Appendix A. Minnesota River AUID Consolidation Summary

Table A-1. AUID consolidation summary for Minnesota River main stem segments

New AUID	New AUID Description	Potential 2018 Impaired Waters Inventory	Former AUID	Former AUID Description	AUID Use Classes	2016 Impaired Waters Inventory	AUID Length (miles)
07020004-747	Lac Qui Parle dam to Granite Falls Dam	Turbidity; Fecal Coliform; Mercury in fish tissue; IBI impairment based on macroinvertebrate data	07020004-688	Lac qui Parle dam to Chippewa R	1C, 2Bd, 3C	Mercury in fish tissue	14.53
			07020004-501	Chippewa R to Stony Run Cr	1C, 2Bd, 3C	Turbidity; Fecal Coliform; Mercury in fish tissue	10.85
			07020004-519	Stony Run Cr to Palmer Cr	1C, 2Bd, 3C	Mercury in fish tissue	4.41
			07020004-583	Palmer Cr to Granite Falls City N boundary	1C, 2Bd, 3C	Mercury in fish tissue	0.73
			07020004-575	Granite Falls City N boundary to Granite Falls Dam	1C, 2Bd, 3C	Mercury in fish tissue	1.85
07020004-748	Granite Falls Dam to Yellow Medicine R	Turbidity; Mercury in fish tissue; PCB in fish tissue; River eutrophication impairment based on phosphorus and Chl-a data	07020004-612	Granite Falls Dam to 8th Ave and Baldwin St bridge	2B, 3C	Mercury in fish tissue	0.16
			07020004-613	8th Ave and Baldwin St bridge to Minnesota Falls Dam	2B, 3C	Mercury in fish tissue	3.2
			07020004-515	Minnesota Falls Dam to Hazel Cr	2B, 3C	Turbidity; Mercury in fish tissue; PCB in fish tissue	4.17
			07020004-516	Hazel Cr to Yellow Medicine R	2B, 3C	Mercury in fish tissue; PCB in fish tissue	7.23

New AUID	New AUID Description	Potential 2018 Impaired Waters Inventory	Former AUID	Former AUID Description	AUID Use Classes	2016 Impaired Waters Inventory	AUID Length (miles)
07020004-749	Yellow Medicine R to Echo Cr	TSS; Mercury in fish tissue; PCB in fish tissue; IBI impairment based on macroinvertebrate data; River eutrophication impairment based on phosphorus and Chl-a data	07020004-517	Yellow Medicine R to Hawk Cr	2B, 3C	Mercury in fish tissue; PCB in fish tissue	0.34
			07020004-506	Hawk Cr to Wood Lake Cr	2B, 3C	Mercury in fish tissue; PCB in fish tissue	2.75
07020004-750	Echo Cr to Beaver Cr	Turbidity; Mercury in fish tissue; PCB in fish tissue; Eutrophication impairment due to phosphorus, chl-a and BOD 5 data; IBI impairment based on macroinvertebrate data	07020004-507	Sacred Heart Cr to Timms Cr	2B, 3C	Mercury in fish tissue; PCB in fish tissue	4.06
			07020004-509	Timms Cr to Redwood R	2B, 3C	Turbidity; Mercury in fish tissue; PCB in fish tissue; Eutrophication impairment due to phosphorus, chl-a and BOD 5 data	9.4
			07020004-511	Redwood R to Beaver Cr	2B, 3C	Mercury in fish tissue; PCB in fish tissue	2.86
			07020004-629	Alternate channel between 509 and 511	2B, 3C	Mercury in fish tissue; PCB in fish tissue	0.68

New AUID	New AUID Description	Potential 2018 Impaired Waters Inventory	Former AUID	Former AUID Description	AUID Use Classes	2016 Impaired Waters Inventory	AUID Length (miles)
07020007-720	Beaver Cr to Little Rock Cr	Turbidity; Mercury in fish tissue; PCB in fish tissue; Eutrophication impairment based on phosphorus, chl-a and BOD data	07020007-514	Beaver Cr to Birch Coulee	2B, 3C	Turbidity; Mercury in fish tissue; PCB in fish tissue	9.34
			07020007-559	Birch Coulee to Redwood CSAH 11	2B, 3C	Mercury in fish tissue; PCB in fish tissue	7.01
			07020007-560	Redwood CSAH 11 to Wabasha Cr	2B, 3C	Mercury in fish tissue; PCB in fish tissue	1.15
			07020007-512	Wabasha Cr to Fort Ridgely Cr	2B, 3C	Mercury in fish tissue; PCB in fish tissue	14.52
			07020007-511	Fort Ridgely Cr to Spring Cr	2B, 3C	Mercury in fish tissue; PCB in fish tissue	7.16
			07020007-510	Spring Cr to Little Rock Cr	2B, 3C	Mercury in fish tissue; PCB in fish tissue	7.57
07020007-721	Little Rock Cr to Cottonwood R	TSS; Mercury in fish tissue; PCB in fish tissue; River Eutrophication impairment based on phosphorus and Chl-a data	07020007-509	Little Rock Cr to Eightmile Cr	2B, 3C	Mercury in fish tissue; PCB in fish tissue	1.47
			07020007-508	Eightmile Cr to Cottonwood R	2B, 3C	Mercury in fish tissue; PCB in fish tissue	20.09

New AUID	New AUID Description	Potential 2018 Impaired Waters Inventory	Former AUID	Former AUID Description	AUID Use Classes	2016 Impaired Waters Inventory	AUID Length (miles)
07020007-722	Cottonwood R to Blue Earth R	Turbidity; Mercury in fish tissue; Mercury in water column; PCB in fish tissue; PCB in water column; Eutrophication impairment due to phosphorus and chl-a data	07020007-503	Cottonwood R to Little Cottonwood R	2B, 3C	Turbidity; Mercury in fish tissue; PCB in fish tissue	7.83
			07020007-507	Little Cottonwood R to Morgan Cr	2B, 3C	Mercury in fish tissue; PCB in fish tissue	0.54
			07020007-506	Morgan Cr to Swan Lk outlet	2B, 3C	Mercury in fish tissue; PCB in fish tissue	12.93
			07020007-505	Swan Lk outlet to Minneopa Cr	2B, 3C	Turbidity; Mercury in fish tissue; Mercury in water column; PCB in fish tissue; PCB in water column; Eutrpohication impairment due to phosphorus and chl-a data	8.58
			07020007-504	Minneopa Cr to Blue Earth R	2B, 3C	Turbidity; Mercury in fish tissue; PCB in fish tissue	3.15

New AUID	New AUID Description	Potential 2018 Impaired Waters Inventory	Former AUID	Former AUID Description	AUID Use Classes	2016 Impaired Waters Inventory	AUID Length (miles)
07020007-723	Blue Earth R to Cherry Cr	Turbidity; Fecal coliform; Mercury in fish tissue; Mercury in water column; PCB in fish tissue; PCB in water column; Eutrophication due to phosphorus and chl-a data	07020007-502	Blue Earth R to Shanaska Cr	2B, 3C	Turbidity; Mercury in fish tissue; PCB in fish tissue	17.02
			07020007-501	Shanaska Cr to Rogers Cr	2B, 3C	Turbidity; Fecal coliform; Mercury in fish tissue; Mercury in water column; PCB in fish tissue; PCB in water column; Eutrophication due to phosphorus and chl-a data	6.28
			07020007-599	Rogers Cr to Cherry Cr	2B, 3C	Mercury in fish tissue; PCB in fish tissue	0.72
07020012-799	Cherry Cr to High Island Cr	Turbidity; Fecal coliform; Mercury in fish tissue; Mercury in water column; PCB in fish tissue; Eutrophication due to phosphorus and chl-a data	07020012-507	Cherry Cr to Le Sueur Cr	2B, 3C	Turbidity; Fecal coliform; Mercury in fish tissue; PCB in fish tissue	11.81
			07020012-504	Le Sueur Cr to Rush R	2B, 3C	Mercury in fish tissue; PCB in fish tissue	2.01
			07020012-503	Rush R to High Island Cr	2B, 3C	Turbidity; Fecal coliform; Mercury in fish tissue; Mercury in water column; PCB in fish tissue; Eutrophication due to phosphorus and chl-a data	10.8

New AUID	New AUID Description	Potential 2018 Impaired Waters Inventory	Former AUID	Former AUID Description	AUID Use Classes	2016 Impaired Waters Inventory	AUID Length (miles)
07020012-800	High Island Cr to Carver Cr	Turbidity; Fecal coliform; Mercury in fish tissue; Mercury in water column; PCB in fish tissue; Eutrophication due to phosphorus, chl-a and BOD data	07020012-502	High Island Cr to Bevens Cr	2B, 3C	Fecal coliform; Mercury in fish tissue; PCB in fish tissue	19.33
			07020012-501	Bevens Cr to Sand Cr	2B, 3C	Turbidity; Fecal coliform; Mercury in fish tissue; Mercury in water column; PCB in fish tissue; Eutrophication due to phosphorus, chl-a and BOD data	8.59
			07020012-532	Sand Cr to Carver Cr	2B, 3C	Mercury in fish tissue; Mercury in water column; PCB in fish tissue	1.23
07020012-506 (same)	Carver Cr to RM 22	Turbidity; Mercury in fish tissue; Mercury in water column; PCB in fish tissue; Eutrophication due to phosphorus, chl-a and BOD data	07020012-506	Carver Cr to RM 22	2B, 3C	Turbidity; Mercury in fish tissue; Mercury in water column; PCB in fish tissue; Eutrophication due to phosphorus, chl-a and BOD data	10.46

New AUID	New AUID Description	Potential 2018 Impaired Waters Inventory	Former AUID	Former AUID Description	AUID Use Classes	2016 Impaired Waters Inventory	AUID Length (miles)
07020012-505 (same)	RM 22 to Mississippi R	Turbidity; Dissolved oxygen; Mercury in fish tissue; Mercury in water column; PCB in fish tissue; Eutrophication due to phosphorus, chl-a and BOD data	07020012-505	RM 22 to Mississippi R	2C, 3C	Turbidity; Dissolved oxygen; Mercury in fish tissue; Mercury in water column; PCB in fish tissue; Eutrophication due to phosphorus, chl-a and BOD data	23.83

Appendix B. Water Quality Summary Tables

Contents

Tables

B1. Hawk-Yellow Medicine (HUC 07020004)

Table B-1. Annual summary of TSS data at Yellow Medicine River (AUID 07020004-502; April–September)

Year	Sample count	Mean (mg/L)	Minimum (mg/L)	Maximum (mg/L)	Number of exceedances	Frequency of exceedances
2006	19	46	20	166	3	16%
2007	0	–	–	–	–	–
2008	24	45	7	170	4	17%
2009	23	21	6	54	0	0%
2010	36	61	3	180	11	31%
2011	12	70	14	140	7	58%
2012	17	158	14	590	10	59%
2013	24	111	11	372	13	54%
2014	25	112	2	440	13	52%
2015	20	135	24	326	12	60%

Values in red indicate years in which the TSS standard of 65 mg/L was exceeded in greater than 10 percent of the samples collected in April through September.

Table B-2. Monthly summary of TSS data at Yellow Medicine River (AUID 07020004-502; 2006–2015)

Month	Sample count	Mean (mg/L)	Minimum (mg/L)	Maximum (mg/L)	Number of exceedances	Frequency of exceedances
January	6	5	2	12	n/a	–
February	8	12	1	28	n/a	–
March	25	110	8	380	n/a	–
April	31	39	2	252	3	10%
May	38	79	3	570	13	34%
June	63	140	8	590	43	68%
July	21	58	16	107	9	43%
August	21	38	7	159	1	5%
September	26	48	7	130	4	15%
October	18	22	3	43	n/a	–
November	9	18	2	84	n/a	–
December	8	5	2	12	n/a	–

Values in red indicate years in which the TSS standard of 65 mg/L was exceeded in greater than 10 percent of the samples collected in April through September.

Table B-3. Annual summary of TSS data at Minnesota River (AUID 07020004-747; April–September)

Year	Sample count	Mean (mg/L)	Minimum (mg/L)	Maximum (mg/L)	Number of exceedances	Frequency of exceedances
2006	0	–	–	–	–	–
2007	21	37	11	160	2	10%
2008	23	35	6	167	2	9%
2009	25	42	13	150	5	20%
2010	18	41	9	100	2	11%
2011	13	18	8	55	0	0%
2012	17	42	16	100	3	18%
2013	20	70	15	770	2	10%
2014	36	47	15	120	9	25%
2015	19	52	8	190	3	16%

Values in red indicate years in which the TSS standard of 65 mg/L was exceeded in greater than 10 percent of the samples collected in April through September.

Table B-4. Monthly summary of TSS data at Minnesota River (AUID 07020004-747; 2006–2015)

Month	Sample count	Mean (mg/L)	Minimum (mg/L)	Maximum (mg/L)	Number of exceedances	Frequency of exceedances
January	6	4	3	7	n/a	–
February	7	3	1	7	n/a	–
March	24	61	3	640	n/a	–
April	52	47	6	770	5	10%
May	37	43	10	167	6	16%
June	46	42	8	95	10	22%
July	21	36	14	58	0	0%
August	22	53	8	190	6	27%
September	14	35	10	100	1	7%
October	12	25	11	59	n/a	–
November	9	20	3	50	n/a	–
December	8	5	2	12	n/a	–

Values in red indicate years in which the TSS standard of 65 mg/L was exceeded in greater than 10 percent of the samples collected in April through September.

Table B-5. Annual summary of TSS data at Minnesota River (AUID 07020004-748; April–September)

Year	Sample count	Mean (mg/L)	Minimum (mg/L)	Maximum (mg/L)	Number of exceedances	Frequency of exceedances
2006	0	–	–	–	–	–
2007	68	45	11	460	9	13%
2008	0	–	–	–	–	–
2009	0	–	–	–	–	–
2010	0	–	–	–	–	–
2011	0	–	–	–	–	–
2012	0	–	–	–	–	–
2013	0	–	–	–	–	–
2014	8	63	43	90	2	25%
2015	2	61	37	84	1	50%

Values in red indicate years in which the TSS standard of 65 mg/L was exceeded in greater than 10 percent of the samples collected in April through September.

Table B-6. Monthly summary of TSS data at Minnesota River (AUID 07020004-748; 2006–2015)

Month	Sample count	Mean (mg/L)	Minimum (mg/L)	Maximum (mg/L)	Number of exceedances	Frequency of exceedances
January	5	3	2	6	n/a	–
February	7	5	4	7	n/a	–
March	12	73	4	260	n/a	–
April	11	34	11	92	2	18%
May	16	40	11	90	2	13%
June	10	60	32	150	2	20%
July	13	81	34	460	3	23%
August	14	50	21	120	3	21%
September	14	24	11	59	0	0%
October	8	19	12	35	n/a	–
November	10	10	7	15	n/a	–
December	9	12	2	36	n/a	–

Values in red indicate years in which the TSS standard of 65 mg/L was exceeded in greater than 10 percent of the samples collected in April through September.

Table B-7. Annual summary of TSS data at Minnesota River (AUID 07020004-749; April–September)

Year	Sample count	Mean (mg/L)	Minimum (mg/L)	Maximum (mg/L)	Number of exceedances	Frequency of exceedances
2006	0	–	–	–	–	–
2007	0	–	–	–	–	–
2008	0	–	–	–	–	–
2009	0	–	–	–	–	–
2010	0	–	–	–	–	–
2011	0	–	–	–	–	–
2012	0	–	–	–	–	–
2013	0	–	–	–	–	–
2014	8	93	56	140	7	88%
2015	2	61	28	93	1	50%

Values in red indicate years in which the TSS standard of 65 mg/L was exceeded in greater than 10 percent of the samples collected in April through September.

Table B-8. Monthly summary of TSS data at Minnesota River (AUID 07020004-749; 2006–2015)

Month	Sample count	Mean (mg/L)	Minimum (mg/L)	Maximum (mg/L)	Number of exceedances	Frequency of exceedances
January	0	–	–	–	n/a	–
February	0	–	–	–	n/a	–
March	0	–	–	–	n/a	–
April	0	–	–	–	–	–
May	2	102	93	110	2	100%
June	2	130	120	140	2	100%
July	2	82	79	84	2	100%
August	2	67	56	78	1	50%
September	2	52	28	76	1	50%
October	0	–	–	–	n/a	–
November	0	–	–	–	n/a	–
December	0	–	–	–	n/a	–

Values in red indicate years in which the TSS standard of 65 mg/L was exceeded in greater than 10 percent of the samples collected in April through September.

Table B-9. Annual summary of TSS data at Minnesota River (AUID 07020004-750; April–September)

Year	Sample count	Mean (mg/L)	Minimum (mg/L)	Maximum (mg/L)	Number of exceedances	Frequency of exceedances
2006	6	44	26	70	1	17%
2007	0	–	–	–	–	–
2008	0	–	–	–	–	–
2009	6	44	27	56	0	0%
2010	0	–	–	–	–	–
2011	0	–	–	–	–	–
2012	0	–	–	–	–	–
2013	0	–	–	–	–	–
2014	24	95	28	160	21	88%
2015	6	76	33	120	3	50%

Values in red indicate years in which the TSS standard of 65 mg/L was exceeded in greater than 10 percent of the samples collected in April through September.

Table B-10. Monthly summary of TSS data at Minnesota River (AUID 07020004-750; 2006–2015)

Month	Sample count	Mean (mg/L)	Minimum (mg/L)	Maximum (mg/L)	Number of exceedances	Frequency of exceedances
January	0	–	–	–	n/a	–
February	2	9	4	14	n/a	–
March	2	130	9	250	n/a	–
April	2	44	40	47	0	0%
May	8	91	38	120	6	75%
June	8	123	50	160	7	88%
July	8	78	40	93	6	75%
August	8	55	26	86	3	38%
September	8	50	27	87	3	38%
October	1	20	20	20	n/a	–
November	1	34	34	34	n/a	–
December	0	–	–	–	n/a	–

Values in red indicate years in which the TSS standard of 65 mg/L was exceeded in greater than 10 percent of the samples collected in April through September.

B2. Chippewa (HUC 07020005)

Table B-11. Annual summary of TSS data at Chippewa River (AUID 07020005-501; April–September)

Year	Sample count	Mean (mg/L)	Minimum (mg/L)	Maximum (mg/L)	Number of exceedances	Frequency of exceedances
2006	0	–	–	–	–	–
2007	0	–	–	–	–	–
2008	0	–	–	–	–	–
2009	10	38	18	56	0	0%
2010	0	–	–	–	–	–
2011	0	–	–	–	–	–
2012	0	–	–	–	–	–
2013	0	–	–	–	–	–
2014	0	–	–	–	–	–
2015	0	–	–	–	–	–

Table B-12. Monthly summary of TSS data at Chippewa River (AUID 07020005-501; 2006–2015)

Month	Sample count	Mean (mg/L)	Minimum (mg/L)	Maximum (mg/L)	Number of exceedances	Frequency of exceedances
January	0	–	–	–	n/a	–
February	0	–	–	–	n/a	–
March	0	–	–	–	n/a	–
April	0	–	–	–	0	–
May	2	23	18	28	0	0%
June	3	50	44	56	0	0%
July	1	36	36	36	0	0%
August	2	36	30	42	0	0%
September	2	36	29	43	0	0%
October	0	–	–	–	n/a	–
November	0	–	–	–	n/a	–
December	0	–	–	–	n/a	–

Table B-13. Annual summary of transparency tube data at Chippewa River (AUID 07020005-501; April–September)

Year	Sample count	Mean (cm)	Minimum (cm)	Maximum (cm)
2006	9	13	9	16
2007	9	14	10	21
2008	9	9	6	13
2009	60	22	10	53
2010	40	16	9	25
2011	9	40	17	56
2012	9	17	14	22
2013	9	24	17	32
2014	31	21	3	46
2015	6	13	11	17

In previous assessment cycles, a transparency tube measurement of less than 20 cm indicated a violation of the 25 NTU turbidity standard.

Table B-14. Monthly summary of transparency tube data at Chippewa River (AUID 07020005-501; 2006–2015)

Month	Sample count	Mean (cm)	Minimum (cm)	Maximum (cm)
January	0	–	–	–
February	0	–	–	–
March	0	–	–	–
April	0	–	–	–
May	7	26	18	38
June	50	19	3	56
July	64	18	9	31
August	51	20	9	53
September	19	22	13	40
October	6	50	31	91
November	0	–	–	–
December	0	–	–	–

In previous assessment cycles, a transparency tube measurement of less than 20 cm indicated a violation of the 25 NTU turbidity standard.

B3. Redwood (HUC 07020006)

Table B-15. Annual summary of TSS data at Redwood River (AUID 07020006-501; April–September)

Year	Sample count	Mean (mg/L)	Minimum (mg/L)	Maximum (mg/L)	Number of exceedances	Frequency of exceedances
2006	6	44	23	81	1	17%
2007	0	–	–	–	–	–
2008	0	–	–	–	–	–
2009	6	40	25	62	0	0%
2010	0	–	–	–	–	–
2011	0	–	–	–	–	–
2012	0	–	–	–	–	–
2013	0	–	–	–	–	–
2014	0	–	–	–	–	–
2015	0	–	–	–	–	–

Values in red indicate years in which the TSS standard of 65 mg/L was exceeded in greater than 10 percent of the samples collected in April through September.

Table B-16. Monthly summary of TSS data at Redwood River (AUID 07020006-501; 2006–2015)

Month	Sample count	Mean (mg/L)	Minimum (mg/L)	Maximum (mg/L)	Number of exceedances	Frequency of exceedances
January	0	–	–	–	n/a	–
February	2	111	41	180	n/a	–
March	2	129	97	160	n/a	–
April	2	43	40	46	0	0%
May	2	31	29	32	0	0%
June	2	57	52	62	0	0%
July	2	36	23	49	0	0%
August	2	33	27	39	0	0%
September	2	53	25	81	1	50%
October	1	16	16	16	n/a	–
November	1	6	6	6	n/a	–
December	0	–	–	–	n/a	–

Values in red indicate years in which the TSS standard of 65 mg/L was exceeded in greater than 10 percent of the samples collected in April through September.

B4. Middle Minnesota (HUC 07020007)

Table B-17. Annual summary of TSS data at Minnesota River (AUID 07020007-720; April–September)

Year	Sample count	Mean (mg/L)	Minimum (mg/L)	Maximum (mg/L)	Number of exceedances	Frequency of exceedances
2006	6	50	28	74	2	33%
2007	25	67	33	115	14	56%
2008	10	65	34	158	3	30%
2009	27	51	17	78	3	11%
2010	30	82	22	266	17	57%
2011	12	52	28	119	1	8%
2012	17	123	33	413	11	65%
2013	21	97	54	236	19	90%
2014	38	129	27	320	35	92%
2015	26	104	19	262	22	85%

Values in red indicate years in which the TSS standard of 65 mg/L was exceeded in greater than 10 percent of the samples collected in April through September.

Table B-18. Monthly summary of TSS data at Minnesota River (AUID 07020007-720; 2006–2015)

Month	Sample count	Mean (mg/L)	Minimum (mg/L)	Maximum (mg/L)	Number of exceedances	Frequency of exceedances
January	5	4	2	9	n/a	–
February	6	16	5	53	n/a	–
March	17	68	6	210	n/a	–
April	26	56	21	107	9	35%
May	38	109	33	413	24	63%
June	57	117	27	320	47	82%
July	27	78	46	113	18	67%
August	31	75	34	158	17	55%
September	33	65	17	207	12	36%
October	21	35	14	83	n/a	–
November	11	24	6	61	n/a	–
December	5	10	6	20	n/a	–

Values in red indicate years in which the TSS standard of 65 mg/L was exceeded in greater than 10 percent of the samples collected in April through September.

Table B-19. Annual summary of TSS data at Minnesota River (AUID 07020007-721; April–September)

Year	Sample count	Mean (mg/L)	Minimum (mg/L)	Maximum (mg/L)	Number of exceedances	Frequency of exceedances
2006	0	–	–	–	–	–
2007	0	–	–	–	–	–
2008	0	–	–	–	–	–
2009	0	–	–	–	–	–
2010	0	–	–	–	–	–
2011	0	–	–	–	–	–
2012	0	–	–	–	–	–
2013	0	–	–	–	–	–
2014	16	103	42	200	13	81%
2015	4	84	34	140	2	50%

Values in red indicate years in which the TSS standard of 65 mg/L was exceeded in greater than 10 percent of the samples collected in April through September.

Table B-20. Monthly summary of TSS data at Minnesota River (AUID 07020007-721; 2006–2015)

Month	Sample count	Mean (mg/L)	Minimum (mg/L)	Maximum (mg/L)	Number of exceedances	Frequency of exceedances
January	0	–	–	–	n/a	–
February	0	–	–	–	n/a	–
March	0	–	–	–	n/a	–
April	0	–	–	–	–	–
May	4	115	80	140	4	100%
June	4	130	64	200	3	75%
July	4	86	42	130	2	50%
August	4	90	70	98	4	100%
September	4	74	34	110	2	50%
October	0	–	–	–	n/a	–
November	0	–	–	–	n/a	–
December	0	–	–	–	n/a	–

Values in red indicate years in which the TSS standard of 65 mg/L was exceeded in greater than 10 percent of the samples collected in April through September.

Table B-21. Annual summary of transparency tube data at Minnesota River (AUID 07020007-721; April–September)

Year	Sample count	Mean (cm)	Minimum (cm)	Maximum (cm)
2006	0	–	–	–
2007	0	–	–	–
2008	21	13	6	28
2009	27	11	6	17
2010	18	14	4	29
2011	18	23	10	36
2012	21	7	1	17
2013	15	10	4	33
2014	43	12	3	22
2015	48	11	3	25

In previous assessment cycles, a transparency tube measurement of less than 20 cm indicated a violation of the 25 NTU turbidity standard.

Table B-22. Monthly summary of transparency tube data at Minnesota River (AUID 07020007-721; 2006–2015)

Month	Sample count	Mean (cm)	Minimum (cm)	Maximum (cm)
January	0	–	–	–
February	0	–	–	–
March	5	11	4	17
April	19	13	5	23
May	38	11	1	36
June	47	14	3	36
July	43	12	4	32
August	35	10	4	20
September	29	12	5	25
October	16	16	6	23
November	5	20	10	30
December	1	27	27	27

In previous assessment cycles, a transparency tube measurement of less than 20 cm indicated a violation of the 25 NTU turbidity standard.

Table B-23. Annual summary of TSS data at Minnesota River (AUID 07020007-722; April–September)

Year	Sample count	Mean (mg/L)	Minimum (mg/L)	Maximum (mg/L)	Number of exceedances	Frequency of exceedances
2006	26	118	37	556	13	50%
2007	0	–	–	–	–	–
2008	26	107	23	234	19	73%
2009	28	65	5	122	13	46%
2010	28	85	31	165	15	54%
2011	20	55	28	165	5	25%
2012	26	153	2	430	17	65%
2013	23	102	42	418	20	87%
2014	33	169	27	1,170	30	91%
2015	27	152	28	354	23	85%

Values in red indicate years in which the TSS standard of 65 mg/L was exceeded in greater than 10 percent of the samples collected in April through September.

Table B-24. Monthly summary of TSS data at Minnesota River (AUID 07020007-722; 2006–2015)

Month	Sample count	Mean (mg/L)	Minimum (mg/L)	Maximum (mg/L)	Number of exceedances	Frequency of exceedances
January	8	25	2	131	n/a	–
February	10	9	3	37	n/a	–
March	32	121	4	526	n/a	–
April	43	99	28	556	20	47%
May	52	141	29	430	42	81%
June	62	145	5	1,170	50	81%
July	28	101	27	348	19	68%
August	29	77	23	154	16	55%
September	23	67	2	165	8	35%
October	16	50	17	108	n/a	–
November	11	45	6	91	n/a	–
December	10	16	2	39	n/a	–

Values in red indicate years in which the TSS standard of 65 mg/L was exceeded in greater than 10 percent of the samples collected in April through September.

Table B-25. Annual summary of TSS data at Minnesota River (AUID 07020007-723; April–September)

Year	Sample count	Mean (mg/L)	Minimum (mg/L)	Maximum (mg/L)	Number of exceedances	Frequency of exceedances
2006	29	163	38	780	23	79%
2007	23	148	35	632	16	70%
2008	27	142	24	374	22	81%
2009	28	73	23	156	17	61%
2010	27	137	31	658	17	63%
2011	20	63	34	102	9	45%
2012	33	141	24	490	21	64%
2013	32	153	29	790	28	88%
2014	67	184	50	1,970	64	96%
2015	53	185	32	510	43	81%

Values in red indicate years in which the TSS standard of 65 mg/L was exceeded in greater than 10 percent of the samples collected in April through September.

Table B-26. Monthly summary of TSS data at Minnesota River (AUID 07020007-723; 2006–2015)

Month	Sample count	Mean (mg/L)	Minimum (mg/L)	Maximum (mg/L)	Number of exceedances	Frequency of exceedances
January	7	23	2	92	n/a	–
February	13	30	2	220	n/a	–
March	47	200	15	1,030	n/a	–
April	58	140	23	780	37	64%
May	75	157	31	512	64	85%
June	83	211	42	1,970	79	95%
July	42	106	41	336	37	88%
August	47	109	24	632	27	57%
September	34	103	24	658	16	47%
October	23	106	11	398	n/a	–
November	12	54	3	206	n/a	–
December	11	41	4	244	n/a	–

Values in red indicate years in which the TSS standard of 65 mg/L was exceeded in greater than 10 percent of the samples collected in April through September.

B5. Cottonwood (HUC 07020008)

Table B-27. Annual summary of TSS data at Cottonwood River (AUID 07020008-501; April–September)

Year	Sample count	Mean (mg/L)	Minimum (mg/L)	Maximum (mg/L)	Number of exceedances	Frequency of exceedances
2006	21	140	27	360	12	57%
2007	17	135	28	430	11	65%
2008	17	132	9	448	8	47%
2009	29	32	7	84	2	7%
2010	47	163	16	790	31	66%
2011	17	160	30	518	13	76%
2012	17	243	7	960	10	59%
2013	22	126	6	590	11	50%
2014	29	263	24	1,550	17	59%
2015	28	163	13	748	21	75%

Values in red indicate years in which the TSS standard of 65 mg/L was exceeded in greater than 10 percent of the samples collected in April through September.

Table B-28. Monthly summary of TSS data at Cottonwood River (AUID 07020008-501; 2006–2015)

Month	Sample count	Mean (mg/L)	Minimum (mg/L)	Maximum (mg/L)	Number of exceedances	Frequency of exceedances
January	10	4	2	8	n/a	–
February	12	9	2	22	n/a	–
March	31	294	3	1,150	n/a	–
April	36	94	13	360	16	44%
May	43	180	15	960	23	53%
June	68	250	15	1,550	59	87%
July	30	87	28	281	15	50%
August	32	68	16	239	9	28%
September	35	141	6	790	14	40%
October	23	54	2	398	n/a	–
November	15	85	2	504	n/a	–
December	12	12	2	45	n/a	–

Values in red indicate years in which the TSS standard of 65 mg/L was exceeded in greater than 10 percent of the samples collected in April through September.

B6. Blue Earth (HUC 07020009)

Table B-29. Annual summary of TSS data at Blue Earth River (AUID 07020009-501; April–September)

Year	Sample count	Mean (mg/L)	Minimum (mg/L)	Maximum (mg/L)	Number of exceedances	Frequency of exceedances
2006	6	121	25	250	3	50%
2007	0	–	–	–	–	–
2008	0	–	–	–	–	–
2009	6	29	11	52	0	0%
2010	0	–	–	–	–	–
2011	0	–	–	–	–	–
2012	0	–	–	–	–	–
2013	0	–	–	–	–	–
2014	0	–	–	–	–	–
2015	18	268	54	760	16	89%

Values in red indicate years in which the TSS standard of 65 mg/L was exceeded in greater than 10 percent of the samples collected in April through September.

Table B-30. Monthly summary of TSS data at Blue Earth River (AUID 07020009-501; 2006–2015)

Month	Sample count	Mean (mg/L)	Minimum (mg/L)	Maximum (mg/L)	Number of exceedances	Frequency of exceedances
January	0	–	–	–	n/a	–
February	2	28	25	31	n/a	–
March	3	51	13	119	n/a	–
April	2	139	27	250	1	50%
May	2	118	36	200	1	50%
June	14	304	32	760	13	93%
July	4	142	46	240	2	50%
August	4	58	11	86	2	50%
September	4	38	13	58	0	–
October	1	7	7	7	n/a	–
November	0	–	–	–	n/a	–
December	2	5	4	5	n/a	–

Values in red indicate years in which the TSS standard of 65 mg/L was exceeded in greater than 10 percent of the samples collected in April through September.

Table B-31. Annual summary of transparency tube data at Blue Earth River (AUID 07020009-501; April–September)

Year	Sample count	Mean (cm)	Minimum (cm)	Maximum (cm)
2006	32	21	5	38
2007	25	19	9	28
2008	62	21	5	56
2009	42	27	11	48
2010	58	19	3	45
2011	41	19	6	40
2012	47	27	3	66
2013	30	22	9	40
2014	5	14	7	25
2015	32	13	3	35

In previous assessment cycles, a transparency tube measurement of less than 20 cm indicated a violation of the 25 NTU turbidity standard.

Table B-32. Monthly summary of transparency tube data at Blue Earth River (AUID 07020009-501; 2006–2015)

Month	Sample count	Mean (cm)	Minimum (cm)	Maximum (cm)
January	0	–	–	–
February	0	–	–	–
March	2	17	10	23
April	36	22	5	40
May	61	20	3	45
June	80	15	3	45
July	69	19	7	52
August	73	27	6	56
September	55	25	3	66
October	33	34	8	76
November	1	30	30	30
December	0	–	–	–

In previous assessment cycles, a transparency tube measurement of less than 20 cm indicated a violation of the 25 NTU turbidity standard.

Table B-33. Annual summary of TSS data at Elm Creek (AUID 07020009-502; April–September)

Year	Sample count	Mean (mg/L)	Minimum (mg/L)	Maximum (mg/L)	Number of exceedances	Frequency of exceedances
2006	69	65	13	207	29	42%
2007	33	57	4	156	12	36%
2008	30	69	2	164	16	53%
2009	0	–	–	–	–	–
2010	0	–	–	–	–	–
2011	0	–	–	–	–	–
2012	0	–	–	–	–	–
2013	0	–	–	–	–	–
2014	17	58	5	218	6	35%
2015	0	–	–	–	–	–

Values in red indicate years in which the TSS standard of 65 mg/L was exceeded in greater than 10 percent of the samples collected in April through September.

Table B-34. Monthly summary of TSS data at Elm Creek (AUID 07020009-502; 2006–2015)

Month	Sample count	Mean (mg/L)	Minimum (mg/L)	Maximum (mg/L)	Number of exceedances	Frequency of exceedances
January	0	–	–	–	n/a	–
February	0	–	–	–	n/a	–
March	7	82	40	106	n/a	–
April	33	74	14	207	15	45%
May	28	65	17	156	13	46%
June	34	100	32	218	28	82%
July	18	49	4	144	6	33%
August	25	27	2	79	1	4%
September	11	18	11	25	0	0%
October	7	39	6	99	n/a	–
November	0	–	–	–	n/a	–
December	3	6	2	10	n/a	–

Values in red indicate years in which the TSS standard of 65 mg/L was exceeded in greater than 10 percent of the samples collected in April through September.

Table B-35. Annual summary of TSS data at Center Creek (AUID 07020009-503; April–September)

Year	Sample count	Mean (mg/L)	Minimum (mg/L)	Maximum (mg/L)	Number of exceedances	Frequency of exceedances
2006	49	87	7	650	18	37%
2007	33	62	4	181	15	45%
2008	30	72	2	274	17	57%
2009	10	16	2	36	0	0%
2010	0	–	–	–	–	–
2011	0	–	–	–	–	–
2012	1	17	17	17	0	0%
2013	0	–	–	–	–	–
2014	0	–	–	–	–	–
2015	0	–	–	–	–	–

Values in red indicate years in which the TSS standard of 65 mg/L was exceeded in greater than 10 percent of the samples collected in April through September.

Table B-36. Monthly summary of TSS data at Center Creek (AUID 07020009-503; 2006–2015)

Month	Sample count	Mean (mg/L)	Minimum (mg/L)	Maximum (mg/L)	Number of exceedances	Frequency of exceedances
January	0	–	–	–	n/a	–
February	2	38	33	42	n/a	–
March	10	67	11	121	n/a	–
April	26	79	17	274	13	50%
May	24	65	7	146	10	42%
June	21	87	35	156	16	76%
July	22	53	2	650	3	14%
August	18	98	3	552	7	39%
September	12	24	2	113	1	8%
October	6	25	5	53	n/a	–
November	1	6	6	6	n/a	–
December	0	–	–	–	n/a	–

Values in red indicate years in which the TSS standard of 65 mg/L was exceeded in greater than 10 percent of the samples collected in April through September.

Table B-37. Annual summary of TSS data at Blue Earth River (AUID 07020009-504; April–September)

Year	Sample count	Mean (mg/L)	Minimum (mg/L)	Maximum (mg/L)	Number of exceedances	Frequency of exceedances
1996	0	–	–	–	–	–
1997	0	–	–	–	–	–
1998	5	33	10	86	1	20%
1999	0	–	–	–	–	–
2000	8	35	8	90	2	25%
2001	0	–	–	–	–	–
2002	0	–	–	–	–	–
2003	0	–	–	–	–	–
2004	0	–	–	–	–	–
2005	0	–	–	–	–	–

Values in red indicate years in which the TSS standard of 65 mg/L was exceeded in greater than 10 percent of the samples collected in April through September.

Table B-38. Monthly summary of TSS data at Blue Earth River (AUID 07020009-504; 1996–2005)

Month	Sample count	Mean (mg/L)	Minimum (mg/L)	Maximum (mg/L)	Number of exceedances	Frequency of exceedances
January	0	–	–	–	n/a	–
February	0	–	–	–	n/a	–
March	0	–	–	–	n/a	–
April	0	–	–	–	–	–
May	0	–	–	–	–	–
June	3	79	62	90	2	67%
July	3	38	16	72	1	33%
August	4	17	9	28	0	0%
September	3	9	8	10	0	0%
October	0	–	–	–	n/a	–
November	0	–	–	–	n/a	–
December	0	–	–	–	n/a	–

Values in red indicate years in which the TSS standard of 65 mg/L was exceeded in greater than 10 percent of the samples collected in April through September.

Table B-39. Annual summary of TSS data at Blue Earth River (AUID 07020009-507; April–September)

Year	Sample count	Mean (mg/L)	Minimum (mg/L)	Maximum (mg/L)	Number of exceedances	Frequency of exceedances
1996	0	–	–	–	–	–
1997	0	–	–	–	–	–
1998	0	–	–	–	–	–
1999	7	119	19	320	4	57%
2000	8	108	34	270	5	63%
2001	0	–	–	–	–	–
2002	0	–	–	–	–	–
2003	0	–	–	–	–	–
2004	1	420	420	420	1	100%
2005	0	–	–	–	–	–

Values in red indicate years in which the TSS standard of 65 mg/L was exceeded in greater than 10 percent of the samples collected in April through September.

Table B-40. Monthly summary of TSS data at Blue Earth River (AUID 07020009-507; 1996–2005)

Month	Sample count	Mean (mg/L)	Minimum (mg/L)	Maximum (mg/L)	Number of exceedances	Frequency of exceedances
January	0	–	–	–	n/a	–
February	0	–	–	–	n/a	–
March	0	–	–	–	n/a	–
April	0	–	–	–	–	–
May	0	–	–	–	–	–
June	2	220	170	270	2	100%
July	5	236	130	420	5	100%
August	5	75	48	120	3	60%
September	4	31	19	36	0	–
October	0	–	–	–	n/a	–
November	0	–	–	–	n/a	–
December	0	–	–	–	n/a	–

Values in red indicate years in which the TSS standard of 65 mg/L was exceeded in greater than 10 percent of the samples collected in April through September.

Table B-41. Annual summary of transparency tube data at Blue Earth River (AUID 07020009-507; April–September)

Year	Sample count	Mean (cm)	Minimum (cm)	Maximum (cm)
2006	10	14	7	18
2007	7	13	6	22
2008	6	12	6	30
2009	6	18	5	41
2010	9	15	10	32
2011	4	12	5	20
2012	0	–	–	–
2013	0	–	–	–
2014	0	–	–	–
2015	0	–	–	–

In previous assessment cycles, a transparency tube measurement of less than 20 cm indicated a violation of the 25 NTU turbidity standard.

Table B-42. Monthly summary of transparency tube data at Blue Earth River (AUID 07020009-507; 2006–2015)

Month	Sample count	Mean (cm)	Minimum (cm)	Maximum (cm)
January	0	–	–	–
February	0	–	–	–
March	1	4	4	4
April	4	12	6	14
May	12	16	7	32
June	9	9	5	11
July	5	11	5	16
August	7	16	6	30
September	5	20	10	41
October	5	24	7	50
November	2	60	60	60
December	0	–	–	–

In previous assessment cycles, a transparency tube measurement of less than 20 cm indicated a violation of the 25 NTU turbidity standard.

Table B-43. Annual summary of TSS data at Blue Earth River (AUID 07020009-508; April–September)

Year	Sample count	Mean (mg/L)	Minimum (mg/L)	Maximum (mg/L)	Number of exceedances	Frequency of exceedances
1996	0	–	–	–	–	–
1997	0	–	–	–	–	–
1998	0	–	–	–	–	–
1999	8	115	15	440	5	63%
2000	8	61	27	100	4	50%
2001	0	–	–	–	–	–
2002	0	–	–	–	–	–
2003	0	–	–	–	–	–
2004	0	–	–	–	–	–
2005	0	–	–	–	–	–

Values in red indicate years in which the TSS standard of 65 mg/L was exceeded in greater than 10 percent of the samples collected in April through September.

Table B-44. Monthly summary of TSS data at Blue Earth River (AUID 07020009-508; 1996–2005)

Month	Sample count	Mean (mg/L)	Minimum (mg/L)	Maximum (mg/L)	Number of exceedances	Frequency of exceedances
January	0	–	–	–	n/a	–
February	0	–	–	–	n/a	–
March	0	–	–	–	n/a	–
April	0	–	–	–	–	–
May	0	–	–	–	–	–
June	2	97	94	100	2	100%
July	5	168	91	440	5	100%
August	5	50	27	77	2	40%
September	4	29	15	43	0	0%
October	0	–	–	–	n/a	–
November	0	–	–	–	n/a	–
December	0	–	–	–	n/a	–

Values in red indicate years in which the TSS standard of 65 mg/L was exceeded in greater than 10 percent of the samples collected in April through September.

Table B-45. Annual summary of TSS data at Blue Earth River (AUID 07020009-509; April–September)

Year	Sample count	Mean (mg/L)	Minimum (mg/L)	Maximum (mg/L)	Number of exceedances	Frequency of exceedances
2006	17	271	31	1,630	10	59%
2007	24	165	30	594	14	58%
2008	27	231	5	784	17	63%
2009	24	61	22	185	7	29%
2010	32	156	18	1,100	18	56%
2011	19	82	20	240	9	47%
2012	22	129	10	480	10	45%
2013	22	131	34	460	11	50%
2014	21	166	20	1,380	10	48%
2015	23	100	2	326	10	43%

Values in red indicate years in which the TSS standard of 65 mg/L was exceeded in greater than 10 percent of the samples collected in April through September.

Table B-46. Monthly summary of TSS data at Blue Earth River (AUID 07020009-509; 2006–2015)

Month	Sample count	Mean (mg/L)	Minimum (mg/L)	Maximum (mg/L)	Number of exceedances	Frequency of exceedances
January	7	13	1	71	n/a	–
February	11	51	1	234	n/a	–
March	41	267	6	954	n/a	–
April	45	164	2	1,630	20	44%
May	48	149	20	784	22	46%
June	58	180	22	1,380	41	71%
July	27	81	5	231	12	44%
August	27	131	25	594	11	41%
September	26	138	24	1,100	10	38%
October	21	155	5	572	n/a	–
November	11	36	3	263	n/a	–
December	9	72	2	408	n/a	–

Values in red indicate years in which the TSS standard of 65 mg/L was exceeded in greater than 10 percent of the samples collected in April through September.

Table B-47. Annual summary of TSS data at Blue Earth River (AUID 07020009-514; April–September)

Year	Sample count	Mean (mg/L)	Minimum (mg/L)	Maximum (mg/L)	Number of exceedances	Frequency of exceedances
1996	0	–	–	–	–	–
1997	0	–	–	–	–	–
1998	0	–	–	–	–	–
1999	2	161	22	300	1	50%
2000	0	–	–	–	–	–
2001	0	–	–	–	–	–
2002	0	–	–	–	–	–
2003	0	–	–	–	–	–
2004	0	–	–	–	–	–
2005	0	–	–	–	–	–

Values in red indicate years in which the TSS standard of 65 mg/L was exceeded in greater than 10 percent of the samples collected in April through September.

Table B-48. Monthly summary of TSS data at Blue Earth River (AUID 07020009-514; 1996–2005)

Month	Sample count	Mean (mg/L)	Minimum (mg/L)	Maximum (mg/L)	Number of exceedances	Frequency of exceedances
January	0	–	–	–	n/a	–
February	0	–	–	–	n/a	–
March	0	–	–	–	n/a	–
April	0	–	–	–	–	–
May	0	–	–	–	–	–
June	0	–	–	–	–	–
July	1	300	300	300	1	100%
August	0	–	–	–	–	–
September	1	22	22	22	0	0%
October	0	–	–	–	n/a	–
November	0	–	–	–	n/a	–
December	0	–	–	–	n/a	–

Values in red indicate years in which the TSS standard of 65 mg/L was exceeded in greater than 10 percent of the samples collected in April through September.

