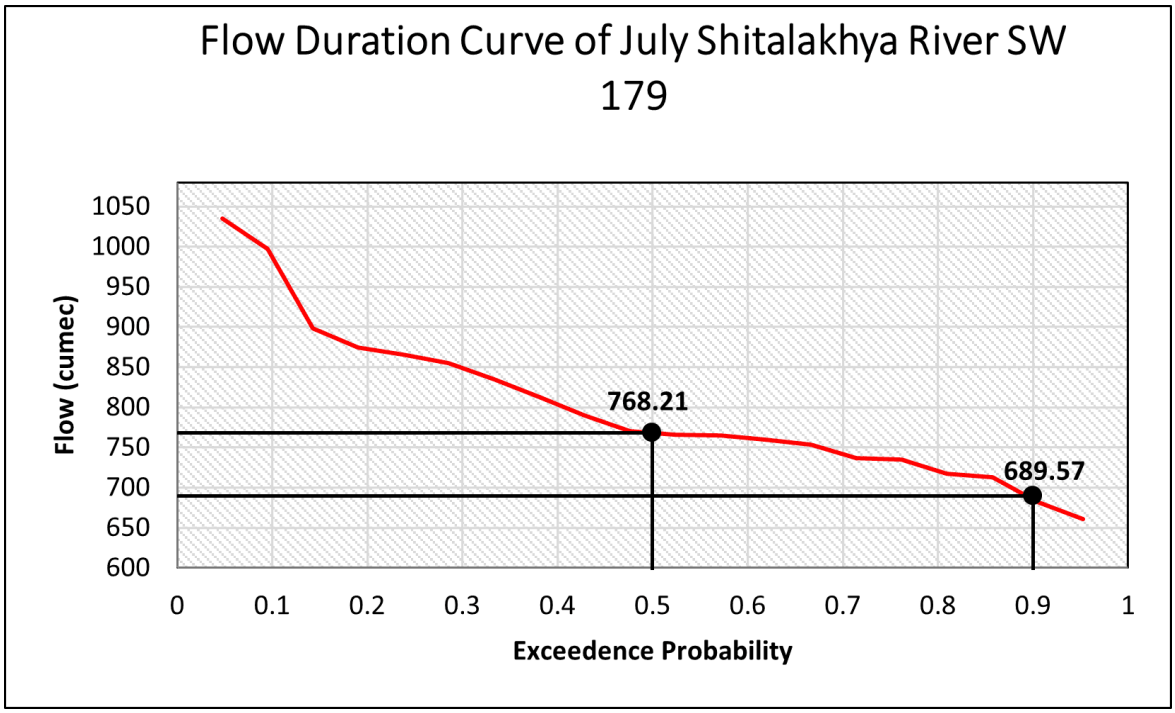
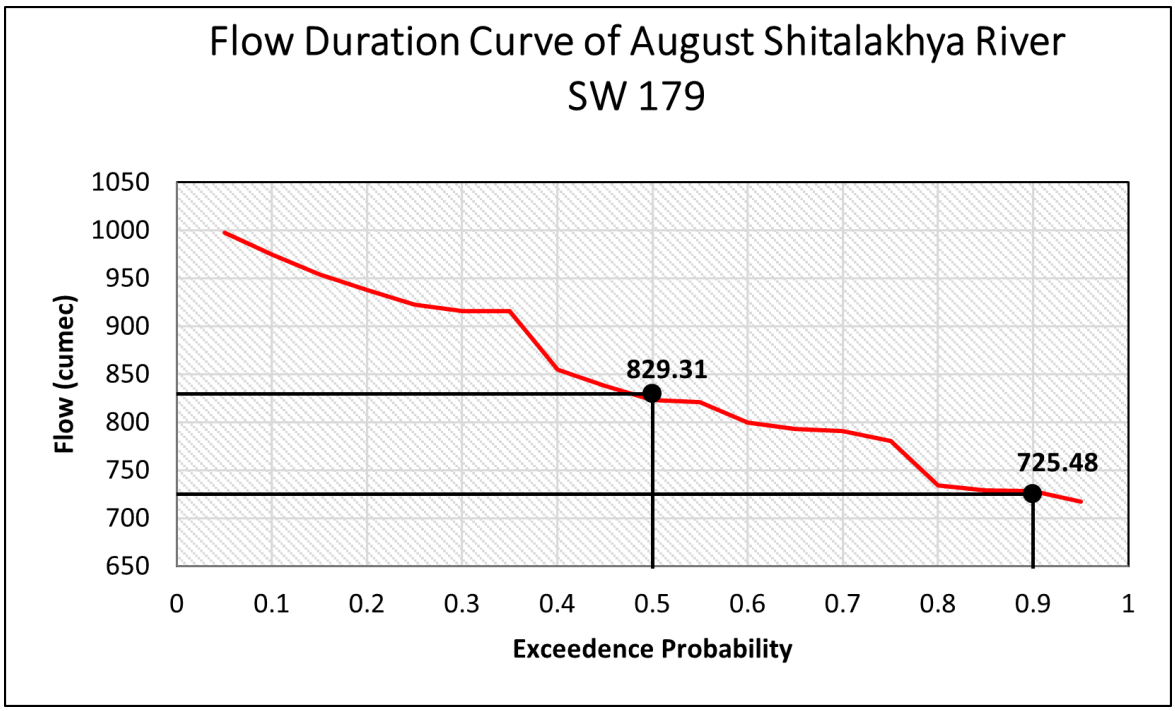


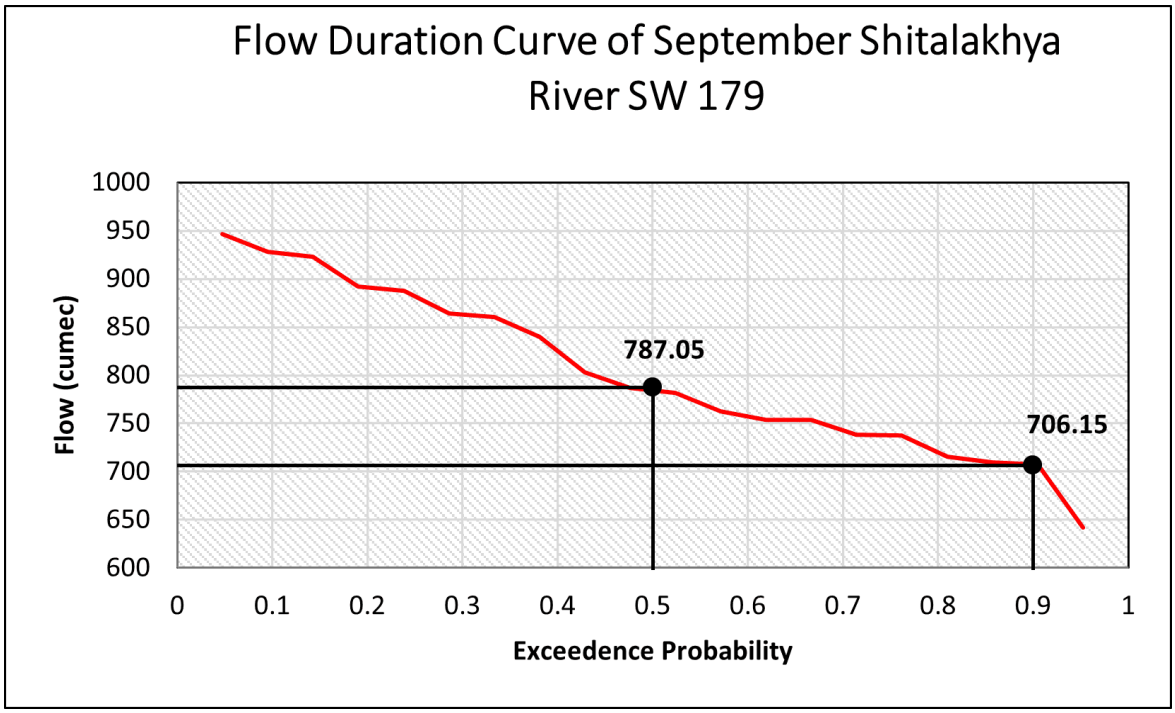
Figure 2(e): Flow duration curve at Jagir of Demra of Shitalakhya (SW 179) for Low Flow Season.




Flow Duration Curve of June Shitalakhya River SW 179
700
650
600
550
500
450
400
Flow (cumec)
572.77
475.36
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
Exceedence Probability


Flow Duration Curve of July Shitalakhya River SW 179
1050
1000
950
900
850
800
750
700
650
600
Flow (cumec)
768.21
689.57
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
Exceedence Probability


Flow Duration Curve of August Shitalakhya River SW 179
1050
1000
950
900
850
800
750
700
650
Flow (cumec)
829.31
725.48
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
Exceedence Probability


Flow Duration Curve of September Shitalakhya River SW 179
1000
950
900
850
800
750
700
650
600
Flow (cumec)
787.05
706.15
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
Exceedence Probability