Table B-49. Annual summary of transparency tube data at Blue Earth River (AUID 07020009-514; April–September)

Year	Sample count	Mean (cm)	Minimum (cm)	Maximum (cm)
2006	0	–	–	–
2007	21	18	10	30
2008	24	21	8	33
2009	27	21	9	35
2010	0	–	–	–
2011	22	15	6	26
2012	21	19	3	35
2013	23	16	5	30
2014	21	15	4	35
2015	21	15	5	20

In previous assessment cycles, a transparency tube measurement of less than 20 cm indicated a violation of the 25 NTU turbidity standard.

Table B-50. Monthly summary of transparency tube data at Blue Earth River (AUID 07020009-514; 2006–2015)

Month	Sample count	Mean (cm)	Minimum (cm)	Maximum (cm)
January	0	–	–	–
February	0	–	–	–
March	9	19	7	30
April	30	20	10	35
May	35	19	3	35
June	35	13	4	31
July	31	13	6	24
August	24	20	10	33
September	25	22	8	35
October	18	36	11	86
November	1	32	32	32
December	0	–	–	–

In previous assessment cycles, a transparency tube measurement of less than 20 cm indicated a violation of the 25 NTU turbidity standard.

Table B-51. Annual summary of TSS data at Blue Earth River (AUID 07020009-515; April–September)

Year	Sample count	Mean (mg/L)	Minimum (mg/L)	Maximum (mg/L)	Number of exceedances	Frequency of exceedances
2006	0	–	–	–	–	–
2007	0	–	–	–	–	–
2008	0	–	–	–	–	–
2009	0	–	–	–	–	–
2010	0	–	–	–	–	–
2011	0	–	–	–	–	–
2012	0	–	–	–	–	–
2013	27	89	17	730	12	44%
2014	27	231	21	2,730	21	78%
2015	23	101	3	258	16	70%

Values in red indicate years in which the TSS standard of 65 mg/L was exceeded in greater than 10 percent of the samples collected in April through September.

Table B-52. Monthly summary of TSS data at Blue Earth River (AUID 07020009-515; 2006–2015)

Month	Sample count	Mean (mg/L)	Minimum (mg/L)	Maximum (mg/L)	Number of exceedances	Frequency of exceedances
January	0	–	–	–	n/a	–
February	0	–	–	–	n/a	–
March	6	32	7	52	n/a	–
April	14	76	3	139	7	50%
May	22	94	17	258	15	68%
June	24	284	48	2,730	20	83%
July	7	67	30	103	4	57%
August	6	56	23	94	2	33%
September	4	50	21	98	1	25%
October	3	8	5	14	n/a	–
November	0	–	–	–	n/a	–
December	0	–	–	–	n/a	–

Values in red indicate years in which the TSS standard of 65 mg/L was exceeded in greater than 10 percent of the samples collected in April through September.

Table B-53. Annual summary of TSS data at Blue Earth River (AUID 07020009-518; April–September)

Year	Sample count	Mean (mg/L)	Minimum (mg/L)	Maximum (mg/L)	Number of exceedances	Frequency of exceedances
2006	0	–	–	–	–	–
2007	0	–	–	–	–	–
2008	0	–	–	–	–	–
2009	0	–	–	–	–	–
2010	0	–	–	–	–	–
2011	0	–	–	–	–	–
2012	0	–	–	–	–	–
2013	27	39	11	280	2	7%
2014	28	72	6	524	5	18%
2015	24	56	13	165	6	25%

Values in red indicate years in which the TSS standard of 65 mg/L was exceeded in greater than 10 percent of the samples collected in April through September.

Table B-54. Monthly summary of TSS data at Blue Earth River (AUID 07020009-518; 2006–2015)

Month	Sample count	Mean (mg/L)	Minimum (mg/L)	Maximum (mg/L)	Number of exceedances	Frequency of exceedances
January	0	–	–	–	n/a	–
February	0	–	–	–	n/a	–
March	6	22	9	41	n/a	–
April	14	26	6	65	0	0%
May	21	36	13	165	2	10%
June	24	113	25	524	11	46%
July	8	32	16	54	0	0%
August	7	27	11	47	0	0%
September	5	25	12	46	0	0%
October	3	5	4	5	n/a	–
November	0	–	–	–	n/a	–
December	0	–	–	–	n/a	–

Values in red indicate years in which the TSS standard of 65 mg/L was exceeded in greater than 10 percent of the samples collected in April through September.

Table B-55. Annual summary of TSS data at Cedar Creek (AUID 07020009-521; April–September)

Year	Sample count	Mean (mg/L)	Minimum (mg/L)	Maximum (mg/L)	Number of exceedances	Frequency of exceedances
1996	0	–	–	–	–	–
1997	0	–	–	–	–	–
1998	0	–	–	–	–	–
1999	0	–	–	–	–	–
2000	4	46	29	89	1	25%
2001	0	–	–	–	–	–
2002	0	–	–	–	–	–
2003	0	–	–	–	–	–
2004	0	–	–	–	–	–
2005	0	–	–	–	–	–

Values in red indicate years in which the TSS standard of 65 mg/L was exceeded in greater than 10 percent of the samples collected in April through September.

Table B-56. Monthly summary of TSS data at Cedar Creek (AUID 07020009-521; 1996–2005)

Month	Sample count	Mean (mg/L)	Minimum (mg/L)	Maximum (mg/L)	Number of exceedances	Frequency of exceedances
January	0	–	–	–	n/a	–
February	0	–	–	–	n/a	–
March	0	–	–	–	n/a	–
April	0	–	–	–	–	–
May	0	–	–	–	–	–
June	0	–	–	–	–	–
July	2	30	29	31	0	0%
August	2	63	36	89	1	50%
September	0	–	–	–	–	–
October	0	–	–	–	n/a	–
November	0	–	–	–	n/a	–
December	0	–	–	–	n/a	–

Values in red indicate years in which the TSS standard of 65 mg/L was exceeded in greater than 10 percent of the samples collected in April through September.

Table B-57. Annual summary of transparency tube data at Cedar Creek (AUID 07020009-521; April–September)

Year	Sample count	Mean (cm)	Minimum (cm)	Maximum (cm)
1996	0	–	–	–
1997	0	–	–	–
1998	0	–	–	–
1999	0	–	–	–
2000	10	19	13	24
2001	15	17	5	50
2002	0	–	–	–
2003	0	–	–	–
2004	0	–	–	–
2005	0	–	–	–

In previous assessment cycles, a transparency tube measurement of less than 20 cm indicated a violation of the 25 NTU turbidity standard.

Table B-58. Monthly summary of transparency tube data at Cedar Creek (AUID 07020009-521; 1996–2005)

Month	Sample count	Mean (cm)	Minimum (cm)	Maximum (cm)
January	0	–	–	–
February	0	–	–	–
March	0	–	–	–
April	0	–	–	–
May	0	–	–	–
June	5	31	16	50
July	10	16	7	24
August	10	13	5	24
September	0	–	–	–
October	0	–	–	–
November	0	–	–	–
December	0	–	–	–

In previous assessment cycles, a transparency tube measurement of less than 20 cm indicated a violation of the 25 NTU turbidity standard.

Table B-59. Annual summary of TSS data at Elm Creek (AUID 07020009-522; April–September)

Year	Sample count	Mean (mg/L)	Minimum (mg/L)	Maximum (mg/L)	Number of exceedances	Frequency of exceedances
2006	26	54	14	164	9	35%
2007	0	–	–	–	–	–
2008	0	–	–	–	–	–
2009	0	–	–	–	–	–
2010	0	–	–	–	–	–
2011	0	–	–	–	–	–
2012	0	–	–	–	–	–
2013	0	–	–	–	–	–
2014	0	–	–	–	–	–
2015	0	–	–	–	–	–

Values in red indicate years in which the TSS standard of 65 mg/L was exceeded in greater than 10 percent of the samples collected in April through September.

Table B-60. Monthly summary of TSS data at Elm Creek (AUID 07020009-522; 2006–2015)

Month	Sample count	Mean (mg/L)	Minimum (mg/L)	Maximum (mg/L)	Number of exceedances	Frequency of exceedances
January	0	–	–	–	n/a	–
February	0	–	–	–	n/a	–
March	0	–	–	–	n/a	–
April	5	68	25	156	2	40%
May	3	30	14	48	0	0%
June	9	51	14	87	4	44%
July	0	–	–	–	–	–
August	9	56	19	164	3	33%
September	0	–	–	–	–	–
October	0	–	–	–	n/a	–
November	0	–	–	–	n/a	–
December	3	9	4	18	n/a	–

Values in red indicate years in which the TSS standard of 65 mg/L was exceeded in greater than 10 percent of the samples collected in April through September.

Table B-61. Annual summary of turbidity data at Elm Creek (AUID 07020009-523; April–September)

Year	Sample count	Mean (NTU)	Minimum (NTU)	Maximum (NTU)
2006	7	24	8	39
2007	7	14	8	19
2008	7	20	6	55
2009	0	–	–	–
2010	0	–	–	–
2011	0	–	–	–
2012	0	–	–	–
2013	0	–	–	–
2014	0	–	–	–
2015	0	–	–	–

The former turbidity standard was 25 NTU.

Table B-62. Monthly summary of turbidity data at Elm Creek (AUID 07020009-523; 2006–2015)

Month	Sample count	Mean (NTU)	Minimum (NTU)	Maximum (NTU)
January	0	–	–	–
February	0	–	–	–
March	0	–	–	–
April	0	–	–	–
May	4	13	6	19
June	4	20	13	38
July	4	20	9	38
August	5	18	7	55
September	4	26	10	39
October	3	20	8	35
November	0	–	–	–
December	0	–	–	–

The former turbidity standard was 25 NTU.

Table B-63. Annual summary of turbidity data at Elm Creek, South Fork (AUID 07020009-524; April–September)

Year	Sample count	Mean (NTU)	Minimum (NTU)	Maximum (NTU)
2006	7	17	3	35
2007	7	21	2	47
2008	7	20	5	57
2009	0	–	–	–
2010	0	–	–	–
2011	0	–	–	–
2012	0	–	–	–
2013	0	–	–	–
2014	0	–	–	–
2015	0	–	–	–

The former turbidity standard was 25 NTU.

Table B-64. Monthly summary of turbidity data at Elm Creek, South Fork (AUID 07020009-524; 2006–2015)

Month	Sample count	Mean (NTU)	Minimum (NTU)	Maximum (NTU)
January	0	–	–	–
February	0	–	–	–
March	0	–	–	–
April	0	–	–	–
May	4	11	2	28
June	4	7	3	15
July	4	13	5	22
August	5	33	15	47
September	4	30	13	57
October	3	21	14	35
November	0	–	–	–
December	0	–	–	–

The former turbidity standard was 25 NTU.

Table B-65. Annual summary of TSS data at Lily Creek (AUID 07020009-525; April–September)

Year	Sample count	Mean (mg/L)	Minimum (mg/L)	Maximum (mg/L)	Number of exceedances	Frequency of exceedances
1996	0	–	–	–	–	–
1997	0	–	–	–	–	–
1998	0	–	–	–	–	–
1999	0	–	–	–	–	–
2000	0	–	–	–	–	–
2001	6	132	13	632	1	17%
2002	0	–	–	–	–	–
2003	0	–	–	–	–	–
2004	0	–	–	–	–	–
2005	0	–	–	–	–	–

Values in red indicate years in which the TSS standard of 65 mg/L was exceeded in greater than 10 percent of the samples collected in April through September.

Table B-66. Monthly summary of TSS data at Lily Creek (AUID 07020009-525; 1996–2005)

Month	Sample count	Mean (mg/L)	Minimum (mg/L)	Maximum (mg/L)	Number of exceedances	Frequency of exceedances
January	0	–	–	–	n/a	–
February	0	–	–	–	n/a	–
March	0	–	–	–	n/a	–
April	0	–	–	–	–	–
May	0	–	–	–	–	–
June	2	219	38	400	2	100%
July	2	23	12	34	0	0%
August	2	44	41	47	2	100%
September	0	–	–	–	–	–
October	0	–	–	–	n/a	–
November	0	–	–	–	n/a	–
December	0	–	–	–	n/a	–

Values in red indicate years in which the TSS standard of 65 mg/L was exceeded in greater than 10 percent of the samples collected in April through September.

Table B-67. Annual summary of transparency tube data at Lily Creek (AUID 07020009-525; April–September)

Year	Sample count	Mean (cm)	Minimu m (cm)	Maximum (cm)
1996	0	–	–	–
1997	0	–	–	–
1998	0	–	–	–
1999	0	–	–	–
2000	10	24	10	46
2001	15	18	3	33
2002	0	–	–	–
2003	0	–	–	–
2004	0	–	–	–
2005	19	25	8	42

In previous assessment cycles, a transparency tube measurement of less than 20 cm indicated a violation of the 25 NTU turbidity standard.

Table B-68. Monthly summary of transparency tube data at Lily Creek (AUID 07020009-525; 1996–2005)

Month	Sample count	Mean (cm)	Minimum (cm)	Maximum (cm)
January	0	–	–	–
February	0	–	–	–
March	0	–	–	–
April	3	36	30	41
May	3	31	18	40
June	9	26	3	42
July	12	26	13	46
August	14	14	8	25
September	3	14	10	18
October	0	–	–	–
November	0	–	–	–
December	0	–	–	–

In previous assessment cycles, a transparency tube measurement of less than 20 cm indicated a violation of the 25 NTU turbidity standard.

Table B-69. Annual summary of TSS data at Dutch Creek (AUID 07020009-527; April–September)

Year	Sample count	Mean (mg/L)	Minimum (mg/L)	Maximum (mg/L)	Number of exceedances	Frequency of exceedances
2006	42	47	5	460	6	14%
2007	33	21	5	58	0	0%
2008	29	35	3	128	4	14%
2009	0	–	–	–	–	–
2010	0	–	–	–	–	–
2011	0	–	–	–	–	–
2012	0	–	–	–	–	–
2013	0	–	–	–	–	–
2014	0	–	–	–	–	–
2015	0	–	–	–	–	–

Values in red indicate years in which the TSS standard of 65 mg/L was exceeded in greater than 10 percent of the samples collected in April through September.

Table B-70. Monthly summary of TSS data at Dutch Creek (AUID 07020009-527; 2006–2015)

Month	Sample count	Mean (mg/L)	Minimum (mg/L)	Maximum (mg/L)	Number of exceedances	Frequency of exceedances
January	0	–	–	–	n/a	–
February	0	–	–	–	n/a	–
March	7	62	5	126	n/a	–
April	23	58	5	460	5	22%
May	22	25	5	61	0	0%
June	18	43	12	174	2	11%
July	16	29	6	79	2	13%
August	15	26	3	135	1	7%
September	10	14	5	25	0	0%
October	5	10	7	16	n/a	–
November	0	–	–	–	n/a	–
December	0	–	–	–	n/a	–

Values in red indicate years in which the TSS standard of 65 mg/L was exceeded in greater than 10 percent of the samples collected in April through September.

Table B-71. Annual summary of TSS data at Blue Earth River, East Branch (AUID 07020009-553; April–September)

Year	Sample count	Mean (mg/L)	Minimum (mg/L)	Maximum (mg/L)	Number of exceedances	Frequency of exceedances
2006	0	–	–	–	–	–
2007	0	–	–	–	–	–
2008	0	–	–	–	–	–
2009	0	–	–	–	–	–
2010	0	–	–	–	–	–
2011	0	–	–	–	–	–
2012	0	–	–	–	–	–
2013	28	69	12	500	8	29%
2014	27	107	5	560	18	67%
2015	26	85	8	201	19	73%

Values in red indicate years in which the TSS standard of 65 mg/L was exceeded in greater than 10 percent of the samples collected in April through September.

Table B-72. Monthly summary of TSS data at Blue Earth River, East Branch (AUID 07020009-553; 2006–2015)

Month	Sample count	Mean (mg/L)	Minimum (mg/L)	Maximum (mg/L)	Number of exceedances	Frequency of exceedances
January	0	–	–	–	n/a	–
February	0	–	–	–	n/a	–
March	5	13	6	19	n/a	–
April	14	94	31	560	5	36%
May	22	65	13	141	10	45%
June	26	120	18	500	19	73%
July	6	60	8	95	4	67%
August	8	63	9	140	4	50%
September	5	59	5	107	3	60%
October	3	12	3	30	n/a	–
November	0	–	–	–	n/a	–
December	0	–	–	–	n/a	–

Values in red indicate years in which the TSS standard of 65 mg/L was exceeded in greater than 10 percent of the samples collected in April through September.

Table B-73. Annual summary of transparency tube data at Blue Earth River, East Branch (AUID 07020009-554; April–September)

Year	Sample count	Mean (cm)	Minimum (cm)	Maximum (cm)
2006	26	14	5	32
2007	24	24	7	56
2008	18	14	2	32
2009	26	18	7	55
2010	25	28	4	53
2011	10	22	13	36
2012	11	29	17	47
2013	15	39	3	69
2014	11	50	14	77
2015	0	–	–	–

In previous assessment cycles, a transparency tube measurement of less than 20 cm indicated a violation of the 25 NTU turbidity standard.

Table B-74. Monthly summary of transparency tube data at Blue Earth River, East Branch (AUID 07020009-554; 2006–2015)

Month	Sample count	Mean (cm)	Minimum (cm)	Maximum (cm)
January	0	–	–	–
February	0	–	–	–
March	0	–	–	–
April	23	35	5	69
May	33	31	2	73
June	33	15	3	26
July	28	22	8	66
August	26	21	7	58
September	23	24	4	77
October	18	22	10	81
November	1	29	29	29
December	0	–	–	–

In previous assessment cycles, a transparency tube measurement of less than 20 cm indicated a violation of the 25 NTU turbidity standard.

Table B-75. Annual summary of TSS data at Blue Earth River (AUID 07020009-565; April–September)

Year	Sample count	Mean (mg/L)	Minimum (mg/L)	Maximum (mg/L)	Number of exceedances	Frequency of exceedances
2006	0	–	–	–	–	–
2007	0	–	–	–	–	–
2008	0	–	–	–	–	–
2009	0	–	–	–	–	–
2010	0	–	–	–	–	–
2011	0	–	–	–	–	–
2012	0	–	–	–	–	–
2013	1	38	38	38	0	0%
2014	1	34	34	34	0	0%
2015	0	–	–	–	–	–

Values in red indicate years in which the TSS standard of 65 mg/L was exceeded in greater than 10 percent of the samples collected in April through September.

Table B-76. Monthly summary of TSS data at Blue Earth River (AUID 07020009-565; 2006–2015)

Month	Sample count	Mean (mg/L)	Minimum (mg/L)	Maximum (mg/L)	Number of exceedances	Frequency of exceedances
January	0	–	–	–	n/a	–
February	0	–	–	–	n/a	–
March	0	–	–	–	n/a	–
April	0	–	–	–	–	–
May	0	–	–	–	–	–
June	2	36	34	38	0	0%
July	0	–	–	–	–	–
August	0	–	–	–	–	–
September	0	–	–	–	–	–
October	0	–	–	–	n/a	–
November	0	–	–	–	n/a	–
December	0	–	–	–	n/a	–

Values in red indicate years in which the TSS standard of 65 mg/L was exceeded in greater than 10 percent of the samples collected in April through September.

Table B-77. Annual summary of transparency tube data at Blue Earth River (AUID 07020009-565; April–September)

Year	Sample count	Mean (cm)	Minimum (cm)	Maximum (cm)
2006	29	27	4	60
2007	25	24	6	50
2008	28	26	6	49
2009	22	28	9	55
2010	0	–	–	–
2011	20	25	7	45
2012	21	20	6	38
2013	26	32	4	70
2014	27	36	13	75
2015	22	33	14	55

In previous assessment cycles, a transparency tube measurement of less than 20 cm indicated a violation of the 25 NTU turbidity standard.

Table B-78. Monthly summary of transparency tube data at Blue Earth River (AUID 07020009-565; 2006–2015)

Month	Sample count	Mean (cm)	Minimum (cm)	Maximum (cm)
January	0	–	–	–
February	0	–	–	–
March	6	38	16	85
April	38	31	4	75
May	40	32	6	68
June	39	20	4	36
July	39	25	7	49
August	41	28	6	55
September	23	34	12	70
October	26	36	14	100
November	0	–	–	–
December	0	–	–	–

In previous assessment cycles, a transparency tube measurement of less than 20 cm indicated a violation of the 25 NTU turbidity standard.

B7. Watonwan (HUC 07020010)

Table B-79. Annual summary of TSS data at Watonwan River (AUID 07020010-501; April–September)

Year	Sample count	Mean (mg/L)	Minimum (mg/L)	Maximum (mg/L)	Number of exceedances	Frequency of exceedances
2006	49	69	20	170	18	37%
2007	46	71	9	488	17	37%
2008	39	66	7	183	18	46%
2009	27	33	5	124	4	15%
2010	39	83	18	504	20	51%
2011	18	50	10	161	5	28%
2012	24	118	14	527	14	58%
2013	30	77	12	654	7	23%
2014	24	75	14	227	9	38%
2015	19	74	12	205	9	47%

Values in red indicate years in which the TSS standard of 65 mg/L was exceeded in greater than 10 percent of the samples collected in April through September.

Table B-80. Monthly summary of TSS data at Watonwan River (AUID 07020010-501; 2006–2015)

Month	Sample count	Mean (mg/L)	Minimum (mg/L)	Maximum (mg/L)	Number of exceedances	Frequency of exceedances
January	5	3	2	4	n/a	–
February	9	12	2	33	n/a	–
March	47	104	3	346	n/a	–
April	61	60	5	186	20	33%
May	76	73	12	527	23	30%
June	76	108	24	654	59	78%
July	34	39	9	98	7	21%
August	38	60	6	488	9	24%
September	30	52	8	504	3	10%
October	26	46	4	145	n/a	–
November	10	33	2	148	n/a	–
December	11	22	2	81	n/a	–

Values in red indicate years in which the TSS standard of 65 mg/L was exceeded in greater than 10 percent of the samples collected in April through September.

Table B-81. Annual summary of TSS data at Watonwan River (AUID 07020010-510; April–September)

Year	Sample count	Mean (mg/L)	Minimum (mg/L)	Maximum (mg/L)	Number of exceedances	Frequency of exceedances
2006	0	–	–	–	–	–
2007	0	–	–	–	–	–
2008	0	–	–	–	–	–
2009	0	–	–	–	–	–
2010	0	–	–	–	–	–
2011	0	–	–	–	–	–
2012	0	–	–	–	–	–
2013	20	45	6	196	3	15%
2014	0	–	–	–	–	–
2015	1	32	32	32	0	0%

Values in red indicate years in which the TSS standard of 65 mg/L was exceeded in greater than 10 percent of the samples collected in April through September.

Table B-82. Monthly summary of TSS data at Watonwan River (AUID 07020010-510; 2006–2015)

Month	Sample count	Mean (mg/L)	Minimum (mg/L)	Maximum (mg/L)	Number of exceedances	Frequency of exceedances
January	0	–	–	–	n/a	–
February	0	–	–	–	n/a	–
March	0	–	–	–	n/a	–
April	0	–	–	–	–	–
May	4	28	12	36	0	0%
June	4	94	53	196	1	25%
July	4	59	17	97	2	50%
August	5	27	20	34	0	0%
September	4	17	6	30	0	0%
October	0	–	–	–	n/a	–
November	0	–	–	–	n/a	–
December	0	–	–	–	n/a	–

Values in red indicate years in which the TSS standard of 65 mg/L was exceeded in greater than 10 percent of the samples collected in April through September.

Table B-83. Annual summary of transparency tube data at Watonwan River (AUID 07020010-510; April–September)

Year	Sample count	Mean (cm)	Minimum (cm)	Maximum (cm)
2006	60	24	10	55
2007	73	26	10	56
2008	72	31	10	60
2009	75	33	12	50
2010	70	24	5	55
2011	45	28	9	51
2012	47	26	5	47
2013	48	33	8	61
2014	36	30	8	58
2015	25	28	14	51

In previous assessment cycles, a transparency tube measurement of less than 20 cm indicated a violation of the 25 NTU turbidity standard.

Table B-84. Monthly summary of transparency tube data at Watonwan River (AUID 07020010-510; 2006–2015)

Month	Sample count	Mean (cm)	Minimum (cm)	Maximum (cm)
January	1	22	22	22
February	0	–	–	–
March	2	40	26	53
April	75	29	10	51
May	95	27	5	58
June	95	17	8	31
July	107	26	9	58
August	93	34	12	60
September	86	39	5	61
October	52	48	12	100
November	3	34	20	60
December	0	–	–	–

In previous assessment cycles, a transparency tube measurement of less than 20 cm indicated a violation of the 25 NTU turbidity standard.

Table B-85. Annual summary of TSS data at Watonwan River (AUID 07020010-511; April–September)

Year	Sample count	Mean (mg/L)	Minimum (mg/L)	Maximum (mg/L)	Number of exceedances	Frequency of exceedances
2006	0	–	–	–	–	–
2007	0	–	–	–	–	–
2008	0	–	–	–	–	–
2009	0	–	–	–	–	–
2010	0	–	–	–	–	–
2011	0	–	–	–	–	–
2012	0	–	–	–	–	–
2013	33	57	6	296	10	30%
2014	28	75	5	264	13	46%
2015	24	92	2	209	15	63%

Values in red indicate years in which the TSS standard of 65 mg/L was exceeded in greater than 10 percent of the samples collected in April through September.

Table B-86. Monthly summary of TSS data at Watonwan River (AUID 07020010-511; 2006–2015)

Month	Sample count	Mean (mg/L)	Minimum (mg/L)	Maximum (mg/L)	Number of exceedances	Frequency of exceedances
January	0	–	–	–	n/a	–
February	0	–	–	–	n/a	–
March	3	26	3	60	n/a	–
April	12	36	2	70	2	17%
May	22	58	15	198	6	27%
June	26	120	14	296	20	77%
July	9	72	16	157	5	56%
August	11	57	6	163	5	45%
September	5	15	5	29	0	0%
October	3	14	2	32	n/a	–
November	0	–	–	–	n/a	–
December	0	–	–	–	n/a	–

Values in red indicate years in which the TSS standard of 65 mg/L was exceeded in greater than 10 percent of the samples collected in April through September.

Table B-87. Annual summary of TSS data at Butterfield Creek (AUID 07020010-516; April–September)

Year	Sample count	Mean (mg/L)	Minimum (mg/L)	Maximum (mg/L)	Number of exceedances	Frequency of exceedances
2006	0	–	–	–	–	–
2007	0	–	–	–	–	–
2008	0	–	–	–	–	–
2009	0	–	–	–	–	–
2010	0	–	–	–	–	–
2011	0	–	–	–	–	–
2012	0	–	–	–	–	–
2013	10	25	7	70	1	10%
2014	0	–	–	–	–	–
2015	7	38	7	100	2	29%

Values in red indicate years in which the TSS standard of 65 mg/L was exceeded in greater than 10 percent of the samples collected in April through September.

Table B-88. Monthly summary of TSS data at Butterfield Creek (AUID 07020010-516; 2006–2015)

Month	Sample count	Mean (mg/L)	Minimum (mg/L)	Maximum (mg/L)	Number of exceedances	Frequency of exceedances
January	0	–	–	–	n/a	–
February	0	–	–	–	n/a	–
March	0	–	–	–	n/a	–
April	0	–	–	–	–	–
May	2	14	10	19	0	0%
June	4	52	18	88	2	50%
July	5	39	7	100	1	20%
August	4	10	7	18	0	0%
September	2	20	12	28	0	0%
October	0	–	–	–	n/a	–
November	0	–	–	–	n/a	–
December	0	–	–	–	n/a	–

Values in red indicate years in which the TSS standard of 65 mg/L was exceeded in greater than 10 percent of the samples collected in April through September.

Table B-89. Annual summary of transparency tube data at Butterfield Creek (AUID 07020010-516; April–September)

Year	Sample count	Mean (cm)	Minimum (cm)	Maximum (cm)
2006	15	25	8	60
2007	0	–	–	–
2008	0	–	–	–
2009	0	–	–	–
2010	28	21	4	39
2011	0	–	–	–
2012	0	–	–	–
2013	13	63	13	100
2014	5	55	13	80
2015	7	37	14	80

In previous assessment cycles, a transparency tube measurement of less than 20 cm indicated a violation of the 25 NTU turbidity standard.

Table B-90. Monthly summary of transparency tube data at Butterfield Creek (AUID 07020010-516; 2006–2015)

Month	Sample count	Mean (cm)	Minimum (cm)	Maximum (cm)
January	0	–	–	–
February	0	–	–	–
March	0	–	–	–
April	3	31	10	52
May	6	43	17	93
June	19	23	4	60
July	22	35	7	92
August	15	40	8	100
September	3	57	9	100
October	0	–	–	–
November	0	–	–	–
December	0	–	–	–

In previous assessment cycles, a transparency tube measurement of less than 20 cm indicated a violation of the 25 NTU turbidity standard.

Table B-91. Annual summary of TSS data at Watonwan River, South Fork (AUID 07020010-517; April–September)

Year	Sample count	Mean (mg/L)	Minimum (mg/L)	Maximum (mg/L)	Number of exceedances	Frequency of exceedances
2006	0	–	–	–	–	–
2007	0	–	–	–	–	–
2008	0	–	–	–	–	–
2009	0	–	–	–	–	–
2010	0	–	–	–	–	–
2011	0	–	–	–	–	–
2012	0	–	–	–	–	–
2013	33	51	8	308	7	21%
2014	22	78	10	538	8	36%
2015	17	84	4	306	9	53%

Values in red indicate years in which the TSS standard of 65 mg/L was exceeded in greater than 10 percent of the samples collected in April through September.

Table B-92. Monthly summary of TSS data at Watonwan River, South Fork (AUID 07020010-517; 2006–2015)

Month	Sample count	Mean (mg/L)	Minimum (mg/L)	Maximum (mg/L)	Number of exceedances	Frequency of exceedances
January	0	–	–	–	n/a	–
February	0	–	–	–	n/a	–
March	3	25	6	36	n/a	–
April	10	29	12	46	0	0%
May	17	33	4	99	2	12%
June	25	132	30	538	18	72%
July	7	46	8	122	2	29%
August	9	29	8	92	2	22%
September	4	18	13	29	0	0%
October	3	7	5	10	n/a	–
November	0	–	–	–	n/a	–
December	0	–	–	–	n/a	–

Values in red indicate years in which the TSS standard of 65 mg/L was exceeded in greater than 10 percent of the samples collected in April through September.

Table B-93. Annual summary of TSS data at Perch Creek (AUID 07020010-524; April–September)

Year	Sample count	Mean (mg/L)	Minimum (mg/L)	Maximum (mg/L)	Number of exceedances	Frequency of exceedances
2006	0	–	–	–	–	–
2007	0	–	–	–	–	–
2008	0	–	–	–	–	–
2009	0	–	–	–	–	–
2010	0	–	–	–	–	–
2011	0	–	–	–	–	–
2012	0	–	–	–	–	–
2013	0	–	–	–	–	–
2014	0	–	–	–	–	–
2015	3	14	8	20	0	–

Table B-94. Monthly summary of TSS data at Perch Creek (AUID 07020010-524; 2006–2015)

Month	Sample count	Mean (mg/L)	Minimum (mg/L)	Maximum (mg/L)	Number of exceedances	Frequency of exceedances
January	0	–	–	–	n/a	–
February	0	–	–	–	n/a	–
March	0	–	–	–	n/a	–
April	0	–	–	–	–	–
May	0	–	–	–	–	–
June	2	17	13	20	0	0%
July	0	–	–	–	–	–
August	0	–	–	–	–	–
September	1	8	8	8	0	0%
October	0	–	–	–	n/a	–
November	0	–	–	–	n/a	–
December	0	–	–	–	n/a	–

Table B-95. Annual summary of transparency tube data at Perch Creek (AUID 07020010-524; April–September)

Year	Sample count	Mean (cm)	Minimum (cm)	Maximum (cm)
1996	0	–	–	–
1997	0	–	–	–
1998	0	–	–	–
1999	0	–	–	–
2000	26	22	6	50
2001	81	27	4	60
2002	82	24	5	60
2003	60	33	11	60
2004	112	30	0	60
2005	0	–	–	–

In previous assessment cycles, a transparency tube measurement of less than 20 cm indicated a violation of the 25 NTU turbidity standard.

Table B-96. Monthly summary of transparency tube data at Perch Creek (AUID 07020010-524; 1996–2005)

Month	Sample count	Mean (cm)	Minimum (cm)	Maximum (cm)
January	0	–	–	–
February	0	–	–	–
March	0	–	–	–
April	60	40	15	60
May	77	29	0	60
June	68	20	0	60
July	53	27	0	60
August	52	25	8	53
September	51	28	0	60
October	16	38	23	51
November	6	49	36	60
December	0	–	–	–

In previous assessment cycles, a transparency tube measurement of less than 20 cm indicated a violation of the 25 NTU turbidity standard.

Table B-97. Annual summary of TSS data at St. James Creek (AUID 07020010-528; April–September)

Year	Sample count	Mean (mg/L)	Minimum (mg/L)	Maximum (mg/L)	Number of exceedances	Frequency of exceedances
1992	6	229	33	746	4	67%

Values in red indicate years in which the TSS standard of 65 mg/L was exceeded in greater than 10 percent of the samples collected in April through September.

Table B-98. Monthly summary of TSS data at St. James Creek (AUID 07020010-528; 1992)

Month	Sample count	Mean (mg/L)	Minimum (mg/L)	Maximum (mg/L)	Number of exceedances	Frequency of exceedances
January	0	–	–	–	n/a	–
February	0	–	–	–	n/a	–
March	0	–	–	–	n/a	–
April	0	–	–	–	–	–
May	0	–	–	–	–	–
June	2	403	61	746	1	50%
July	0	–	–	–	–	–
August	2	124	33	216	1	50%
September	2	160	66	254	2	100%
October	0	–	–	–	n/a	–
November	2	47	21	74	n/a	–
December	0	–	–	–	n/a	–

Table B-99. Annual summary of transparency tube data at Watonwan River, South Fork (AUID 07020010-547; April–September)

Year	Sample count	Mean (cm)	Minimum (cm)	Maximum (cm)
2006	26	26	7	60
2007	18	23	11	60
2008	17	21	9	60
2009	15	25	8	53
2010	13	24	11	44
2011	9	21	9	38
2012	0	–	–	–
2013	0	–	–	–
2014	0	–	–	–
2015	5	24	12	30

In previous assessment cycles, a transparency tube measurement of less than 20 cm indicated a violation of the 25 NTU turbidity standard.

Table B-100. Monthly summary of transparency tube data at Watonwan River, South Fork (AUID 07020010-547; 2006–2015)

Month	Sample count	Mean (cm)	Minimum (cm)	Maximum (cm)
January	0	–	–	–
February	0	–	–	–
March	0	–	–	–
April	15	16	7	28
May	21	22	9	53
June	22	16	8	28
July	18	24	9	45

Month	Sample count	Mean (cm)	Minimum (cm)	Maximum (cm)
August	13	34	18	60
September	14	38	12	60
October	9	43	11	60
November	0	–	–	–
December	0	–	–	–

In previous assessment cycles, a transparency tube measurement of less than 20 cm indicated a violation of the 25 NTU turbidity standard.

Table B-101. Summary of TSS data at Watonwan River (AUID 07020010-562; April–September)

There are no TSS, turbidity, or transparency tube data available on this reach. This reach is a split from the parent AUID 07020010-512, and the impairment listing carried over to the splits (AUIDs 07020010-562 and 563). The data used to list the parent reach is located on AUID 07020010-563 (Table B-102 through Table B-105).

Table B-102. Annual summary of TSS data at Watonwan River (AUID 07020010-563; April–September)

Year	Sample count	Mean (mg/L)	Minimum (mg/L)	Maximum (mg/L)	Number of exceedances	Frequency of exceedances
2006	0	–	–	–	–	–
2007	0	–	–	–	–	–
2008	0	–	–	–	–	–
2009	0	–	–	–	–	–
2010	0	–	–	–	–	–
2011	0	–	–	–	–	–
2012	0	–	–	–	–	–
2013	10	37	7	85	3	30%
2014	0	–	–	–	–	–
2015	0	–	–	–	–	–

Values in red indicate years in which the TSS standard of 65 mg/L was exceeded in greater than 10 percent of the samples collected in April through September.

Table B-103. Monthly summary of TSS data at Watonwan River (AUID 07020010-563; 2006–2015)

Month	Sample count	Mean (mg/L)	Minimum (mg/L)	Maximum (mg/L)	Number of exceedances	Frequency of exceedances
January	0	–	–	–	n/a	–
February	0	–	–	–	n/a	–
March	0	–	–	–	n/a	–
April	0	–	–	–	–	–
May	2	41	23	58	0	0%
June	2	73	68	78	2	100%
July	2	48	11	85	1	50%
August	2	9	7	11	0	0%
September	2	13	7	18	0	0%
October	0	–	–	–	n/a	–
November	0	–	–	–	n/a	–
December	0	–	–	–	n/a	–

Values in red indicate years in which the TSS standard of 65 mg/L was exceeded in greater than 10 percent of the samples collected in April through September.

Table B-104. Annual summary of TSS data at Watonwan River (AUID 07020010-563; April–September, 1996–2005)

Year	Sample count	Mean (mg/L)	Minimum (mg/L)	Maximum (mg/L)	Number of exceedances	Frequency of exceedances
1996	0	–	–	–	–	–
1997	0	–	–	–	–	–
1998	0	–	–	–	–	–
1999	0	–	–	–	–	–
2000	19	148	11	510	13	68%
2001	20	66	16	196	8	40%
2002	21	95	23	248	9	43%
2003	0	–	–	–	–	–
2004	0	–	–	–	–	–
2005	0	–	–	–	–	–

Values in red indicate years in which the TSS standard of 65 mg/L was exceeded in greater than 10 percent of the samples collected in April through September.

Table B-105. Monthly summary of TSS data at Watonwan River (AUID 07020010-563; 1996–2005)

Month	Sample count	Mean (mg/L)	Minimum (mg/L)	Maximum (mg/L)	Number of exceedances	Frequency of exceedances
January	0	–	–	–	n/a	–
February	0	–	–	–	n/a	–
March	0	–	–	–	n/a	–
April	7	74	36	160	3	43%
May	14	119	24	510	5	36%
June	16	130	44	248	12	75%
July	12	102	20	254	7	58%
August	7	80	16	170	3	43%
September	4	23	11	35	0	0%
October	0	–	–	–	n/a	–
November	0	–	–	–	n/a	–
December	0	–	–	–	n/a	–

Values in red indicate years in which the TSS standard of 65 mg/L was exceeded in greater than 10 percent of the samples collected in April through September.

Table B-106. Annual summary of TSS data at Watonwan River, North Fork (AUID 07020010-564; April–September)

Year	Sample count	Mean (mg/L)	Minimum (mg/L)	Maximum (mg/L)	Number of exceedances	Frequency of exceedances
2006	0	–	–	–	–	–
2007	0	–	–	–	–	–
2008	0	–	–	–	–	–
2009	0	–	–	–	–	–
2010	0	–	–	–	–	–
2011	0	–	–	–	–	–
2012	0	–	–	–	–	–
2013	10	24	7	74	1	10%
2014	0	–	–	–	–	–
2015	5	10	3	33	0	0%

Table B-107. Monthly summary of TSS data at Watonwan River, North Fork (AUID 07020010-564; 2006–2015)

Month	Sample count	Mean (mg/L)	Minimum (mg/L)	Maximum (mg/L)	Number of exceedances	Frequency of exceedances
January	0	–	–	–	n/a	–
February	0	–	–	–	n/a	–
March	0	–	–	–	n/a	–
April	0	–	–	–	–	–
May	2	19	8	30	0	0%
June	4	42	4	74	1	25%
July	2	18	8	28	0	0%
August	5	7	3	10	0	0%
September	2	8	7	9	0	0%
October	0	–	–	–	n/a	–
November	0	–	–	–	n/a	–
December	0	–	–	–	n/a	–

Values in red indicate years in which the TSS standard of 65 mg/L was exceeded in greater than 10 percent of the samples collected in April through September.

Table B-108. Annual summary of transparency tube data at Watonwan River, North Fork (AUID 07020010-564; April–September)

Year	Sample count	Mean (cm)	Minimum (cm)	Maximum (cm)
2006	34	43	4	60
2007	31	44	7	60
2008	0	–	–	–
2009	0	–	–	–
2010	28	46	1	60
2011	0	–	–	–
2012	0	–	–	–
2013	13	55	17	100
2014	6	26	7	43
2015	12	63	22	100

In previous assessment cycles, a transparency tube measurement of less than 20 cm indicated a violation of the 25 NTU turbidity standard.

Table B-109. Monthly summary of transparency tube data at Watonwan River, North Fork (AUID 07020010-564; 2006–2015)

Month	Sample count	Mean (cm)	Minimum (cm)	Maximum (cm)
January	0	–	–	–
February	0	–	–	–
March	7	19	4	60
April	16	40	4	60
May	17	51	10	76
June	27	31	1	100
July	19	49	23	60
August	25	54	13	100
September	20	56	1	96
October	15	40	10	60
November	8	58	45	60
December	0	–	–	–

In previous assessment cycles, a transparency tube measurement of less than 20 cm indicated a violation of the 25 NTU turbidity standard.

Table B-110. Annual summary of transparency tube data at Watonwan River (AUID 07020010-566; April–September)

Year	Sample count	Mean (cm)	Minimum (cm)	Maximum (cm)
2006	75	37	6	60
2007	39	40	10	60
2008	32	41	6	60
2009	15	52	16	60
2010	10	37	18	60
2011	10	31	13	46
2012	3	9	8	10
2013	3	17	8	22
2014	0	–	–	–
2015	0	–	–	–

In previous assessment cycles, a transparency tube measurement of less than 20 cm indicated a violation of the 25 NTU turbidity standard.

Table B-111. Monthly summary of transparency tube data at Watonwan River (AUID 07020010-566; 2006–2015)

Month	Sample count	Mean (cm)	Minimum (cm)	Maximum (cm)
January	0	–	–	–
February	0	–	–	–
March	0	–	–	–
April	36	28	6	60
May	41	34	8	60
June	32	28	6	60
July	24	54	18	60
August	31	47	12	60
September	23	52	20	60
October	17	40	12	60
November	0	–	–	–
December	0	–	–	–

In previous assessment cycles, a transparency tube measurement of less than 20 cm indicated a violation of the 25 NTU turbidity standard.

Table B-112. Annual summary of TSS data at Watonwan River (AUID 07020010-567; April–September)

Year	Sample count	Mean (mg/L)	Minimum (mg/L)	Maximum (mg/L)	Number of exceedances	Frequency of exceedances
2006	0	–	–	–	–	–
2007	0	–	–	–	–	–
2008	0	–	–	–	–	–
2009	0	–	–	–	–	–
2010	0	–	–	–	–	–
2011	0	–	–	–	–	–
2012	0	–	–	–	–	–
2013	10	47	3	158	2	20%
2014	0	–	–	–	–	–
2015	2	7	4	10	0	0%

Values in red indicate years in which the TSS standard of 65 mg/L was exceeded in greater than 10 percent of the samples collected in April through September.

Table B-113. Monthly summary of TSS data at Watonwan River (AUID 07020010-567; 2006–2015)

Month	Sample count	Mean (mg/L)	Minimum (mg/L)	Maximum (mg/L)	Number of exceedances	Frequency of exceedances
January	0	–	–	–	n/a	–
February	0	–	–	–	n/a	–
March	0	–	–	–	n/a	–
April	0	–	–	–	–	–
May	2	53	46	59	0	0%
June	2	111	64	158	1	50%
July	3	30	4	83	1	33%
August	3	8	3	12	0	0%
September	2	19	13	25	0	0%
October	0	–	–	–	n/a	–
November	0	–	–	–	n/a	–
December	0	–	–	–	n/a	–

Values in red indicate years in which the TSS standard of 65 mg/L was exceeded in greater than 10 percent of the samples collected in April through September.

Table B-114. Annual summary of TSS data at Watonwan River (AUID 07020010-567; April–September)

Year	Sample count	Mean (mg/L)	Minimum (mg/L)	Maximum (mg/L)	Number of exceedances	Frequency of exceedances
1996	0	–	–	–	–	–
1997	0	–	–	–	–	–
1998	0	–	–	–	–	–
1999	0	–	–	–	–	–
2000	19	120	2	460	12	63%
2001	20	93	4	564	9	45%
2002	22	86	11	234	11	50%
2003	0	–	–	–	–	–
2004	0	–	–	–	–	–
2005	0	–	–	–	–	–

Values in red indicate years in which the TSS standard of 65 mg/L was exceeded in greater than 10 percent of the samples collected in April through September.

Table B-115. Monthly summary of TSS data at Watonwan River (AUID 07020010-567; 1996–2005)

Month	Sample count	Mean (mg/L)	Minimum (mg/L)	Maximum (mg/L)	Number of exceedances	Frequency of exceedances
January	0	–	–	–	n/a	–
February	0	–	–	–	n/a	–
March	0	–	–	–	n/a	–
April	7	104	21	204	4	57%
May	14	100	26	460	6	43%
June	17	119	20	564	11	65%
July	12	88	11	285	6	50%
August	7	112	4	234	5	71%
September	4	12	2	27	0	0%
October	0	–	–	–	n/a	–
November	0	–	–	–	n/a	–
December	0	–	–	–	n/a	–

Values in red indicate years in which the TSS standard of 65 mg/L was exceeded in greater than 10 percent of the samples collected in April through September.

B8. Le Sueur (HUC 07020011)

Table B-116. Annual summary of TSS data at Le Sueur River (AUID 07020011-501; April–September)

Year	Sample count	Mean (mg/L)	Minimum (mg/L)	Maximum (mg/L)	Number of exceedances	Frequency of exceedances
2006	19	222	12	792	14	74%
2007	22	184	13	840	13	59%
2008	33	127	6	439	19	58%
2009	23	88	9	307	9	39%
2010	31	298	17	1,940	23	74%
2011	20	126	12	854	9	45%
2012	36	208	4	983	24	67%
2013	35	240	17	1,280	29	83%
2014	28	482	9	2,000	24	86%
2015	37	385	13	2,280	29	78%

Values in red indicate years in which the TSS standard of 65 mg/L was exceeded in greater than 10 percent of the samples collected in April through September.

Table B-117. Monthly summary of TSS data at Le Sueur River (AUID 07020011-501; 2006–2015)

Month	Sample count	Mean (mg/L)	Minimum (mg/L)	Maximum (mg/L)	Number of exceedances	Frequency of exceedances
January	7	36	1	220	n/a	–
February	9	75	1	576	n/a	–
March	53	322	4	1,490	n/a	–
April	57	204	13	1,550	38	67%
May	69	245	17	1,080	50	72%
June	72	342	13	2,000	66	92%
July	33	177	10	800	21	64%
August	28	164	6	1,970	9	32%
September	25	250	4	2,280	9	36%
October	22	103	3	658	n/a	–
November	9	72	2	336	n/a	–
December	10	73	2	446	n/a	–

Values in red indicate years in which the TSS standard of 65 mg/L was exceeded in greater than 10 percent of the samples collected in April through September.

Table B-118. Annual summary of TSS data at Unnamed Creek (AUID 07020011-503; April–September)

Year	Sample count	Mean (mg/L)	Minimum (mg/L)	Maximum (mg/L)	Number of exceedances	Frequency of exceedances
2006	11	43	3	271	2	18%
2007	20	43	1	468	3	15%
2008	19	41	3	318	3	16%
2009	19	24	2	63	0	0%
2010	29	44	0	314	6	21%
2011	18	18	6	62	0	0%
2012	15	35	3	142	2	13%
2013	19	18	2	64	0	0%
2014	22	105	6	936	5	23%
2015	15	66	2	504	3	20%

Values in red indicate years in which the TSS standard of 65 mg/L was exceeded in greater than 10 percent of the samples collected in April through September.

Table B-119. Monthly summary of TSS data at Unnamed Creek (AUID 07020011-503; 2006–2015)

Month	Sample count	Mean (mg/L)	Minimum (mg/L)	Maximum (mg/L)	Number of exceedances	Frequency of exceedances
January	2	24	4	44	n/a	–
February	4	9	1	14	n/a	–
March	33	75	4	524	n/a	–
April	36	49	0	380	7	19%
May	47	39	2	936	3	6%
June	50	44	2	504	5	10%
July	22	31	4	112	2	9%
August	19	63	5	468	3	16%
September	13	53	5	160	4	31%
October	15	63	3	648	n/a	–
November	2	6	4	7	n/a	–
December	0	–	–	–	n/a	–

Values in red indicate years in which the TSS standard of 65 mg/L was exceeded in greater than 10 percent of the samples collected in April through September.

Table B-120. Annual summary of TSS data at Little Cobb River (AUID 07020011-504; April–September)

Year	Sample count	Mean (mg/L)	Minimum (mg/L)	Maximum (mg/L)	Number of exceedances	Frequency of exceedances
2006	15	65	22	169	6	40%
2007	25	92	20	273	15	60%
2008	39	61	5	281	13	33%
2009	28	65	2	507	7	25%
2010	36	76	7	551	9	25%
2011	24	44	18	170	4	17%
2012	18	72	9	182	9	50%
2013	0	–	–	–	–	–
2014	0	–	–	–	–	–
2015	0	–	–	–	–	–

Values in red indicate years in which the TSS standard of 65 mg/L was exceeded in greater than 10 percent of the samples collected in April through September.

Table B-121. Monthly summary of TSS data at Little Cobb River (AUID 07020011-504; 2006–2015)

Month	Sample count	Mean (mg/L)	Minimum (mg/L)	Maximum (mg/L)	Number of exceedances	Frequency of exceedances
January	2	34	3	65	n/a	–
February	3	18	2	48	n/a	–
March	28	65	8	267	n/a	–
April	30	42	8	281	4	13%
May	42	83	20	507	17	40%
June	44	82	13	551	22	50%
July	22	57	2	180	8	36%
August	23	64	11	273	8	35%
September	24	60	10	445	4	17%
October	11	28	3	61	n/a	–
November	1	14	14	14	n/a	–
December	1	7	7	7	n/a	–

Values in red indicate years in which the TSS standard of 65 mg/L was exceeded in greater than 10 percent of the samples collected in April through September.

Table B-122. Monthly summary of TSS data at Le Sueur River (AUID 07020011-506; 2006–2015)

Month	Sample count	Mean (mg/L)	Minimum (mg/L)	Maximum (mg/L)	Number of exceedances	Frequency of exceedances
January	0	–	–	–	n/a	–
February	0	–	–	–	n/a	–
March	2	384	18	750	n/a	–
April	0	–	–	–	–	–
May	0	–	–	–	–	–
June	0	–	–	–	–	–
July	0	–	–	–	–	–
August	0	–	–	–	–	–
September	0	–	–	–	–	–
October	0	–	–	–	n/a	–
November	0	–	–	–	n/a	–
December	0	–	–	–	n/a	–

Table B-123. Annual summary of transparency tube data at Le Sueur River (AUID 07020011-506; April–September)

Year	Sample count	Mean (cm)	Minimum (cm)	Maximum (cm)
1996	0	–	–	–
1997	0	–	–	–
1998	0	–	–	–
1999	0	–	–	–
2000	0	–	–	–
2001	0	–	–	–
2002	0	–	–	–
2003	0	–	–	–
2004	0	–	–	–
2005	15	14	3	26

In previous assessment cycles, a transparency tube measurement of less than 20 cm indicated a violation of the 25 NTU turbidity standard.

Table B-124. Monthly summary of transparency tube data at Le Sueur River (AUID 07020011-506; 1996–2005)

Month	Sample count	Mean (cm)	Minimum (cm)	Maximum (cm)
January	0	–	–	–
February	0	–	–	–
March	0	–	–	–
April	2	15	11	19
May	3	22	19	26
June	4	11	7	13
July	2	20	15	24
August	2	11	6	16
September	2	8	3	12
October	1	13	13	13
November	0	–	–	–
December	0	–	–	–

In previous assessment cycles, a transparency tube measurement of less than 20 cm indicated a violation of the 25 NTU turbidity standard.

Table B-125. Annual summary of TSS data at Le Sueur River (AUID 07020011-507; April–September)

Year	Sample count	Mean (mg/L)	Minimum (mg/L)	Maximum (mg/L)	Number of exceedances	Frequency of exceedances
2006	37	307	8	3,130	25	68%
2007	49	212	20	2,070	32	65%
2008	53	187	8	1,730	31	58%
2009	52	75	9	366	20	38%
2010	62	159	12	814	37	60%
2011	40	83	14	329	17	43%
2012	46	126	6	573	24	52%
2013	26	170	25	656	21	81%
2014	25	497	12	2,200	21	84%
2015	32	410	26	1,510	29	91%

Values in red indicate years in which the TSS standard of 65 mg/L was exceeded in greater than 10 percent of the samples collected in April through September.

Table B-126. Monthly summary of TSS data at Le Sueur River (AUID 07020011-507; 2006–2015)

Month	Sample count	Mean (mg/L)	Minimum (mg/L)	Maximum (mg/L)	Number of exceedances	Frequency of exceedances
January	0	–	–	–	n/a	–
February	1	5	5	5	n/a	–
March	60	381	9	2,720	n/a	–
April	82	242	11	3,130	50	61%
May	95	164	14	1,340	55	58%
June	106	235	22	1,830	88	83%
July	48	184	9	856	32	67%
August	48	187	7	2,070	16	33%
September	43	145	6	1,510	16	37%
October	36	150	2	1,120	n/a	–
November	2	16	13	18	n/a	–
December	0	–	–	–	n/a	–

Values in red indicate years in which the TSS standard of 65 mg/L was exceeded in greater than 10 percent of the samples collected in April through September.

Table B-127. Annual summary of TSS data at Rice Creek (AUID 07020011-531; April–September)

Year	Sample count	Mean (mg/L)	Minimum (mg/L)	Maximum (mg/L)	Number of exceedances	Frequency of exceedances
2006	0	–	–	–	–	–
2007	0	–	–	–	–	–
2008	14	40	10	110	2	14%
2009	0	–	–	–	–	–
2010	0	–	–	–	–	–
2011	0	–	–	–	–	–
2012	0	–	–	–	–	–
2013	0	–	–	–	–	–
2014	0	–	–	–	–	–
2015	0	–	–	–	–	–

Table B-128. Monthly summary of TSS data at Rice Creek (AUID 07020011-531; 2006–2015)

Month	Sample count	Mean (mg/L)	Minimum (mg/L)	Maximum (mg/L)	Number of exceedances	Frequency of exceedances
January	0	–	–	–	n/a	–
February	0	–	–	–	n/a	–
March	0	–	–	–	n/a	–
April	0	–	–	–	–	–
May	2	37	26	47	0	0%
June	3	42	18	56	0	0%
July	4	51	15	88	1	25%
August	3	45	10	110	1	33%
September	2	10	10	11	0	0%
October	0	–	–	–	n/a	–
November	0	–	–	–	n/a	–
December	0	–	–	–	n/a	–

Table B-129. Annual summary of transparency tube data at Rice Creek (AUID 07020011-531; April–September)

Year	Sample count	Mean (cm)	Minimum (cm)	Maximum (cm)
2006	0	–	–	–
2007	0	–	–	–
2008	50	19	4	64
2009	32	15	6	34
2010	46	25	8	60
2011	22	15	8	30
2012	16	8	7	10
2013	22	16	6	24
2014	17	14	4	20
2015	22	14	6	26

In previous assessment cycles, a transparency tube measurement of less than 20 cm indicated a violation of the 25 NTU turbidity standard.

Table B-130. Monthly summary of transparency tube data at Rice Creek (AUID 07020011-531; 2006–2015)

Month	Sample count	Mean (cm)	Minimum (cm)	Maximum (cm)
January	0	–	–	–
February	0	–	–	–
March	2	15	8	21
April	35	16	4	31
May	41	17	4	33
June	45	14	4	59
July	59	20	8	60
August	34	18	7	46
September	13	16	8	64
October	0	–	–	–
November	0	–	–	–
December	0	–	–	–

In previous assessment cycles, a transparency tube measurement of less than 20 cm indicated a violation of the 25 NTU turbidity standard.

Table B-131. Annual summary of TSS data at Maple River (AUID 07020011-534; April–September)

Year	Sample count	Mean (mg/L)	Minimum (mg/L)	Maximum (mg/L)	Number of exceedances	Frequency of exceedances
2006	83	82	10	488	35	42%
2007	83	113	2	1,200	36	43%
2008	88	81	2	1,500	25	28%
2009	65	170	8	647	37	57%
2010	48	146	12	1,210	23	48%
2011	34	68	15	234	12	35%
2012	25	98	23	628	13	52%
2013	55	127	8	1,440	17	31%
2014	50	244	5	2,040	27	54%
2015	46	131	2	760	24	52%

Values in red indicate years in which the TSS standard of 65 mg/L was exceeded in greater than 10 percent of the samples collected in April through September.

Table B-132. Monthly summary of TSS data at Maple River (AUID 07020011-534; 2006–2015)

Month	Sample count	Mean (mg/L)	Minimum (mg/L)	Maximum (mg/L)	Number of exceedances	Frequency of exceedances
January	0	–	–	–	n/a	–
February	0	–	–	–	n/a	–
March	57	155	4	1,020	n/a	–
April	114	104	2	1,500	44	39%
May	135	99	2	706	47	35%
June	160	198	8	2,040	114	71%
July	68	65	2	306	23	34%
August	57	91	2	1,200	14	25%
September	43	108	2	1,210	7	16%
October	30	50	3	216	n/a	–
November	0	–	–	–	n/a	–
December	0	–	–	–	n/a	–

Values in red indicate years in which the TSS standard of 65 mg/L was exceeded in greater than 10 percent of the samples collected in April through September.

Table B-133. Annual summary of TSS data at Maple River (AUID 07020011-535; April–September)

Year	Sample count	Mean (mg/L)	Minimum (mg/L)	Maximum (mg/L)	Number of exceedances	Frequency of exceedances
2006	0	–	–	–	–	–
2007	0	–	–	–	–	–
2008	0	–	–	–	–	–
2009	4	86	83	95	4	100%
2010	0	–	–	–	–	–
2011	0	–	–	–	–	–
2012	0	–	–	–	–	–
2013	0	–	–	–	–	–
2014	0	–	–	–	–	–
2015	0	–	–	–	–	–

Values in red indicate years in which the TSS standard of 65 mg/L was exceeded in greater than 10 percent of the samples collected in April through September.

Table B-134. Monthly summary of TSS data at Maple River (AUID 07020011-535; 2006–2015)

Month	Sample count	Mean (mg/L)	Minimum (mg/L)	Maximum (mg/L)	Number of exceedances	Frequency of exceedances
January	0	–	–	–	n/a	–
February	0	–	–	–	n/a	–
March	0	–	–	–	n/a	–
April	4	86	83	95	4	100%
May	0	–	–	–	–	–
June	0	–	–	–	–	–
July	0	–	–	–	–	–
August	0	–	–	–	–	–
September	0	–	–	–	–	–
October	0	–	–	–	n/a	–
November	0	–	–	–	n/a	–
December	0	–	–	–	n/a	–

Values in red indicate years in which the TSS standard of 65 mg/L was exceeded in greater than 10 percent of the samples collected in April through September.

Table B-135. Annual summary of turbidity data at Maple River (AUID 07020011-535; April–September)

Year	Sample count	Mean (NTU)	Minimum (NTU)	Maximum (NTU)
2006	0	–	–	–
2007	0	–	–	–
2008	7	45	15	75
2009	18	25	1	74
2010	0	–	–	–
2011	0	–	–	–
2012	0	–	–	–
2013	0	–	–	–
2014	0	–	–	–
2015	0	–	–	–

The former turbidity standard was 25 NTU.

Table B-136. Monthly summary of turbidity data at Maple River (AUID 07020011-535; 2006–2015)

Month	Sample count	Mean (NTU)	Minimum (NTU)	Maximum (NTU)
January	0	–	–	–
February	0	–	–	–
March	0	–	–	–
April	3	16	15	18
May	4	22	1	38
June	8	33	2	74
July	7	45	15	75
August	3	14	8	22
September	0	–	–	–
October	0	–	–	–
November	0	–	–	–
December	0	–	–	–

The former turbidity standard was 25 NTU.

Table B-137. Annual summary of TSS data at County Ditch 3 (AUID 07020011-552; April–September)

Year	Sample count	Mean (mg/L)	Minimum (mg/L)	Maximum (mg/L)	Number of exceedances	Frequency of exceedances
2006	0	–	–	–	–	–
2007	0	–	–	–	–	–
2008	10	28	4	73	1	10%
2009	1	18	18	18	0	0%
2010	0	–	–	–	–	–
2011	0	–	–	–	–	–
2012	0	–	–	–	–	–
2013	0	–	–	–	–	–
2014	0	–	–	–	–	–
2015	0	–	–	–	–	–

Values in red indicate years in which the TSS standard of 65 mg/L was exceeded in greater than 10 percent of the samples collected in April through September.

Table B-138. Monthly summary of TSS data at County Ditch 3 (AUID 07020011-552; 2006–2015)

Month	Sample count	Mean (mg/L)	Minimum (mg/L)	Maximum (mg/L)	Number of exceedances	Frequency of exceedances
January	0	–	–	–	n/a	–
February	0	–	–	–	n/a	–
March	0	–	–	–	n/a	–
April	1	18	18	18	0	0%
May	2	31	13	49	0	0%
June	2	27	17	36	0	0%
July	2	42	11	73	1	50%
August	2	8	4	12	0	0%
September	2	30	22	38	0	0%
October	0	–	–	–	n/a	–
November	0	–	–	–	n/a	–
December	0	–	–	–	n/a	–

Values in red indicate years in which the TSS standard of 65 mg/L was exceeded in greater than 10 percent of the samples collected in April through September.

Table B-139. Annual summary of TSS data at Cobb River (AUID 07020011-556; April–September)

Year	Sample count	Mean (mg/L)	Minimum (mg/L)	Maximum (mg/L)	Number of exceedances	Frequency of exceedances
2006	32	184	13	1,230	23	72%
2007	23	123	8	612	13	57%
2008	36	95	8	676	20	56%
2009	25	65	7	249	9	36%
2010	31	118	23	600	19	61%
2011	20	52	13	138	5	25%
2012	20	89	5	377	10	50%
2013	23	71	11	148	10	43%
2014	24	214	5	824	20	83%
2015	20	138	15	472	14	70%

Values in red indicate years in which the TSS standard of 65 mg/L was exceeded in greater than 10 percent of the samples collected in April through September.

Table B-140. Monthly summary of TSS data at Cobb River (AUID 07020011-556; 2006–2015)

Month	Sample count	Mean (mg/L)	Minimum (mg/L)	Maximum (mg/L)	Number of exceedances	Frequency of exceedances
January	0	–	–	–	n/a	–
February	1	12	12	12	n/a	–
March	37	199	5	1,150	n/a	–
April	47	149	9	1,230	22	47%
May	58	106	5	532	34	59%
June	64	149	16	824	53	83%
July	31	80	7	236	19	61%
August	29	83	5	612	8	28%
September	25	85	7	518	7	28%
October	17	53	6	196	n/a	–
November	1	20	20	20	n/a	–
December	0	–	–	–	n/a	–

Values in red indicate years in which the TSS standard of 65 mg/L was exceeded in greater than 10 percent of the samples collected in April through September.

Table B-141. Annual summary of transparency tube data at Cobb River (AUID 07020011-568; April–September)

Year	Sample count	Mean (cm)	Minimum (cm)	Maximum (cm)
2006	11	30	5	53
2007	0	–	–	–
2008	6	10	2	19
2009	3	34	6	54
2010	0	–	–	–
2011	0	–	–	–
2012	0	–	–	–
2013	0	–	–	–
2014	0	–	–	–
2015	0	–	–	–

In previous assessment cycles, a transparency tube measurement of less than 20 cm indicated a violation of the 25 NTU turbidity standard.

Table B-142. Monthly summary of transparency tube data at Cobb River (AUID 07020011-568; 2006–2015)

Month	Sample count	Mean (cm)	Minimum (cm)	Maximum (cm)
January	0	–	–	–
February	0	–	–	–
March	0	–	–	–
April	0	–	–	–
May	5	24	2	54
June	7	10	4	17
July	6	39	19	53
August	2	34	25	42
September	0	–	–	–
October	0	–	–	–
November	0	–	–	–
December	0	–	–	–

In previous assessment cycles, a transparency tube measurement of less than 20 cm indicated a violation of the 25 NTU turbidity standard.

Table B-143. Annual summary of transparency tube data at Le Sueur River (AUID 07020011-619; April–September)

Year	Sample count	Mean (cm)	Minimum (cm)	Maximum (cm)
2006	0	–	–	–
2007	0	–	–	–
2008	0	–	–	–
2009	0	–	–	–
2010	14	18	11	34
2011	0	–	–	–
2012	0	–	–	–
2013	0	–	–	–
2014	0	–	–	–
2015	0	–	–	–

In previous assessment cycles, a transparency tube measurement of less than 20 cm indicated a violation of the 25 NTU turbidity standard.

Table B-144. Monthly summary of transparency tube data at Le Sueur River (AUID 07020011-619; 2006–2015)

Month	Sample count	Mean (cm)	Minimum (cm)	Maximum (cm)
January	0	–	–	–
February	0	–	–	–
March	0	–	–	–
April	0	–	–	–
May	0	–	–	–
June	2	19	14	24
July	12	18	11	34
August	0	–	–	–
September	0	–	–	–
October	0	–	–	–
November	0	–	–	–
December	0	–	–	–

In previous assessment cycles, a transparency tube measurement of less than 20 cm indicated a violation of the 25 NTU turbidity standard.

Table B-145. Annual summary of TSS data at Le Sueur River (AUID 07020011-620; April–September)

Year	Sample count	Mean (mg/L)	Minimum (mg/L)	Maximum (mg/L)	Number of exceedances	Frequency of exceedances
2006	0	–	–	–	–	–
2007	0	–	–	–	–	–
2008	0	–	–	–	–	–
2009	3	63	50	72	2	67%
2010	0	–	–	–	–	–
2011	0	–	–	–	–	–
2012	0	–	–	–	–	–
2013	0	–	–	–	–	–
2014	0	–	–	–	–	–
2015	0	–	–	–	–	–

Values in red indicate years in which the TSS standard of 65 mg/L was exceeded in greater than 10 percent of the samples collected in April through September.

Table B-146. Monthly summary of TSS data at Le Sueur River (AUID 07020011-620; 2006–2015)

Month	Sample count	Mean (mg/L)	Minimum (mg/L)	Maximum (mg/L)	Number of exceedances	Frequency of exceedances
January	0	–	–	–	n/a	–
February	0	–	–	–	n/a	–
March	0	–	–	–	n/a	–
April	3	63	50	72	2	67%
May	0	–	–	–	–	–
June	0	–	–	–	–	–
July	0	–	–	–	–	–
August	0	–	–	–	–	–
September	0	–	–	–	–	–
October	0	–	–	–	n/a	–
November	0	–	–	–	n/a	–
December	0	–	–	–	n/a	–

Values in red indicate years in which the TSS standard of 65 mg/L was exceeded in greater than 10 percent of the samples collected in April through September.

Table B-147. Annual summary of turbidity data at Le Sueur River (AUID 07020011-620; April–September)

Year	Sample count	Mean (NTU)	Minimum (NTU)	Maximum (NTU)
2006	0	–	–	–
2007	0	–	–	–
2008	10	111	6	316
2009	18	24	3	121
2010	0	–	–	–
2011	0	–	–	–
2012	0	–	–	–
2013	0	–	–	–
2014	0	–	–	–
2015	0	–	–	–

The former turbidity standard was 25 NTU.

Table B-148. Monthly summary of turbidity data at Le Sueur River (AUID 07020011-620; 2006–2015)

Month	Sample count	Mean (NTU)	Minimum (NTU)	Maximum (NTU)
January	0	–	–	–
February	0	–	–	–
March	0	–	–	–
April	3	10	8	11
May	4	11	6	13
June	8	41	24	121
July	10	111	6	316
August	3	10	3	22
September	0	–	–	–
October	0	–	–	–
November	0	–	–	–
December	0	–	–	–

The former turbidity standard was 25 NTU.

Table B-149. Annual summary of transparency tube data at Le Sueur River (AUID 07020011-620; April–September)

Year	Sample count	Mean (cm)	Minimum (cm)	Maximum (cm)
2006	2	34	25	43
2007	27	22	5	60
2008	17	27	7	43
2009	13	31	19	60
2010	28	22	4	60
2011	11	31	7	60
2012	5	7	2	21
2013	9	9	2	17
2014	0	–	–	–
2015	0	–	–	–

In previous assessment cycles, a transparency tube measurement of less than 20 cm indicated a violation of the 25 NTU turbidity standard.

Table B-150. Monthly summary of transparency tube data at Le Sueur River (AUID 07020011-620; 2006–2015)

Month	Sample count	Mean (cm)	Minimum (cm)	Maximum (cm)
January	0	–	–	–
February	0	–	–	–
March	0	–	–	–
April	3	42	31	60
May	28	27	2	60
June	29	18	2	47
July	24	18	5	43
August	17	28	7	60
September	11	26	6	60
October	2	35	10	60
November	0	–	–	–
December	0	–	–	–

In previous assessment cycles, a transparency tube measurement of less than 20 cm indicated a violation of the 25 NTU turbidity standard.

B9. Lower Minnesota (HUC 07020012)

Table B-151. Annual summary of TSS data at Minnesota River (AUID 07020012-505; April–September)

Year	Sample count	Mean (mg/L)	Minimum (mg/L)	Maximum (mg/L)	Number of exceedances	Frequency of exceedances
2006	67	101	24	614	34	51%
2007	39	94	31	365	23	59%
2008	37	81	24	182	21	57%
2009	37	69	21	239	9	24%
2010	38	84	24	352	23	61%
2011	41	50	20	120	9	22%
2012	38	64	28	332	10	26%
2013	39	102	26	212	25	64%
2014	35	139	34	410	20	57%
2015	39	96	32	532	12	31%

Values in red indicate years in which the TSS standard of 65 mg/L was exceeded in greater than 10 percent of the samples collected in April through September.

Table B-152. Monthly summary of TSS data at Minnesota River (AUID 07020012-505; 2006–2015)

Month	Sample count	Mean (mg/L)	Minimum (mg/L)	Maximum (mg/L)	Number of exceedances	Frequency of exceedances
January	42	8	2	17	n/a	–
February	42	19	2	168	n/a	–
March	62	54	3	362	n/a	–
April	66	90	20	332	34	52%
May	66	102	34	422	45	68%
June	71	154	22	614	60	85%
July	66	81	22	203	31	47%
August	73	55	24	365	11	15%
September	68	48	21	352	5	7%
October	60	50	15	248	n/a	–
November	43	50	13	310	n/a	–
December	40	29	5	328	n/a	–

Values in red indicate years in which the TSS standard of 65 mg/L was exceeded in greater than 10 percent of the samples collected in April through September.

Table B-153. Annual summary of TSS data at Minnesota River (AUID 07020012-506; April–September)

Year	Sample count	Mean (mg/L)	Minimum (mg/L)	Maximum (mg/L)	Number of exceedances	Frequency of exceedances
2006	23	86	40	300	12	52%
2007	0	–	–	–	–	–
2008	0	–	–	–	–	–
2009	0	–	–	–	–	–
2010	0	–	–	–	–	–
2011	0	–	–	–	–	–
2012	0	–	–	–	–	–
2013	0	–	–	–	–	–
2014	37	180	33	714	35	95%
2015	4	119	52	180	2	50%

Values in red indicate years in which the TSS standard of 65 mg/L was exceeded in greater than 10 percent of the samples collected in April through September.

Table B-154. Monthly summary of TSS data at Minnesota River (AUID 07020012-506; 2006–2015)

Month	Sample count	Mean (mg/L)	Minimum (mg/L)	Maximum (mg/L)	Number of exceedances	Frequency of exceedances
January	2	13	5	21	n/a	–
February	2	74	15	133	n/a	–
March	4	155	21	372	n/a	–
April	5	130	40	336	4	80%
May	11	181	46	438	10	91%
June	11	281	124	714	11	100%
July	13	112	33	164	10	77%
August	14	85	40	142	9	64%
September	10	73	49	120	5	50%
October	0	–	–	–	n/a	–
November	0	–	–	–	n/a	–
December	0	–	–	–	n/a	–

Values in red indicate years in which the TSS standard of 65 mg/L was exceeded in greater than 10 percent of the samples collected in April through September.

Table B-155. Annual summary of TSS data at Minnesota River (AUID 07020012-799; April–September)

Year	Sample count	Mean (mg/L)	Minimum (mg/L)	Maximum (mg/L)	Number of exceedances	Frequency of exceedances
2006	6	114	53	230	3	50%
2007	0	–	–	–	–	–
2008	0	–	–	–	–	–
2009	6	68	14	94	4	67%
2010	0	–	–	–	–	–
2011	0	–	–	–	–	–
2012	0	–	–	–	–	–
2013	0	–	–	–	–	–
2014	22	145	67	480	22	100%
2015	6	120	51	200	3	50%

Values in red indicate years in which the TSS standard of 65 mg/L was exceeded in greater than 10 percent of the samples collected in April through September.

Table B-156. Monthly summary of TSS data at Minnesota River (AUID 07020012-799; 2006–2015)

Month	Sample count	Mean (mg/L)	Minimum (mg/L)	Maximum (mg/L)	Number of exceedances	Frequency of exceedances
January	0	–	–	–	n/a	–
February	1	40	40	40	n/a	–
March	2	62	30	94	n/a	–
April	2	155	79	230	2	100%
May	8	159	94	200	8	100%
June	8	194	94	480	8	100%
July	6	104	56	140	5	83%
August	8	69	14	98	6	75%
September	8	85	47	150	3	38%
October	1	23	23	23	n/a	–
November	1	50	50	50	n/a	–
December	0	–	–	–	n/a	–

Values in red indicate years in which the TSS standard of 65 mg/L was exceeded in greater than 10 percent of the samples collected in April through September.

Table B-157. Annual summary of TSS data at Minnesota River (AUID 07020012-800; April–September)

Year	Sample count	Mean (mg/L)	Minimum (mg/L)	Maximum (mg/L)	Number of exceedances	Frequency of exceedances
2006	43	127	35	535	22	51%
2007	27	126	58	320	24	89%
2008	24	107	37	211	17	71%
2009	24	90	43	250	13	54%
2010	25	124	30	808	20	80%
2011	27	63	20	136	11	41%
2012	33	162	22	882	23	70%
2013	28	131	22	260	22	79%
2014	35	205	43	1,100	34	97%
2015	30	166	35	487	21	70%

Values in red indicate years in which the TSS standard of 65 mg/L was exceeded in greater than 10 percent of the samples collected in April through September.

Table B-158. Monthly summary of TSS data at Minnesota River (AUID 07020012-800; 2006–2015)

Month	Sample count	Mean (mg/L)	Minimum (mg/L)	Maximum (mg/L)	Number of exceedances	Frequency of exceedances
January	19	10	1	70	n/a	–
February	19	17	1	198	n/a	–
March	39	75	2	429	n/a	–
April	54	113	20	570	33	61%
May	56	167	35	882	42	75%
June	47	215	38	1,100	45	96%
July	46	118	23	440	38	83%
August	49	90	43	320	31	63%
September	44	95	36	808	18	41%
October	39	70	5	403	n/a	–
November	21	47	9	251	n/a	–
December	20	29	4	327	n/a	–

Values in red indicate years in which the TSS standard of 65 mg/L was exceeded in greater than 10 percent of the samples collected in April through September.

Appendix C. Flow Data Sources

Table C-1. Flow Data Sources

AUID	Flow Data Source [a]	Extended/Area-Weighted	Period of Record
07020004-502	USGS 05313500	Area-Weighted	01/01/1986-10/15/2015
07020004-747	USGS 05311000	Area-Weighted	01/01/1986-12/31/2015
07020004-748	USGS 05311000	Area-Weighted	01/01/1986-12/31/2015
07020004-749	USGS 05311000	Area-Weighted	01/01/1986-12/31/2015
07020004-750	USGS 05316580	Area-Weighted	10/01/2000-11/27/2015
07020005-501	HSPF 101		01/01/1995-12/31/2012
07020006-501	USGS 05316500	Area-Weighted	01/01/1986-11/26/2015
07020007-720	USGS 05316580	Area-Weighted	10/01/2000-11/27/2015
07020007-721	USGS 05316580	Area-Weighted	10/01/2000-11/27/2015
07020007-722	USGS 05325000	Area-Weighted	01/01/1986-12/31/2015
07020007-723	USGS 05325000	Area-Weighted	01/01/1986-12/31/2015
07020008-501	USGS 05317000	Area-Weighted	01/01/1986-12/28/2015
07020009-501	USGS 05320500	Area-Weighted	01/01/1986-12/31/2015
07020009-502	HSPF 317		01/01/1995-12/31/2012
07020009-503	HSPF 245		01/01/1995-12/31/2012
07020009-504	HSPF 50		01/01/1995-12/31/2012
07020009-507	USGS 05320000	Area-Weighted	01/01/1986-12/31/2015
07020009-508	HSPF 190		01/01/1995-12/31/2012
07020009-509	USGS 05320000	Area-Weighted	01/01/1986-12/31/2015
07020009-514	HSPF 250		01/01/1995-12/31/2012
07020009-515	USGS 05320000	Area-Weighted	01/01/1986-12/31/2015
07020009-518	USGS 05320000	Area-Weighted	01/01/1986-12/31/2015
07020009-521	HSPF 301		01/01/1995-12/31/2012
07020009-522	HSPF 285		01/01/1995-12/31/2012
07020009-523	HSPF 263		01/01/1995-12/31/2012
07020009-524	HSPF 271		01/01/1995-12/31/2012
07020009-525	HSPF 217		01/01/1995-12/31/2012
07020009-527	HSPF 225		01/01/1995-12/31/2012
07020009-553	HSPF 133		01/01/1995-12/31/2012
07020009-554	HSPF 109		01/01/1995-12/31/2012
07020009-565	HSPF 90		01/01/1995-12/31/2012
07020010-501	USGS 05319500	Area-Weighted	01/01/1986-12/31/2015
07020010-510	USGS 05319500	Area-Weighted	01/01/1986-12/31/2015
07020010-511	HSPF 170		01/01/1995-12/31/2012
07020010-516	HSPF 123		01/01/1995-12/31/2012
07020010-517	HSPF 205		01/01/1995-12/31/2012
07020010-524	HSPF 249		01/01/1995-12/31/2012
07020010-528	HSPF 125		01/01/1995-12/31/2012
07020010-547	HSPF 185		01/01/1995-12/31/2012
07020010-562	HSPF 110	Area-Weighted	01/01/1995-12/31/2012

AUID	Flow Data Source [a]	Extended/Area-Weighted	Period of Record
07020010-563	HSPF 110		01/01/1995-12/31/2012
07020010-564	HSPF 99	Area-Weighted	01/01/1995-12/31/2012
07020010-566	HSPF 70		01/01/1995-12/31/2012
07020010-567	HSPF 90		01/01/1995-12/31/2012
07020011-501	USGS 05320500		01/01/1986-12/31/2015
07020011-503	HSPF 747		01/01/1995-12/31/2012
07020011-504	HSPF 743		01/01/1995-12/31/2012
07020011-506	USGS 05320500	Area-Weighted	01/01/1986-12/31/2015
07020011-507	HSPF 730		01/01/1995-12/31/2012
07020011-531	HSPF 809		01/01/1995-12/31/2012
07020011-534	HSPF 819		01/01/1995-12/31/2012
07020011-535	HSPF 799		01/01/1995-12/31/2012
07020011-552	HSPF 789		01/01/1995-12/31/2012
07020011-556	HSPF 751		01/01/1995-12/31/2012
07020011-568	HSPF 729		01/01/1995-12/31/2012
07020011-619	HSPF 490		01/01/1995-12/31/2012
07020011-620	HSPF 610		01/01/1995-12/31/2012
07020012-505	USGS 05330920	Area-Weighted	01/21/2004-12/31/2015
07020012-506	USGS 05330000	Area-Weighted	01/01/1986-12/31/2015
07020012-799	USGS 05330000	Area-Weighted	01/01/1986-12/31/2015
07020012-800	USGS 05330000	Area-Weighted	01/01/1986-12/31/2015

a. Flow data sources are USGS continuous recording gages or HSPF model segments.

Appendix D. Load Duration Curves and TMDLs

Contents

Tables

Figures

D1. Hawk-Yellow Medicine (HUC 07020004)

Yellow Medicine River (07020004-502)

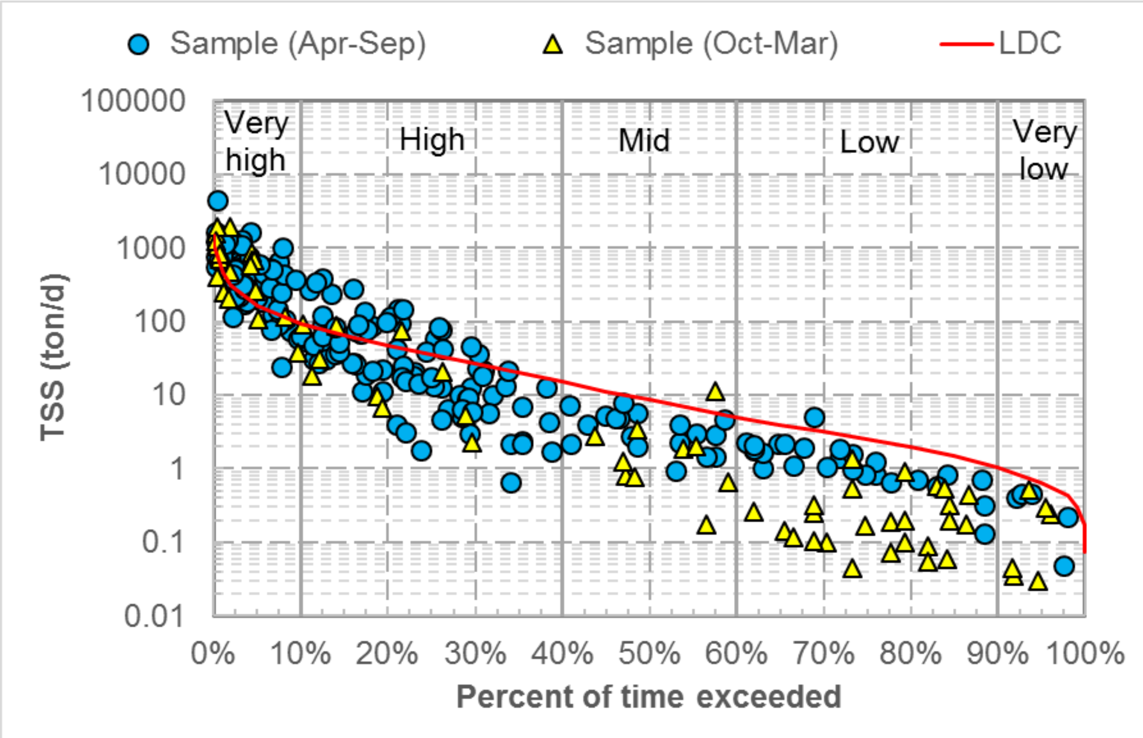


Figure D-1. TSS load duration curve, Yellow Medicine River (07020004-502).

Table D-1. TSS TMDL summary, Yellow Medicine River (07020004-502)

TMDL Parameter	Flow Regimes				
	Very High	High	Mid	Low	Very Low
	TSS Load (ton/d)				
WLA: Industrial/Construction Stormwater	0.29	0.062	0.013	0.0024	– [b]
WLA: Wastewater	1.0	1.0	1.0	1.0	– [a]
Load Allocation	146	31	6.7	1.2	– [b]
Margin of Safety	16	3.6	0.86	0.25	0.064
Loading Capacity	163	36	8.6	2.5	0.64
Existing Concentration (mg/L)	211				
Percent Reduction to Achieve Concentration Standard	69%				

[a] Permitted wastewater design flows exceed stream flow in the indicated flow zone(s). The allocations are expressed as an equation rather than an absolute number: allocation = flow contribution from a given source x 65 mg/L (or NPDES permit concentration). See *Municipal and Industrial Wastewater* (Section 5.4.1) for more detail.

[b] Unable to calculate allocations because the wastewater WLA exceeds the loading capacity. The allocations are expressed as an equation rather than an absolute number: allocation = flow contribution from a given source x 65 mg/L. See Sections 5.4.2 and 5.6 for more detail.

Minnesota River (07020004-747)

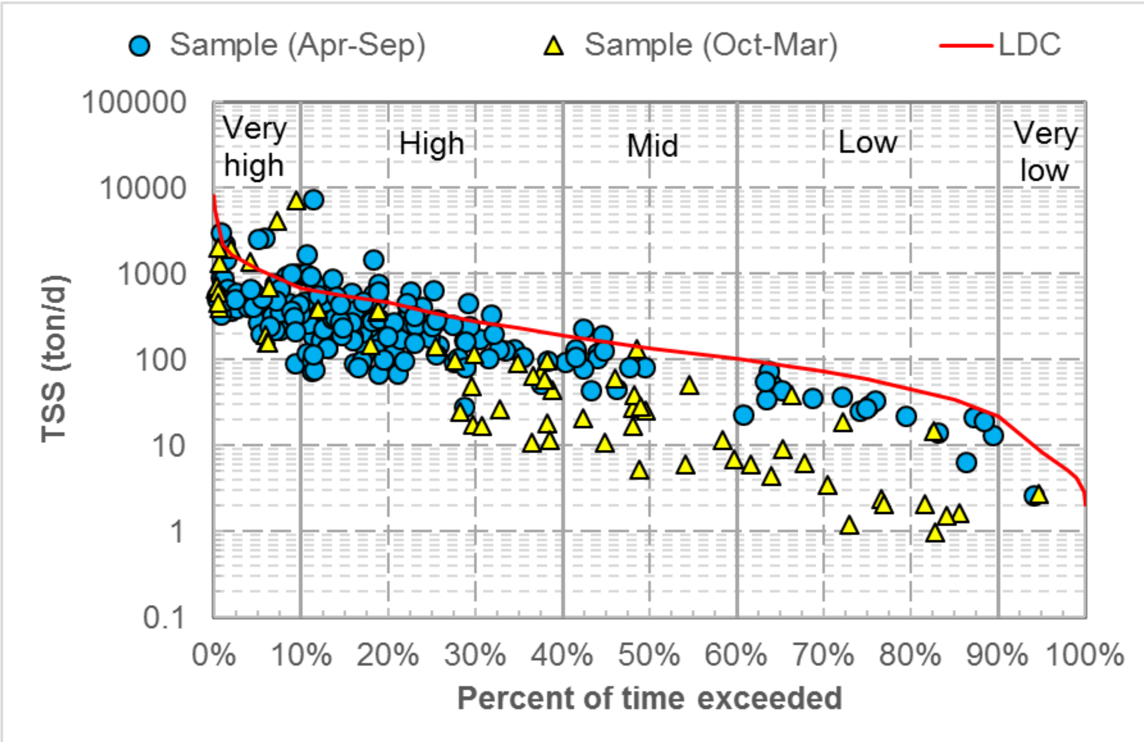


Figure D-2. TSS load duration curve, Minnesota River (07020004-747).

Table D-2. TSS TMDL summary, Minnesota River (07020004-747)

TMDL Parameter	**Flow Regimes**				
	Very High	**High**	**Mid**	**Low**	**Very Low**
	TSS Load (ton/d)				
Upstream Boundary Condition	802	247	94	39	4.2
WLA: City, County, and/or Township MS4 [a]	1.29	0.48	0.19	0.088	0.042
WLA: Industrial/Construction Stormwater	0.59	0.18	0.069	0.029	– [c]
WLA: Wastewater	4.2	4.2	4.2	4.2	– [b]
Load Allocation	291	91	35	15	– [c]
Margin of Safety	33	11	4.3	2.1	0.43
Loading Capacity	1,132	354	138	60	8.5
Existing Concentration (mg/L)	78				
Percent Reduction to Achieve Concentration Standard	17%				

[a] To meet the WLAs for permitted MS4s, TSS loading does not need to be reduced but is not allowed to increase.

[b] Permitted wastewater design flows exceed stream flow in the indicated flow zone(s). The allocations are expressed as an equation rather than an absolute number: allocation = flow contribution from a given source x 65 mg/L (or NPDES permit concentration). See *Municipal and Industrial Wastewater* (Section 5.4.1) for more detail.

[c] Unable to calculate allocations because the sum of the wastewater WLA and boundary condition at Very Low flows exceeds the loading capacity. The allocations are expressed as an equation rather than an absolute number: allocation = flow contribution from a given source x 65 mg/L (or NPDES permit concentration). See Sections 5.4.2 and 5.6 for more detail.

Minnesota River (07020004-748)

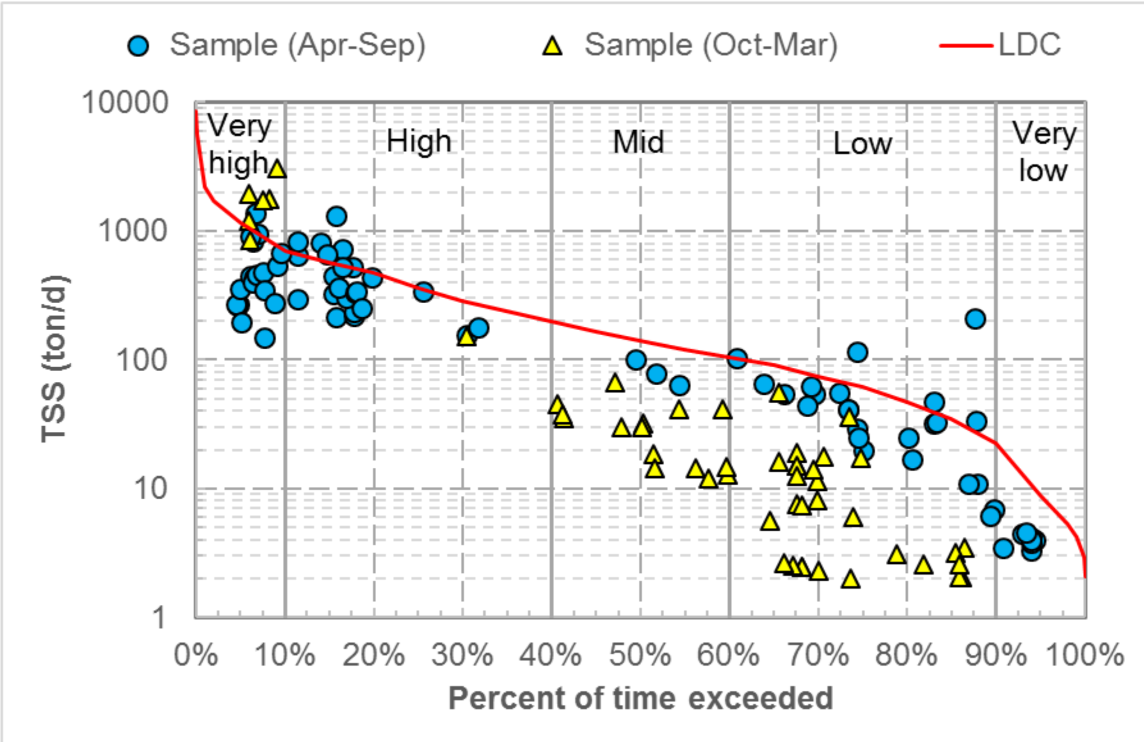


Figure D-3. TSS load duration curve, Minnesota River (07020004-748).