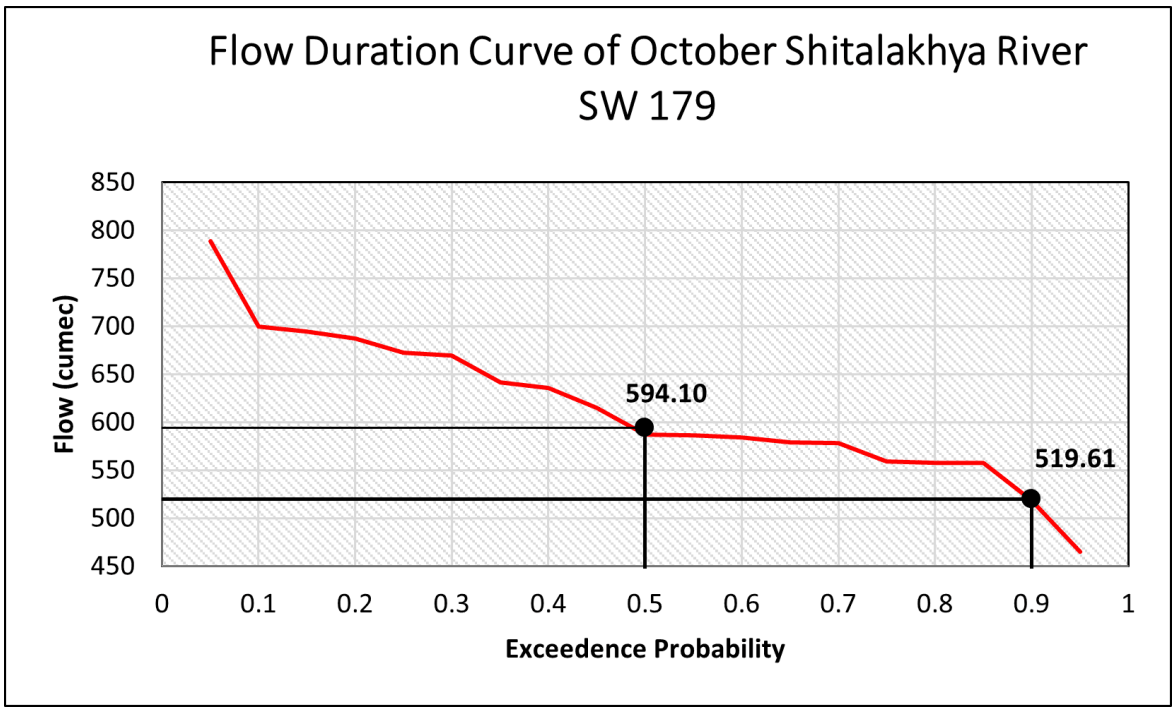
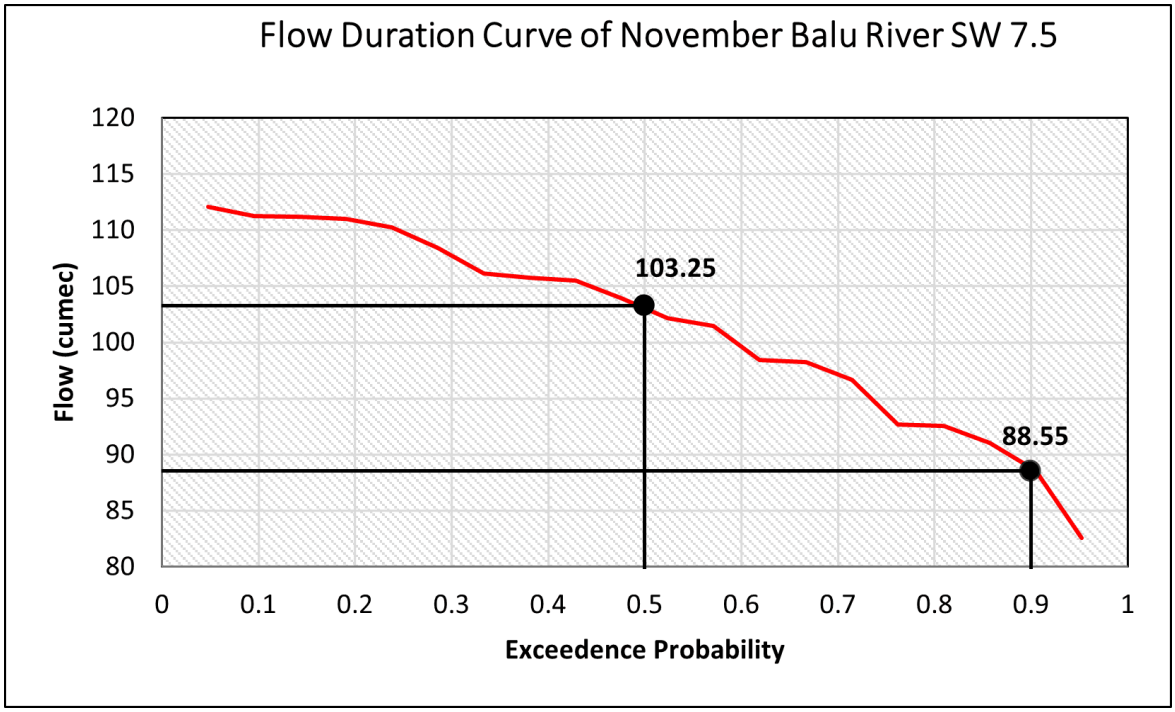
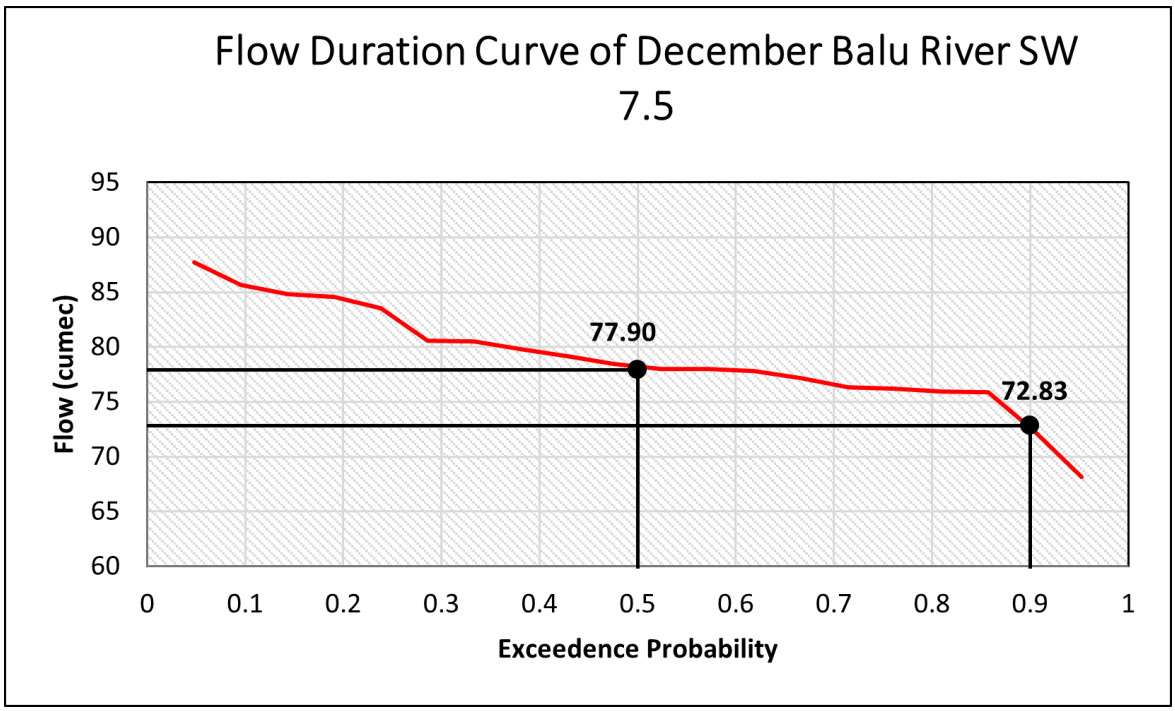


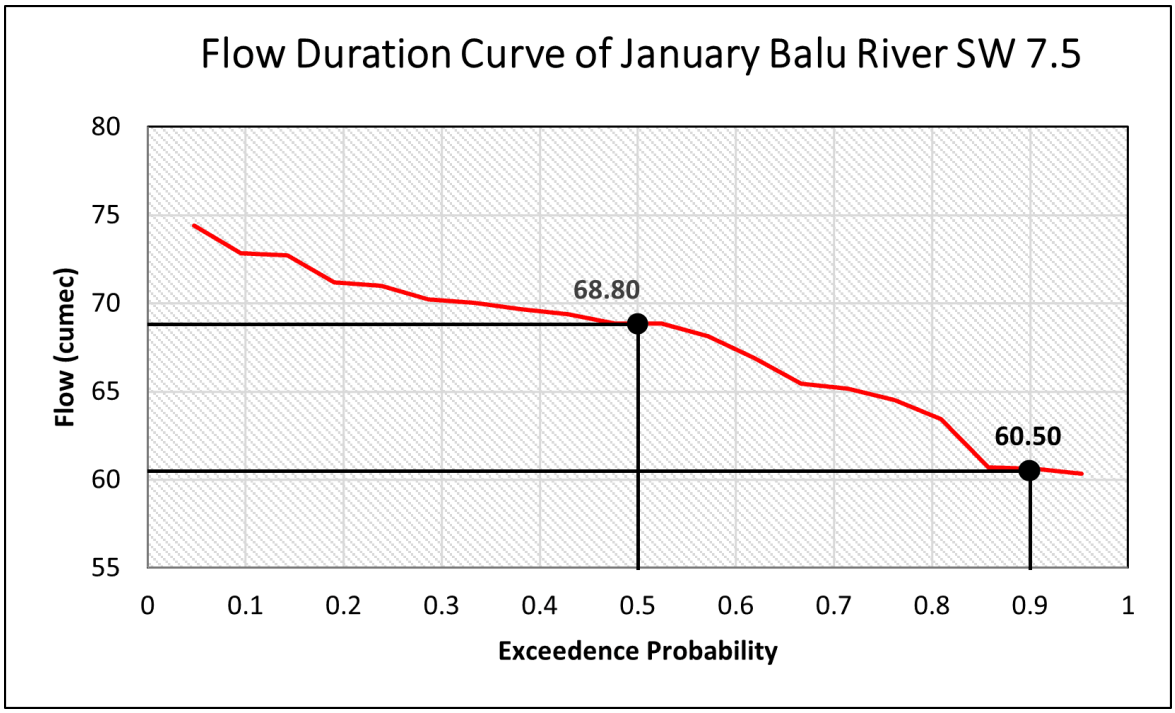
Figure 2(e) (continued): Flow duration curve at Jagir of Demra of Shitalakhya (SW 179) for High Flow Season.

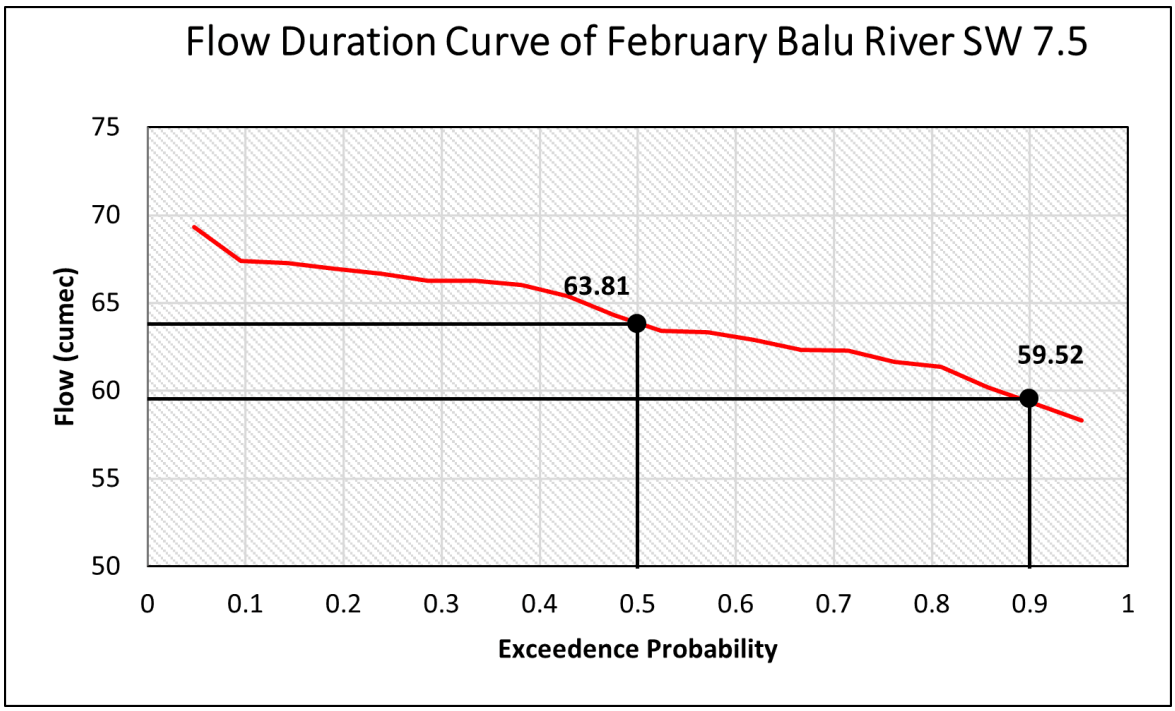
Table 2(e): Environmental flow requirement (EFR) using Flow duration curve method at Demra of Shitalakhya River (SW 179)

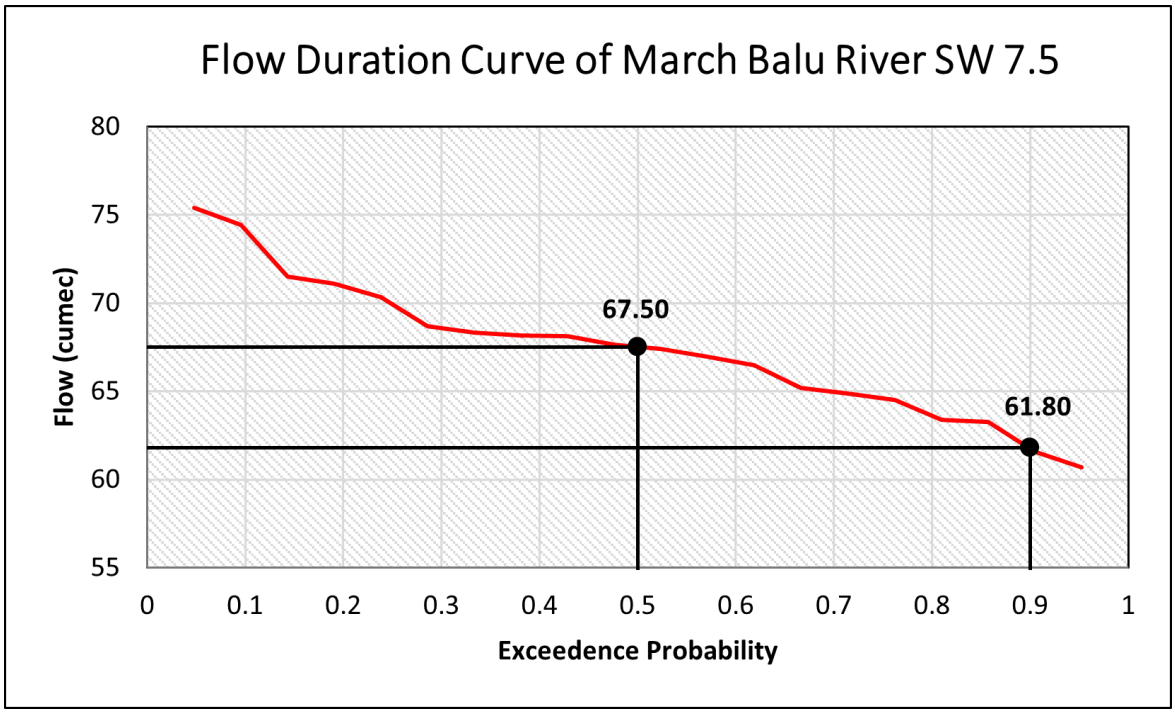
Month	January	February	March	April	May	June	July	August	September	October	November	December
Flow Season	Low	Low	Low	Low	High	High	High	High	High	High	Low	Low
50th Percentile Flow (cumec)	215.31	194.00	207.78	265.67	376.27	572.77	768.21	829.31	787.05	594.10	377.05	269.07
90th Percentile Flow (cumec)	175.21	169.31	180.15	240.53	329.50	475.36	689.57	725.48	706.15	519.61	316.64	229.86
ERF (cumec)	175.21	169.31	180.15	240.53	376.27	572.77	768.21	829.31	787.05	594.10	316.64	229.86




Flow Duration Curve of December Balu River SW 7.5
95
90
85
80
75
70
65
60
Flow (cumec)
77.90
72.83
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
Exceedence Probability


Flow Duration Curve of January Balu River SW 7.5
80
75
70
65
60
55
Flow (cumec)
68.80
60.50
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
Exceedence Probability


Flow Duration Curve of February Balu River SW 7.5
75
70
65
60
55
50
Flow (cumec)
63.81
59.52
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
Exceedence Probability


Flow Duration Curve of March Balu River SW 7.5
80
75
70
65
60
55
Flow (cumec)
67.50
61.80
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
Exceedence Probability