Table D-3. TSS TMDL summary, Minnesota River (07020004-748)*

TMDL Parameter	Flow Regimes				
	Very High	High	Mid	Low	Very Low
	TSS Load (ton/d)				
Upstream Boundary Condition	802	247	94	39	4.2
WLA: City, County, and/or Township MS4 [a]	1.29	0.48	0.19	0.088	0.042
WLA: Industrial/Construction Stormwater	0.63	0.20	0.073	0.030	– [c]
WLA: Wastewater	4.9	4.9	4.9	4.9	– [b]
Load Allocation	312	98	36	15	– [c]
Margin of Safety	35	11	4.6	2.2	0.45
Loading Capacity	1,156	362	140	61	8.7
Existing Concentration (mg/L)	76				
Percent Reduction to Achieve Concentration Standard	14%				

[a] To meet the WLAs for permitted MS4s, TSS loading does not need to be reduced but is not allowed to increase.

[b] Permitted wastewater design flows exceed stream flow in the indicated flow zone(s). The allocations are expressed as an equation rather than an absolute number: allocation = flow contribution from a given source x 65 mg/L (or NPDES permit concentration). See *Municipal and Industrial Wastewater* (Section 5.4.1) for more detail.

[c] Unable to calculate allocations because the sum of the wastewater WLA and boundary condition at Very Low flows exceeds the loading capacity. The allocations are expressed as an equation rather than an absolute number: allocation = flow contribution from a given source x 65 mg/L (or NPDES permit concentration). See Sections 5.4.2 and 5.6 for more detail.*TMDL allocations do not apply to adjacent tribal lands.

Minnesota River (07020004-749)

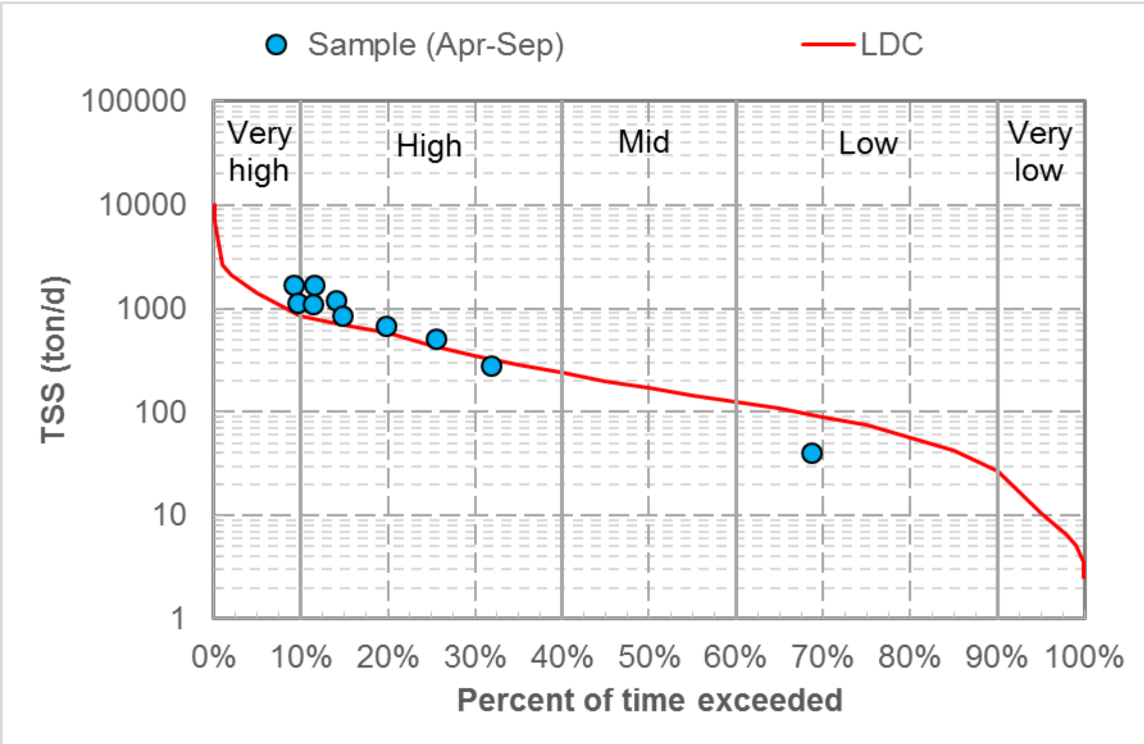


Figure D-4. TSS load duration curve, Minnesota River (07020004-749).

Table D-4. TSS TMDL summary, Minnesota River (07020004-749)

TMDL Parameter	Flow Regimes				
	Very High	High	Mid	Low	Very Low
	TSS Load (ton/d)				
Upstream Boundary Condition	802	247	94	39	4.2
WLA: City, County, and/or Township MS4 [a]	3.88	1.44	0.58	0.26	0.13
WLA: Industrial/Construction Stormwater	1.1	0.33	0.12	0.046	– [c]
WLA: Wastewater	8.7	8.7	8.7	8.7	– [b]
Load Allocation	524	162	59	22.5	– [c]
Margin of Safety	60	19	7.6	3.5	0.63
Loading Capacity	1,400	438	170	74	11
Existing Concentration (mg/L)	122				
Percent Reduction to Achieve Concentration Standard	47%				

[a] To meet the WLAs for permitted MS4s, TSS loading does not need to be reduced but is not allowed to increase.

[b] Permitted wastewater design flows exceed stream flow in the indicated flow zone(s). The allocations are expressed as an equation rather than an absolute number: allocation = flow contribution from a given source x 65 mg/L (or NPDES permit concentration). See *Municipal and Industrial Wastewater* (Section 5.4.1) for more detail.

[c] Unable to calculate allocations because the sum of the wastewater WLA and boundary condition at Very Low flows exceeds the loading capacity. The allocations are expressed as an equation rather than an absolute number: allocation = flow contribution from a given source x 65 mg/L (or NPDES permit concentration). See Sections 5.4.2 and 5.6 for more detail.

Minnesota River (07020004-750)

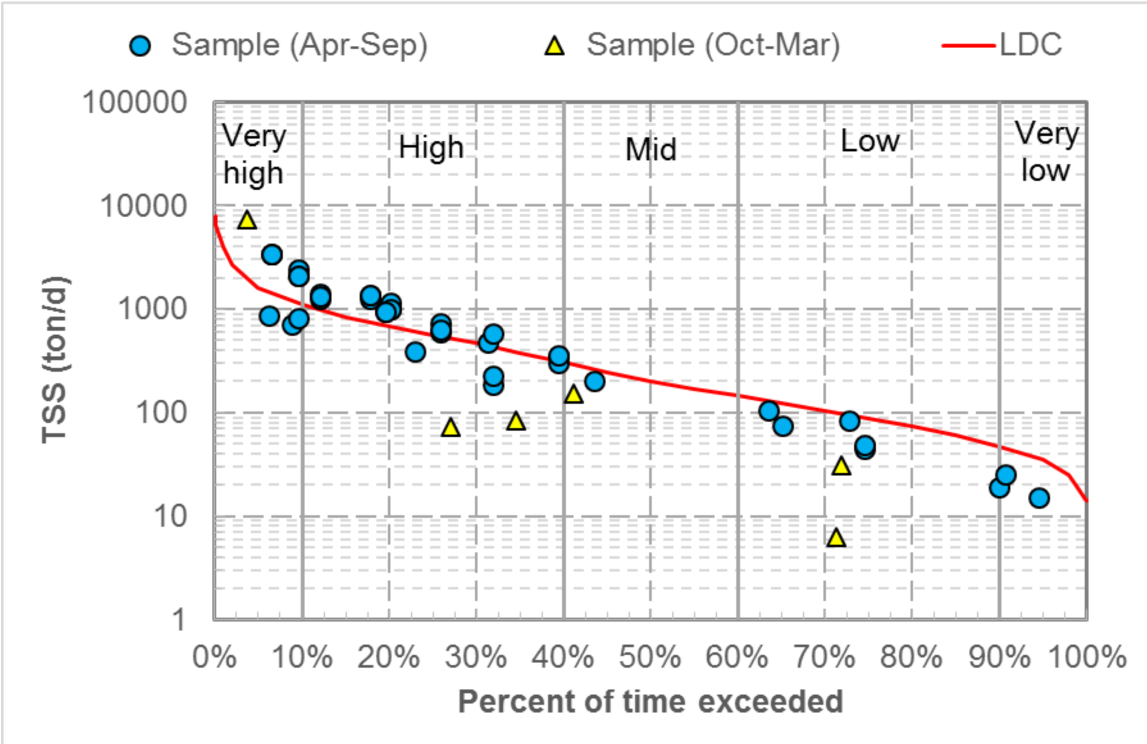


Figure D-5. TSS load duration curve, Minnesota River (07020004-750).

Table D-5. TSS TMDL summary, Minnesota River (07020004-750)

TMDL Parameter	Flow Regimes				
	Very High	High	Mid	Low	Very Low
	TSS Load (ton/d)				
Upstream Boundary Condition	802	247	94	39	4.2
WLA: City, County, and/or Township MS4 [a]	7.23	2.68	1.08	0.49	0.24
WLA: Industrial/Construction Stormwater	1.41	0.54	0.16	0.06	0.03
WLA: Wastewater	15.3	15.3	15.3	15.3	15.3
Load Allocation	695	265.5	78.5	26.3	12.1
Margin of Safety	80	31	11	4.8	3.1
Loading Capacity	1,601	562	200	86	35
Existing Concentration (mg/L)	120				
Percent Reduction to Achieve Concentration Standard	46%				

[a] To meet the WLAs for permitted MS4s, TSS loading does not need to be reduced but is not allowed to increase.

D2. Chippewa (HUC 07020005)

Chippewa River (07020005-501)

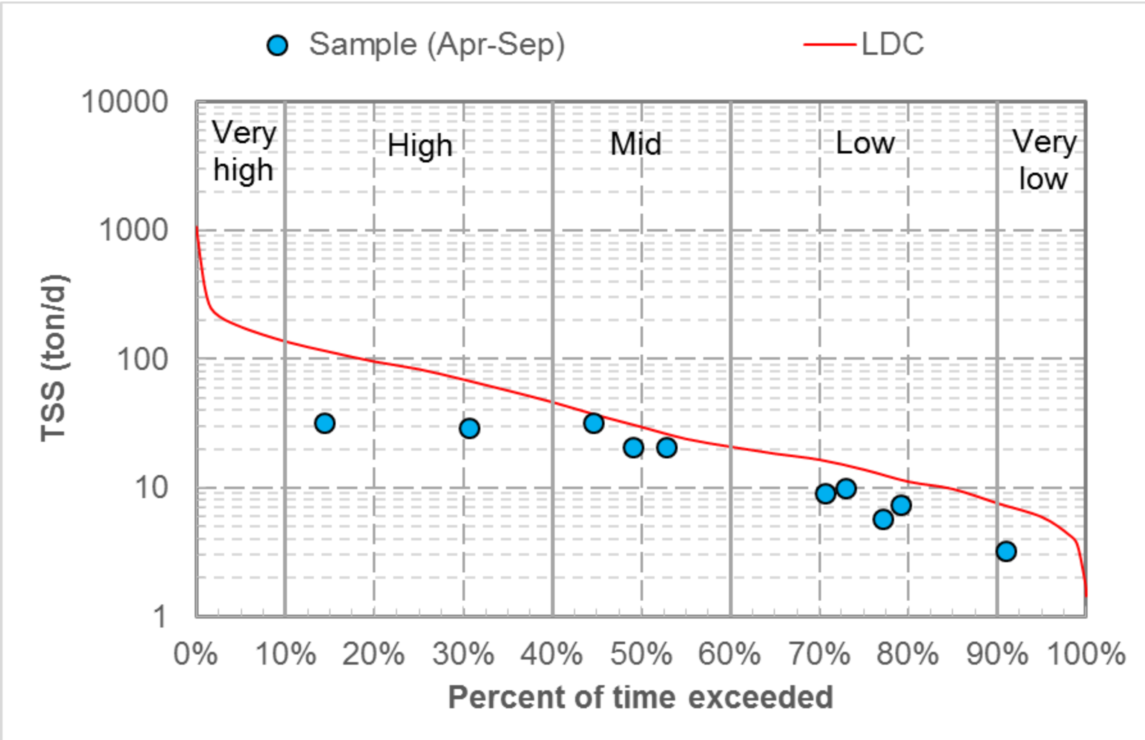


Figure D-6. TSS load duration curve, Chippewa River (07020005-501).

Table D-6. TSS TMDL summary, Chippewa River (07020005-501)

TMDL Parameter	Flow Regimes				
	Very High	High	Mid	Low	Very Low
	TSS Load (ton/d)				
WLA: City, County, and/or Township MS4 [a]	0.63	0.23	0.094	0.043	0.021
WLA: Industrial/Construction Stormwater	0.31	0.15	0.049	0.020	0.0058
WLA: Wastewater	2.4	2.4	2.4	2.4	2.4
Load Allocation	157	72	24.5	10	2.9
Margin of Safety	18	8.3	3.0	1.4	0.59
Loading Capacity	178	83	30	14	5.9
Existing Concentration (mg/L)	52				
Percent Reduction to Achieve Concentration Standard	– [b]				

[a] To meet the WLAs for permitted MS4s, TSS loading does not need to be reduced but is not allowed to increase.

[b] This impairment was originally listed in 2002 based on turbidity data; however, the TSS data presented in this report do not show impairment. Older (1989–1994) TSS data evaluated by MPCA for the impairment assessment include observations that exceed the current TSS standard. The MPCA will reevaluate the reach in the next impairment assessment for this watershed.

D3. Redwood (HUC 07020006)

Redwood River (07020006-501)

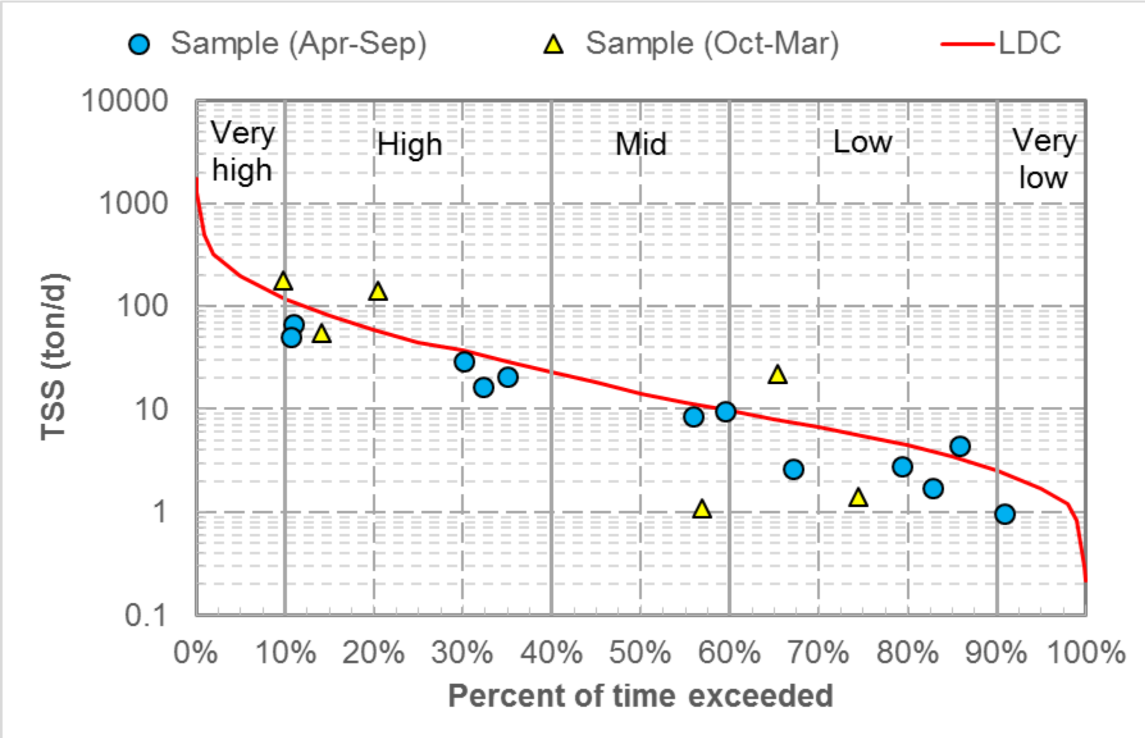


Figure D-7. TSS load duration curve, Redwood River (07020006-501).

Table D-7. TSS TMDL summary, Redwood River (07020006-501)

TMDL Parameter	Flow Regimes				
	Very High	High	Mid	Low	Very Low
	TSS Load (ton/d)				
WLA: City, County, and/or Township MS4 [a]	3.35	1.24	0.50	0.23	0.11
WLA: Industrial/Construction Stormwater	0.35	0.076	0.020	0.0049	– [c]
WLA: Wastewater	2.5	2.5	2.5	2.5	– [b]
Load Allocation	173	37	9.6	2.2	– [c]
Margin of Safety	20	4.5	1.4	0.55	0.17
Loading Capacity	199	45	14	5.5	1.7
Existing Concentration (mg/L)	61				
Percent Reduction to Achieve Concentration Standard	– [d]				

[a] To meet the WLAs for permitted MS4s, TSS loading does not need to be reduced but is not allowed to increase.

[b] Permitted wastewater design flows exceed stream flow in the indicated flow zone(s). The allocations are expressed as an equation rather than an absolute number: allocation = flow contribution from a given source x 65 mg/L (or NPDES permit concentration). See *Municipal and Industrial Wastewater* (Section 5.4.1) for more detail.

[c] Unable to calculate allocations because the wastewater WLA exceeds the loading capacity. The allocations are expressed as an equation rather than an absolute number: allocation = flow contribution from a given source x 65 mg/L. See Sections 5.4.2 and 5.6 for more detail.

[d] This impairment was originally listed in 2004 based on turbidity data; however, the TSS data presented in this report do not show impairment. The MPCA will reevaluate the reach in the next impairment assessment for this watershed.

D4. Minnesota River–Mankato (HUC 07020007)

Minnesota River (07020007-720)

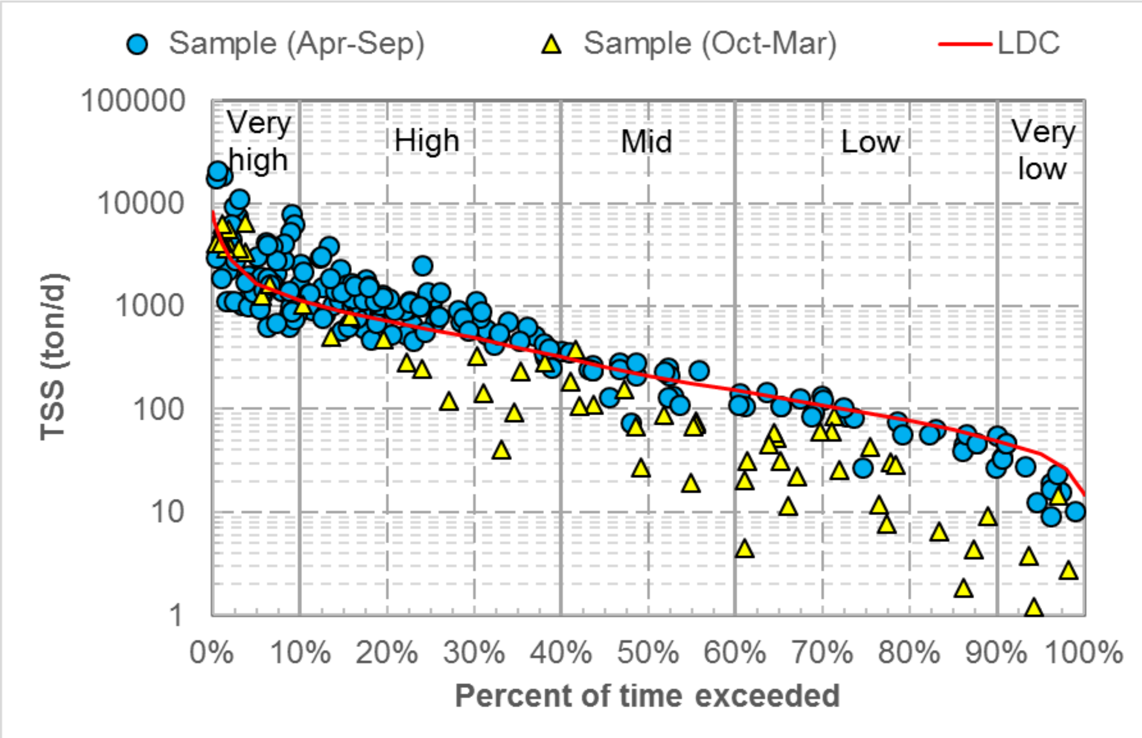


Figure D-8. TSS load duration curve, Minnesota River (07020007-720).

Table D-8. TSS TMDL summary, Minnesota River (07020007-720)*

TMDL Parameter	Flow Regimes				
	Very High	High	Mid	Low	Very Low
	TSS Load (ton/d)				
Upstream Boundary Condition	802	247	94	39	4.2
WLA: City, County, and/or Township MS4 [a]	7.92	2.94	1.18	0.54	0.26
WLA: Industrial/Construction Stormwater	1.54	0.58	0.17	0.06	0.02
WLA: Wastewater	17.5	17.5	17.5	17.5	17.5
Load Allocation	759	286	85	27.7	11.7
Margin of Safety	87	34	11	5.2	3.3
Loading Capacity	1,675	588	209	90	37
Existing Concentration (mg/L)	151				
Percent Reduction to Achieve Concentration Standard	57%				

[a] To meet the WLAs for permitted MS4s, TSS loading does not need to be reduced but is not allowed to increase.

*TMDL allocations do not apply to adjacent tribal lands.

Minnesota River (07020007-721)

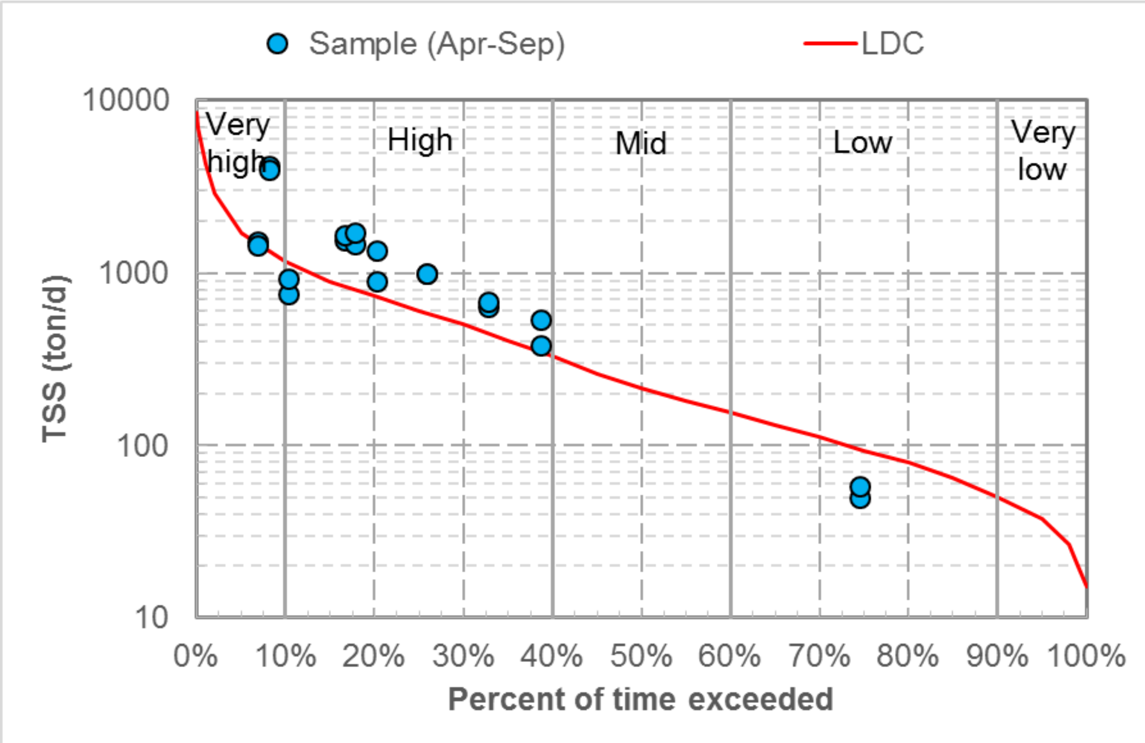


Figure D-9. TSS load duration curve, Minnesota River (07020007-721).

Table D-9. TSS TMDL summary, Minnesota River (07020007-721)

TMDL Parameter	Flow Regimes				
	Very High	High	Mid	Low	Very Low
	TSS Load (ton/d)				
Upstream Boundary Condition	802	247	94	39	4.2
WLA: City, County, and/or Township MS4 [a]	9.40	3.49	1.41	0.64	0.31
WLA: Industrial/Construction Stormwater	1.6	0.60	0.18	0.062	0.025
WLA: Wastewater	17.5	17.5	17.5	17.5	17.5
Load Allocation	794.5	297.4	88.9	30.4	12.6
Margin of Safety	91	36	12	5.4	3.4
Loading Capacity	1,716	602	214	93	38
Existing Concentration (mg/L)	145				
Percent Reduction to Achieve Concentration Standard	55%				

[a] To meet the WLAs for permitted MS4s, TSS loading does not need to be reduced but is not allowed to increase.

Minnesota River (07020007-722)

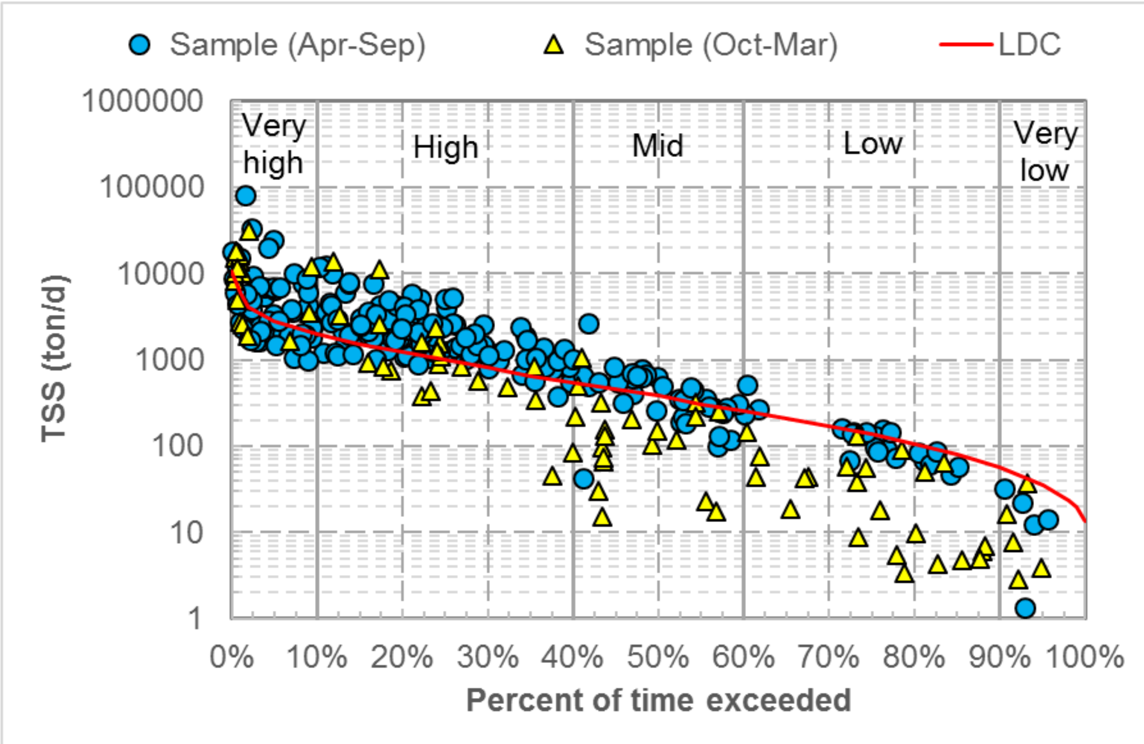


Figure D-10. TSS load duration curve, Minnesota River (07020007-722).

Table D-10. TSS TMDL summary, Minnesota River (07020007-722)

TMDL Parameter	**Flow Regimes**				
	Very High	**High**	**Mid**	**Low**	**Very Low**
	TSS Load (ton/d)				
Upstream Boundary Condition	802	247	94	39	4.2
WLA: MnDOT Outstate MS4 [a]	0.034	0.013	0.0053	0.0023	0.00075
WLA: City, County, and/or Township MS4 [a]	11.52	4.27	1.72	0.78	0.38
WLA: Industrial/Construction Stormwater	3.6	1.3	0.47	0.13	0.010
WLA: Wastewater	23	23	23	23	23
Load Allocation	1798	655.5	234	64.3	5.2
Margin of Safety	204	76	29	9.8	3.2
Loading Capacity	2,842	1,007	382	137	36
Existing Concentration (mg/L)	219				
Percent Reduction to Achieve Concentration Standard	70%				

[a] To meet the WLAs for permitted MS4s, TSS loading does not need to be reduced but is not allowed to increase.

Minnesota River (07020007-723)

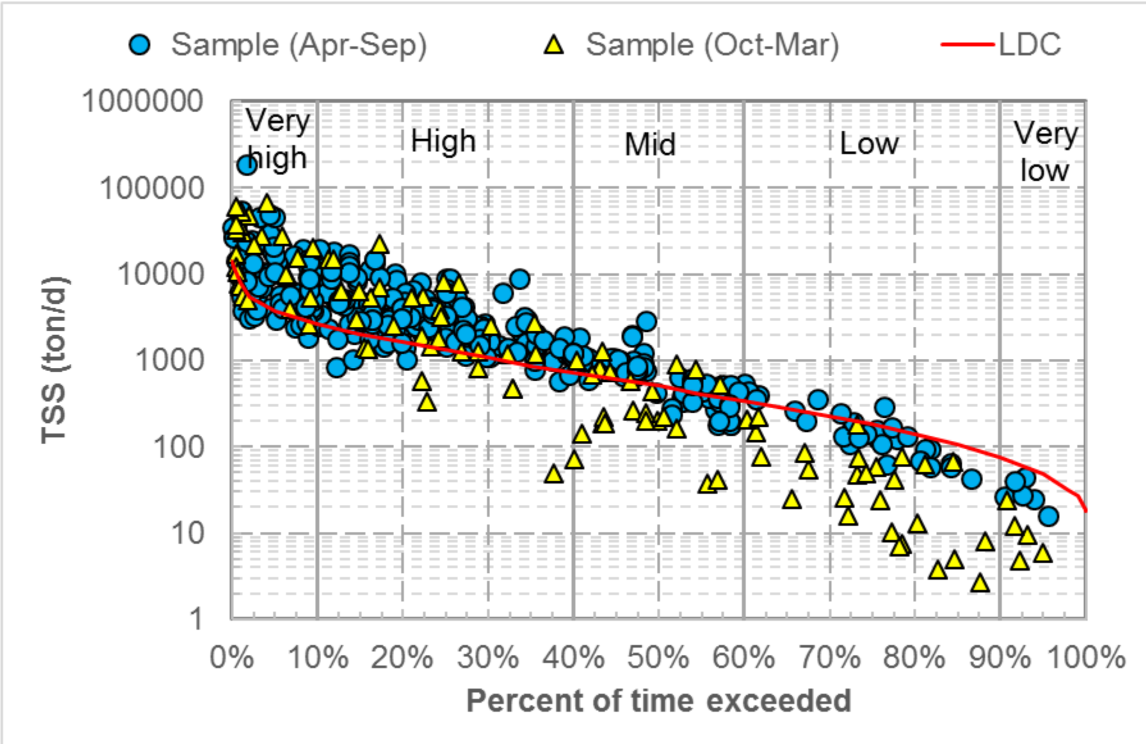


Figure D-11. TSS load duration curve, Minnesota River (07020007-723).

Table D-11. TSS TMDL summary, Minnesota River (07020007-723)

TMDL Parameter	Flow Regimes				
	Very High	High	Mid	Low	Very Low
	TSS Load (ton/d)				
Upstream Boundary Condition	802	247	94	39	4.2
WLA: MnDOT Outstate MS4 [a]	0.45	0.17	0.07	0.03	0.01
WLA: City, County, and/or Township MS4 [a]	25.54	9.47	3.82	1.74	0.84
WLA: Industrial/Construction Stormwater	5.27	1.87	0.65	0.16	– [c]
WLA: Wastewater	45.88	45.88	45.88	45.88	– [b]
Load Allocation	2607.96	927.56	323.66	81.16	– [c]
Margin of Safety	298	109	41	14	4.3
Loading Capacity	3,785	1,341	509	182	48
Existing Concentration (mg/L)	301				
Percent Reduction to Achieve Concentration Standard	78%				

[a] To meet the WLAs for permitted MS4s, TSS loading does not need to be reduced but is not allowed to increase.

[b] Permitted wastewater design flows exceed stream flow in the indicated flow zone(s). The allocations are expressed as an equation rather than an absolute number: allocation = flow contribution from a given source x 65 mg/L (or NPDES permit concentration). See *Municipal and Industrial Wastewater* (Section 5.4.1) for more detail.

[c] Unable to calculate allocations because the wastewater WLA exceeds the loading capacity. The allocations are expressed as an equation rather than an absolute number: allocation = flow contribution from a given source x 65 mg/L. See Sections 5.4.2 and 5.6 for more detail.

D5. Cottonwood (HUC 07020008)

Cottonwood River (07020008-501)

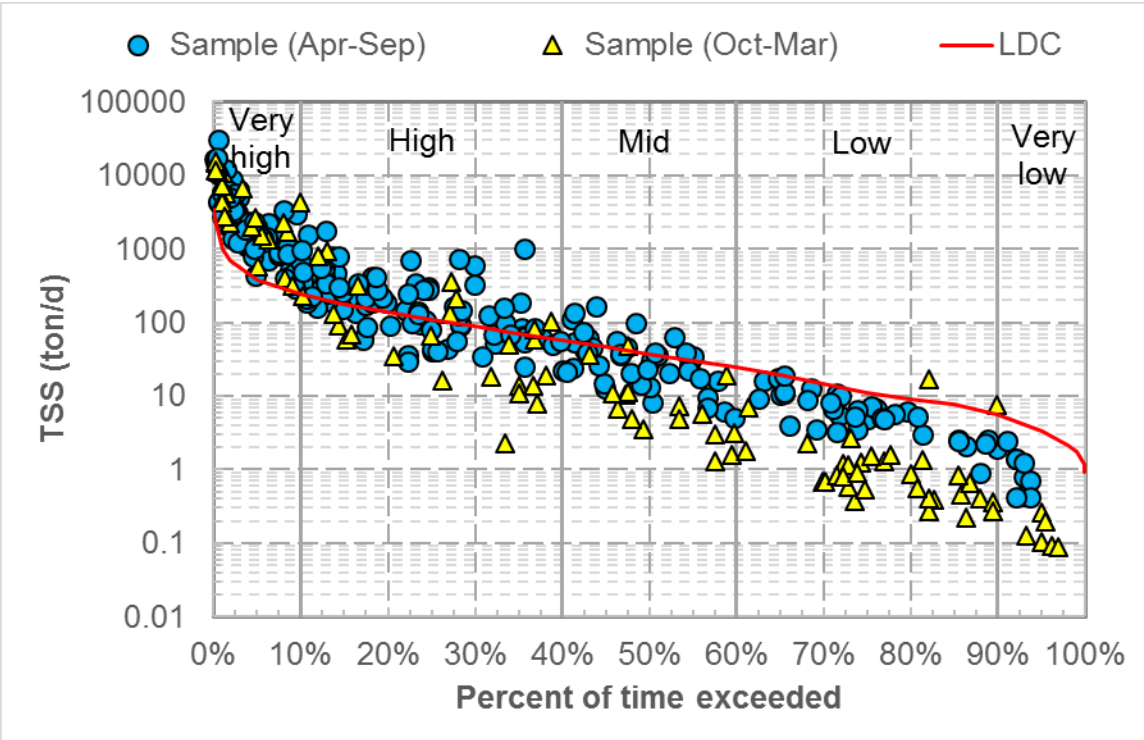


Figure D-12. TSS load duration curve, Cottonwood River (07020008-501).

Table D-12. TSS TMDL summary, Cottonwood River (07020008-501)

TMDL Parameter	Flow Regimes				
	Very High	High	Mid	Low	Very Low
	TSS Load (ton/d)				
WLA: City, County, and/or Township MS4 [a]	1.23	0.46	0.18	0.084	0.040
WLA: Industrial/Construction Stormwater	0.68	0.19	0.056	0.011	– [c]
WLA: Wastewater	4.5	4.5	4.5	4.5	– [b]
Load Allocation	339.6	93	28	5.5	– [c]
Margin of Safety	38	11	3.6	1.1	0.33
Loading Capacity	384	109	36	11	3.3
Existing Concentration (mg/L)	370				
Percent Reduction to Achieve Concentration Standard	82%				

[a] To meet the WLAs for permitted MS4s, TSS loading does not need to be reduced but is not allowed to increase.

[b] Permitted wastewater design flows exceed stream flow in the indicated flow zone(s). The allocations are expressed as an equation rather than an absolute number: allocation = flow contribution from a given source x 65 mg/L (or NPDES permit concentration). See *Municipal and Industrial Wastewater* (Section 5.4.1) for more detail.

[c] Unable to calculate allocations because the wastewater WLA exceeds the loading capacity. The allocations are expressed as an equation rather than an absolute number: allocation = flow contribution from a given source x 65 mg/L. See Sections 5.4.2 and 5.6 for more detail.

D6. Blue Earth (HUC 07020009)

Blue Earth River (07020009-501)

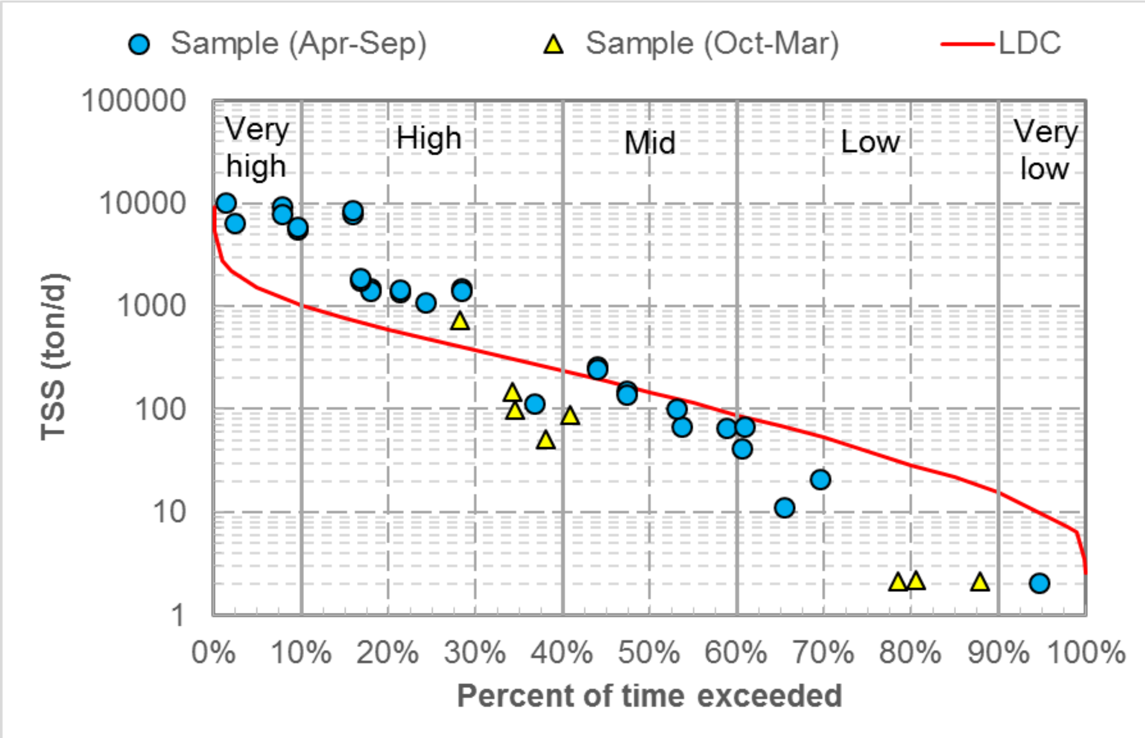


Figure D-13. TSS load duration curve, Blue Earth River (07020009-501).

Table D-13. TSS TMDL summary, Blue Earth River (07020009-501)

TMDL Parameter	Flow Regimes				
	Very High	High	Mid	Low	Very Low
	TSS Load (ton/d)				
WLA: MnDOT Outstate MS4 [a]	0.14	0.052	0.021	0.0091	0.0030
WLA: City, County, and/or Township MS4 [a]	5.60	2.08	0.84	0.38	0.18
WLA: Industrial/Construction Stormwater	2.69	0.82	0.24	0.044	– [c]
WLA: Wastewater	11	11	11	11	– [b]
Load Allocation	1339.6	408	119.9	23.7	– [c]
Margin of Safety	151	47	15	3.9	0.96
Loading Capacity	1,510	469	147	39	9.6
Existing Concentration (mg/L)	437				
Percent Reduction to Achieve Concentration Standard	85%				

[a] To meet the WLAs for permitted MS4s, TSS loading does not need to be reduced but is not allowed to increase.

[b] Permitted wastewater design flows exceed stream flow in the indicated flow zone(s). The allocations are expressed as an equation rather than an absolute number: allocation = flow contribution from a given source x 65 mg/L (or NPDES permit concentration). See *Municipal and Industrial Wastewater* (Section 5.4.1) for more detail.

[c] Unable to calculate allocations because the wastewater WLA exceeds the loading capacity. The allocations are expressed as an equation rather than an absolute number: allocation = flow contribution from a given source x 65 mg/L. See Sections 5.4.2 and 5.6 for more detail.

Elm Creek (07020009-502)

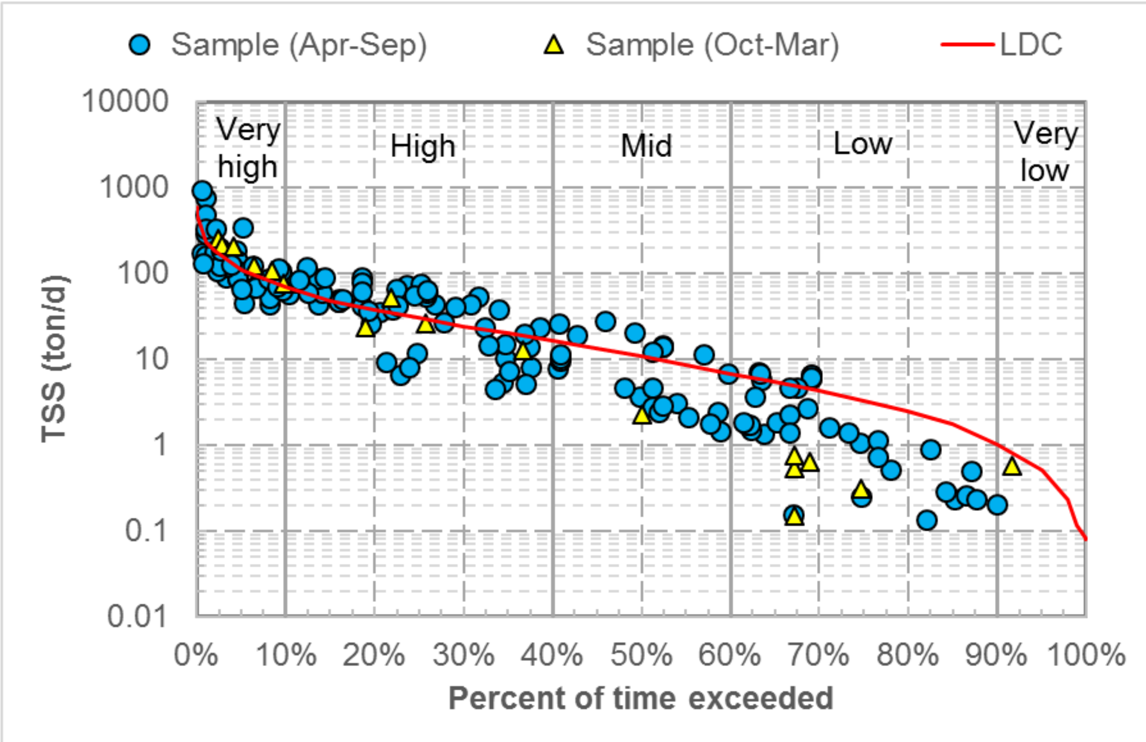


Figure D-14. TSS load duration curve, Elm Creek (07020009-502).