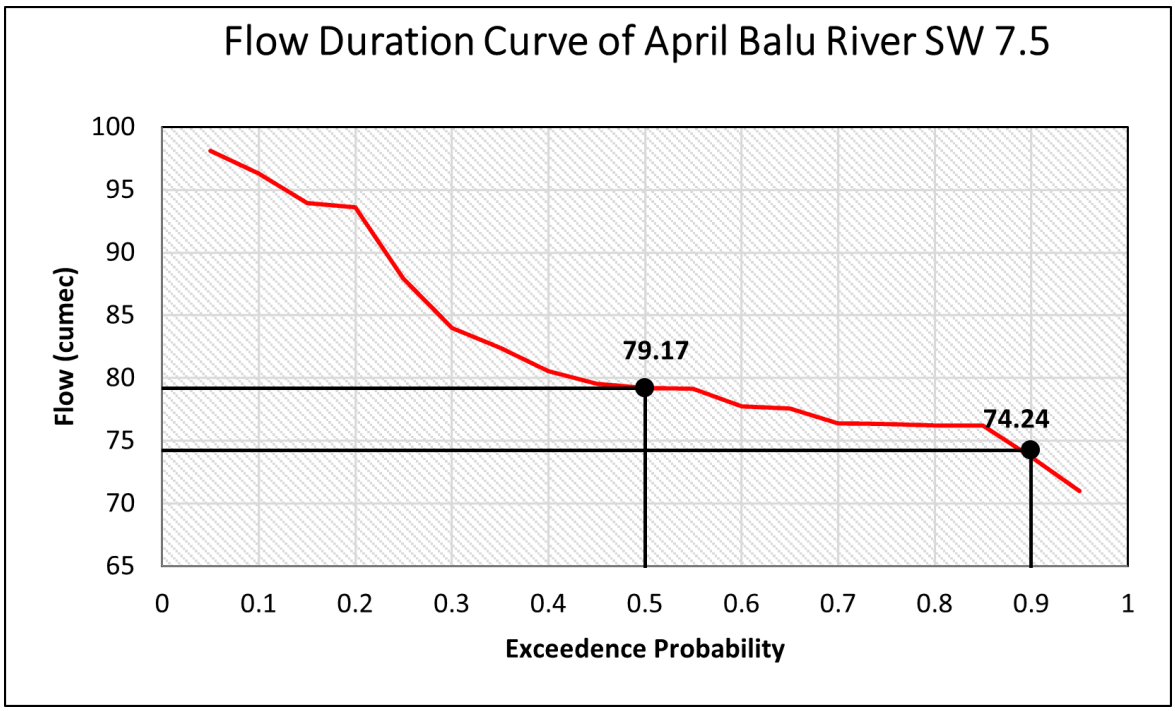
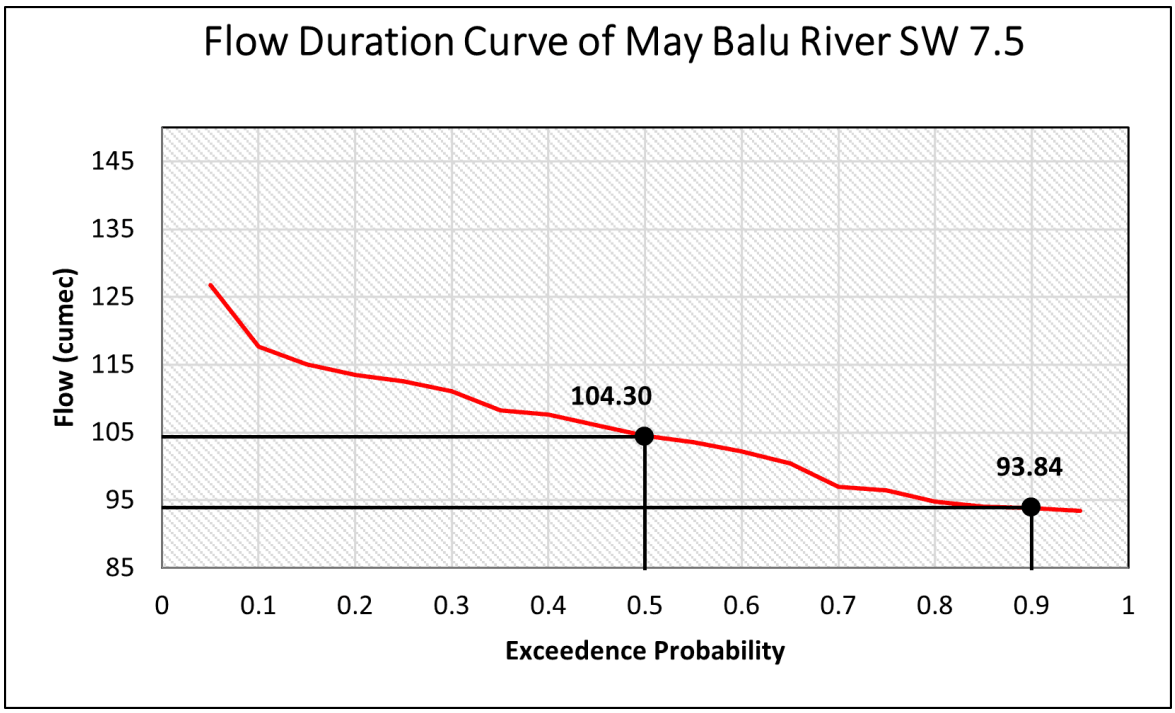
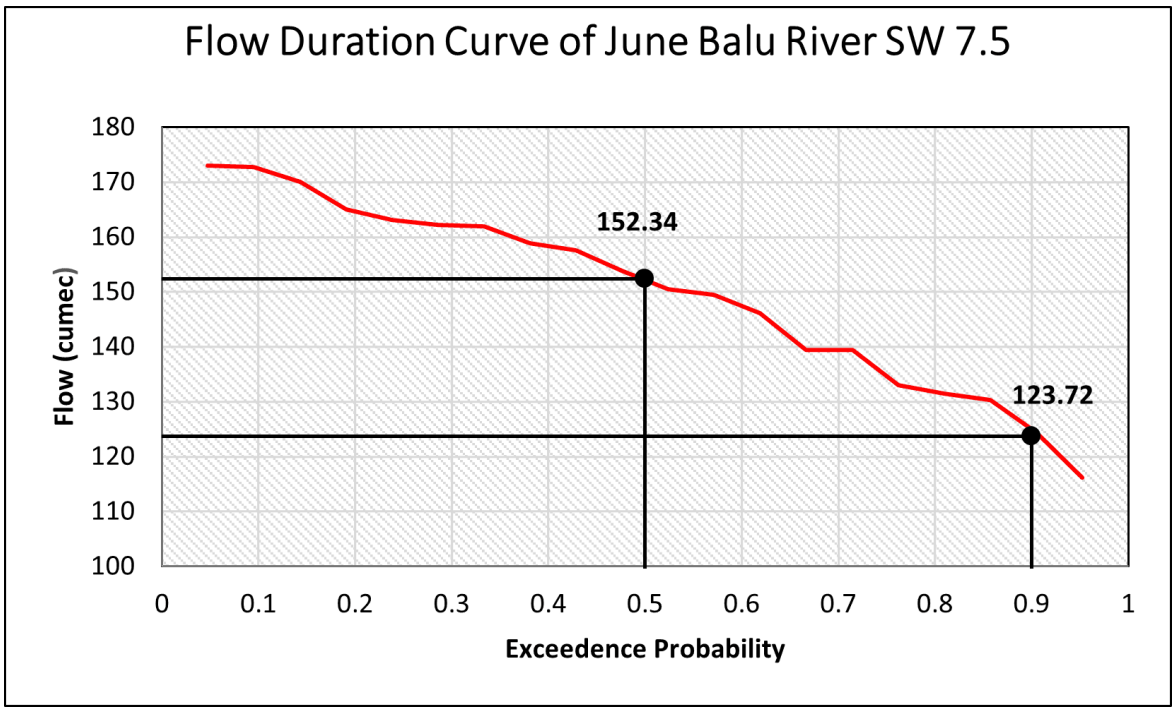
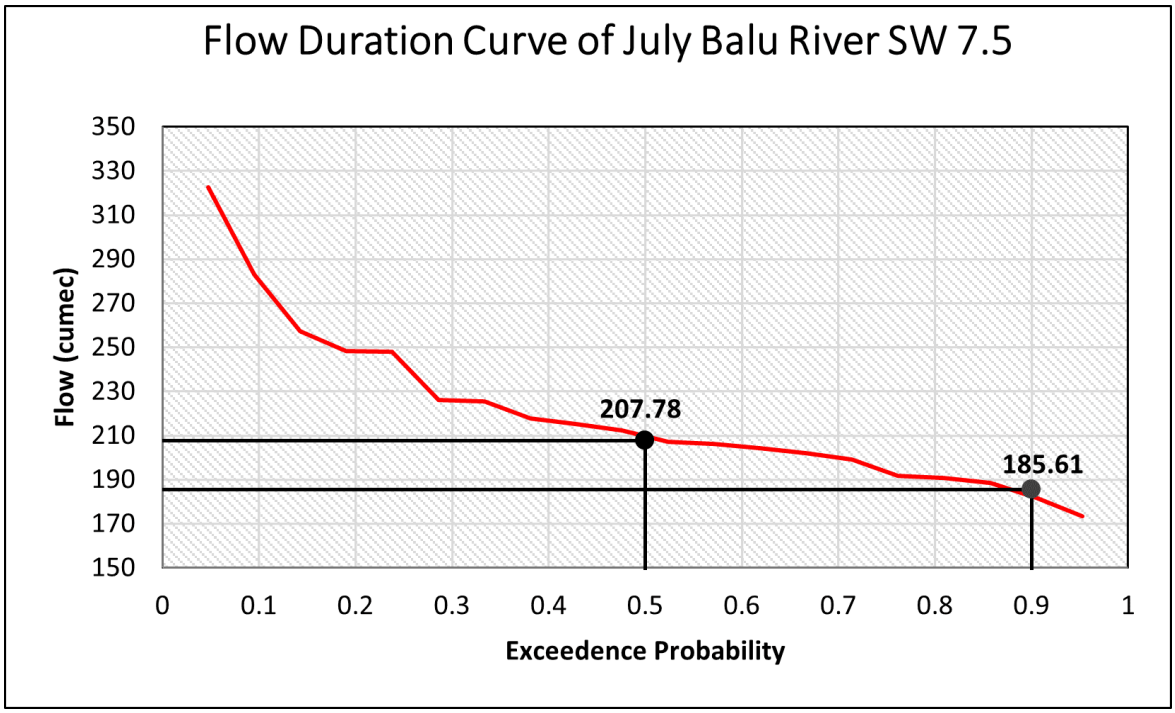
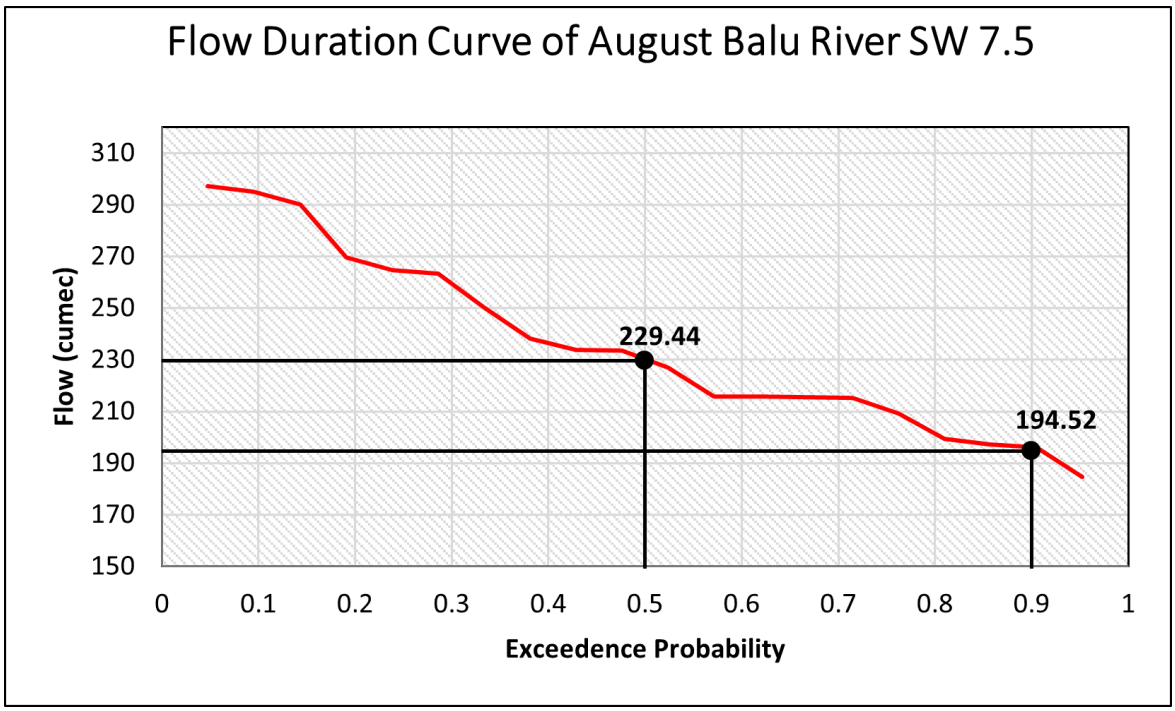


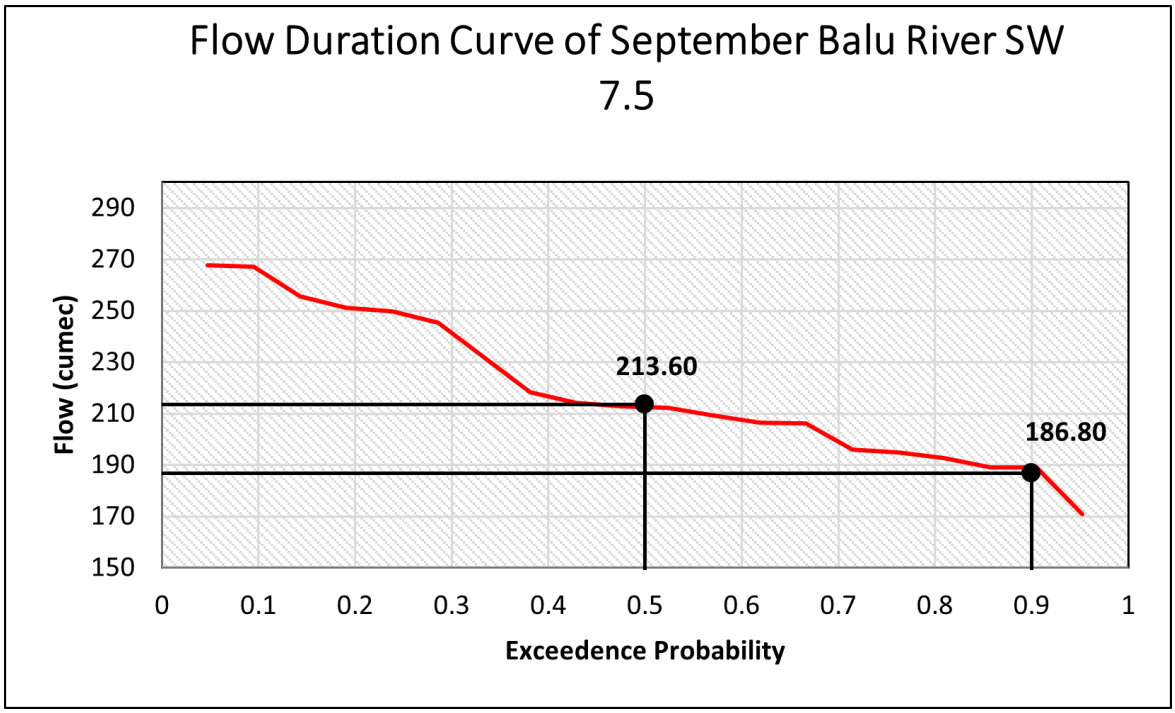
Figure 2(f): Flow duration curve at Demra of Balu (SW 7.5) for Low Flow Season.




Flow Duration Curve of June Balu River SW 7.5
Flow (cumec)
180
170
160
150
140
130
120
110
100
152.34
123.72
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
Exceedence Probability


Flow Duration Curve of July Balu River SW 7.5
Flow (cumec)
350
330
310
290
270
250
230
210
190
170
150
207.78
185.61
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
Exceedence Probability


Flow Duration Curve of August Balu River SW 7.5
Flow (cumec)
310
290
270
250
230
210
190
170
150
229.44
194.52
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
Exceedence Probability


Flow Duration Curve of September Balu River SW 7.5
Flow (cumec)
290
270
250
230
210
190
170
150
213.60
186.80
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
Exceedence Probability

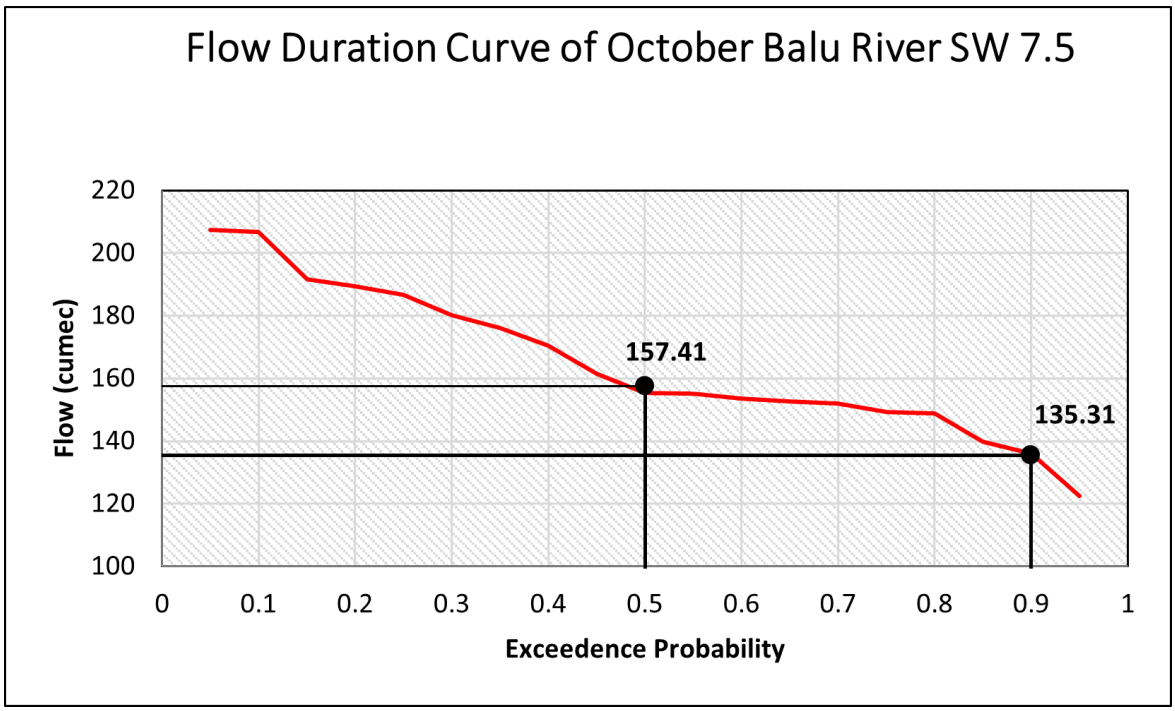
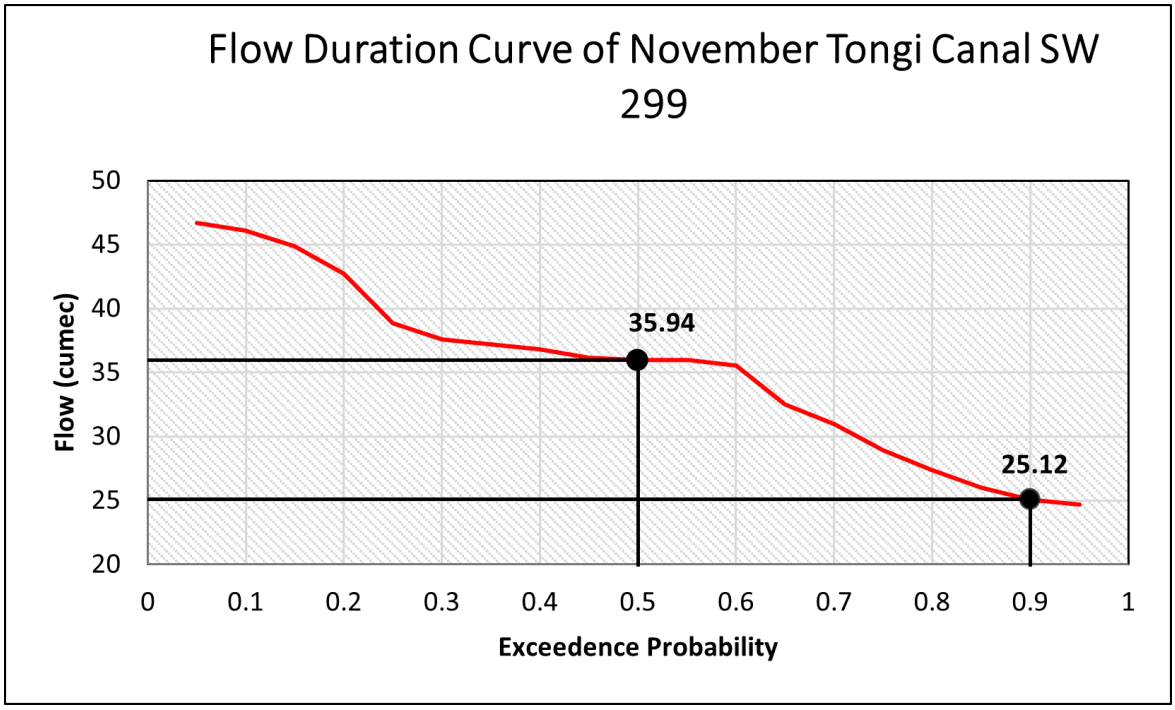
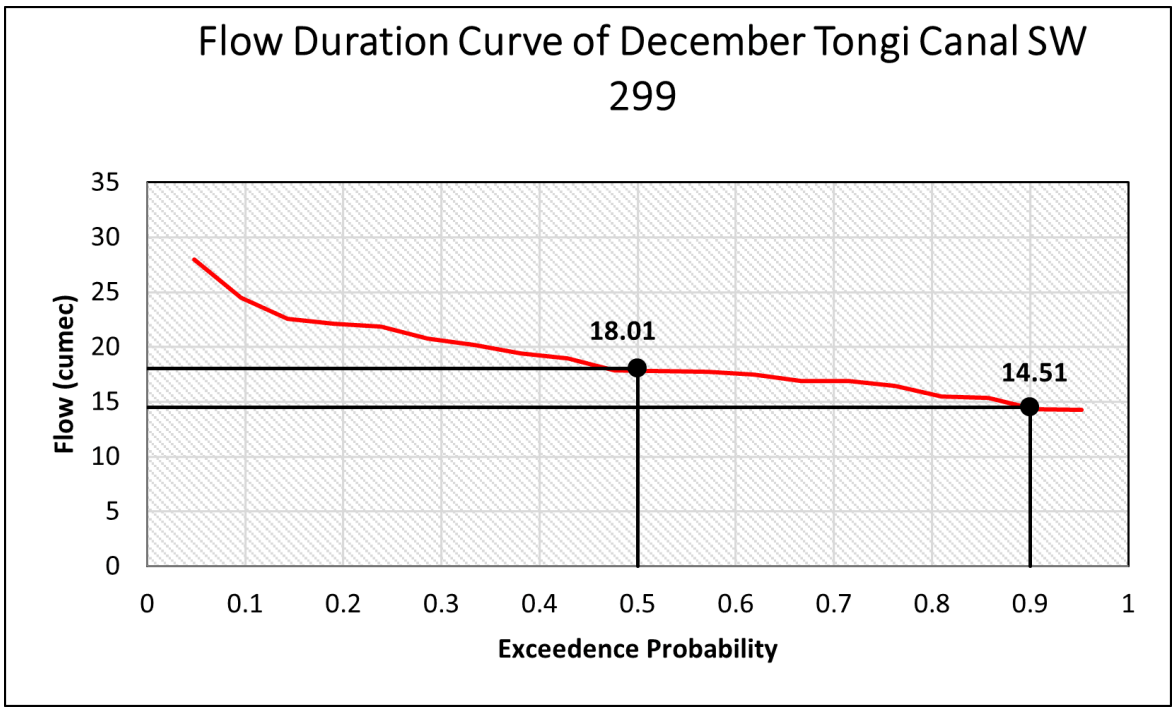