Table D-14. TSS TMDL summary, Elm Creek (07020009-502)

TMDL Parameter	Flow Regimes				
	Very High	High	Mid	Low	Very Low
	TSS Load (ton/d)				
WLA: Industrial/Construction Stormwater	0.19	0.053	0.018	0.0046	– [b]
WLA: Wastewater	.164	.164	.164	.164	– [a]
Load Allocation	96.5	26.5	9.6	2.8	– [b]
Margin of Safety	11	3.0	1.1	0.33	0.051
Loading Capacity	108	30	11	3.3	0.51
Existing Concentration (mg/L)	121				
Percent Reduction to Achieve Concentration Standard	46%				

[a] Permitted wastewater design flows exceed stream flow in the indicated flow zone(s). The allocations are expressed as an equation rather than an absolute number: allocation = flow contribution from a given source x 65 mg/L (or NPDES permit concentration). See *Municipal and Industrial Wastewater* (Section 5.4.1) for more detail.

[b] Unable to calculate allocations because the wastewater WLA exceeds the loading capacity. The allocations are expressed as an equation rather than an absolute number: allocation = flow contribution from a given source x 65 mg/L. See Sections 5.4.2 and 5.6 for more detail.

Center Creek (07020009-503)

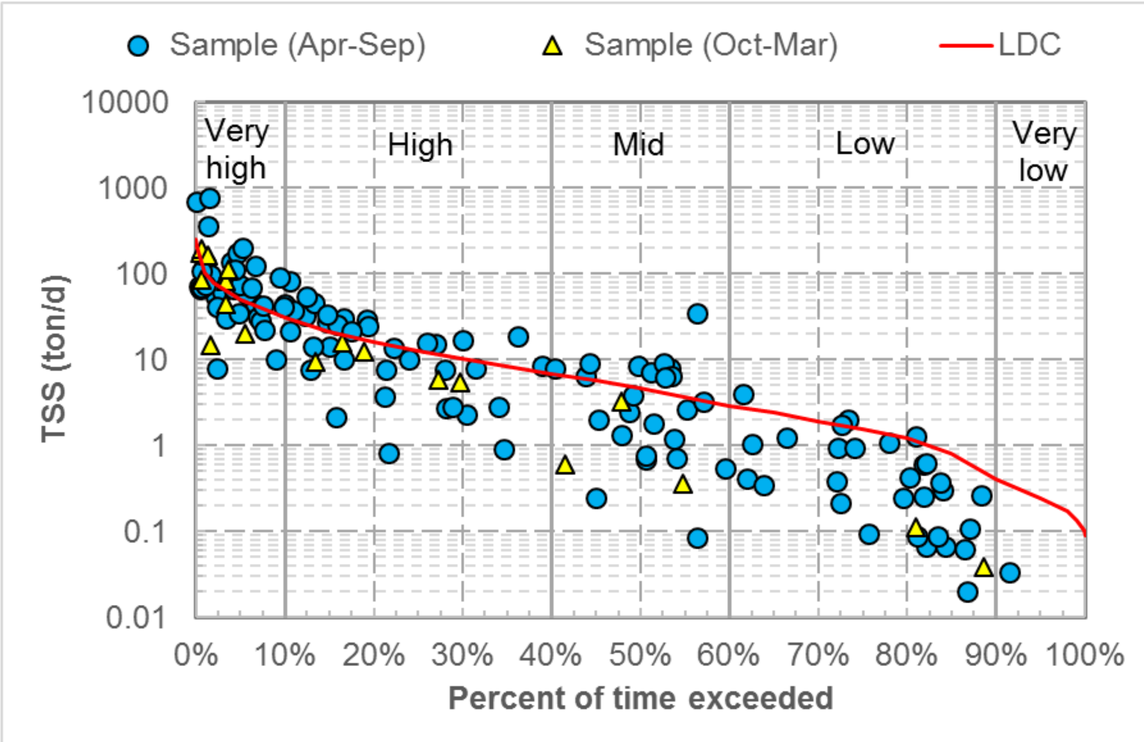


Figure D-15. TSS load duration curve, Center Creek (07020009-503).

Table D-15. TSS TMDL summary, Center Creek (07020009-503)

TMDL Parameter	Flow Regimes				
	Very High	High	Mid	Low	Very Low
	TSS Load (ton/d)				
WLA: City, County, and/or Township MS4 [a]	2.61	0.97	0.39	0.18	0.086
WLA: Industrial/Construction Stormwater	0.088	0.021	0.0068	0.00013	– [c]
WLA: Wastewater	.60	.60	.60	.60	– [b]
Load Allocation	41.6	10.1	3.1	.66	– [c]
Margin of Safety	5.0	1.3	0.46	0.16	0.024
Loading Capacity	50	13	4.6	1.6	0.24
Existing Concentration (mg/L)	139				
Percent Reduction to Achieve Concentration Standard	53%				

[a] To meet the WLAs for permitted MS4s, TSS loading does not need to be reduced but is not allowed to increase.

[b] Permitted wastewater design flows exceed stream flow in the indicated flow zone(s). The allocations are expressed as an equation rather than an absolute number: allocation = flow contribution from a given source x 65 mg/L (or NPDES permit concentration). See *Municipal and Industrial Wastewater* (Section 5.4.1) for more detail.

[c] Unable to calculate allocations because the wastewater WLA exceeds the loading capacity. The allocations are expressed as an equation rather than an absolute number: allocation = flow contribution from a given source x 65 mg/L. See Sections 5.4.2 and 5.6 for more detail.

Blue Earth River (07020009-504)

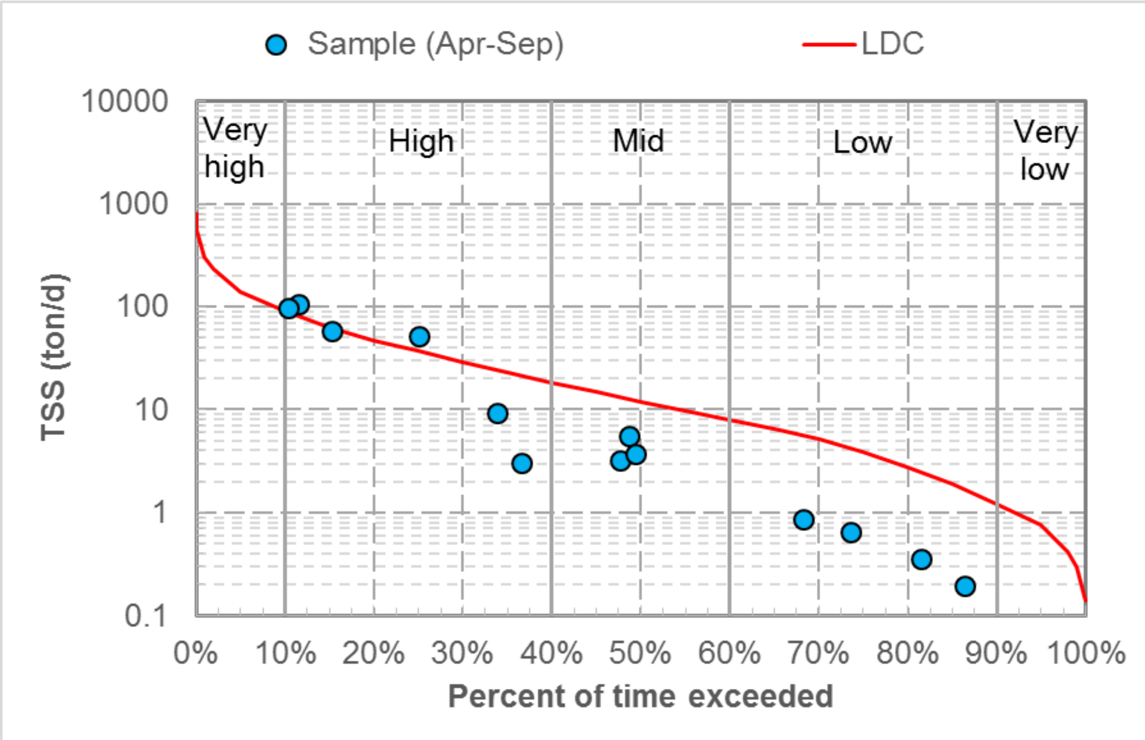


Figure D-16. TSS load duration curve, Blue Earth River (07020009-504).

Table D-16. TSS TMDL summary, Blue Earth River (07020009-504)

TMDL Parameter	Flow Regimes				
	Very High	High	Mid	Low	Very Low
	TSS Load (ton/d)				
WLA: Industrial/Construction Stormwater	0.25	0.066	0.020	0.0060	0.00043
WLA: Wastewater	0.47	0.47	0.47	0.47	0.47
Load Allocation	126	33	10	3.0	0.21
Margin of Safety	14	3.7	1.2	0.39	0.076
Loading Capacity	141	37	12	3.9	0.76
Existing Concentration (mg/L)	– [a]				
Percent Reduction to Achieve Concentration Standard	– [a]				

[a] No data in the TMDL period (2006–2015); data in Figure D-16 are from 1998–2000.

Blue Earth River (07020009-507)

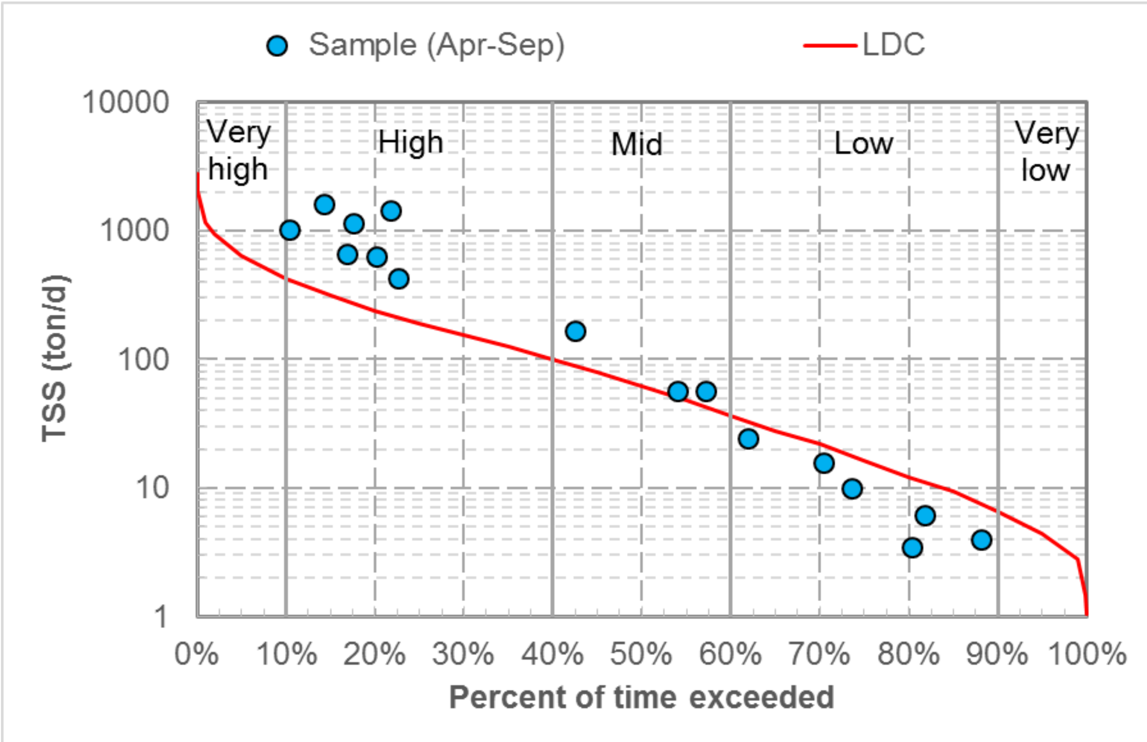


Figure D-17. TSS load duration curve, Blue Earth River (07020009-507).

Table D-17. TSS TMDL summary, Blue Earth River (07020009-507)

TMDL Parameter	Flow Regimes				
	Very High	**High**	**Mid**	**Low**	**Very Low**
	TSS Load (ton/d)				
WLA: City, County, and/or Township MS4 [a]	2.61	0.97	0.39	0.18	0.086
WLA: Industrial/Construction Stormwater	1.14	0.34	0.10	0.023	0.0017
WLA: Wastewater	2.4	2.4	2.4	2.4	2.4
Load Allocation	568.8	167.1	52.8	11.8	1.5
Margin of Safety	64	19	6.2	1.6	0.44
Loading Capacity	639	190	62	16	4.4
Existing Concentration (mg/L)	– [b]				
Percent Reduction to Achieve Concentration Standard	– [b]				

[a] To meet the WLAs for permitted MS4s, TSS loading does not need to be reduced but is not allowed to increase.

[b] No data in the TMDL period (2006–2015); data in Figure D-17 are from 1999–2000.

Blue Earth River (07020009-508)

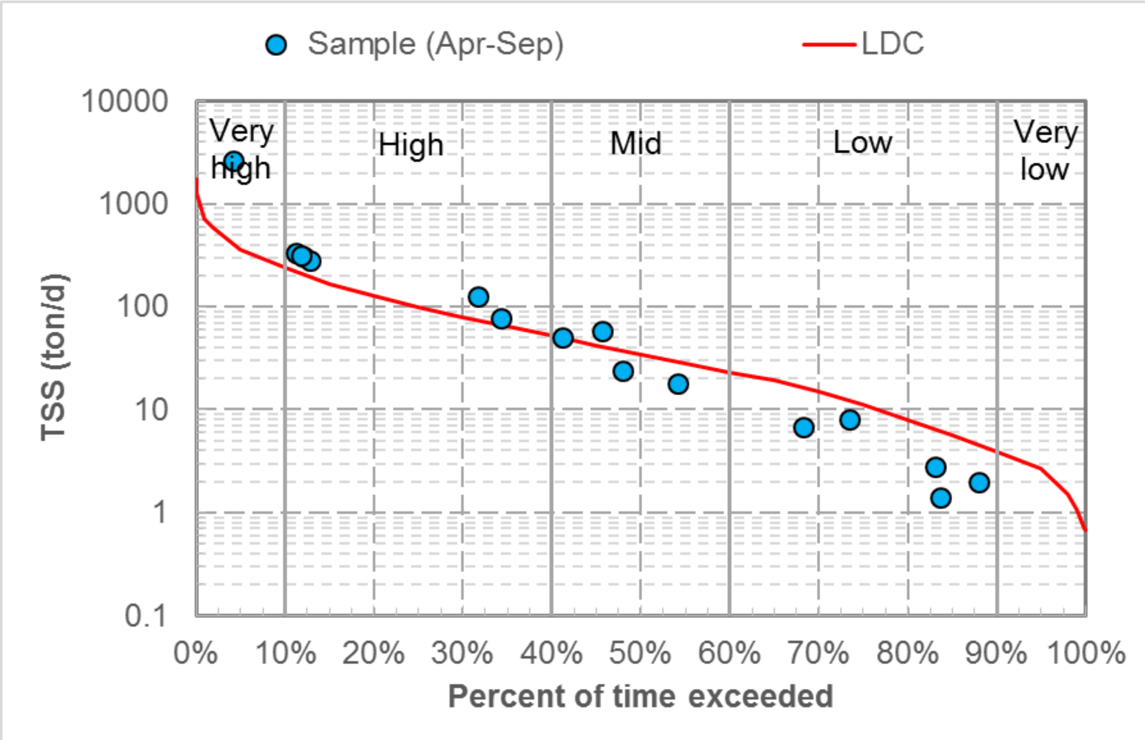


Figure D-18. TSS load duration curve, Blue Earth River (07020009-508).

Table D-18. TSS TMDL summary, Blue Earth River (07020009-508)

TMDL Parameter	**Flow Regimes**				
	Very High	**High**	**Mid**	**Low**	**Very Low**
	TSS Load (ton/d)				
WLA: Industrial/Construction Stormwater	0.64	0.17	0.058	0.017	0.0018
WLA: Wastewater	1.42	1.42	1.42	1.42	1.42
Load Allocation	321.5	86.9	29.2	8.57	0.95
Margin of Safety	36	9.8	3.4	1.1	0.26
Loading Capacity	360	98	34	11	2.6
Existing Concentration (mg/L)	– [a]				
Percent Reduction to Achieve Concentration Standard	– [a]				

[a] No data in the TMDL period (2006–2015); data in Figure D-18 are from 1999–2000.

Blue Earth River (07020009-509)

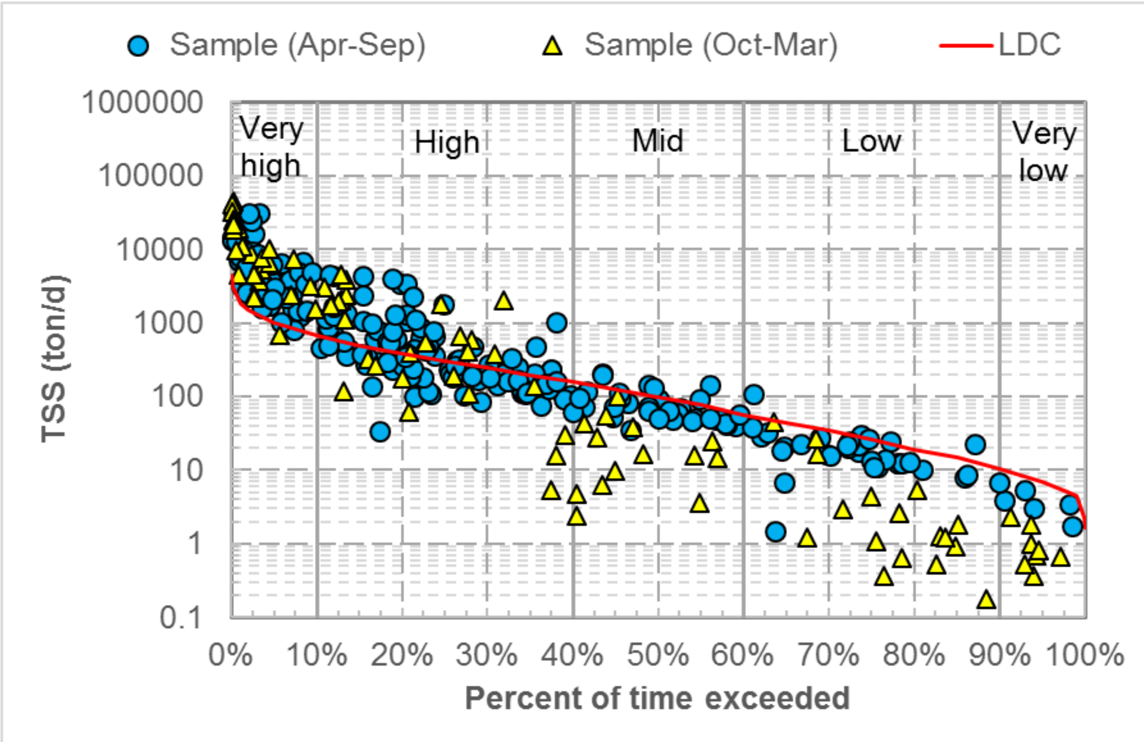


Figure D-19. TSS load duration curve, Blue Earth River (07020009-509).

Table D-19. TSS TMDL summary, Blue Earth River (07020009-509)

TMDL Parameter	Flow Regimes				
	Very High	High	Mid	Low	Very Low
	TSS Load (ton/d)				
WLA: MnDOT Outstate MS4 [a]	0.0050	0.0019	0.00077	0.00033	0.00011
WLA: City, County, and/or Township MS4 [a]	3.03	1.12	0.45	0.21	0.10
WLA: Industrial/Construction Stormwater	1.8	0.53	0.16	0.034	0.0004
WLA: Wastewater	5.42	5.42	5.42	5.42	5.42
Load Allocation	895.6	262.9	81.3	17.8	.74
Margin of Safety	101	30	9.7	2.6	0.69
Loading Capacity	1,007	300	97	26	6.9
Existing Concentration (mg/L)	386				
Percent Reduction to Achieve Concentration Standard	83%				

[a] To meet the WLAs for permitted MS4s, TSS loading does not need to be reduced but is not allowed to increase.

Blue Earth River (07020009-514)

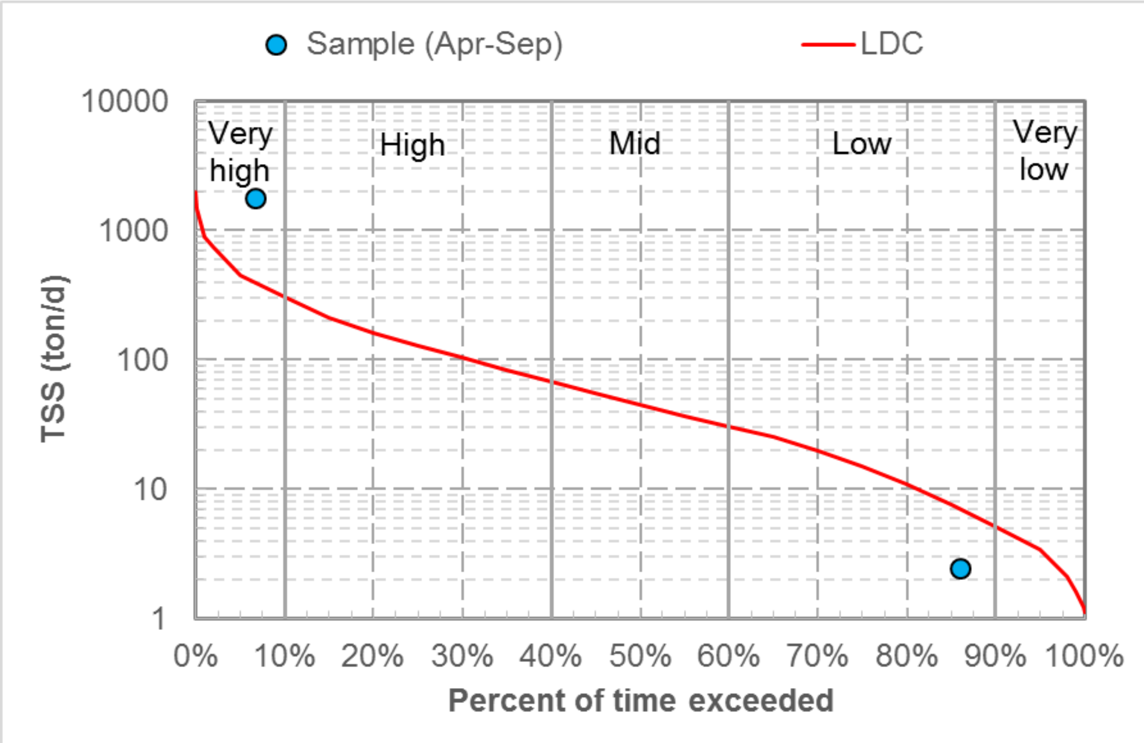


Figure D-20. TSS load duration curve, Blue Earth River (07020009-514).

Table D-20. TSS TMDL summary, Blue Earth River (07020009-514)

TMDL Parameter	Flow Regimes				
	Very High	**High**	**Mid**	**Low**	**Very Low**
	TSS Load (ton/d)				
WLA: City, County, and/or Township MS4 [a]	2.61	0.97	0.39	0.18	0.086
WLA: Industrial/Construction Stormwater	0.81	0.23	0.08	0.022	0.0018
WLA: Wastewater	2.02	2.02	2.02	2.02	2.02
Load Allocation	402.6	111.8	37.9	11.3	.95
Margin of Safety	45	13	4.5	1.5	0.34
Loading Capacity	453	128	45	15	3.4
Existing Concentration (mg/L)	– [b]				
Percent Reduction to Achieve Concentration Standard	– [b]				

[a] To meet the WLAs for permitted MS4s, TSS loading does not need to be reduced but is not allowed to increase.

[b] No data in the TMDL period (2006–2015); data in Figure D-20 are from 1999.

Blue Earth River (07020009-515)

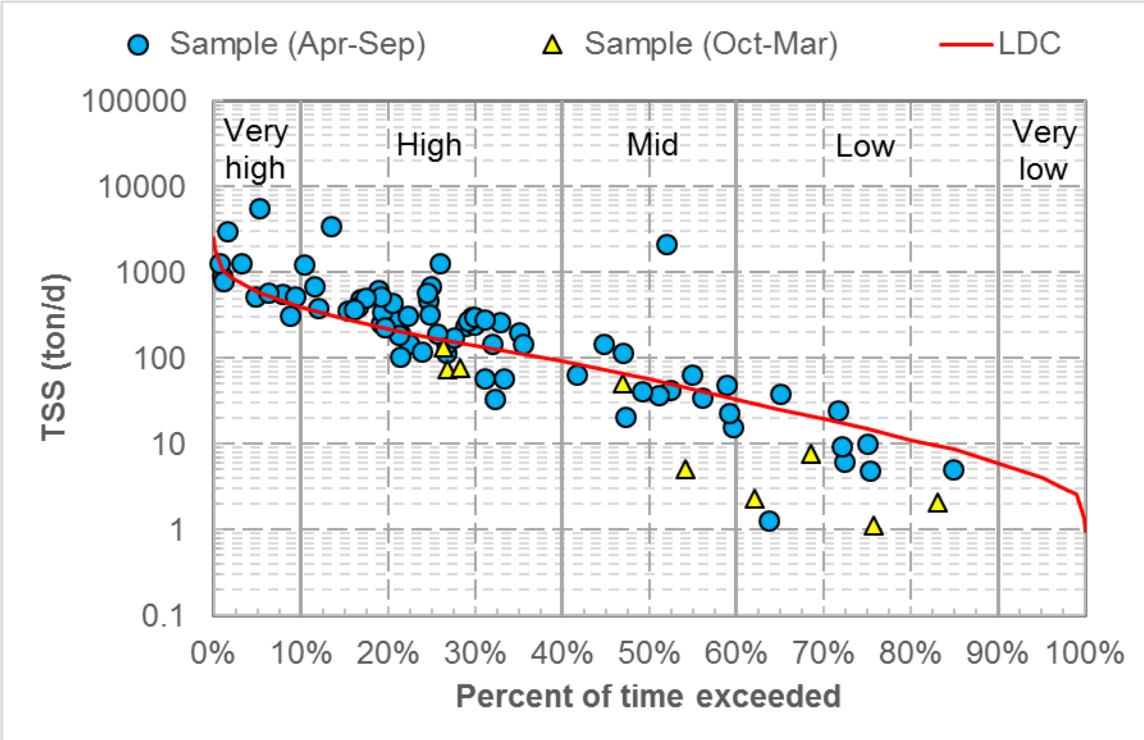


Figure D-21. TSS load duration curve, Blue Earth River (07020009-515).

Table D-21. TSS TMDL summary, Blue Earth River (07020009-515)

TMDL Parameter	Flow Regimes				
	Very High	High	Mid	Low	Very Low
	TSS Load (ton/d)				
WLA: City, County, and/or Township MS4 [a]	2.61	0.97	0.39	0.18	0.086
WLA: Industrial/Construction Stormwater	1.05	0.31	0.096	0.021	0.0011
WLA: Wastewater	2.4	2.4	2.4	2.4	2.4
Load Allocation	519.6	153.4	47.6	10.9	1.1
Margin of Safety	59	17	5.6	1.5	0.40
Loading Capacity	585	174	56	15	4.0
Existing Concentration (mg/L)	189				
Percent Reduction to Achieve Concentration Standard	66%				

[a] To meet the WLAs for permitted MS4s, TSS loading does not need to be reduced but is not allowed to increase.

Blue Earth River (07020009-518)

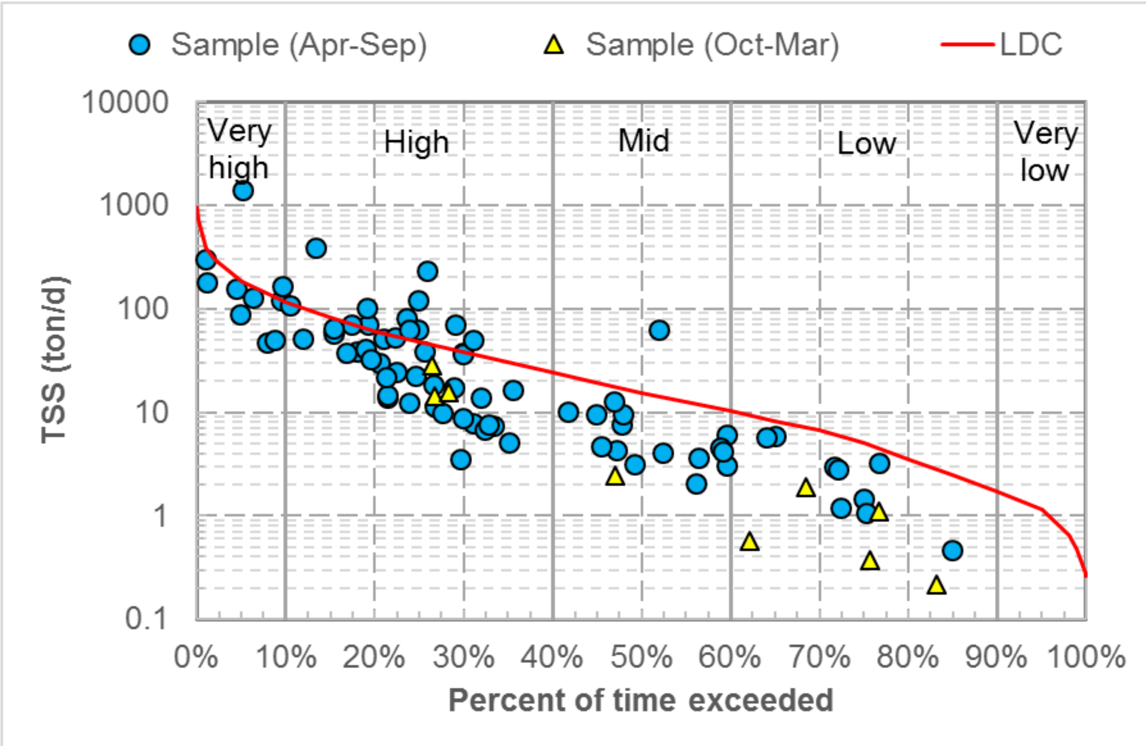


Figure D-22. TSS load duration curve, Blue Earth River (07020009-518).

Table D-22. TSS TMDL summary, Blue Earth River (07020009-518)

TMDL Parameter	Flow Regimes				
	Very High	High	Mid	Low	Very Low
	TSS Load (ton/d)				
WLA: Industrial/Construction Stormwater	0.33	0.09	0.03	0.010	0.001
WLA: Wastewater	0.54	0.54	0.54	0.54	0.54
Load Allocation	162	425	13	3.9	0.49
Margin of Safety	18	4.8	1.5	0.50	0.11
Loading Capacity	181	48	15	5.0	1.1
Existing Concentration (mg/L)	93				
Percent Reduction to Achieve Concentration Standard	30%				

Cedar Creek (07020009-521)

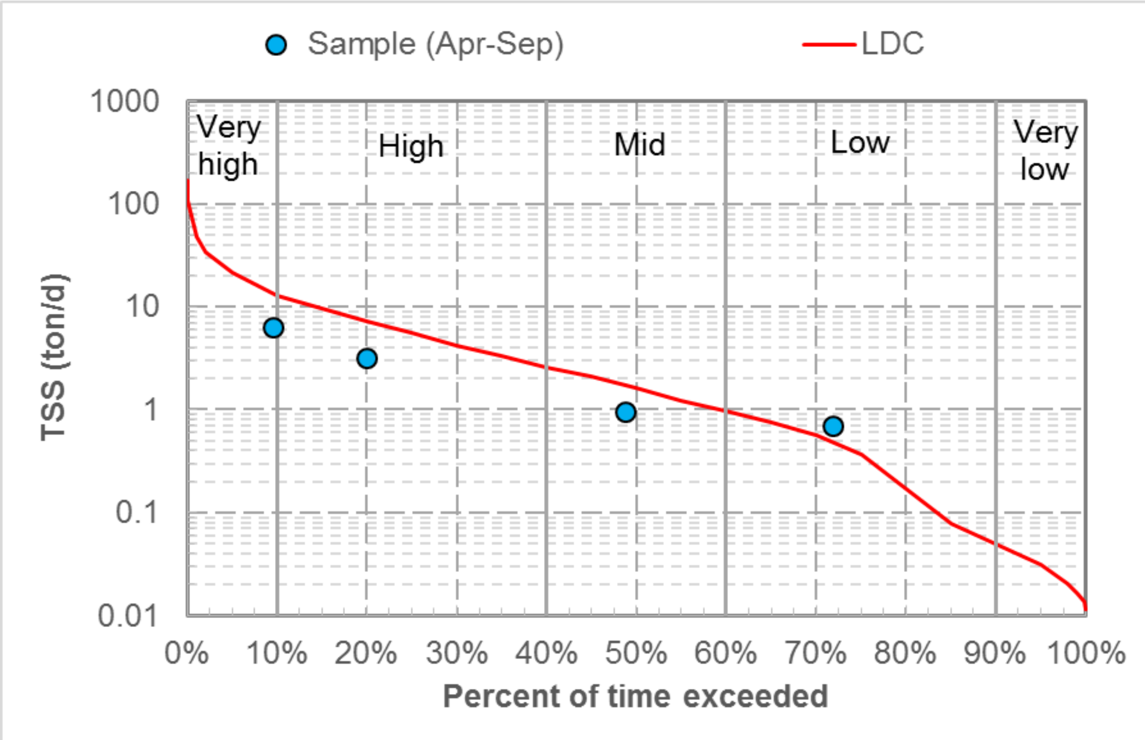


Figure D-23. TSS load duration curve, Cedar Creek (07020009-521).

Table D-23. TSS TMDL summary, Cedar Creek (07020009-521)

TMDL Parameter	Flow Regimes				
	Very High	**High**	**Mid**	**Low**	**Very Low**
	TSS Load (ton/d)				
WLA: Industrial/Construction Stormwater	0.04	0.01	0.0033	– [a]	– [b]
WLA: Wastewater	.024	.024	.024	– [a]	– [a]
Load Allocation	19.4	4.9	1.4	– [a]	– [b]
Margin of Safety	2.2	0.55	0.16	0.037	0.0031
Loading Capacity	22	5.5	1.6	0.37	0.031
Existing Concentration (mg/L)	– [c]				
Percent Reduction to Achieve Concentration Standard	– [c]				

[a] Permitted wastewater design flows exceed stream flow in the indicated flow zone(s). The allocations are expressed as an equation rather than an absolute number: allocation = flow contribution from a given source x 65 mg/L (or NPDES permit concentration). See *Municipal and Industrial Wastewater* (Section 5.4.1) for more detail.
[b] Unable to calculate allocations because the wastewater WLA exceeds the loading capacity. The allocations are expressed as an equation rather than an absolute number: allocation = flow contribution from a given source x 65 mg/L. See Sections 5.4.2 and 5.6 for more detail.

[c] No data in the TMDL period (2006–2015); data in Figure D-23 are from 2000.

Elm Creek (07020009-522)

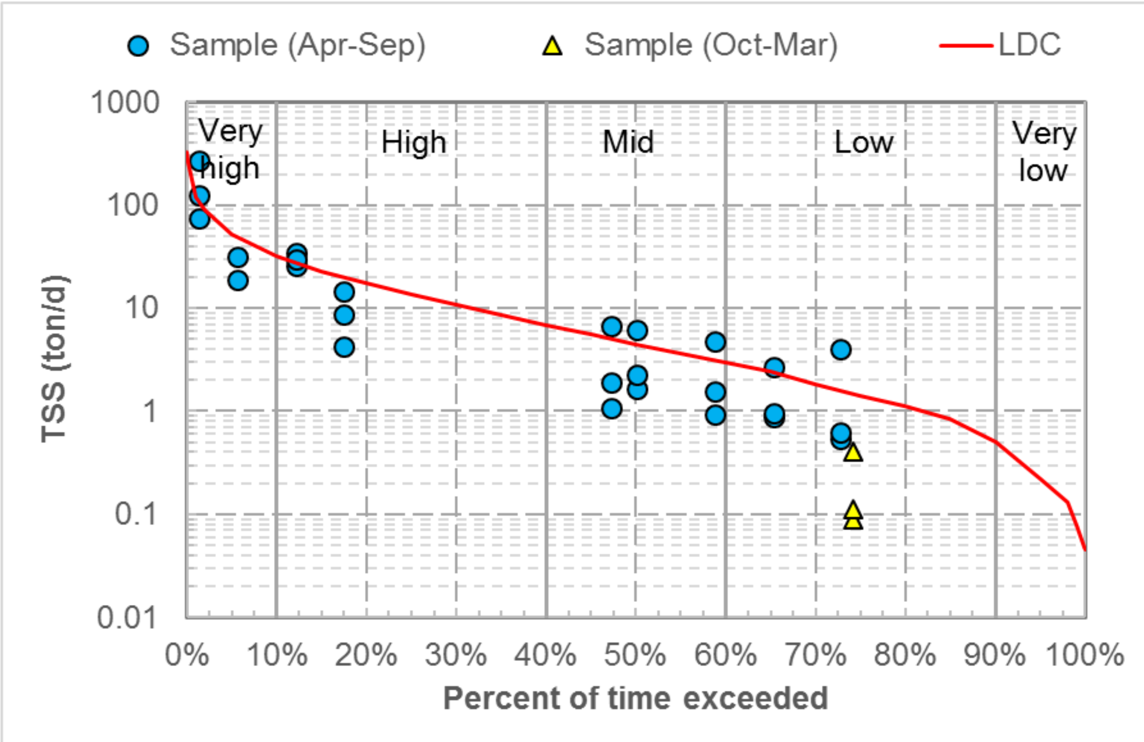


Figure D-24. TSS load duration curve, Elm Creek (07020009-522).

Table D-24. TSS TMDL summary, Elm Creek (07020009-522)

TMDL Parameter	Flow Regimes				
	Very High	High	Mid	Low	Very Low
	TSS Load (ton/d)				
WLA: Industrial/Construction Stormwater	0.094	0.025	0.0080	0.0025	0.00040
Load Allocation	47	13	4.0	1.3	0.20
Margin of Safety	5.2	1.4	0.44	0.14	0.022
Loading Capacity	52	14	4.4	1.4	0.22
Existing Concentration (mg/L)	94				
Percent Reduction to Achieve Concentration Standard	31%				

Elm Creek (07020009-523)*

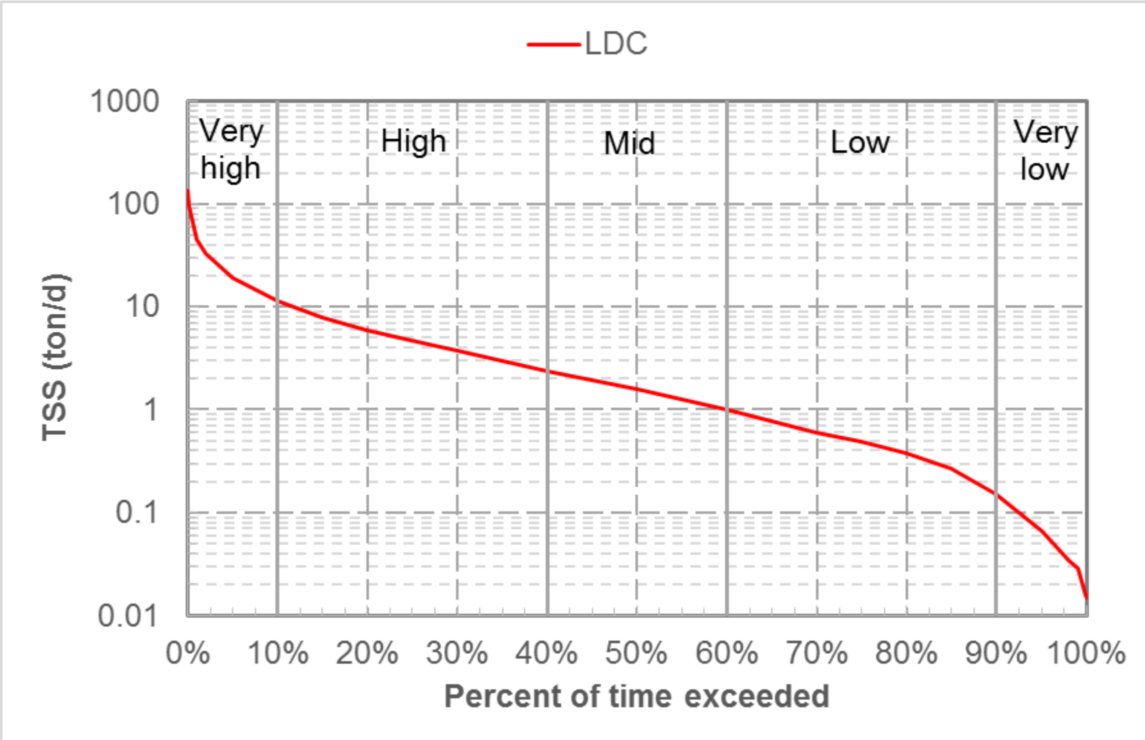


Figure D-25. TSS load duration curve, Elm Creek (07020009-523).

Table D-25. TSS TMDL summary, Elm Creek (07020009-523)*

TMDL Parameter	Flow Regimes				
	Very High	**High**	**Mid**	**Low**	**Very Low**
	TSS Load (ton/d)				
WLA: Industrial/Construction Stormwater	0.034	0.0084	0.0028	0.00087	0.00012
Load Allocation	17	4.2	1.4	0.43	0.058
Margin of Safety	1.9	0.47	0.16	0.048	0.0065
Loading Capacity	19	4.7	1.6	0.48	0.065
Existing Concentration (mg/L)	– [a]				
Percent Reduction to Achieve Concentration Standard	– [a]				

[a] N < 10; existing concentration and percent reduction not calculated.

* AUID 07020009-523 has been split into child AUIDs 07020009-630 and07020009-631. These child AUIDs will be proposed for the 2020 303(d) Impaired Waters List. The allocations in the above table address the impairments for both reaches.

Elm Creek, South Fork (07020009-524)

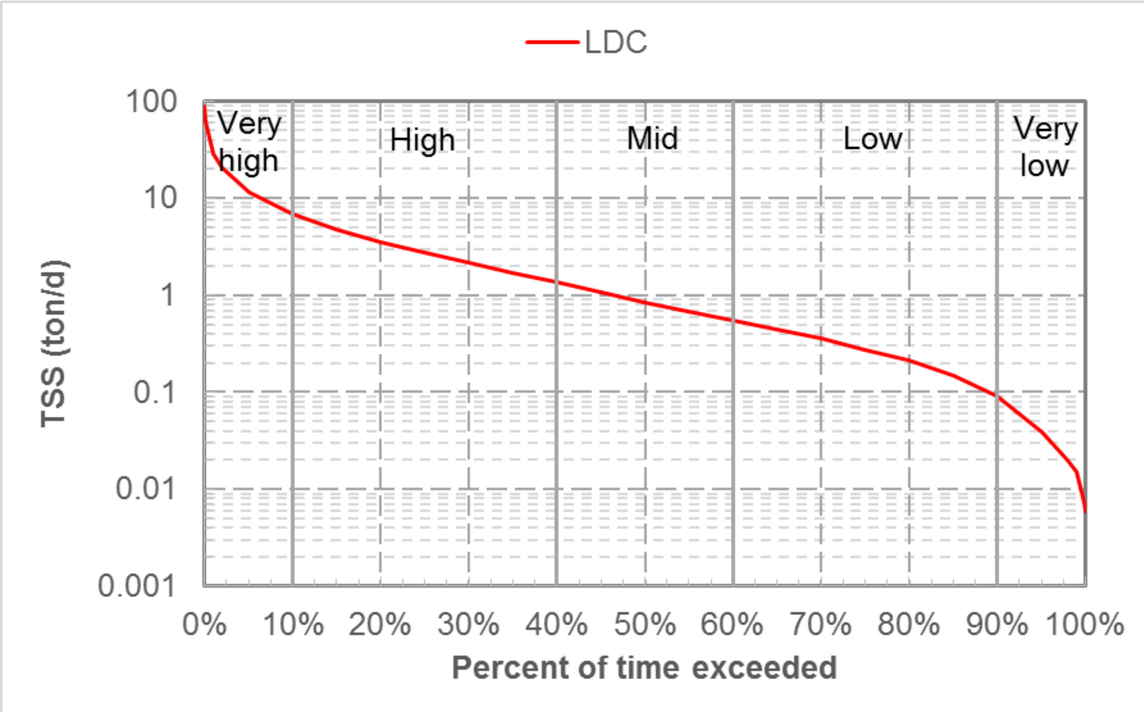


Figure D-26. TSS load duration curve, Elm Creek, South Fork (07020009-524).

Table D-26. TSS TMDL summary, Elm Creek, South Fork (07020009-524)

TMDL Parameter	**Flow Regimes**				
	Very High	**High**	**Mid**	**Low**	**Very Low**
	TSS Load (ton/d)				
WLA: Industrial/Construction Stormwater	0.023	0.0055	0.0017	0.00055	0.000079
Load Allocation	11	2.4	0.75	0.25	0.035
Margin of Safety	1.2	0.27	0.084	0.028	0.0039
Loading Capacity	12	2.7	0.84	0.28	0.039
Existing Concentration (mg/L)	– [a]				
Percent Reduction to Achieve Concentration Standard	– [a]				

[a] N < 10; existing concentration and percent reduction not calculated.