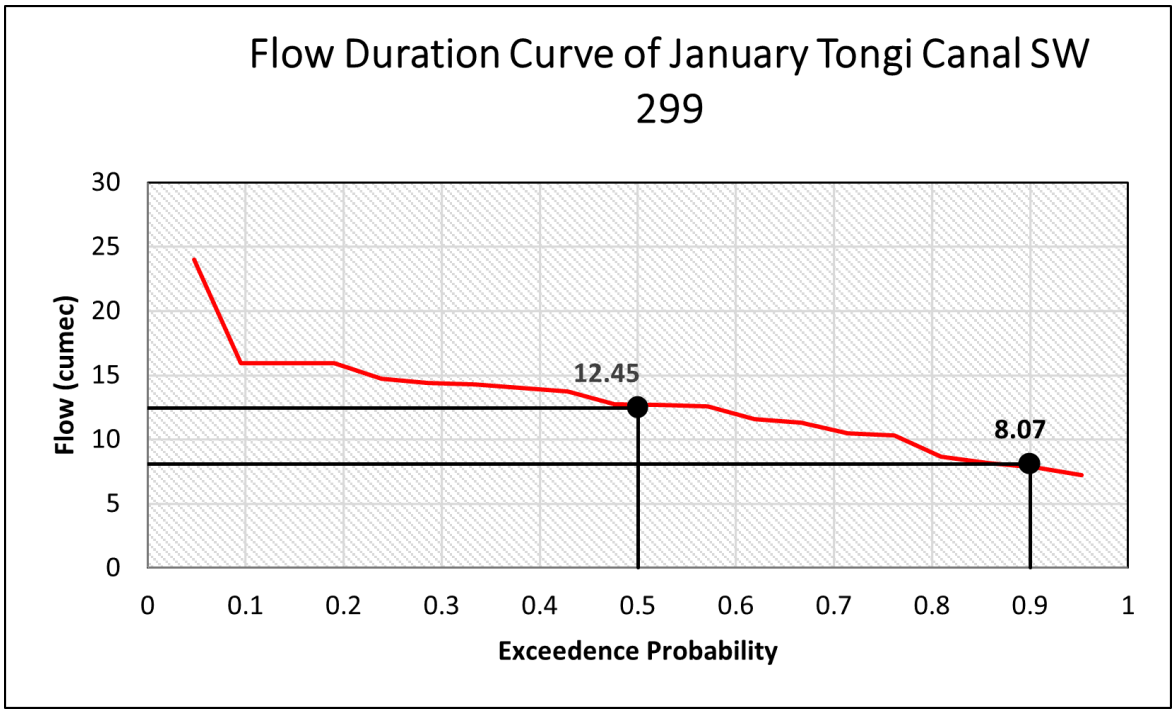
Figure 2(f) (continued): Flow duration curve at Demra of Balu (SW 7.5) for High Flow Season.

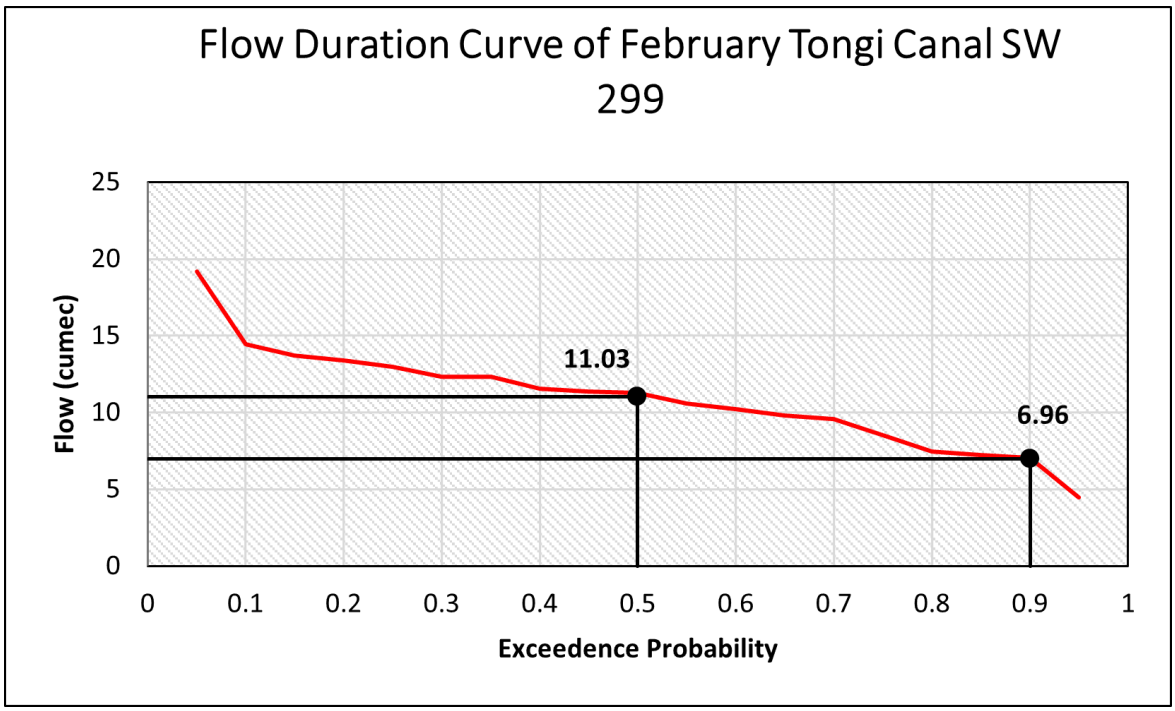
Table 2(f): Environmental flow requirement (EFR) using Flow duration curve method at Demra of Balu River (SW 7.5)

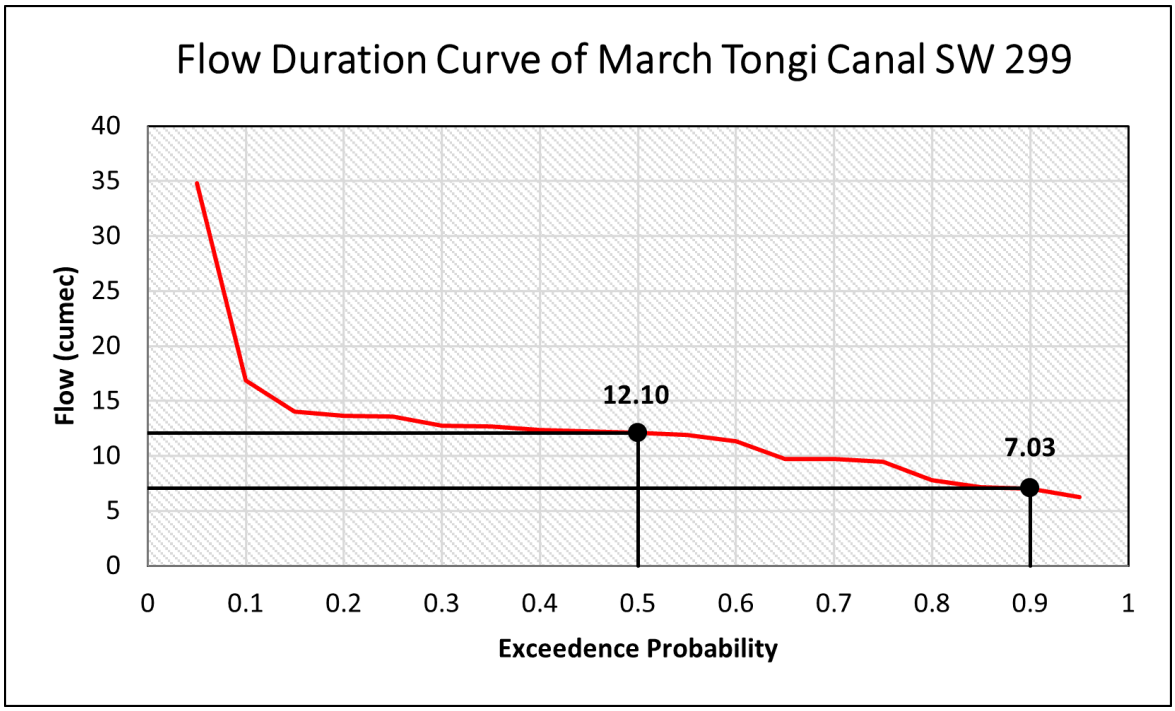
Month	January	February	March	April	May	June	July	August	September	October	November	December
Flow Season	Low	Low	Low	Low	High	High	High	High	High	High	Low	Low
50th Percentile Flow (cumec)	68.80	63.81	67.50	79.17	104.30	152.34	207.78	229.44	213.60	157.41	103.25	77.90
90th Percentile Flow (cumec)	60.50	59.52	61.80	74.24	93.84	123.72	185.61	194.52	186.80	135.31	88.55	72.83
EFR (cumec)	60.50	59.52	61.80	74.24	104.30	152.34	207.78	229.44	213.60	157.41	88.55	72.83




Flow Duration Curve of December Tongi Canal SW 299
Flow (cumec)
35
30
25
20
15
10
5
0
18.01
14.51
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
Exceedence Probability


Flow Duration Curve of January Tongi Canal SW 299
Flow (cumec)
30
25
20
15
10
5
0
12.45
8.07
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
Exceedence Probability


Flow Duration Curve of February Tongi Canal SW 299
Flow (cumec)
25
20
15
10
5
0
11.03
6.96
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
Exceedence Probability


Flow Duration Curve of March Tongi Canal SW 299
Flow (cumec)
40
35
30
25
20
15
10
5
0
12.10
7.03
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
Exceedence Probability