Lily Creek (07020009-525)*

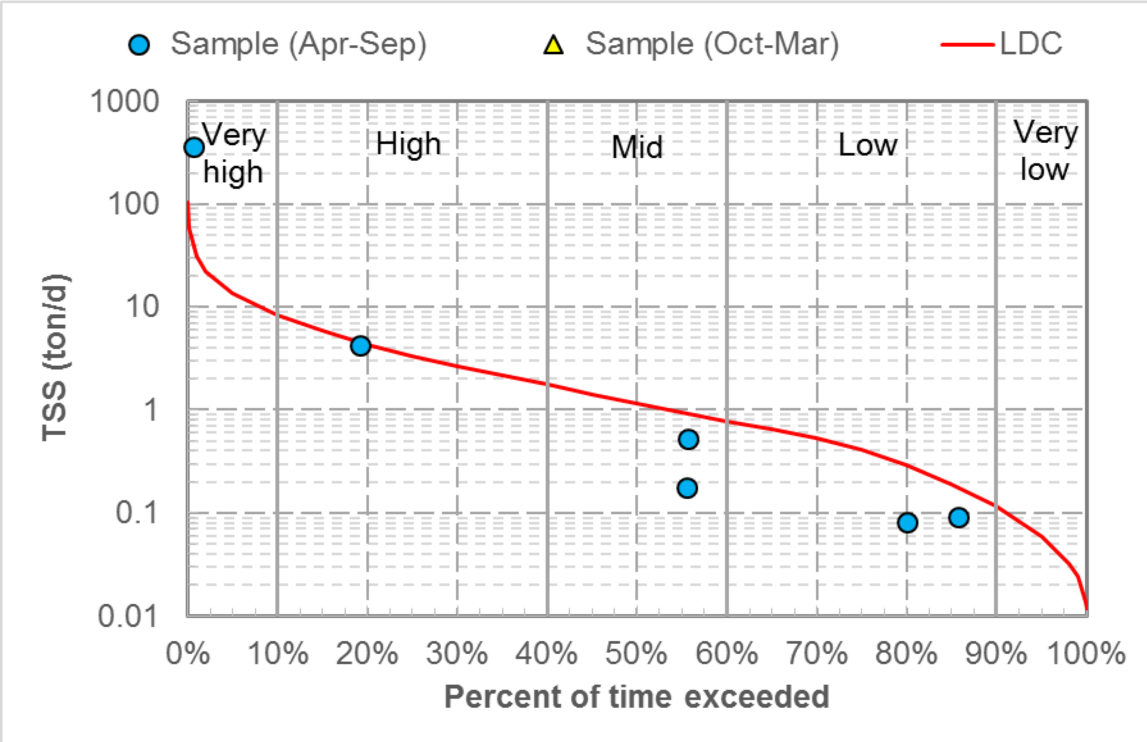


Figure D-27. TSS load duration curve, Lily Creek (07020009-525).

Table D-27. TSS TMDL summary, Lily Creek (07020009-525)

TMDL Parameter	Flow Regimes				
	Very High	High	Mid	Low	Very Low
	TSS Load (ton/d)				
WLA: City, County, Township MS4 [a]	0.024	0.0090	0.0036	0.0017	0.00079
WLA: Industrial/Construction Stormwater	0.024	0.0057	0.0017	0.0038	– [c]
WLA: Wastewater	.0325	.0325	.0325	.0325	– [b]
Load Allocation	11.65	2.95	1.02	0.33	–
Margin of Safety	1.3	0.33	0.12	0.041	0.0059
Loading Capacity	13	3.3	1.2	0.41	0.059
Existing Concentration (mg/L)	– [d]				
Percent Reduction to Achieve Concentration Standard	– [d]				

[a] To meet the WLAs for permitted MS4s, TSS loading does not need to be reduced but is not allowed to increase.

[b] Permitted wastewater design flows exceed stream flow in the indicated flow zone(s). The allocations are expressed as an equation rather than an absolute number: allocation = flow contribution from a given source x 65 mg/L (or NPDES permit concentration). See *Municipal and Industrial Wastewater* (Section 5.4.1) for more detail.

[c] Unable to calculate allocations because the wastewater WLA exceeds the loading capacity. The allocations are expressed as an equation rather than an absolute number: allocation = flow contribution from a given source x 65 mg/L. See Sections 5.4.2 and 5.6 for more detail.

[d] No data in the TMDL period (2006–2015); data in Figure D-27 are from 2001.

* AUID 07020009-525 has been split into child AUIDs 07020009-632 and07020009-633. These child AUIDs will be proposed for the 2020 303(d) Impaired Waters List. The allocations in the above table address the impairments for both reaches.

Dutch Creek (07020009-527)*

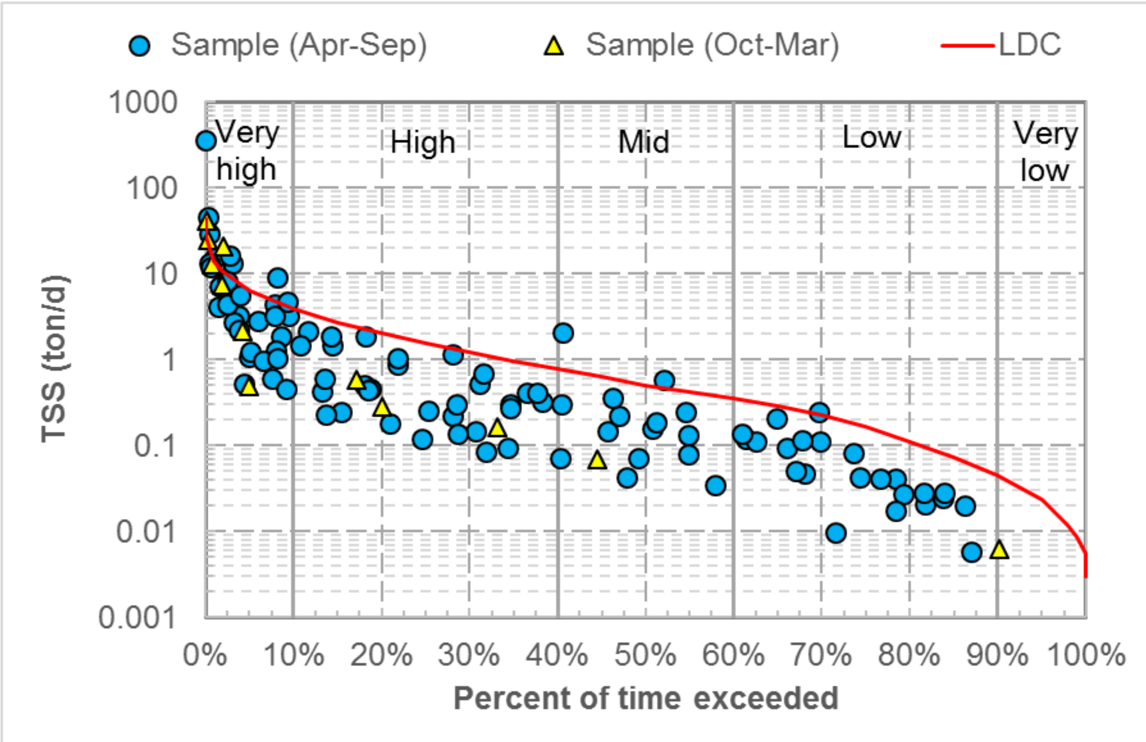


Figure D-28. TSS load duration curve, Dutch Creek (07020009-527).

Table D-28. TSS TMDL summary, Dutch Creek (07020009-527)

TMDL Parameter	Flow Regimes				
	Very High	High	Mid	Low	Very Low
	TSS Load (ton/d)				
WLA: City, County, Township MS4 [a]	0.061	0.023	0.0091	0.0042	0.0020
WLA: Industrial/Construction Stormwater	0.011	0.0028	0.00091	0.00030	0.000041
WLA: Wastewater	0.00038	0.00038	0.00038	0.00038	0.00038
Load Allocation	5.6	1.3	0.44	0.15	0.018
Margin of Safety	0.63	0.15	0.050	0.017	0.0023
Loading Capacity	6.3	1.5	0.50	0.17	0.023
Existing Concentration (mg/L)	64				
Percent Reduction to Achieve Concentration Standard	_ [b]				

[a] To meet the WLAs for permitted MS4s, TSS loading does not need to be reduced but is not allowed to increase.

[b] This impairment was originally listed in 2004 based on turbidity data; however, the TSS data presented in this report do not show impairment. The MPCA will reevaluate the reach in the next impairment assessment for this watershed.

* AUID 07020009-527 has been split into child AUIDs 07020009-634, 07020009-635, 07020009-636 and 07020009-637. These child AUIDs will be proposed for the 2020 303(d) Impaired Waters List. The allocations in the above table address the impairments for all of these reaches.

Blue Earth River, East Branch (07020009-553)

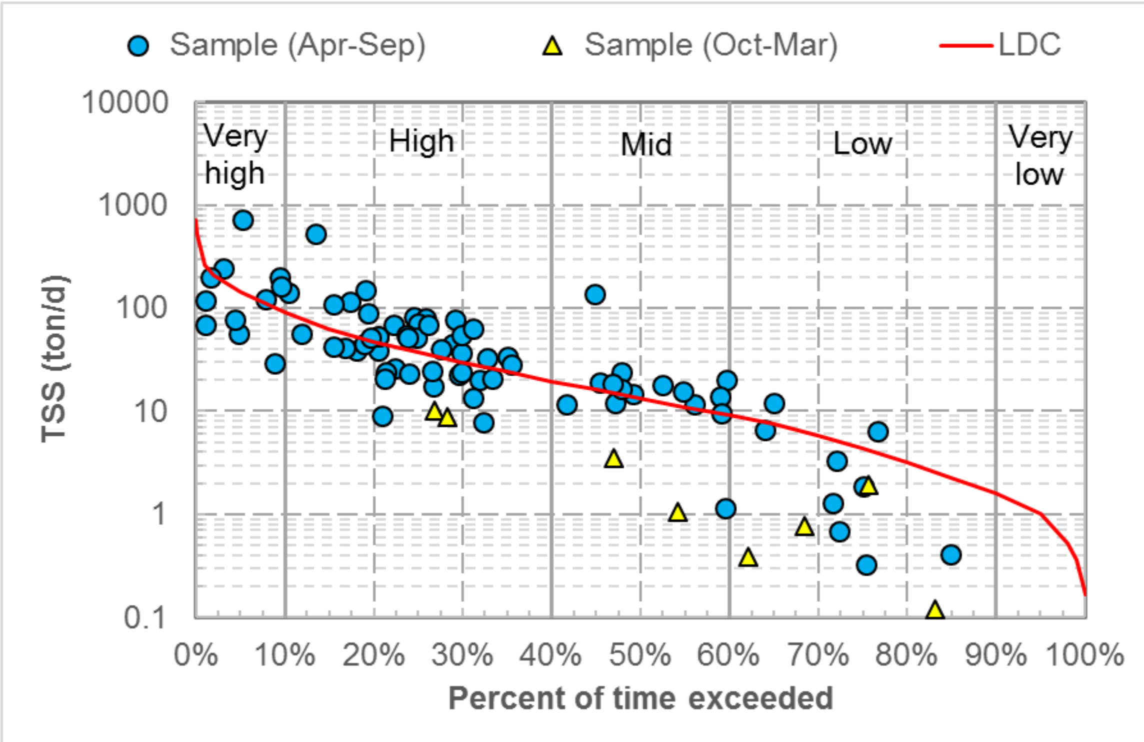


Figure D-29. TSS load duration curve, Blue Earth River, East Branch (07020009-553).

Table D-29. TSS TMDL summary, Blue Earth River, East Branch (07020009-553)

TMDL Parameter	Flow Regimes				
	Very High	**High**	**Mid**	**Low**	**Very Low**
	TSS Load (ton/d)				
WLA: Industrial/Construction Stormwater	0.26	0.065	0.023	0.0062	0.00029
WLA: Wastewater	0.76	0.76	0.76	0.76	0.76
Load Allocation	128	32	11	3.1	0.14
Margin of Safety	14	3.7	1.3	0.43	0.10
Loading Capacity	143	37	13	4.3	1.0
Existing Concentration (mg/L)	141				
Percent Reduction to Achieve Concentration Standard	54%				

Blue Earth River, East Branch (07020009-554)*

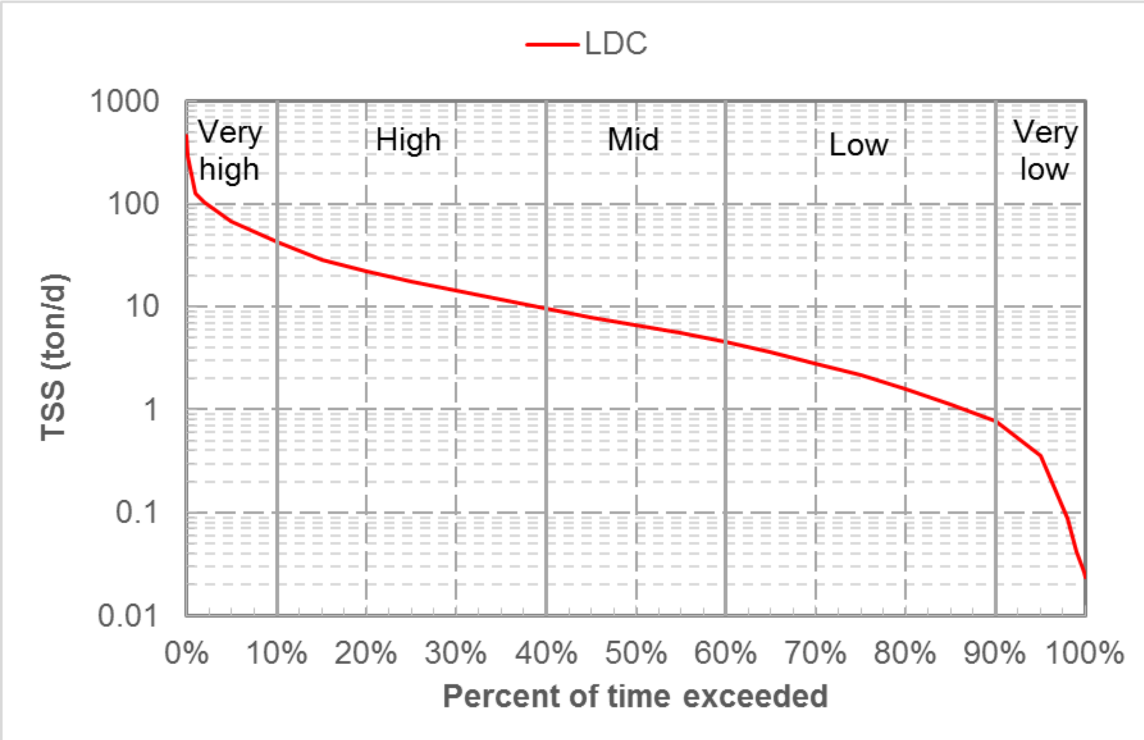


Figure D-30. TSS load duration curve, Blue Earth River, East Branch (07020009-554).

Table D-30. TSS TMDL summary, Blue Earth River, East Branch (07020009-554)

TMDL Parameter	Flow Regimes				
	Very High	**High**	**Mid**	**Low**	**Very Low**
	TSS Load (ton/d)				
WLA: Industrial/Construction Stormwater	0.12	0.030	0.011	0.0029	– [b]
WLA: Wastewater	0.49	0.49	0.49	0.49	– [a]
Load Allocation	61	15	5.4	1.4	– [b]
Margin of Safety	6.8	1.7	0.66	0.21	0.036
Loading Capacity	68	17	6.6	2.1	0.36
Existing Concentration (mg/L)	– [c]				
Percent Reduction to Achieve Concentration Standard	– [c]				

[a] Permitted wastewater design flows exceed stream flow in the indicated flow zone(s). The allocations are expressed as an equation rather than an absolute number: allocation = flow contribution from a given source x 65 mg/L (or NPDES permit concentration). See *Municipal and Industrial Wastewater* (Section 5.4.1) for more detail.

[b] Unable to calculate allocations because the wastewater WLA exceeds the loading capacity. The allocations are expressed as an equation rather than an absolute number: allocation = flow contribution from a given source x 65 mg/L. See Sections 5.4.2 and 5.6 for more detail.

[c] N < 10; existing concentration and percent reduction not calculated.

* AUID 07020009-554 has been split into child AUIDs 07020009-649 and 07020009-650. These child AUIDs will be proposed for the 2020 303(d) Impaired Waters List. The allocations in the above table address the impairments for both reaches.

Blue Earth River (07020009-565)

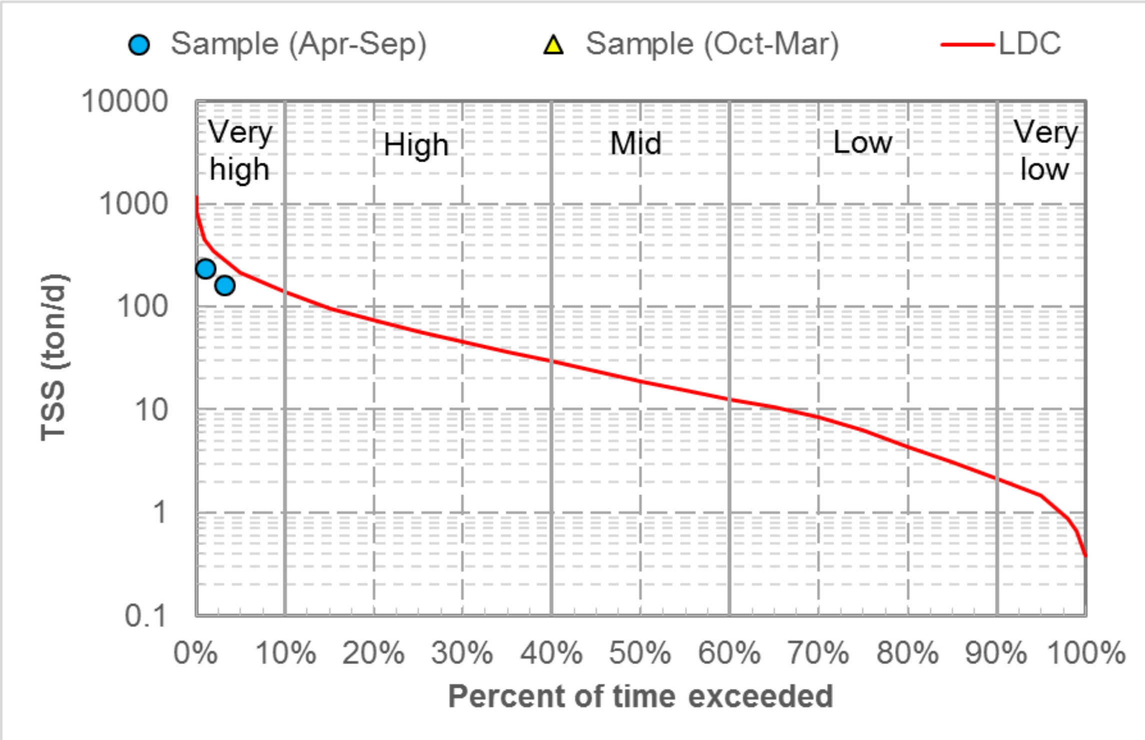


Figure D-31. TSS load duration curve, Blue Earth River (07020009-565).

Table D-31. TSS TMDL summary, Blue Earth River (07020009-565)

TMDL Parameter	Flow Regimes				
	Very High	**High**	**Mid**	**Low**	**Very Low**
	TSS Load (ton/d)				
WLA: Industrial/Construction Stormwater	0.39	0.10	0.032	0.0098	0.0012
WLA: Wastewater	0.66	0.66	0.66	0.66	0.66
Load Allocation	193	51	16	4.9	0.57
Margin of Safety	22	5.8	1.9	0.62	0.14
Loading Capacity	216	58	19	6.2	1.4
Existing Concentration (mg/L)	– [a]				
Percent Reduction to Achieve Concentration Standard	– [a]				

[a] N < 10; existing concentration and percent reduction not calculated.

D7. Watonwan (HUC 07020010)

Watonwan River (07020010-501)

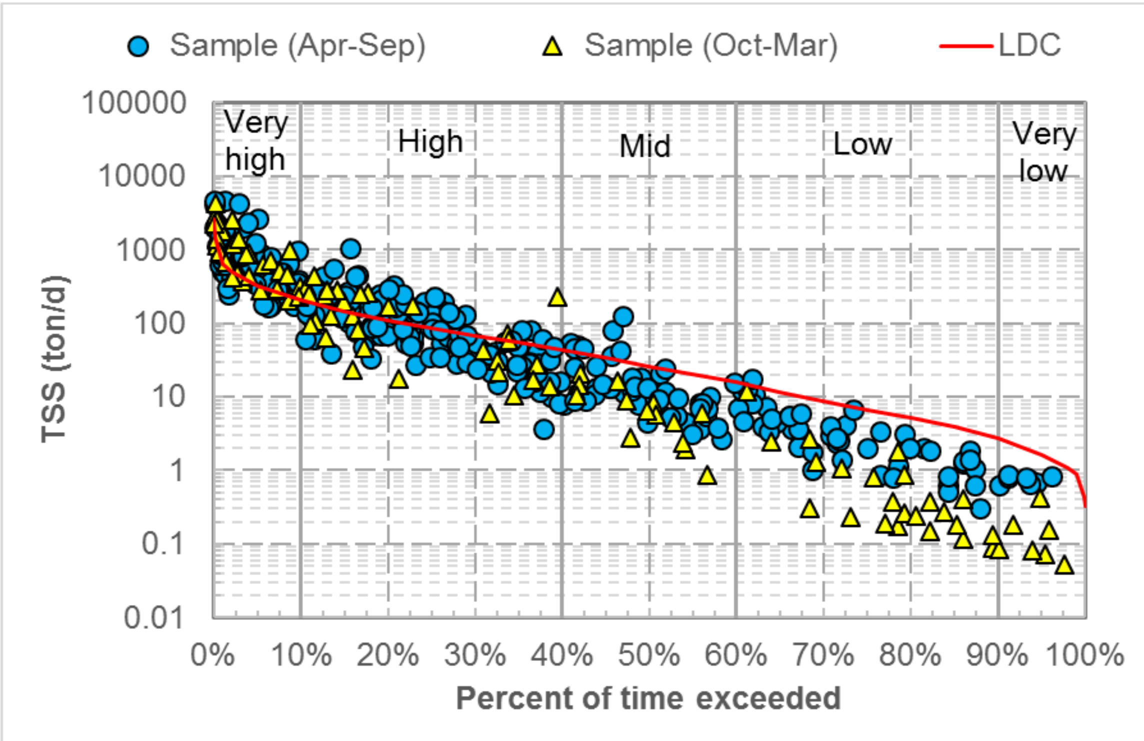


Figure D-32. TSS load duration curve, Watonwan River (07020010-501).

Table D-32. TSS TMDL summary, Watonwan River (07020010-501)

TMDL Parameter	Flow Regimes				
	Very High	High	Mid	Low	Very Low
	TSS Load (ton/d)				
WLA: Industrial/Construction Stormwater	0.57	0.15	0.041	0.0057	– [b]
WLA: Wastewater	3.0	3.0	3.0	3.0	– [a]
Load Allocation	284	73	20	2.8	– [b]
Margin of Safety	32	8.5	2.6	0.65	0.16
Loading Capacity	320	85	26	6.5	1.6
Existing Concentration (mg/L)	141				
Percent Reduction to Achieve Concentration Standard	54%				

[a] Permitted wastewater design flows exceed stream flow in the indicated flow zone(s). The allocations are expressed as an equation rather than an absolute number: allocation = flow contribution from a given source x 65 mg/L (or NPDES permit concentration). See *Municipal and Industrial Wastewater* (Section 5.4.1) for more detail.

[b] Unable to calculate allocations because the wastewater WLA exceeds the loading capacity. The allocations are expressed as an equation rather than an absolute number: allocation = flow contribution from a given source x 65 mg/L. See Sections 5.4.2 and 5.6 for more detail.

Watonwan River (07020010-510)

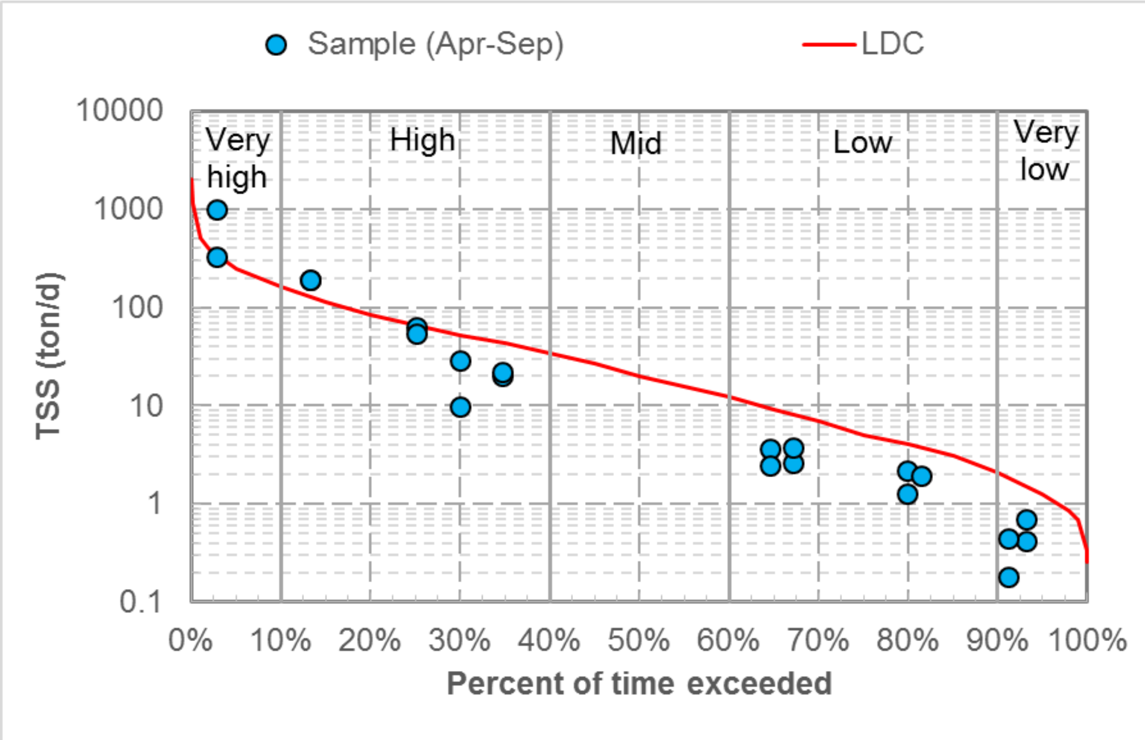


Figure D-33. TSS load duration curve, Watonwan River (07020010-510).

Table D-33. TSS TMDL summary, Watonwan River (07020010-510)

TMDL Parameter	Flow Regimes				
	Very High	High	Mid	Low	Very Low
	TSS Load (ton/d)				
WLA: Industrial/Construction Stormwater	0.44	0.11	0.031	0.0034	– [b]
WLA: Wastewater	2.8	2.8	2.8	2.8	– [a]
Load Allocation	221	56	15	1.7	– [b]
Margin of Safety	25	6.6	2.0	0.50	0.12
Loading Capacity	249	66	20	5.0	1.2
Existing Concentration (mg/L)	95				
Percent Reduction to Achieve Concentration Standard	32%				

[a] Permitted wastewater design flows exceed stream flow in the indicated flow zone(s). The allocations are expressed as an equation rather than an absolute number: allocation = flow contribution from a given source x 65 mg/L (or NPDES permit concentration). See *Municipal and Industrial Wastewater* (Section 5.4.1) for more detail.

[b] Unable to calculate allocations because the wastewater WLA exceeds the loading capacity. The allocations are expressed as an equation rather than an absolute number: allocation = flow contribution from a given source x 65 mg/L. See Sections 5.4.2 and 5.6 for more detail.

Watonwan River (07020010-511)

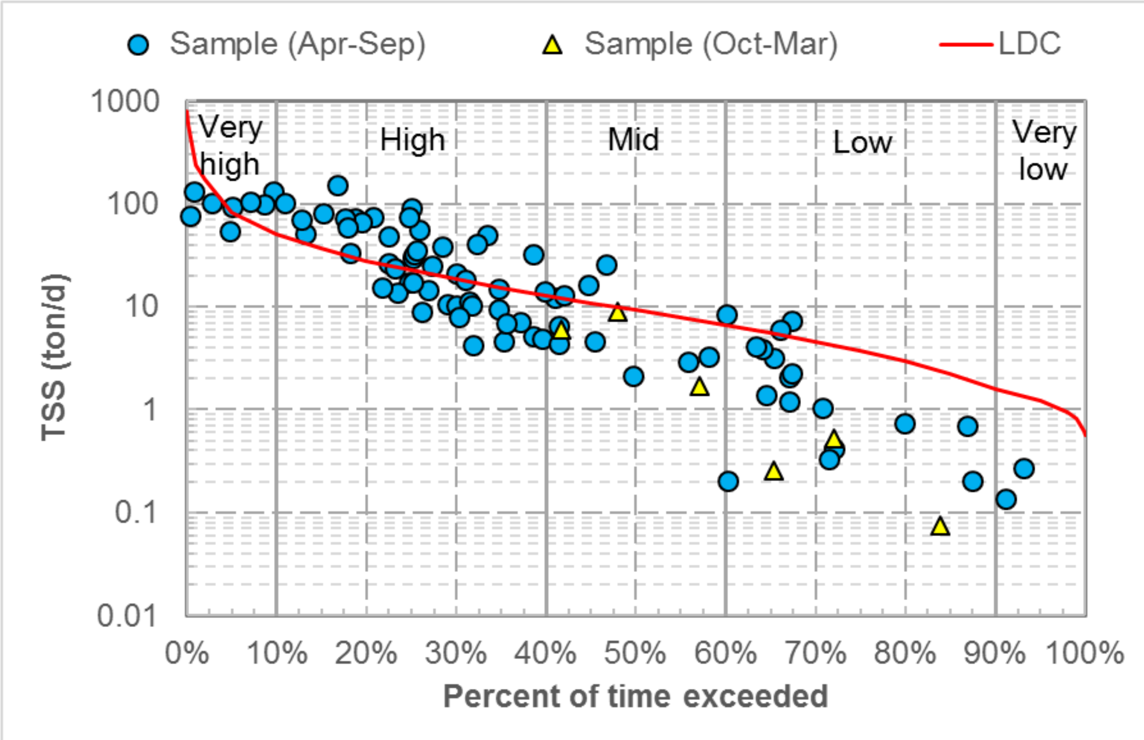


Figure D-34. TSS load duration curve, Watonwan River (07020010-511).

Table D-34. TSS TMDL summary, Watonwan River (07020010-511)

TMDL Parameter	Flow Regimes				
	Very High	**High**	**Mid**	**Low**	**Very Low**
	TSS Load (ton/d)				
WLA: Industrial/Construction Stormwater	0.15	0.036	0.012	0.0024	– [b]
WLA: Wastewater	2.1	2.1	2.1	2.1	– [a]
Load Allocation	72	19	6.2	1.2	– [b]
Margin of Safety	8.3	2.3	0.92	0.37	0.12
Loading Capacity	83	23	9.2	3.7	1.2
Existing Concentration (mg/L)	158				
Percent Reduction to Achieve Concentration Standard	59%				

[a] Permitted wastewater design flows exceed stream flow in the indicated flow zone(s). The allocations are expressed as an equation rather than an absolute number: allocation = flow contribution from a given source x 65 mg/L (or NPDES permit concentration). See *Municipal and Industrial Wastewater* (Section 5.4.1) for more detail.

[b] Unable to calculate allocations because the wastewater WLA exceeds the loading capacity. The allocations are expressed as an equation rather than an absolute number: allocation = flow contribution from a given source x 65 mg/L. See Sections 5.4.2 and 5.6 for more detail.

Butterfield Creek (07020010-516)

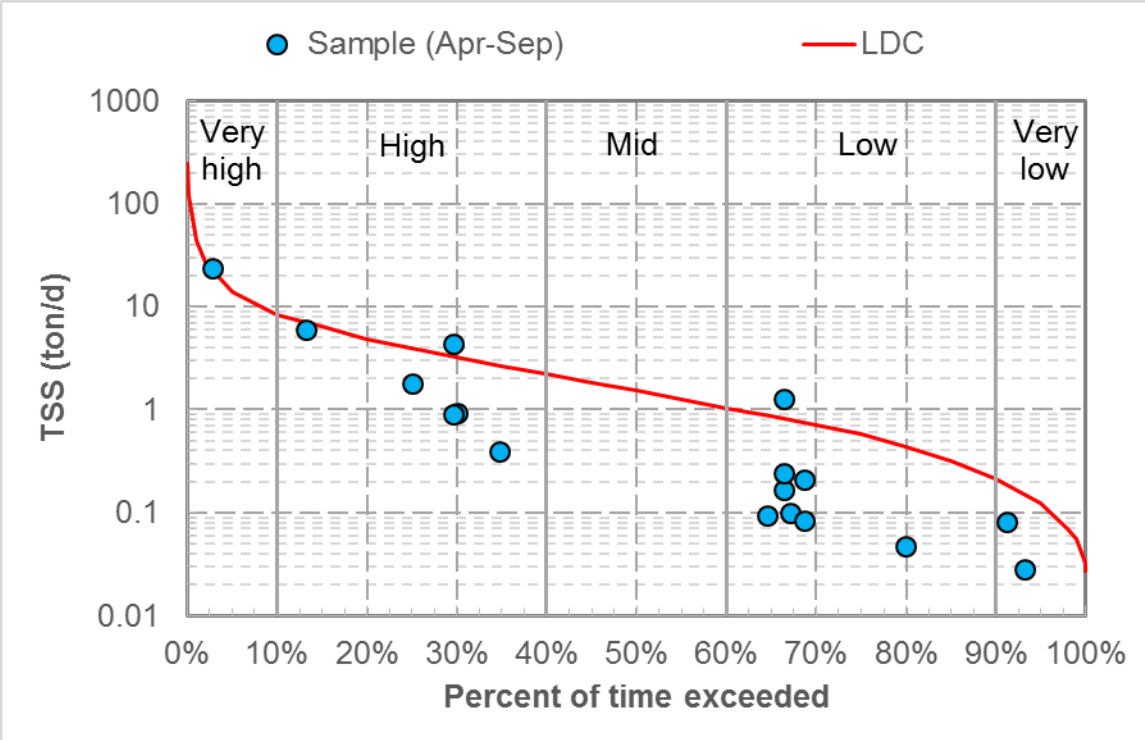


Figure D-35. TSS load duration curve, Butterfield Creek (07020010-516).

Table D-35. TSS TMDL summary, Butterfield Creek (07020010-516)

TMDL Parameter	Flow Regimes				
	Very High	High	Mid	Low	Very Low
	TSS Load (ton/d)				
WLA: Industrial/Construction Stormwater	0.023	0.0052	0.00086	– [b]	– [b]
WLA: Wastewater	0.97	0.97	0.97	– [a]	– [a]
Load Allocation	12	2.6	0.43	– [b]	– [b]
Margin of Safety	1.4	0.40	0.16	0.057	0.012
Loading Capacity	14	4.0	1.6	0.57	0.12
Existing Concentration (mg/L)	77.2				
Percent Reduction to Achieve Concentration Standard	16%				

[a] Permitted wastewater design flows exceed stream flow in the indicated flow zone(s). The allocations are expressed as an equation rather than an absolute number: allocation = flow contribution from a given source x 65 mg/L (or NPDES permit concentration). See *Municipal and Industrial Wastewater* (Section 5.4.1) for more detail.

[b] Unable to calculate allocations because the wastewater WLA exceeds the loading capacity. The allocations are expressed as an equation rather than an absolute number: allocation = flow contribution from a given source x 65 mg/L. See Sections 5.4.2 and 5.6 for more detail.

Watonwan River, South Fork (07020010-517)

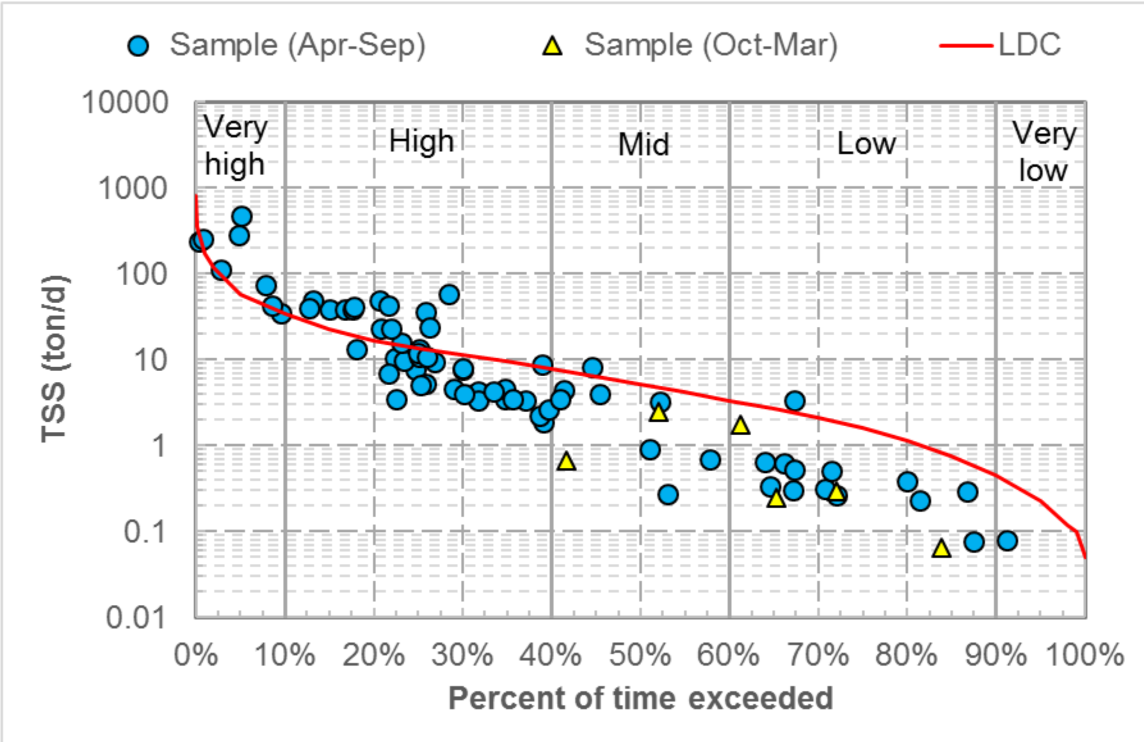


Figure D-36. TSS load duration curve, Watonwan River, South Fork (07020010-517).

Table D-36. TSS TMDL summary, Watonwan River, South Fork (07020010-517)

TMDL Parameter	**Flow Regimes**				
	Very High	**High**	**Mid**	**Low**	**Very Low**
	TSS Load (ton/d)				
WLA: Industrial/Construction Stormwater	0.10	0.025	0.0092	0.0027	0.00024
WLA: Wastewater	0.087	0.087	0.087	0.087	0.087
Load Allocation	52	12	4.6	1.4	0.12
Margin of Safety	5.8	1.4	0.52	0.16	0.023
Loading Capacity	58	13.5	5.2	1.6	0.22
Existing Concentration (mg/L)	132				
Percent Reduction to Achieve Concentration Standard	51%				

Perch Creek (07020010-524)

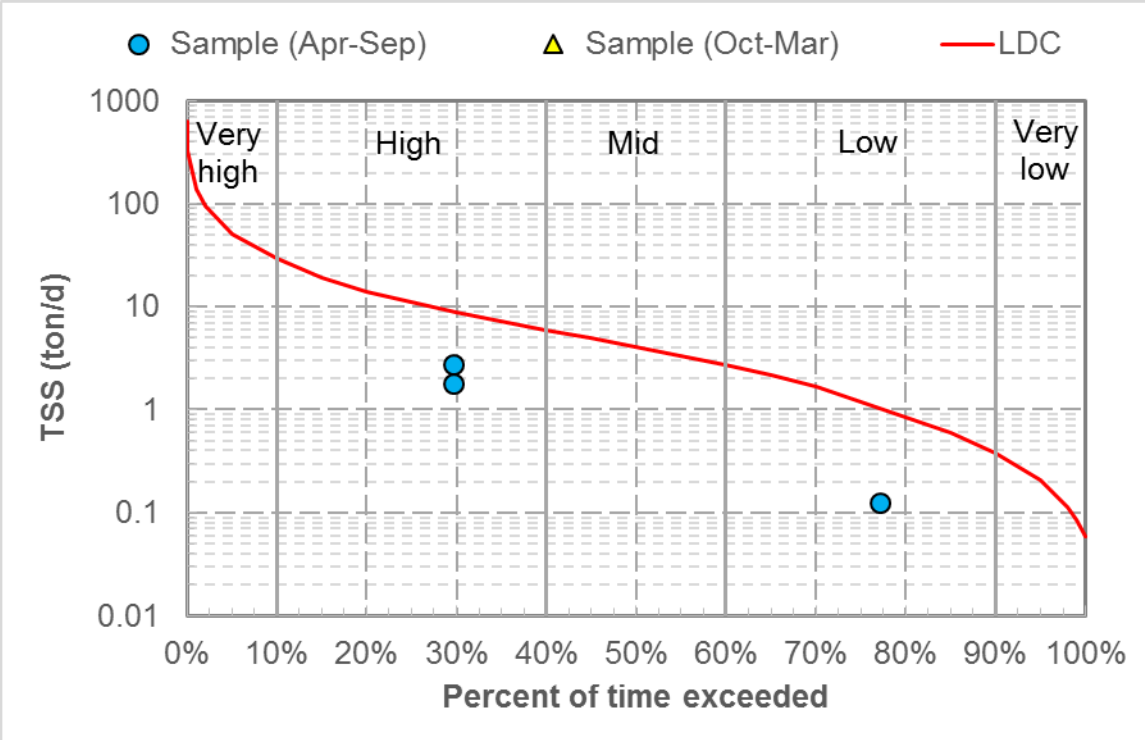


Figure D-37. TSS load duration curve, Perch Creek (07020010-524).

Table D-37. TSS TMDL summary, Perch Creek (07020010-524)

TMDL Parameter	Flow Regimes				
	Very High	High	Mid	Low	Very Low
	TSS Load (ton/d)				
WLA: Industrial/Construction Stormwater	0.092	0.020	0.0070	0.0019	0.00017
WLA: Wastewater	0.10	0.10	0.10	0.10	0.10
Load Allocation	46	9.7	3.5	0.95	0.087
Margin of Safety	5.1	1.1	0.40	0.12	0.021
Loading Capacity	51	11	4.0	1.2	0.21
Existing Concentration (mg/L)	–[a]				
Percent Reduction to Achieve Concentration Standard	–[a]				

a. N < 10; existing concentration and percent reduction not calculated.

St. James Creek (07020010-528)

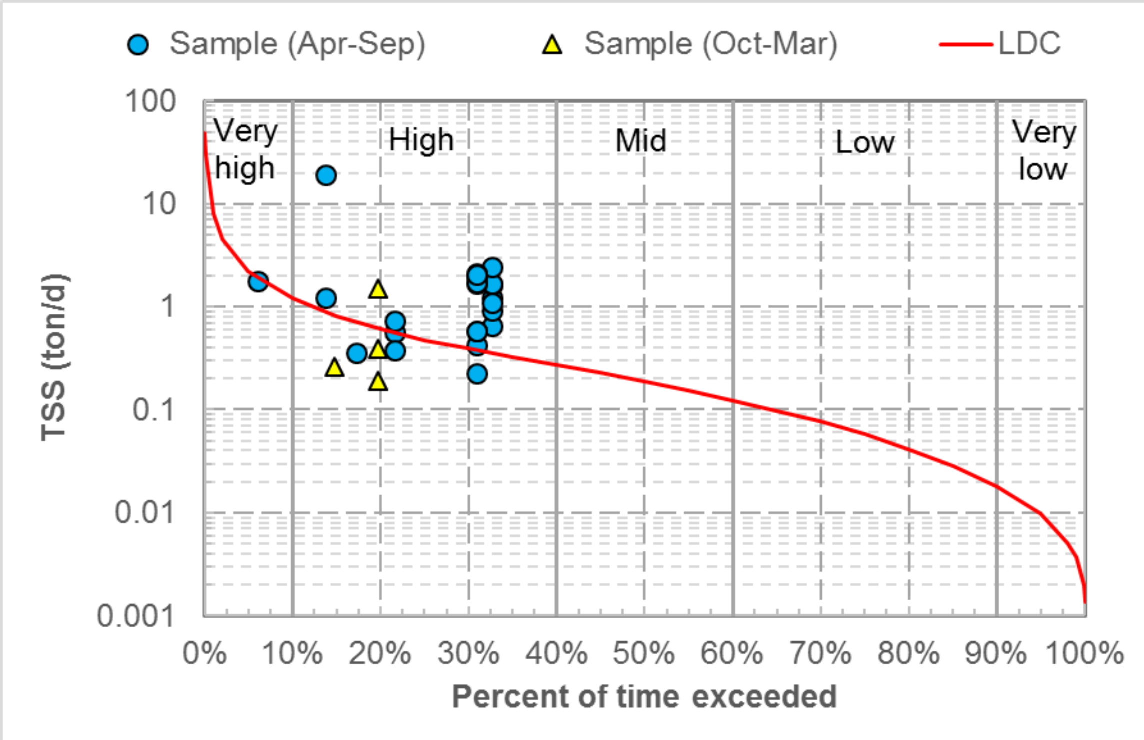


Figure D-38. TSS load duration curve, St. James Creek (07020010-528).

Table D-38. TSS TMDL summary, St. James Creek (07020010-528)

TMDL Parameter	Flow Regimes				
	Very High	**High**	**Mid**	**Low**	**Very Low**
	TSS Load (ton/d)				
WLA: Industrial/Construction Stormwater	0.0040	0.00085	0.00034	0.00010	0.000018
Load Allocation	2.0	0.42	0.17	0.052	0.0087
Margin of Safety	0.22	0.047	0.019	0.0058	0.00097
Loading Capacity	2.2	0.47	0.19	0.058	0.0097
Existing Concentration (mg/L)	– [a]				
Percent Reduction to Achieve Concentration Standard	– [a]				

[a] No data in the TMDL period (2006–2015); data in Figure D-38 are from 1992.