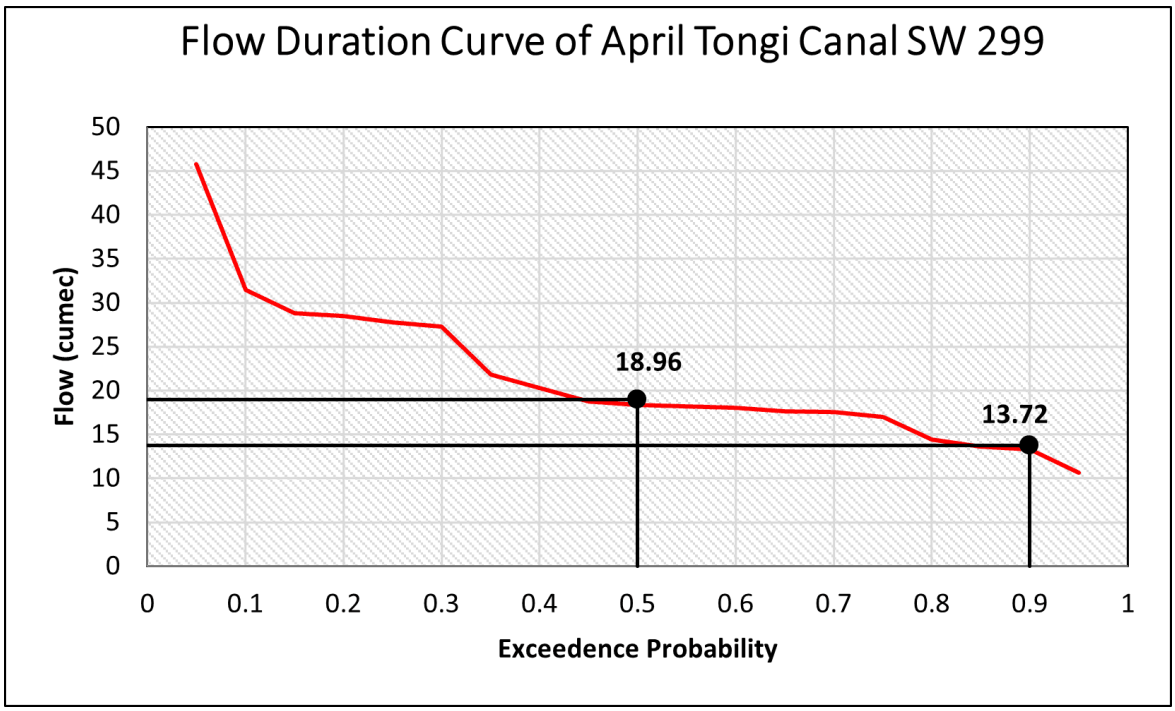
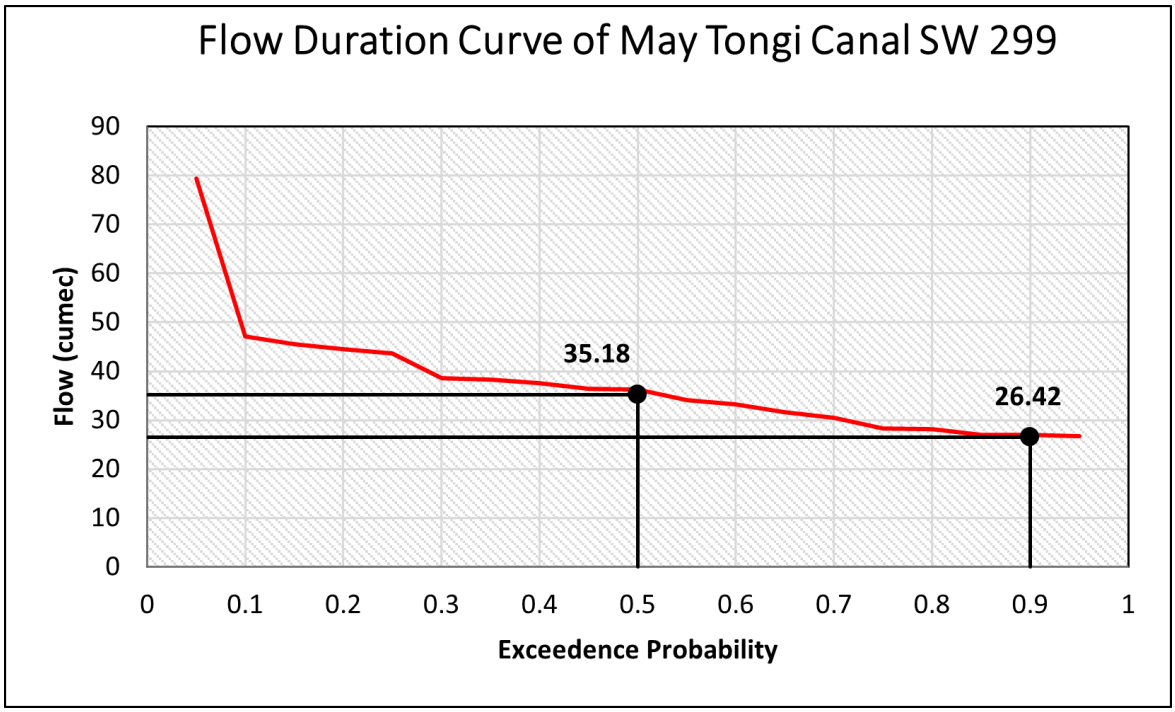
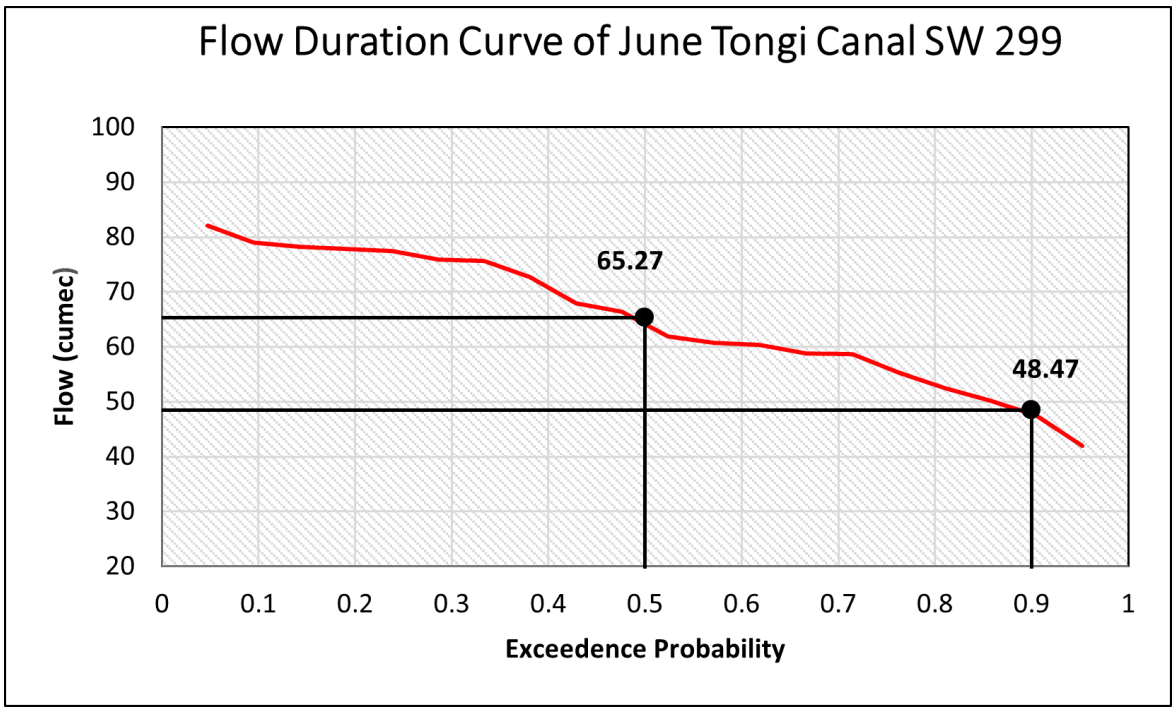
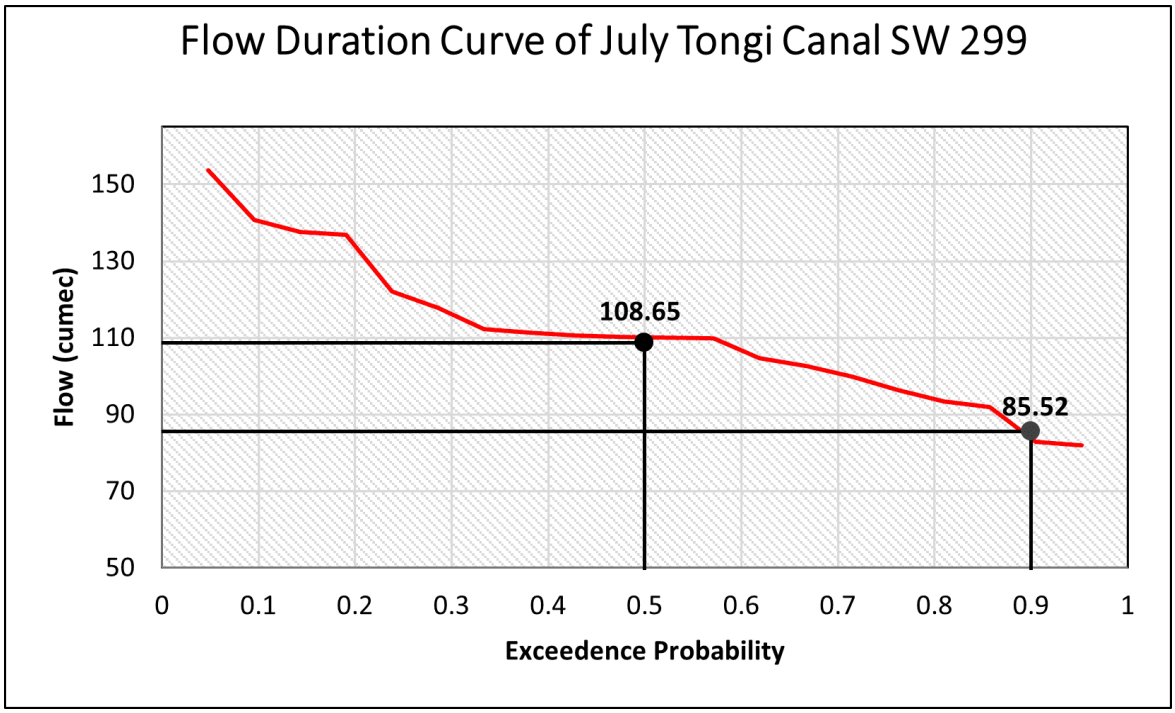
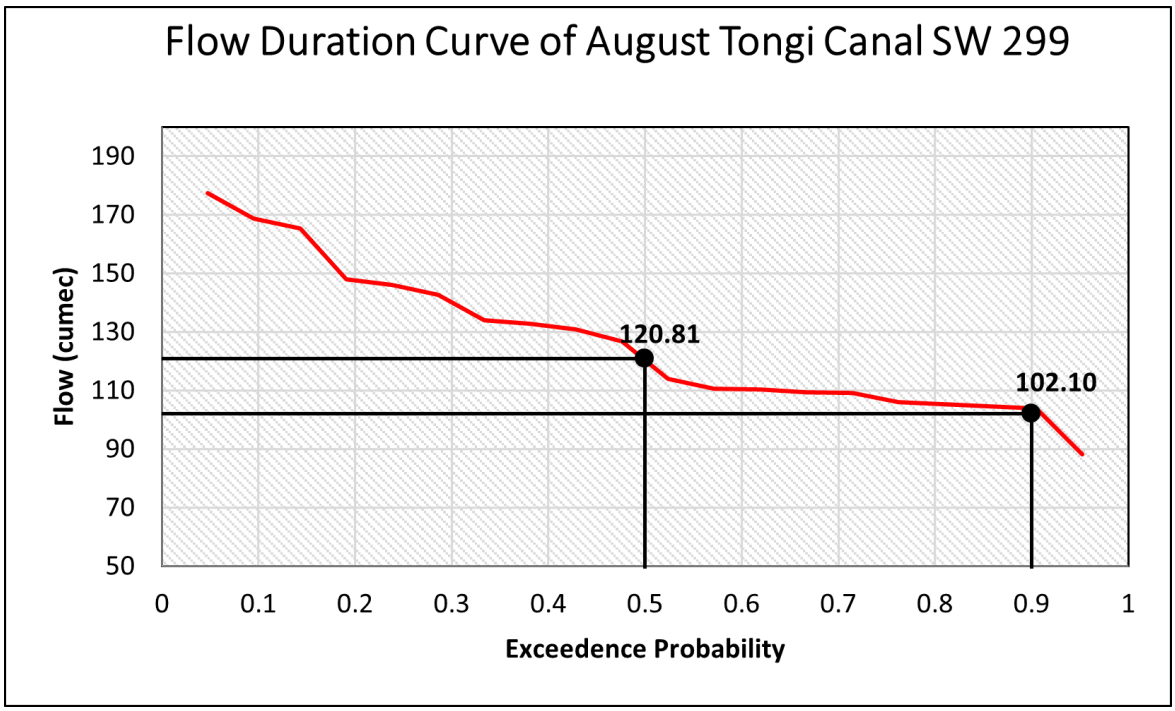


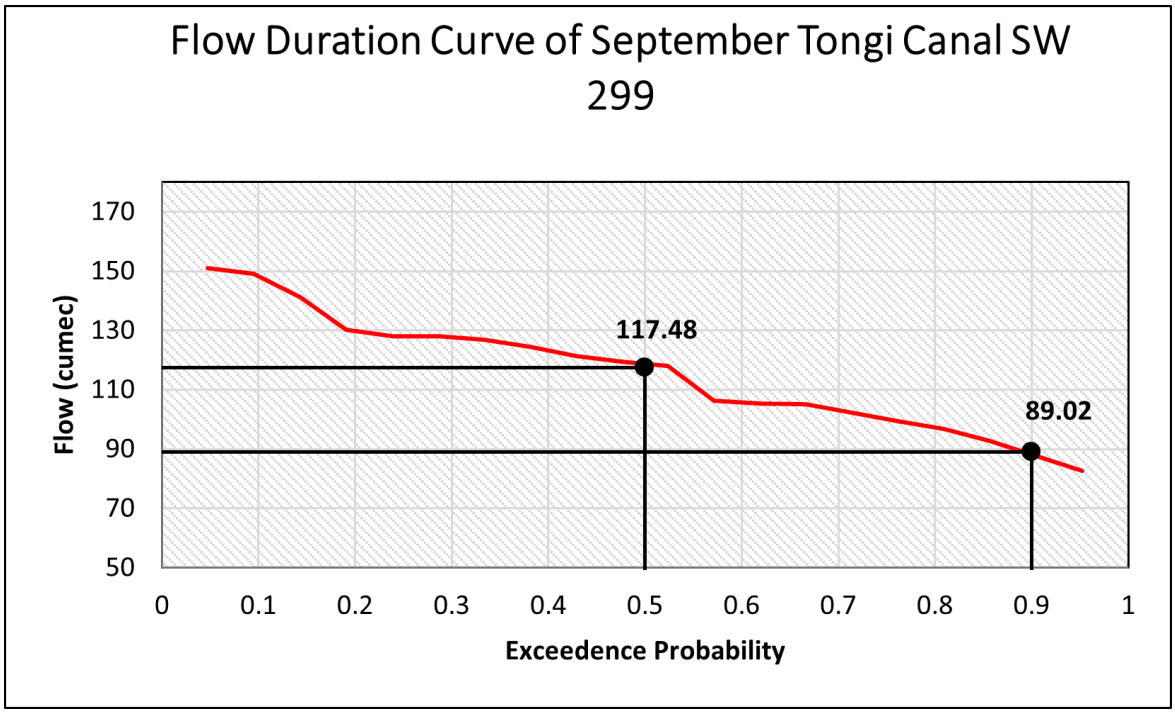
Figure 2(g): Flow duration curve at Tongi of Tongi Canal (SW 299) for Low Flow Season.




Flow Duration Curve of June Tongi Canal SW 299
Flow (cumec)
100
90
80
70
60
50
40
30
20
65.27
48.47
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
Exceedence Probability


Flow Duration Curve of July Tongi Canal SW 299
Flow (cumec)
150
130
110
90
70
50
108.65
85.52
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
Exceedence Probability


Flow Duration Curve of August Tongi Canal SW 299
Flow (cumec)
190
170
150
130
110
90
70
50
120.81
102.10
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
Exceedence Probability


Flow Duration Curve of September Tongi Canal SW 299
Flow (cumec)
170
150
130
110
90
70
50
117.48
89.02
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
Exceedence Probability

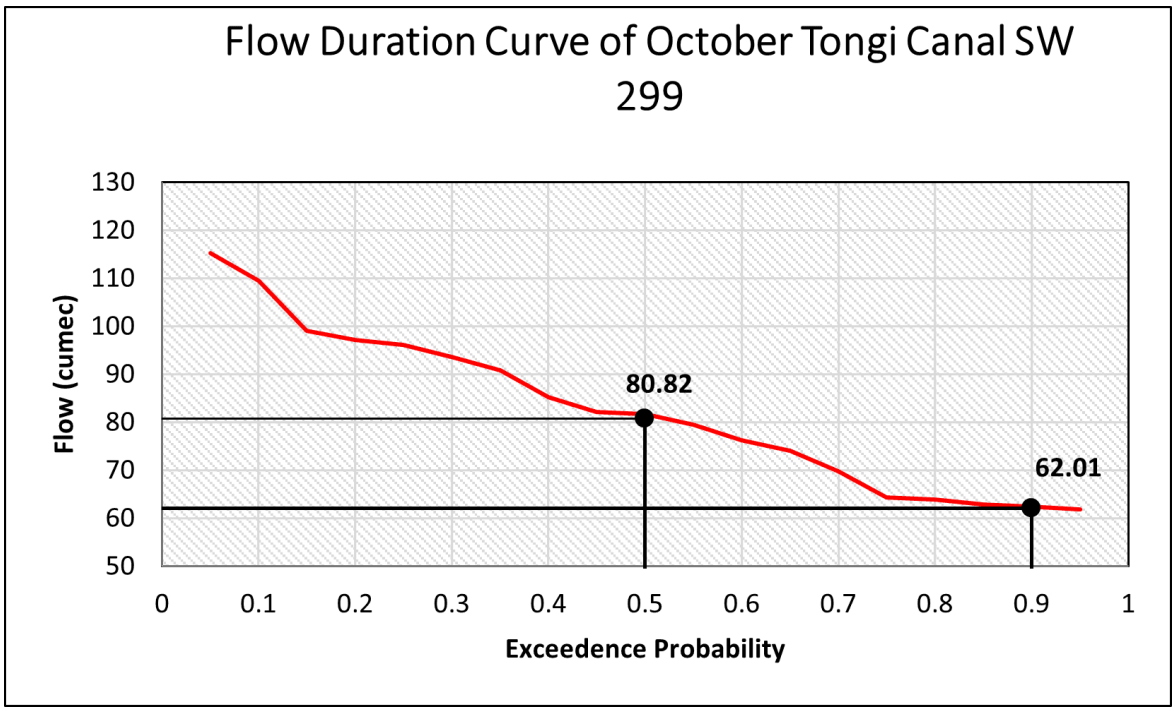


Figure 2(g) (continued): Flow duration curve at Tongi of Tongi Canal (SW 299) for High Flow Season.

Table 2(g): Environmental flow requirement (EFR) using Flow duration curve method at Tongi of Tongi Canal (SW 299)

Month	January	February	March	April	May	June	July	August	September	October	November	December
Flow Season	Low	Low	Low	Low	High	High	High	High	High	High	Low	Low
50th Percentile Flow (cumec)	12.45	11.03	12.10	18.96	35.18	65.27	108.65	120.81	117.48	80.82	35.94	18.01
90th Percentile Flow (cumec)	8.07	6.96	7.03	13.72	26.42	48.47	85.52	102.10	89.02	62.01	25.12	14.51
ERF (cumec)	8.07	6.96	7.03	13.72	35.18	65.27	108.65	120.81	117.48	80.82	25.12	14.51

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ABSTRACT

Environmental flow (e-flow) describes the quantity of water flow required to sustain freshwater and estuarine ecosystems and human well-being. E-flow must be maintained in the river to maintain its natural resources at the desired level and support the various functions of a river, such as carrier, production, and regulation functions. A river slows down and gets shallower if the flow drops below the e-flow, making it harder for aquatic life and humans to survive, both of which depend on the water flow. Therefore, e-flow is essential in the efforts to achieve sustainable management of water resources. E-flow assessment determines the minimum flow required to protect a river's ecosystem while allowing a river's population to access fresh water. Sometimes, it might be challenging to obtain an exact evaluation of e-flow because an ecosystem consists of various living creatures, each requiring a different amount of water to survive. In the recent dry seasons, the rivers around Dhaka City exhibited flow degradation due to natural and anthropogenic activities. Hence, evaluating the e-flow of the Dhaka peripheral river network is vital to understanding the overall situation of the Dhaka peripheral river network and protecting natural morphology and ecosystems. This research work has been carried out to assess the environmental flow of the Dhaka peripheral river network of 195 km consisting of Turag, Buriganga, Dhaleshwari, Shitalakhya, Balu, and Tongi Khal, using two hydrological (Tennant and Flow Duration Curve) approaches. For developing the flow scenario, mean monthly flow (MMF) has been compared to e-flow to analyze the flow availability of the selected rivers. Analysis shows that water availability is satisfactorily above the e-flow requirement in all Dhaka peripheral rivers except Turag River in the low flow season. Only a few months of the station of Buriganga, Balu, Dhaleshwari, and Shitalakhya exhibit the flow scenario as MMF is more than e-flow. For the high flow season, the flow scenario of Dhaleshwari is critical as MMF is severely below the e-flow. Altogether, the e-flow range of Dhaka peripheral river system is in between (7 - 847.30) cumec range. It is hoped that the findings of this study will significantly aid the management of the Dhaka peripheral river system.

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