Watonwan River, South Fork (07020010-547)

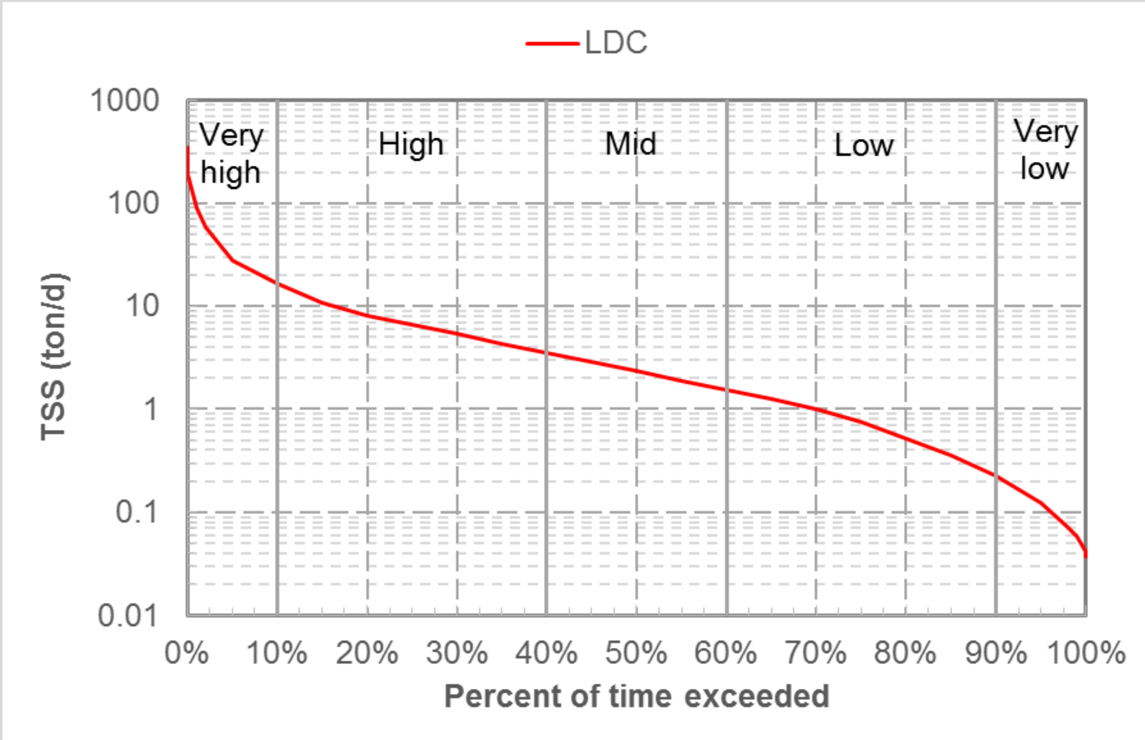


Figure D-39. TSS load duration curve, Watonwan River, South Fork (07020010-547).

Table D-39. TSS TMDL summary, Watonwan River, South Fork (07020010-547)

TMDL Parameter	Flow Regimes				
	Very High	High	Mid	Low	Very Low
	TSS Load (ton/d)				
WLA: Industrial/Construction Stormwater	0.050	0.012	0.0041	0.0012	0.000049
WLA: Wastewater	0.078	0.078	0.078	0.078	0.078
Load Allocation	25	5.8	2.1	0.59	0.024
Margin of Safety	2.8	0.66	0.24	0.075	0.012
Loading Capacity	28	6.6	2.4	0.74	0.11
Existing Concentration (mg/L)	– [a]				
Percent Reduction to Achieve Concentration Standard	– [a]				

[a] N < 10; existing concentration and percent reduction not calculated.

Watonwan River (07020010-562)

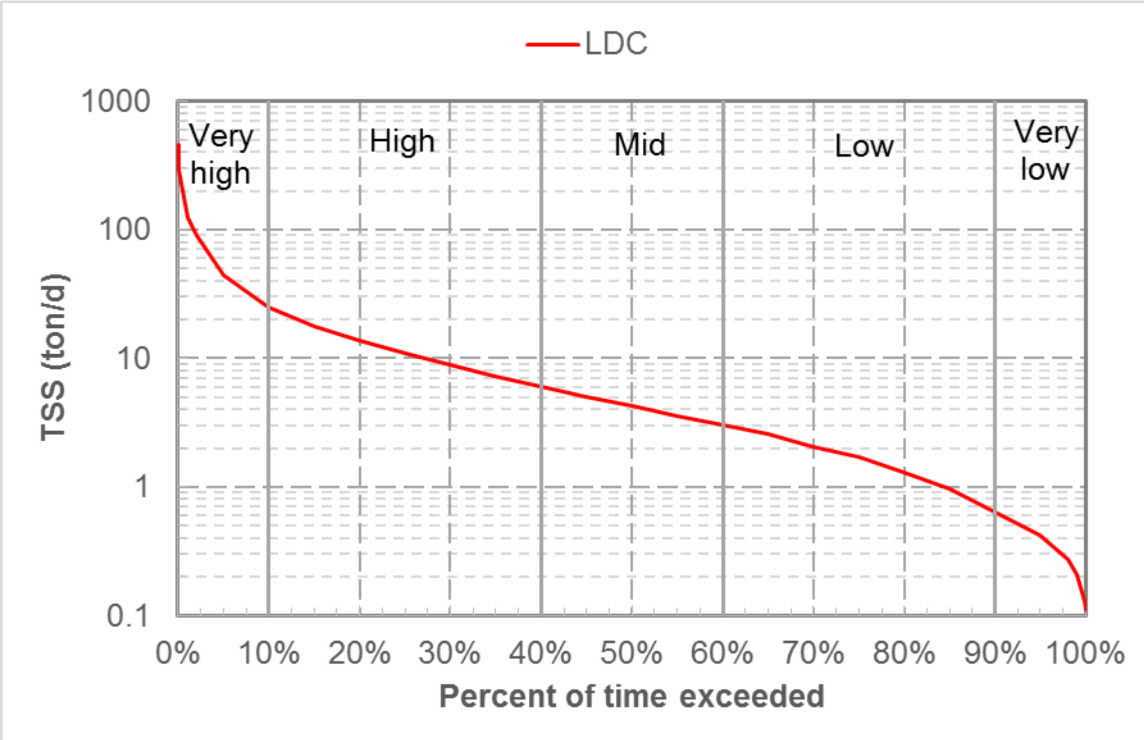


Figure D-40. TSS load duration curve, Watonwan River (07020010-562).

Table D-40. TSS TMDL summary, Watonwan River (07020010-562)

TMDL Parameter	Flow Regimes				
	Very High	High	Mid	Low	Very Low
	TSS Load (ton/d)				
WLA: Industrial/Construction Stormwater	0.077	0.018	0.0061	0.0015	– [b]
WLA: Wastewater	0.77	0.77	0.77	0.77	– [a]
Load Allocation	39	9.0	3.0	0.75	– [b]
Margin of Safety	4.4	1.1	0.42	0.17	0.043
Loading Capacity	44	11	4.2	1.7	0.43
Existing Concentration (mg/L)	– [c]				
Percent Reduction to Achieve Concentration Standard	– [c]				

[a] Permitted wastewater design flows exceed stream flow in the indicated flow zone(s). The allocations are expressed as an equation rather than an absolute number: allocation = flow contribution from a given source x 65 mg/L (or NPDES permit concentration). See *Municipal and Industrial Wastewater* (Section 5.4.1) for more detail.
[b] Unable to calculate allocations because the wastewater WLA exceeds the loading capacity. The allocations are expressed as an equation rather than an absolute number: allocation = flow contribution from a given source x 65 mg/L. See Sections 5.4.2 and 5.6 for more detail.

[c] N < 10; existing concentration and percent reduction not calculated.

Watonwan River (07020010-563)

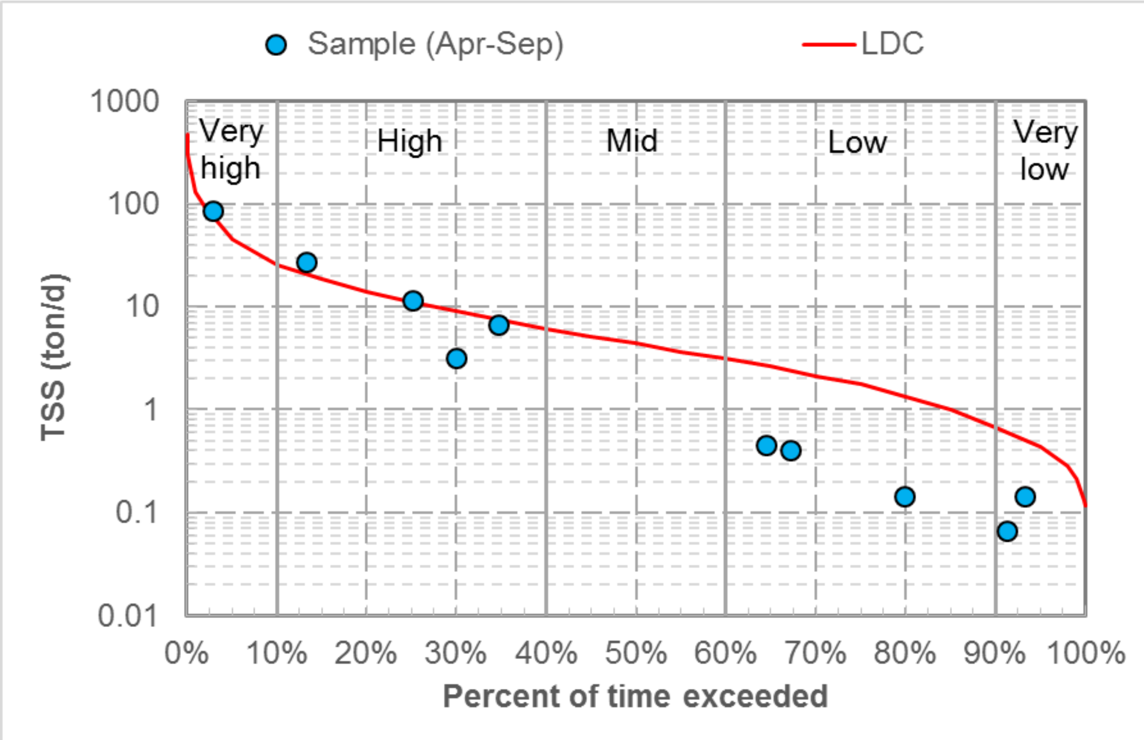


Figure D-41. TSS load duration curve, Watonwan River (07020010-563).

Table D-41. TSS TMDL summary, Watonwan River (07020010-563)

TMDL Parameter	Flow Regimes				
	Very High	**High**	**Mid**	**Low**	**Very Low**
	TSS Load (ton/d)				
WLA: Industrial/Construction Stormwater	0.080	0.019	0.0063	0.0016	– [b]
WLA: Wastewater	0.78	0.78	0.78	0.78	– [a]
Load Allocation	40	9.3	3.2	0.80	– [b]
Margin of Safety	4.5	1.1	0.44	0.18	0.044
Loading Capacity	45	11	4.4	1.8	0.44
Existing Concentration (mg/L)	79				
Percent Reduction to Achieve Concentration Standard	17%				

[a] Permitted wastewater design flows exceed stream flow in the indicated flow zone(s). The allocations are expressed as an equation rather than an absolute number: allocation = flow contribution from a given source x 65 mg/L (or NPDES permit concentration). See *Municipal and Industrial Wastewater* (Section 5.4.1) for more detail.

[b] Unable to calculate allocations because the wastewater WLA exceeds the loading capacity. The allocations are expressed as an equation rather than an absolute number: allocation = flow contribution from a given source x 65 mg/L. See Sections 5.4.2 and 5.6 for more detail.

Watonwan River, North Fork (07020010-564)

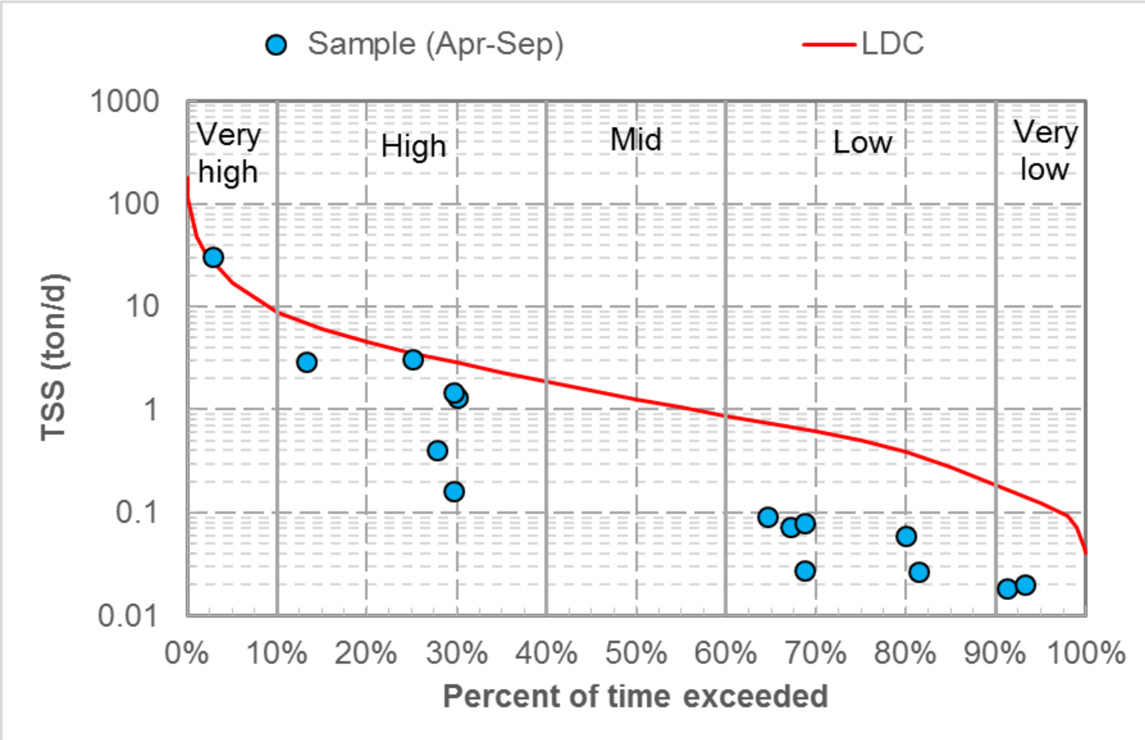


Figure D-42. TSS load duration curve, Watonwan River, North Fork (07020010-564).

Table D-42. TSS TMDL summary, Watonwan River, North Fork (07020010-564)

TMDL Parameter	Flow Regimes				
	Very High	**High**	**Mid**	**Low**	**Very Low**
	TSS Load (ton/d)				
WLA: Industrial/Construction Stormwater	0.031	0.0064	0.0023	0.00090	0.00022
Load Allocation	15	3.2	1.2	0.45	0.11
Margin of Safety	1.7	0.36	0.13	0.050	0.012
Loading Capacity	17	3.6	1.3	0.50	0.12
Existing Concentration (mg/L)	47				
Percent Reduction to Achieve Concentration Standard	– [a]				

[a] This impairment was originally listed in 2004 based on turbidity data; however, the TSS data presented in this report do not show impairment. The MPCA will reevaluate the reach in the next impairment assessment for this watershed.

Watonwan River (07020010-566)

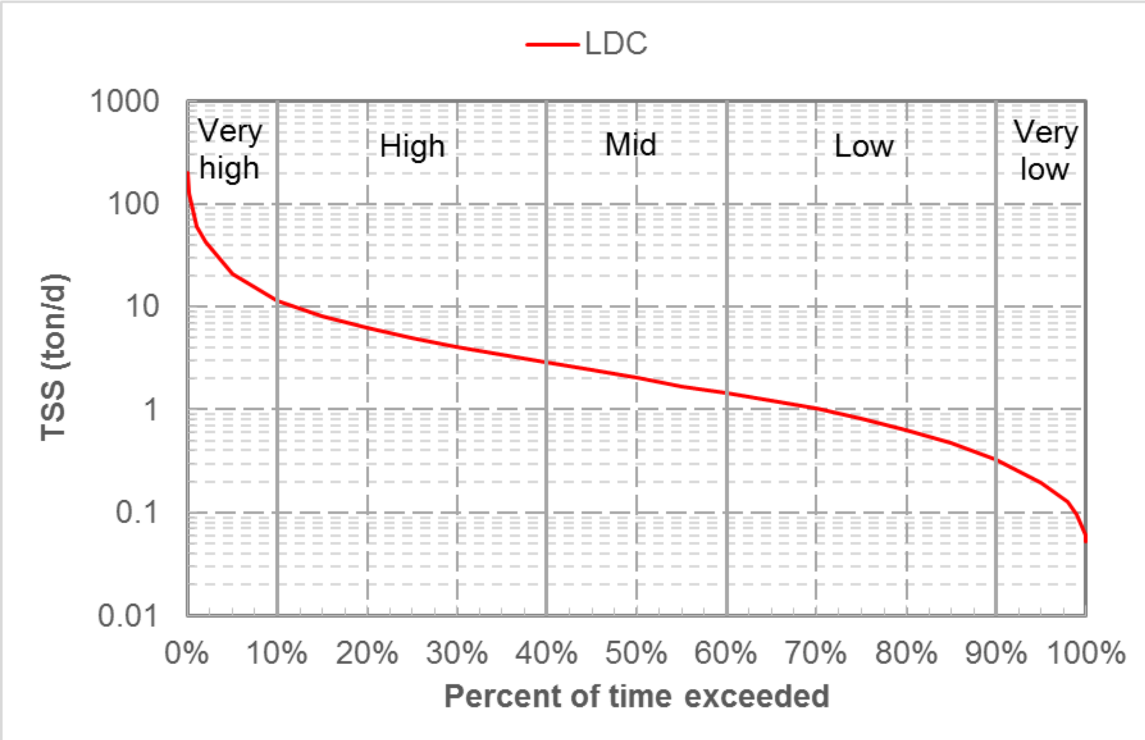


Figure D-43. TSS load duration curve, Watonwan River (07020010-566).

Table D-43. TSS TMDL summary, Watonwan River (07020010-566)

TMDL Parameter	Flow Regimes				
	Very High	High	Mid	Low	Very Low
	TSS Load (ton/d)				
WLA: Industrial/Construction Stormwater	0.036	0.0073	0.0022	– [b]	– [b]
WLA: Wastewater	0.77	0.77	0.77	– [a]	– [a]
Load Allocation	18	3.6	1.1	– [b]	– [b]
Margin of Safety	2.1	0.49	0.21	0.081	0.020
Loading Capacity	21	4.9	2.1	0.81	0.20
Existing Concentration (mg/L)	– [c]				
Percent Reduction to Achieve Concentration Standard	– [c]				

[a] Permitted wastewater design flows exceed stream flow in the indicated flow zone(s). The allocations are expressed as an equation rather than an absolute number: allocation = flow contribution from a given source x 65 mg/L (or NPDES permit concentration). See *Municipal and Industrial Wastewater* (Section 5.4.1) for more detail.

[b] Unable to calculate allocations because the wastewater WLA exceeds the loading capacity. The allocations are expressed as an equation rather than an absolute number: allocation = flow contribution from a given source x 65 mg/L. See Sections 5.4.2 and 5.6 for more detail.

[c] N < 10; existing concentration and percent reduction not calculated.

Watonwan River (07020010-567)

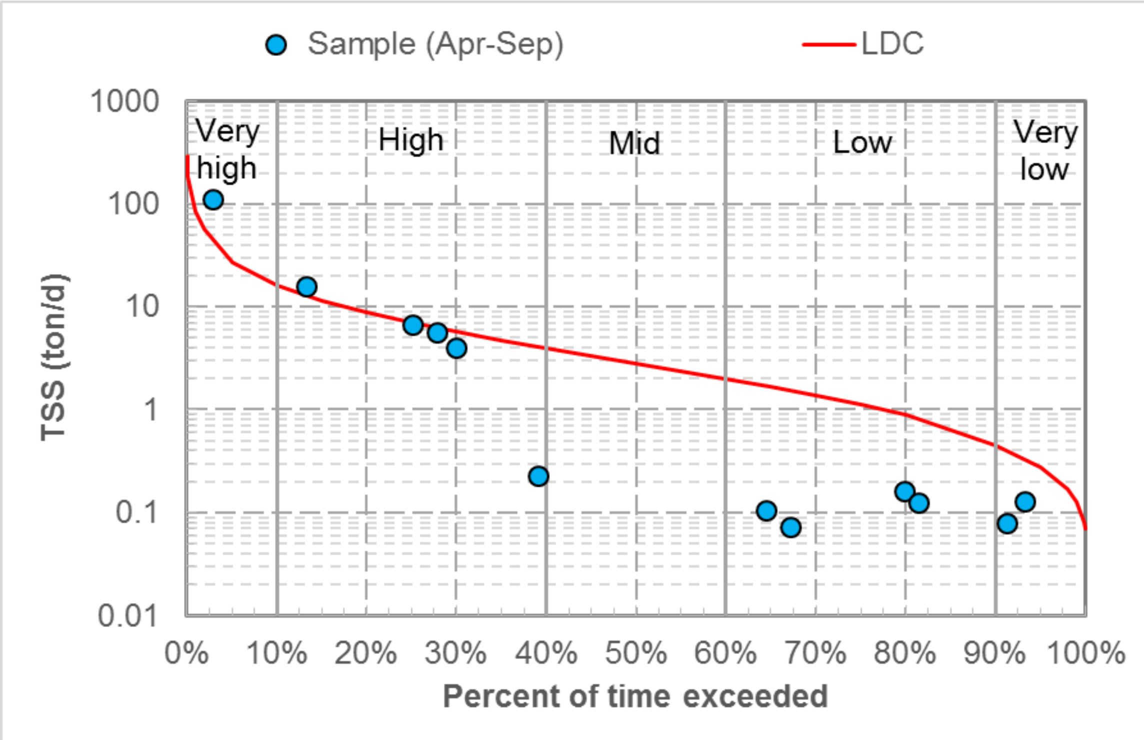


Figure D-44. TSS load duration curve, Watonwan River (07020010-567).

Table D-44. TSS TMDL summary, Watonwan River (07020010-567)

TMDL Parameter	Flow Regimes				
	Very High	High	Mid	Low	Very Low
	TSS Load (ton/d)				
WLA: Industrial/Construction Stormwater	0.048	0.011	0.0036	0.00048	– [b]
WLA: Wastewater	0.77	0.77	0.77	0.77	– [a]
Load Allocation	23	5.4	1.7	0.24	– [b]
Margin of Safety	2.7	0.69	0.28	0.11	0.028
Loading Capacity	27	6.9	2.8	1.1	0.28
Existing Concentration (mg/L)	81				
Percent Reduction to Achieve Concentration Standard	20%				

[a] Permitted wastewater design flows exceed stream flow in the indicated flow zone(s). The allocations are expressed as an equation rather than an absolute number: allocation = flow contribution from a given source x 65 mg/L (or NPDES permit concentration). See *Municipal and Industrial Wastewater* (Section 5.4.1) for more detail.

[b] Unable to calculate allocations because the wastewater WLA exceeds the loading capacity. The allocations are expressed as an equation rather than an absolute number: allocation = flow contribution from a given source x 65 mg/L. See Sections 5.4.2 and 5.6 for more detail.

D8. Le Sueur (HUC 07020011)

Le Sueur River (07020011-501)

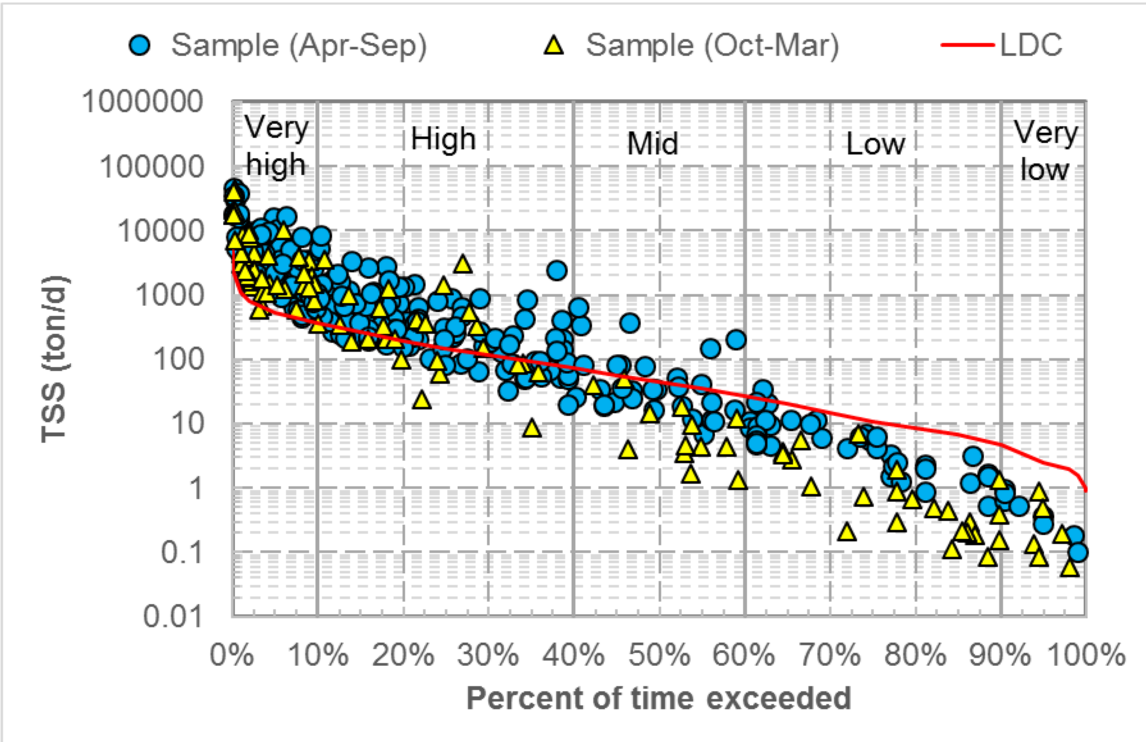


Figure D-45. TSS load duration curve, Le Sueur River (07020011-501).

Table D-45. TSS TMDL summary, Le Sueur River (07020011-501)

TMDL Parameter	Flow Regimes				
	Very High	High	Mid	Low	Very Low
	TSS Load (ton/d)				
WLA: MnDOT Outstate MS4 [a]	0.11	0.041	0.017	0.0072	0.0024
WLA: City, County, and/or Township MS4 [a]	2.13	0.79	0.32	0.15	0.070
WLA: Industrial/Construction Stormwater	0.95	0.26	0.067	0.0072	– [c]
WLA: Wastewater	6.2	6.2	6.2	6.2	– [b]
Load Allocation	472.7	127	33	3.6	– [c]
Margin of Safety	54	15	4.4	1.1	0.25
Loading Capacity	536	149	44	11	2.5
Existing Concentration (mg/L)	592				
Percent Reduction to Achieve Concentration Standard	89%				

[a] To meet the WLAs for permitted MS4s, TSS loading does not need to be reduced but is not allowed to increase.

[b] Permitted wastewater design flows exceed stream flow in the indicated flow zone(s). The allocations are expressed as an equation rather than an absolute number: allocation = flow contribution from a given source x 65 mg/L (or NPDES permit concentration). See *Municipal and Industrial Wastewater* (Section 5.4.1) for more detail.

[c] Unable to calculate allocations because the wastewater WLA exceeds the loading capacity. The allocations are expressed as an equation rather than an absolute number: allocation = flow contribution from a given source x 65 mg/L. See Sections 5.4.2 and 5.6 for more detail.

Unnamed creek (Little Beauford Ditch; 07020011-503)*

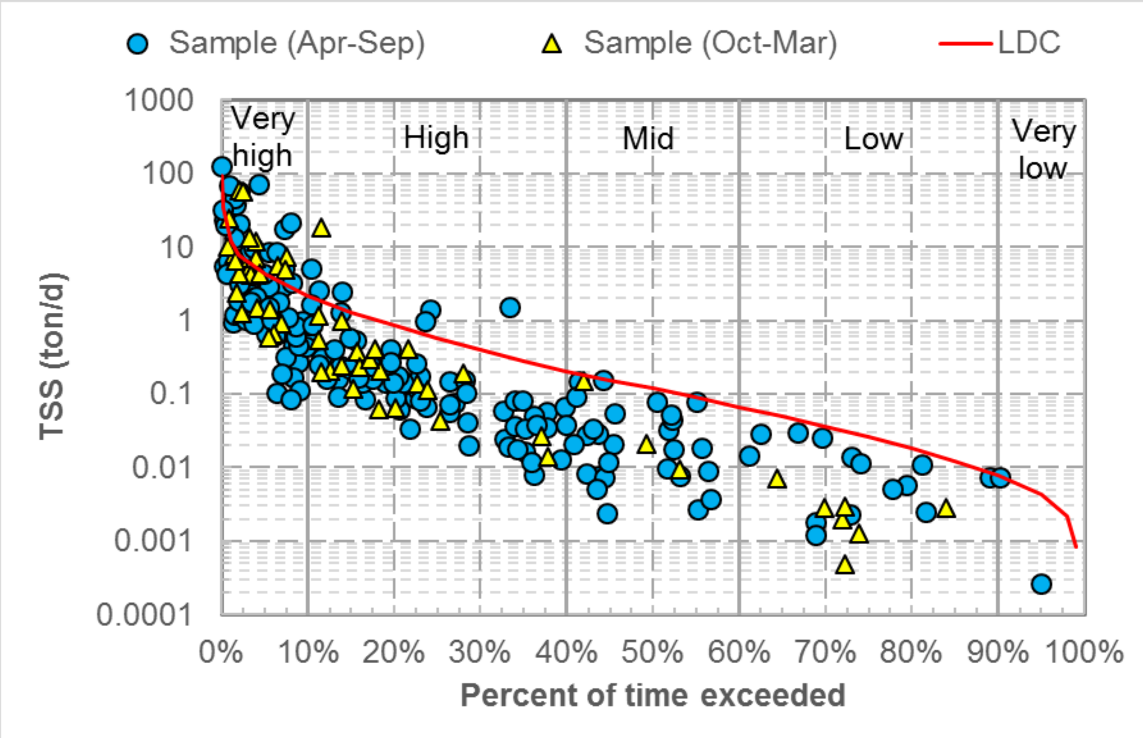


Figure D-46. TSS load duration curve, Unnamed creek (Little Beauford Ditch; 07020011-503).

Table D-46. TSS TMDL summary, Unnamed creek (Little Beauford Ditch; 07020011-503)

TMDL Parameter	Flow Regimes				
	Very High	High	Mid	Low	Very Low
	TSS Load (ton/d)				
WLA: Industrial/Construction Stormwater	0.0076	0.0010	0.00021	0.000046	0.0000076
Load Allocation	3.8	0.52	0.11	0.023	0.0038
Margin of Safety	0.42	0.058	0.012	0.0026	0.00042
Loading Capacity	4.2	0.58	0.12	0.026	0.0042
Existing Concentration (mg/L)	90				
Percent Reduction to Achieve Concentration Standard	28%				

* AUID 07020011-503 has been split into child AUIDs 07020011-642 and 07020011-643. These child AUIDs will be proposed for the 2020 303(d) Impaired Waters List. The allocations in the above table address the impairments for both reaches.

Little Cobb River (07020011-504)

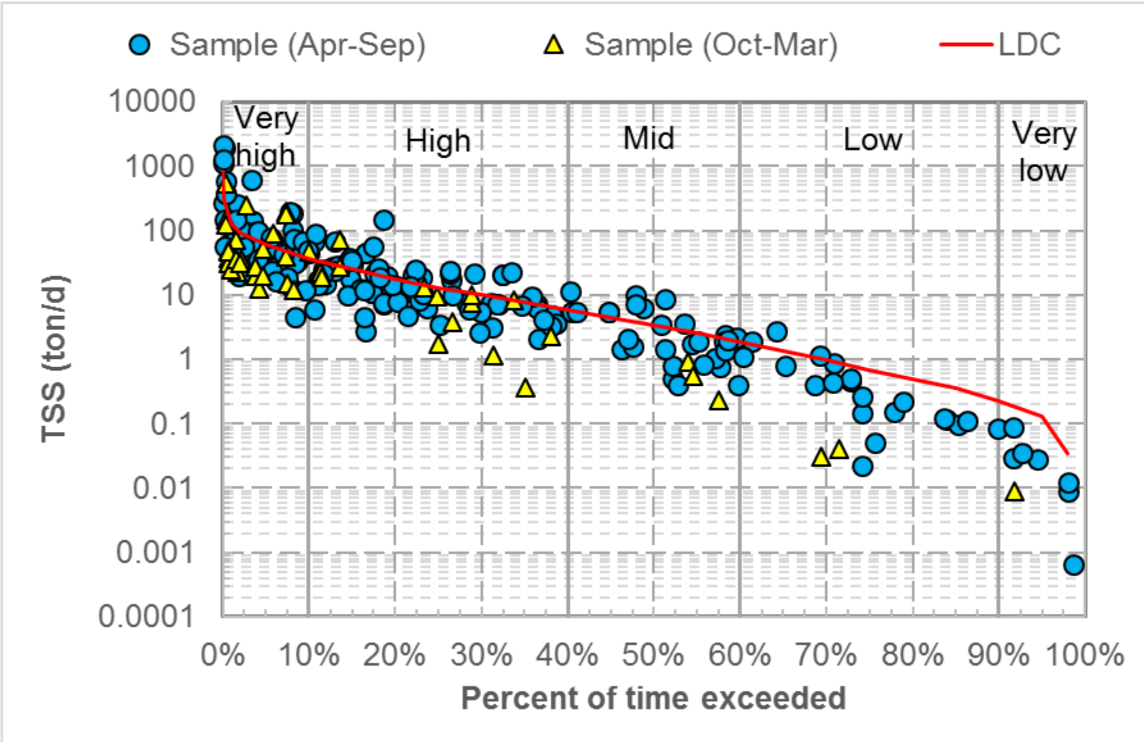


Figure D-47. TSS load duration curve, Little Cobb River (07020011-504).

Table D-47. TSS TMDL summary, Little Cobb River (07020011-504)

TMDL Parameter	Flow Regimes				
	Very High	High	Mid	Low	Very Low
	TSS Load (ton/d)				
WLA: Industrial/Construction Stormwater	0.11	0.023	0.0058	0.00096	– [b]
WLA: Wastewater	0.13	0.13	0.13	0.13	– [a]
Load Allocation	54	12	2.9	0.48	– [b]
Margin of Safety	6.0	1.3	0.34	0.068	0.013
Loading Capacity	60	13	3.4	0.68	0.13
Existing Concentration (mg/L)	128				
Percent Reduction to Achieve Concentration Standard	49%				

[a] Permitted wastewater design flows exceed stream flow in the indicated flow zone(s). The allocations are expressed as an equation rather than an absolute number: allocation = flow contribution from a given source x 65 mg/L (or NPDES permit concentration). See *Municipal and Industrial Wastewater* (Section 5.4.1) for more detail.

[b] Unable to calculate allocations because the wastewater WLA exceeds the loading capacity. The allocations are expressed as an equation rather than an absolute number: allocation = flow contribution from a given source x 65 mg/L. See Sections 5.4.2 and 5.6 for more detail.

Le Sueur River (07020011-506)

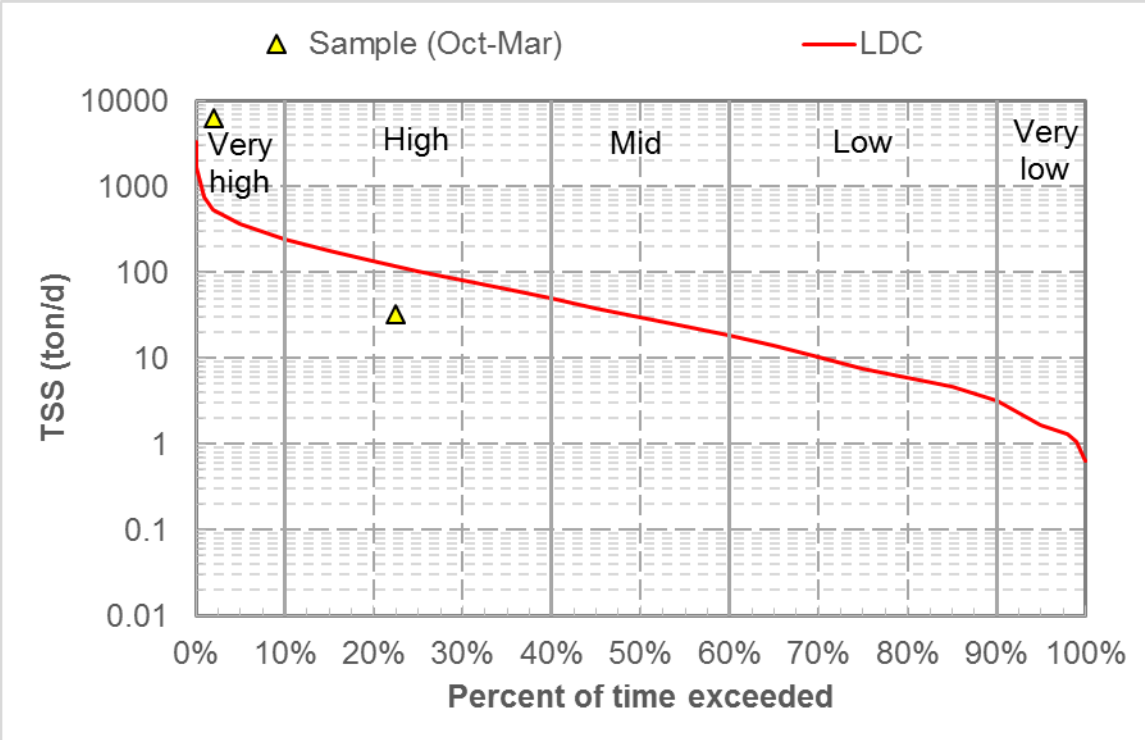


Figure D-48. TSS load duration curve, Le Sueur River (07020011-506).

Table D-48. TSS TMDL summary, Le Sueur River (07020011-506)

TMDL Parameter	Flow Regimes				
	Very High	High	Mid	Low	Very Low
	TSS Load (ton/d)				
WLA: MnDOT Outstate MS4 [a]	0.11	0.041	0.017	0.0072	0.0024
WLA: City, County, and/or Township MS4 [a]	2.04	0.76	0.31	0.14	0.067
WLA: Industrial/Construction Stormwater	0.66	0.18	0.049	0.0083	– [c]
WLA: Wastewater	2.6	2.6	2.6	2.6	– [b]
Load Allocation	324.6	88.5	24	3.9	– [c]
Margin of Safety	37	10	3.0	0.74	0.17
Loading Capacity	367	102	30	7.4	1.7
Existing Concentration (mg/L)	– [d]				
Percent Reduction to Achieve Concentration Standard	– [d]				

[a] To meet the WLAs for permitted MS4s, TSS loading does not need to be reduced but is not allowed to increase.

[b] Permitted wastewater design flows exceed stream flow in the indicated flow zone(s). The allocations are expressed as an equation rather than an absolute number: allocation = flow contribution from a given source x 65 mg/L (or NPDES permit concentration). See *Municipal and Industrial Wastewater* (Section 5.4.1) for more detail.

[c] Unable to calculate allocations because the wastewater WLA exceeds the loading capacity. The allocations are expressed as an equation rather than an absolute number: allocation = flow contribution from a given source x 65 mg/L. See Sections 5.4.2 and 5.6 for more detail.

[d] N < 10; existing concentration and percent reduction not calculated.

Le Sueur River (07020011-507)

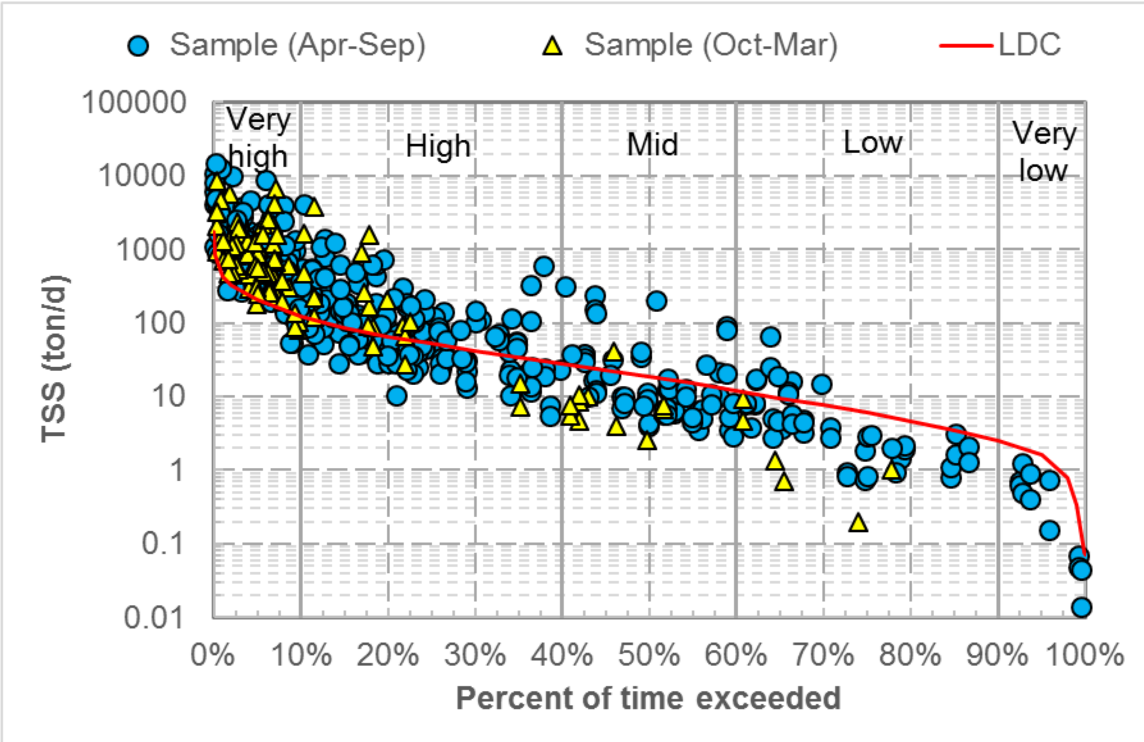


Figure D-49. TSS load duration curve, Le Sueur River (07020011-507).

Table D-49. TSS TMDL summary, Le Sueur River (07020011-507)

TMDL Parameter	Flow Regimes				
	Very High	High	Mid	Low	Very Low
	TSS Load (ton/d)				
WLA: MnDOT Outstate MS4 [a]	0.11	0.041	0.017	0.0072	0.0024
WLA: City, County, and/or Township MS4 [a]	2.04	0.76	0.31	0.14	0.067
WLA: Industrial/Construction Stormwater	0.36	0.091	0.030	0.0073	– [c]
WLA: Wastewater	1.7	1.7	1.7	1.7	– [b]
Load Allocation	178.8	44.2	15	3.5	– [c]
Margin of Safety	20	5.2	1.9	0.60	0.16
Loading Capacity	203	52	19	6.0	1.6
Existing Concentration (mg/L)	476				
Percent Reduction to Achieve Concentration Standard	86%				

[a] To meet the WLAs for permitted MS4s, TSS loading does not need to be reduced but is not allowed to increase.

[b] Permitted wastewater design flows exceed stream flow in the indicated flow zone(s). The allocations are expressed as an equation rather than an absolute number: allocation = flow contribution from a given source x 65 mg/L (or NPDES permit concentration). See *Municipal and Industrial Wastewater* (Section 5.4.1) for more detail.

[c] Unable to calculate allocations because the wastewater WLA exceeds the loading capacity. The allocations are expressed as an equation rather than an absolute number: allocation = flow contribution from a given source x 65 mg/L. See Sections 5.4.2 and 5.6 for more detail.

Rice Creek (07020011-531)

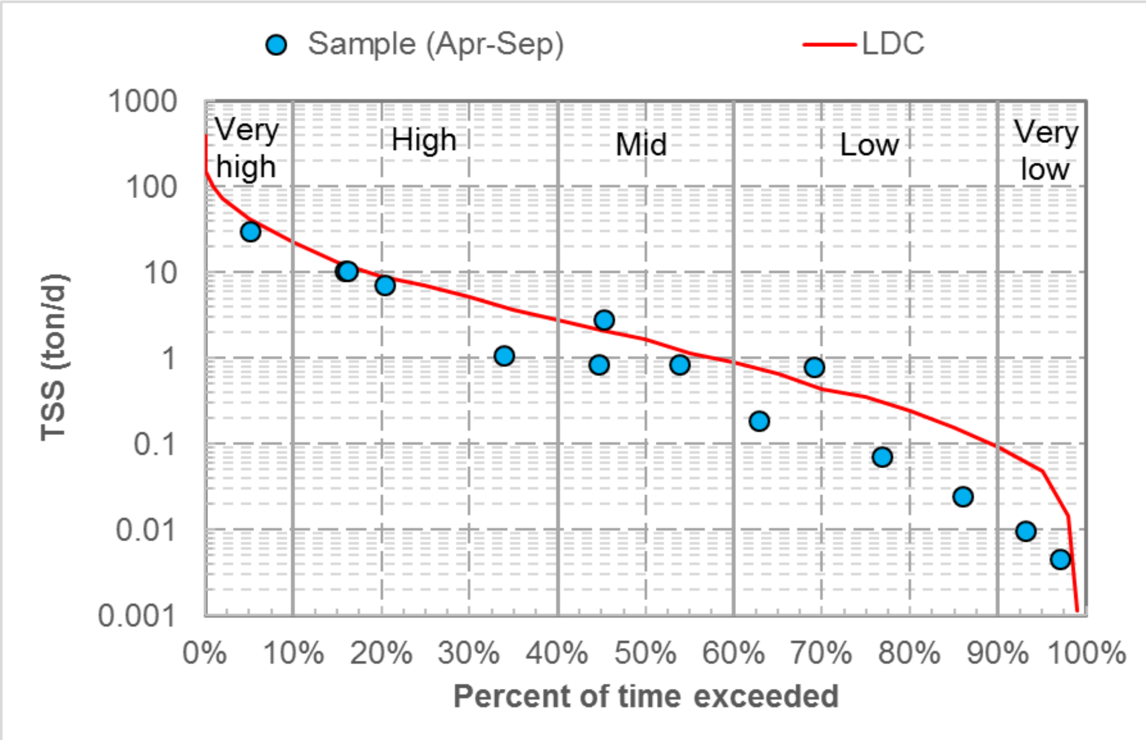


Figure D-50. TSS load duration curve, Rice Creek (07020011-531).

Table D-50. TSS TMDL summary, Rice Creek (07020011-531)

TMDL Parameter	Flow Regimes				
	Very High	High	Mid	Low	Very Low
	TSS Load (ton/d)				
WLA: Industrial/Construction Stormwater	0.075	0.012	0.0028	0.00047	– [b]
WLA: Wastewater	0.076	0.076	0.076	0.076	– [a]
Load Allocation	38	6.2	1.5	0.24	– [b]
Margin of Safety	4.2	0.70	0.17	0.035	0.0048
Loading Capacity	42	7.0	1.7	0.35	0.048
Existing Concentration (mg/L)	79				
Percent Reduction to Achieve Concentration Standard	17%				

[a] Permitted wastewater design flows exceed stream flow in the indicated flow zone(s). The allocations are expressed as an equation rather than an absolute number: allocation = flow contribution from a given source x 65 mg/L (or NPDES permit concentration). See *Municipal and Industrial Wastewater* (Section 5.4.1) for more detail.

[b] Unable to calculate allocations because the wastewater WLA exceeds the loading capacity. The allocations are expressed as an equation rather than an absolute number: allocation = flow contribution from a given source x 65 mg/L. See Sections 5.4.2 and 5.6 for more detail.

Maple River (07020011-534)

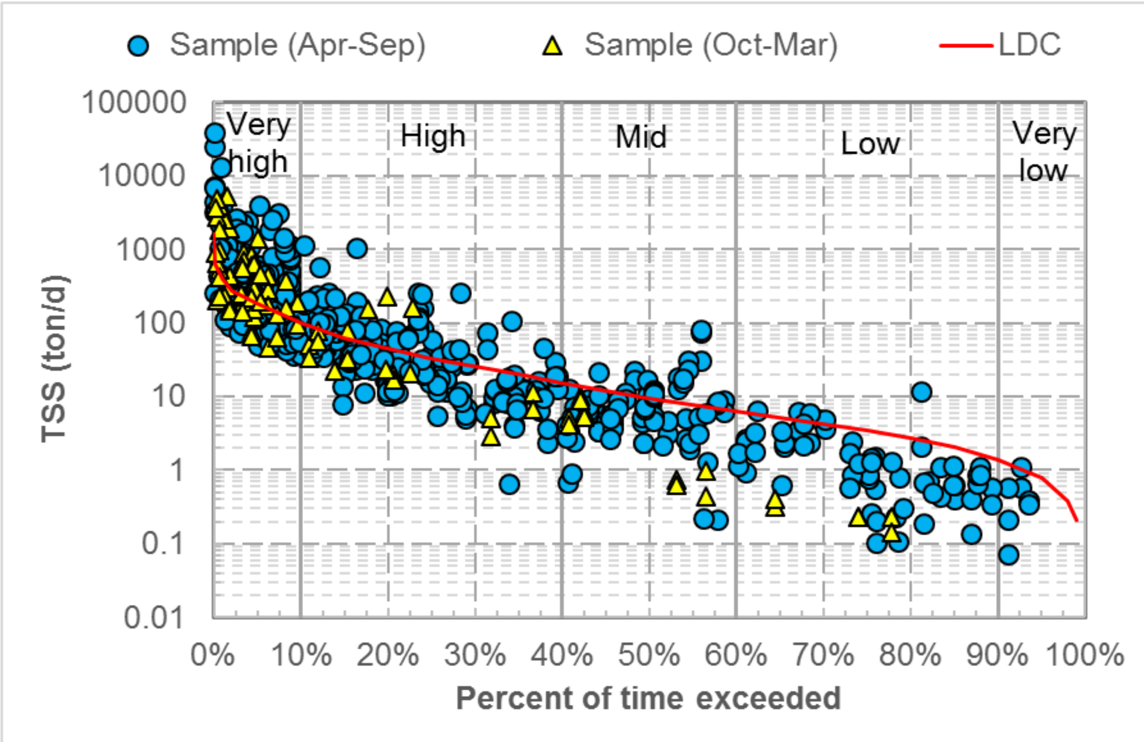


Figure D-51. TSS load duration curve, Maple River (07020011-534).

Table D-51. TSS TMDL summary, Maple River (07020011-534)

TMDL Parameter	Flow Regimes				
	Very High	High	Mid	Low	Very Low
	TSS Load (ton/d)				
WLA: Industrial/Construction Stormwater	0.32	0.053	0.0094	– [b]	– [b]
WLA: Wastewater	3.6	3.6	3.6	– [a]	– [a]
Load Allocation	158	26	4.7	– [b]	– [b]
Margin of Safety	18	3.3	0.92	0.35	0.080
Loading Capacity	180	33	9.2	3.5	0.80
Existing Concentration (mg/L)	293				
Percent Reduction to Achieve Concentration Standard	78%				

[a] Permitted wastewater design flows exceed stream flow in the indicated flow zone(s). The allocations are expressed as an equation rather than an absolute number: allocation = flow contribution from a given source x 65 mg/L (or NPDES permit concentration). See *Municipal and Industrial Wastewater* (Section 5.4.1) for more detail.
[b] Unable to calculate allocations because the wastewater WLA exceeds the loading capacity. The allocations are expressed as an equation rather than an absolute number: allocation = flow contribution from a given source x 65 mg/L. See Sections 5.4.2 and 5.6 for more detail.

Maple River (07020011-535)

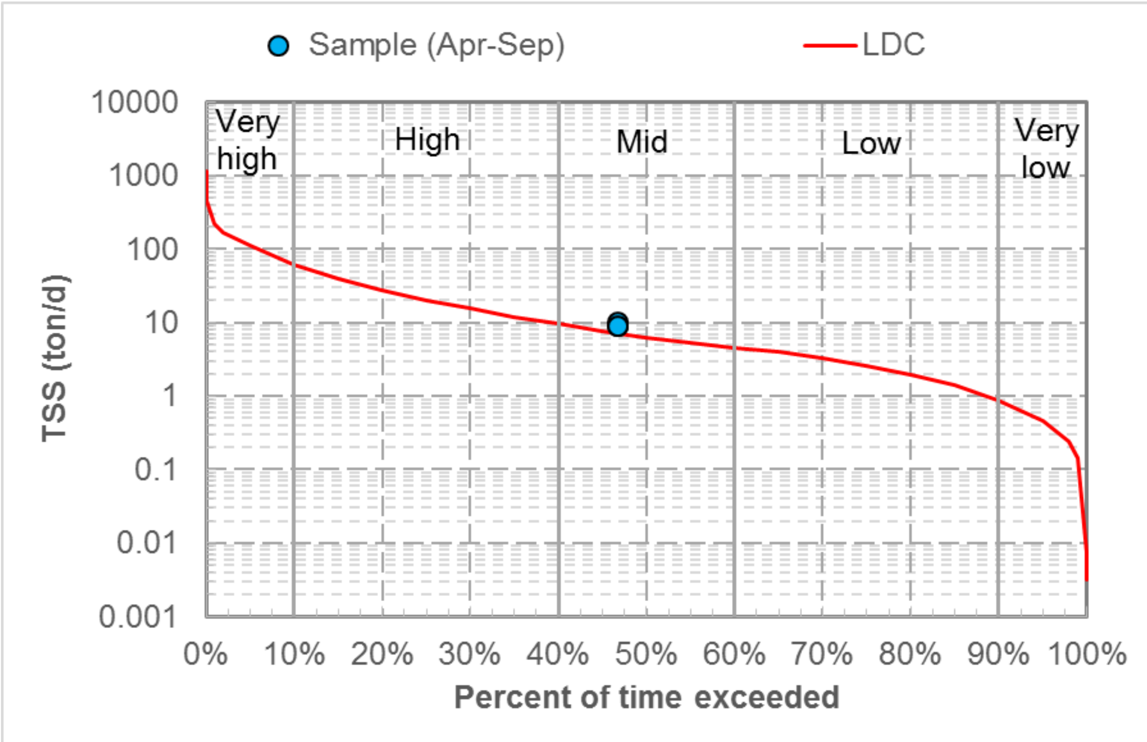


Figure D-52. TSS load duration curve, Maple River (07020011-535).

Table D-52. TSS TMDL summary, Maple River (07020011-535)

TMDL Parameter	Flow Regimes				
	Very High	High	Mid	Low	Very Low
	TSS Load (ton/d)				
WLA: Industrial/Construction Stormwater	0.20	0.031	0.0055	– [b]	– [b]
WLA: Wastewater	2.9	2.9	2.9	– [a]	– [a]
Load Allocation	98	15	2.8	– [b]	– [b]
Margin of Safety	11	2.0	0.63	0.26	0.046
Loading Capacity	112	20	6.3	2.6	0.46
Existing Concentration (mg/L)	– [c]				
Percent Reduction to Achieve Concentration Standard	– [c]				

[a] Permitted wastewater design flows exceed stream flow in the indicated flow zone(s). The allocations are expressed as an equation rather than an absolute number: allocation = flow contribution from a given source x 65 mg/L (or NPDES permit concentration). See *Municipal and Industrial Wastewater* (Section 5.4.1) for more detail.

[b] Unable to calculate allocations because the wastewater WLA exceeds the loading capacity. The allocations are expressed as an equation rather than an absolute number: allocation = flow contribution from a given source x 65 mg/L. See Sections 5.4.2 and 5.6 for more detail.

[c] N < 10; existing concentration and percent reduction not calculated.

County Ditch 3 (07020011-552)*

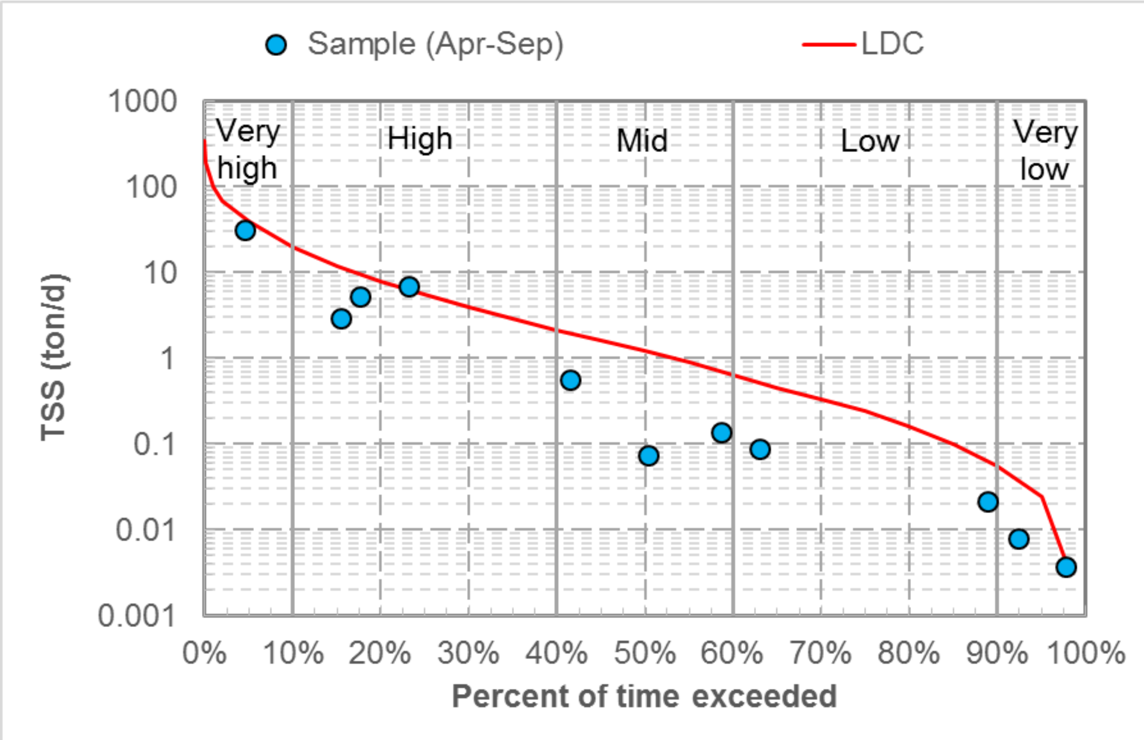


Figure D-53. TSS load duration curve, County Ditch 3 (07020011-552).

Table D-53. TSS TMDL summary, County Ditch 3 (07020011-552)

TMDL Parameter	Flow Regimes				
	Very High	**High**	**Mid**	**Low**	**Very Low**
	TSS Load (ton/d)				
WLA: Industrial/Construction Stormwater	0.071	0.010	0.0022	0.00043	0.000043
Load Allocation	36	4.9	1.1	0.22	0.022
Margin of Safety	4.0	0.55	0.12	0.024	0.0024
Loading Capacity	40	5.5	1.2	0.24	0.024
Existing Concentration (mg/L)	49				
Percent Reduction to Achieve Concentration Standard	– [a]				

[a] This impairment was originally listed in 2004 based on turbidity data; however, the TSS data presented in this report do not show impairment. The MPCA will reevaluate the reach in the next impairment assessment for this watershed.

* AUID 07020011-552 has been split into child AUIDs 07020011-652 and 07020011-653. These child AUIDs will be proposed for the 2020 303(d) Impaired Waters List. The allocations in the above table address the impairments for both reaches.

Cobb River (07020011-556)

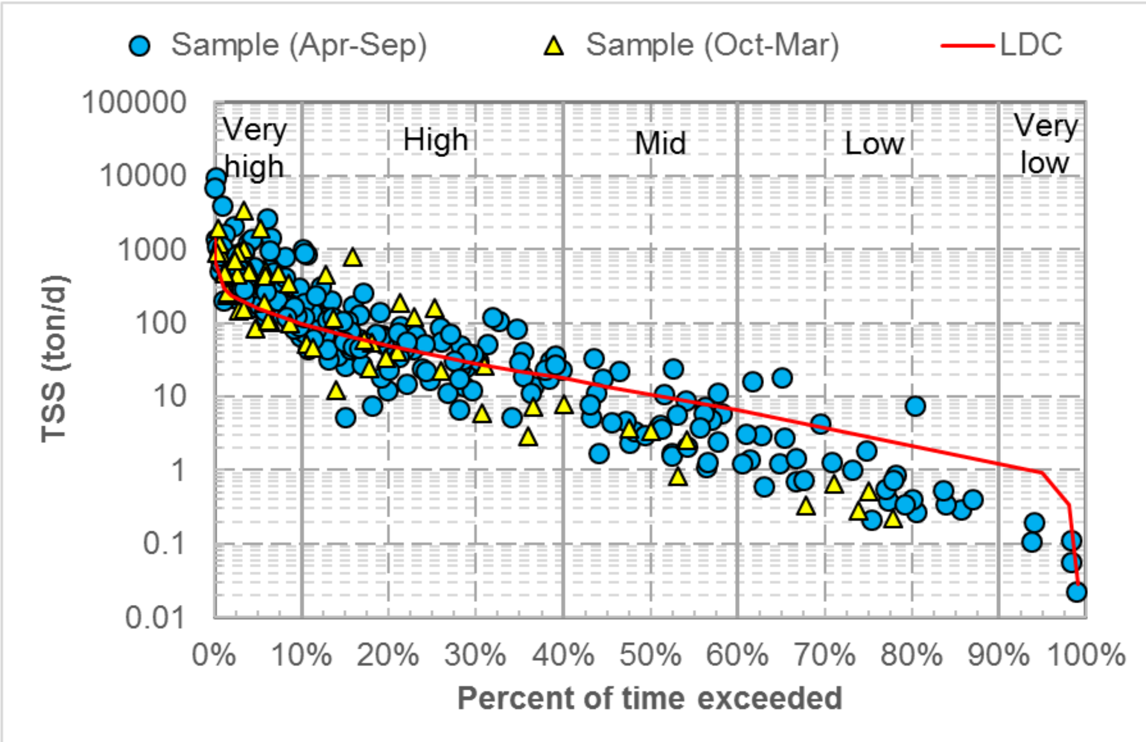


Figure D-54. TSS load duration curve, Cobb River (07020011-556).

Table D-54. TSS TMDL summary, Cobb River (07020011-556)

TMDL Parameter	**Flow Regimes**				
	Very High	**High**	**Mid**	**Low**	**Very Low**
	TSS Load (ton/d)				
WLA: Industrial/Construction Stormwater	0.28	0.064	0.017	0.0034	– [b]
WLA: Wastewater	0.85	0.85	0.85	0.85	– [a]
Load Allocation	138	32	8.6	1.7	– [b]
Margin of Safety	16	3.7	1.1	0.28	0.090
Loading Capacity	155	37	11	2.8	0.90
Existing Concentration (mg/L)	247				
Percent Reduction to Achieve Concentration Standard	74%				

[a] Permitted wastewater design flows exceed stream flow in the indicated flow zone(s). The allocations are expressed as an equation rather than an absolute number: allocation = flow contribution from a given source x 65 mg/L (or NPDES permit concentration). See *Municipal and Industrial Wastewater* (Section 5.4.1) for more detail.
[b] Unable to calculate allocations because the wastewater WLA exceeds the loading capacity. The allocations are expressed as an equation rather than an absolute number: allocation = flow contribution from a given source x 65 mg/L. See Sections 5.4.2 and 5.6 for more detail.

Cobb River (07020011-568)

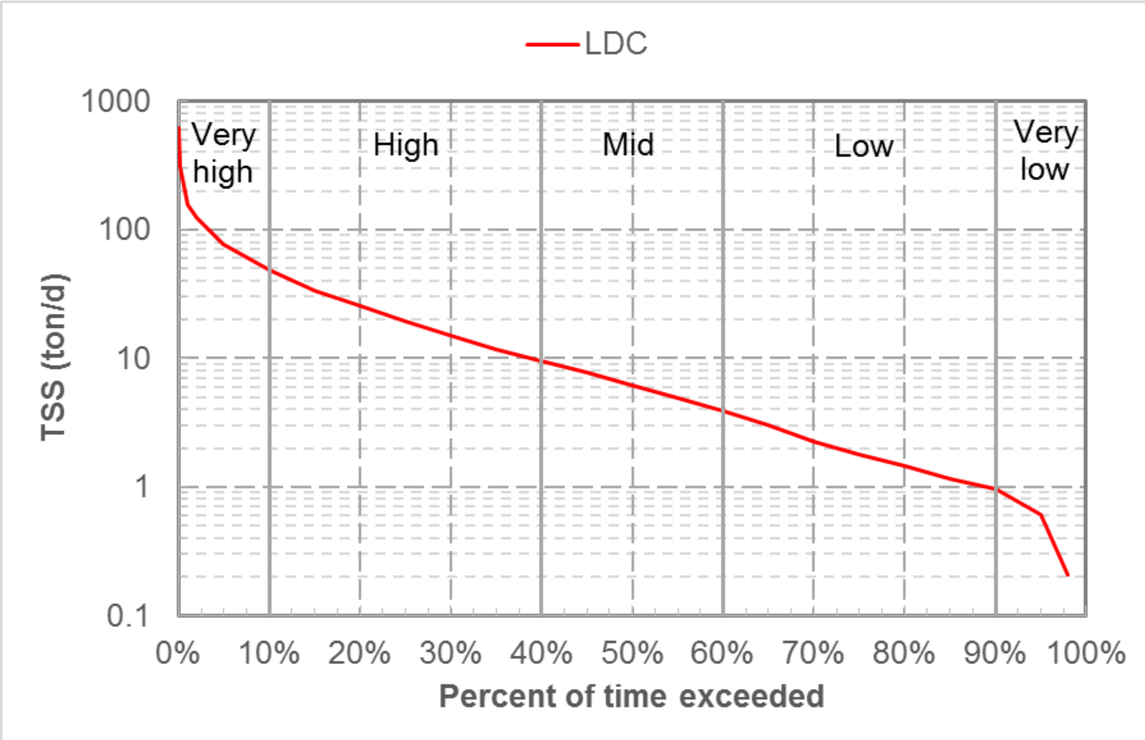


Figure D-55. TSS load duration curve, Cobb River (07020011-568).

Table D-55. TSS TMDL summary, Cobb River (07020011-568)

TMDL Parameter	Flow Regimes				
	Very High	High	Mid	Low	Very Low
	TSS Load (ton/d)				
WLA: Industrial/Construction Stormwater	0.14	0.034	0.0095	0.0018	– [b]
WLA: Wastewater	0.72	0.72	0.72	0.72	– [a]
Load Allocation	68	17	4.8	0.89	– [b]
Margin of Safety	7.6	2.0	0.61	0.18	0.061
Loading Capacity	76	20	6.1	1.8	0.61
Existing Concentration (mg/L)	– [c]				
Percent Reduction to Achieve Concentration Standard	– [c]				

[a] Permitted wastewater design flows exceed stream flow in the indicated flow zone(s). The allocations are expressed as an equation rather than an absolute number: allocation = flow contribution from a given source x 65 mg/L (or NPDES permit concentration). See *Municipal and Industrial Wastewater* (Section 5.4.1) for more detail.

[b] Unable to calculate allocations because the wastewater WLA exceeds the loading capacity. The allocations are expressed as an equation rather than an absolute number: allocation = flow contribution from a given source x 65 mg/L. See Sections 5.4.2 and 5.6 for more detail.

[c] N < 10; existing concentration and percent reduction not calculated.

Le Sueur River (07020011-619)*

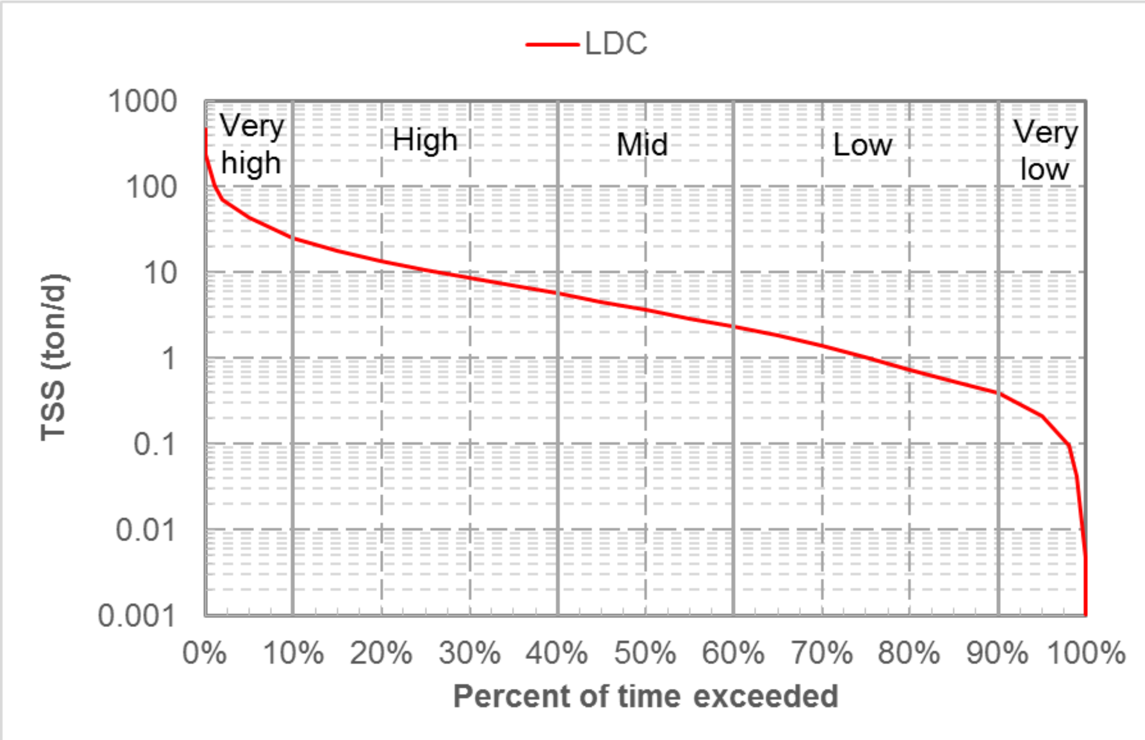


Figure D-56. TSS load duration curve, Le Sueur River (07020011-619).

Table D-56. TSS TMDL summary, Le Sueur River (07020011-619)

TMDL Parameter	Flow Regimes				
	Very High	High	Mid	Low	Very Low
	TSS Load (ton/d)				
WLA: Industrial/Construction Stormwater	0.079	0.019	0.0065	0.0019	0.00038
Load Allocation	40	9.6	3.2	0.93	0.19
Margin of Safety	4.4	1.1	0.36	0.10	0.021
Loading Capacity	44	11	3.6	1.0	0.21
Existing Concentration (mg/L)	– [a]				
Percent Reduction to Achieve Concentration Standard	– [a]				

[a] N < 10; existing concentration and percent reduction not calculated.

* AUID 07020011-619 has been split into child AUIDs 07020011-664 and 07020011-665. These child AUIDs will be proposed for the 2020 303(d) Impaired Waters List. The allocations in the above table address the impairments for both reaches.

Le Sueur River (07020011-620)

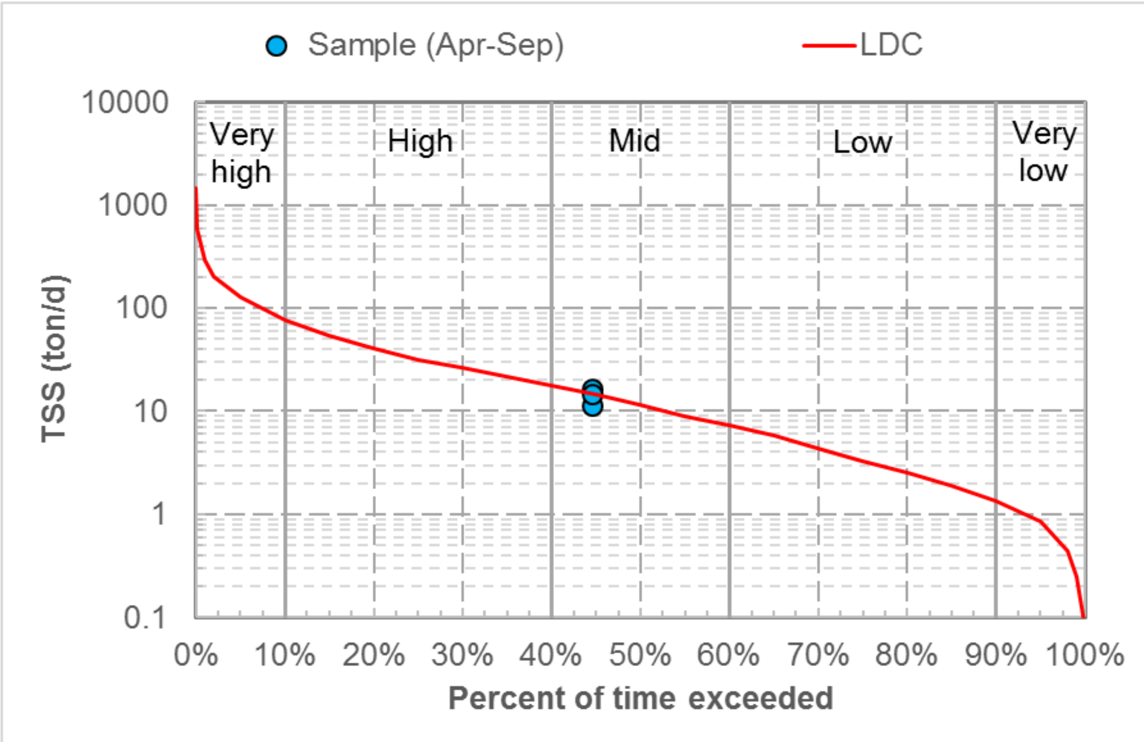


Figure D-57. TSS load duration curve, Le Sueur River (07020011-620).

Table D-57. TSS TMDL summary, Le Sueur River (07020011-620)

TMDL Parameter	Flow Regimes				
	Very High	High	Mid	Low	Very Low
	TSS Load (ton/d)				
WLA: City, County, and/or Township MS4 [a]	0.37	0.14	0.055	0.025	0.012
WLA: Industrial/Construction Stormwater	0.23	0.055	0.018	0.0039	– [c]
WLA: Wastewater	1.0	1.0	1.0	1.0	– [b]
Load Allocation	115.4	26.7	8.8	1.95	– [c]
Margin of Safety	13	3.1	1.1	0.33	0.085
Loading Capacity	130	31	11	3.3	0.85
Existing Concentration (mg/L)	_ [d]				
Percent Reduction to Achieve Concentration Standard	_ [d]				

[a] To meet the WLAs for permitted MS4s, TSS loading does not need to be reduced but is not allowed to increase.

[b] Permitted wastewater design flows exceed stream flow in the indicated flow zone(s). The allocations are expressed as an equation rather than an absolute number: allocation = flow contribution from a given source x 65 mg/L (or NPDES permit concentration). See *Municipal and Industrial Wastewater* (Section 5.4.1) for more detail.

[c] Unable to calculate allocations because the wastewater WLA exceeds the loading capacity. The allocations are expressed as an equation rather than an absolute number: allocation = flow contribution from a given source x 65 mg/L. See Sections 5.4.2 and 5.6 for more detail.

[d] N < 10; existing concentration and percent reduction not calculated.

D9. Lower Minnesota (HUC 07020012)

Minnesota River (07020012-505)

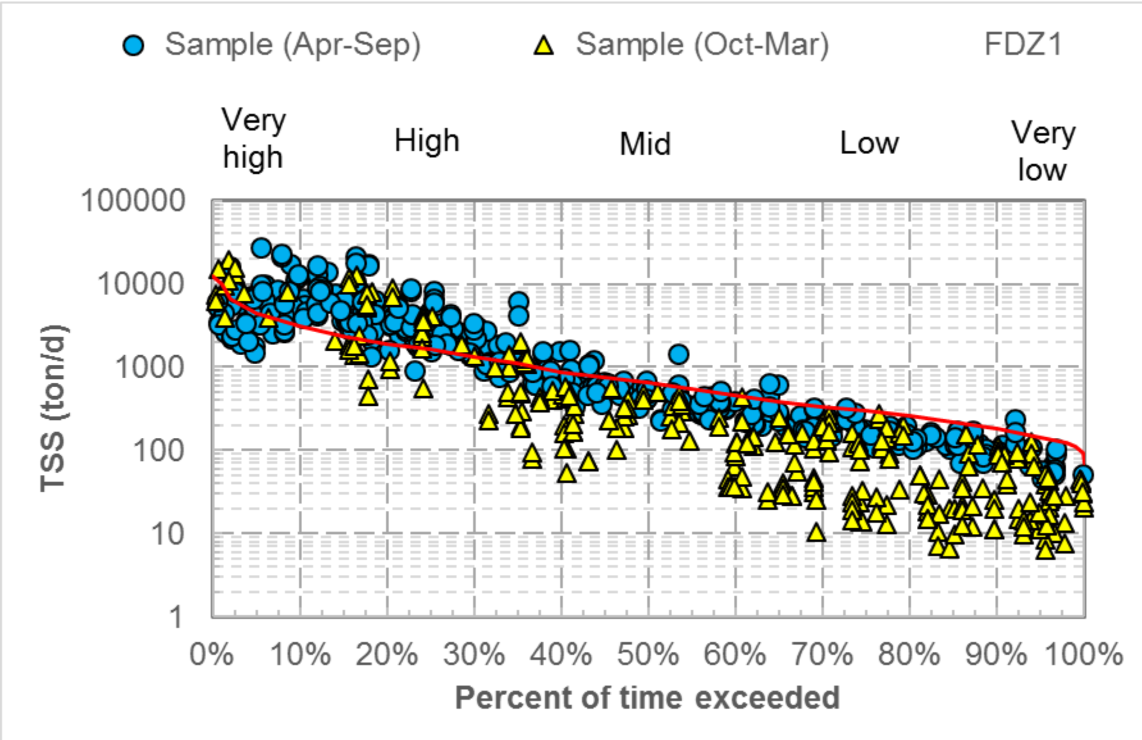


Figure D-58. TSS load duration curve, Minnesota River (07020012-505).

Table D-58. TSS TMDL summary, Minnesota River (07020012-505)

TMDL Parameter	Flow Regimes				
	Very High	**High**	**Mid**	**Low**	**Very Low**
	TSS Load (ton/d)				
Upstream Boundary Condition	802	247	94	39	4.2
WLA: MnDOT Outstate MS4 [a]	0.45	0.17	0.07	0.03	0.01
WLA: MnDOT Metro MS4 [a]	4.87	1.8	0.73	0.33	0.16
WLA: City, County, and/or Township MS4 [a]	119.2	44.21	17.83	8.12	3.9
WLA: Industrial/Construction Stormwater	6.3	2.3	0.83	0.28	0.07
WLA: Wastewater	90.5	90.5	90.5	90.5	90.5
Load Allocation	3009.7	1099.2	395.1	133.8	30.2
Margin of Safety	359	138	56	26	14
Loading Capacity	4,392	1,623	655	298	143
Existing Concentration (mg/L)	163				
Percent Reduction to Achieve Concentration Standard	60%				

[a] To meet the WLAs for permitted MS4s, TSS loading does not need to be reduced but is not allowed to increase.

Minnesota River (07020012-506)

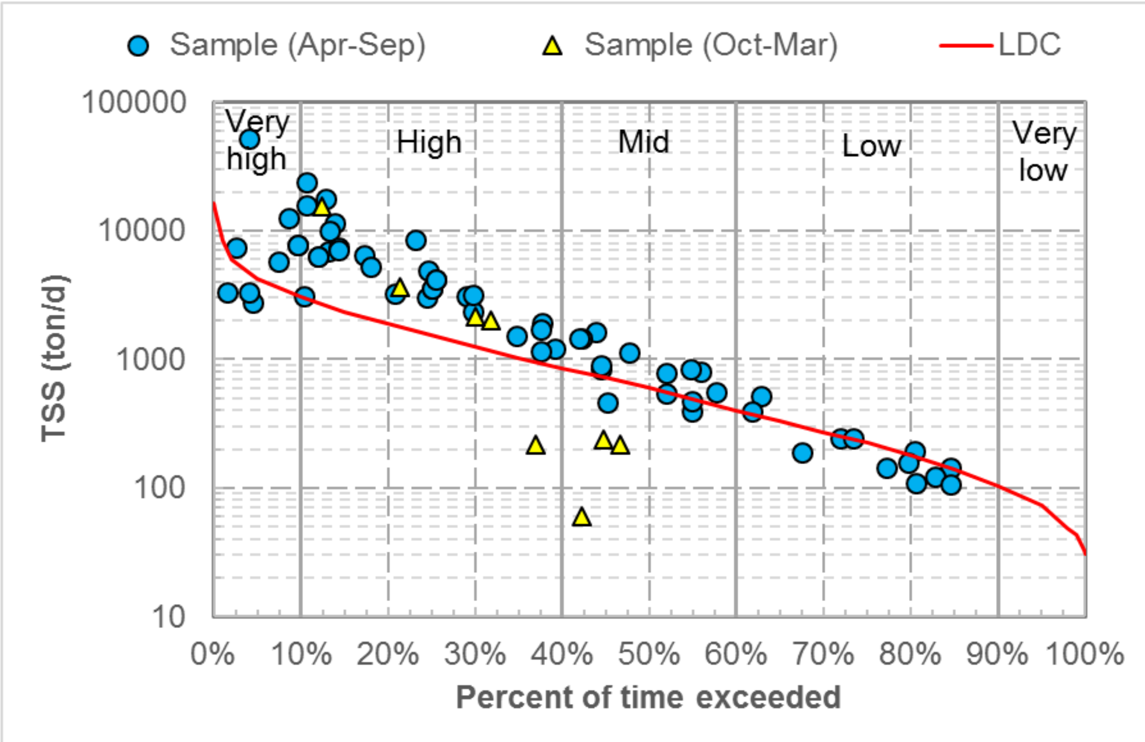


Figure D-59. TSS load duration curve, Minnesota River (07020012-506).

Table D-59. TSS TMDL summary, Minnesota River (07020012-506)

TMDL Parameter	Flow Regimes				
	Very High	**High**	**Mid**	**Low**	**Very Low**
	TSS Load (ton/d)				
Upstream Boundary Condition	802	247	94	39	4.2
WLA: MnDOT Outstate MS4 [a]	0.45	0.17	0.07	0.03	0.01
WLA: MnDOT Metro MS4 [a]	0.81	0.30	0.12	0.055	0.027
WLA: City, County, and/or Township MS4 [a]	45.77	16.98	6.85	3.12	1.50
WLA: Industrial/Construction Stormwater	6.0	2.22	0.79	0.23	0.011
WLA: Wastewater	55.1	55.1	55.1	55.1	55.1
Load Allocation	2965.1	1092.1	388.2	109.5	5.39
Margin of Safety	341	130	50	19	6.8
Loading Capacity	4,216	1,544	595	226	73
Existing Concentration (mg/L)	252				
Percent Reduction to Achieve Concentration Standard	74%				

[a] To meet the WLAs for permitted MS4s, TSS loading does not need to be reduced but is not allowed to increase.

Minnesota River (07020012-799)

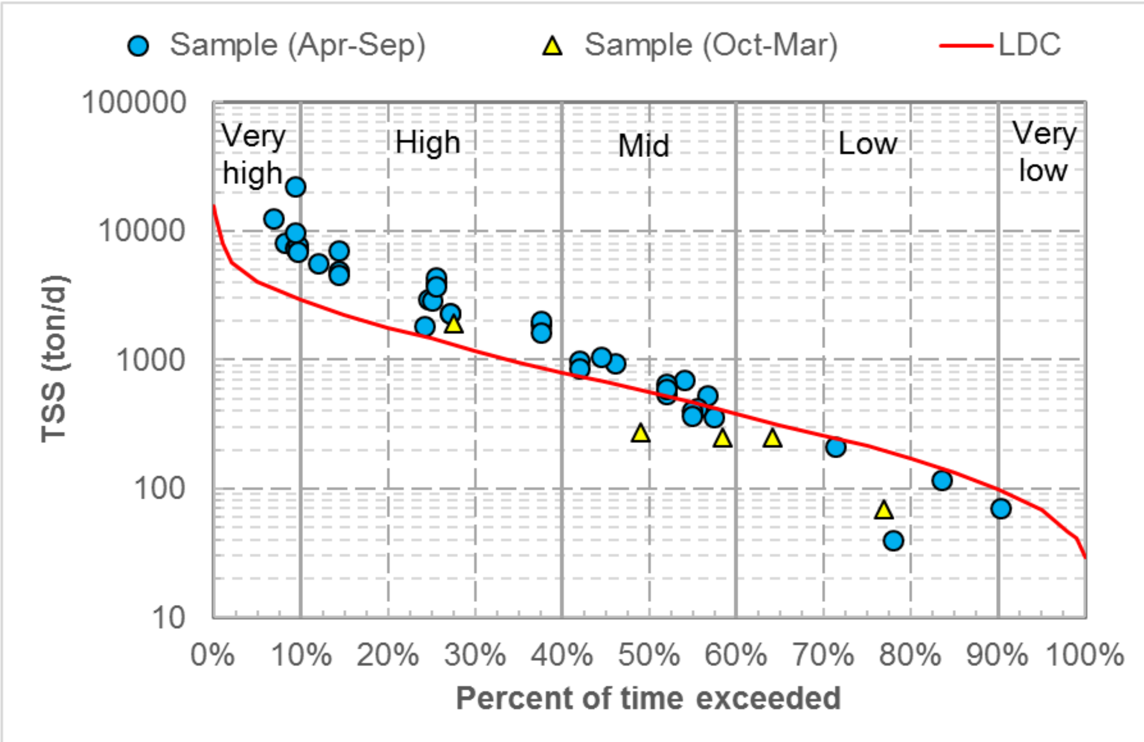


Figure D-60. TSS load duration curve, Minnesota River (07020012-799).

Table D-60. TSS TMDL summary, Minnesota River (07020012-799)

TMDL Parameter	**Flow Regimes**				
	Very High	**High**	**Mid**	**Low**	**Very Low**
	TSS Load (ton/d)				
Upstream Boundary Condition	802	247	94	39	4.2
WLA: MnDOT Outstate MS4 [a]	0.45	0.17	0.07	0.03	0.01
WLA: City, County, and/or Township MS4 [a]	26.38	9.78	3.95	1.80	0.86
WLA: Industrial/Construction Stormwater	5.63	2.08	0.74	0.21	0.01
WLA: Wastewater	52.14	52.14	52.14	52.14	52.14
Load Allocation	2783.4	1027.9	364.5	102.9	5.39
Margin of Safety	319	121	47	18	6.4
Loading Capacity	3,989	1,460	563	214	69
Existing Concentration (mg/L)	200				
Percent Reduction to Achieve Concentration Standard	68%				

[a] To meet the WLAs for permitted MS4s, TSS loading does not need to be reduced but is not allowed to increase.

Minnesota River (07020012-800)

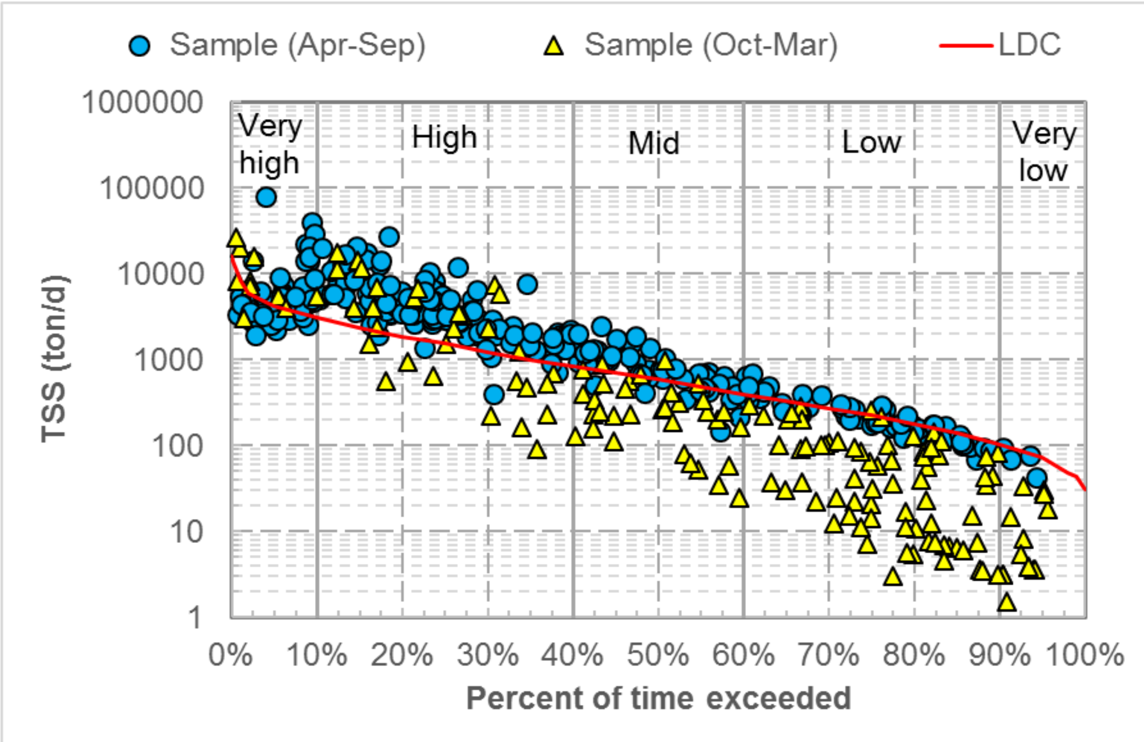


Figure D-61. TSS load duration curve, Minnesota River (07020012-800).

Table D-61. TSS TMDL summary, Minnesota River (07020012-800)

TMDL Parameter	Flow Regimes				
	Very High	High	Mid	Low	Very Low
	TSS Load (ton/d)				
Upstream Boundary Condition	802	247	94	39	4.2
WLA: MnDOT Outstate MS4 [a]	0.45	0.17	0.07	0.03	0.01
WLA: City, County, and/or Township MS4 [a]	30.27	11.23	4.53	2.06	0.99
WLA: Industrial/Construction Stormwater	5.96	2.2	0.78	0.22	0.01
WLA: Wastewater	53.8	53.8	53.8	53.8	53.8
Load Allocation	2945.5	1085.6	386.9	109.9	5.57
Margin of Safety	337	128	50	19	6.8
Loading Capacity	4,175	1,528	590	224	72
Existing Concentration (mg/L)	243				
Percent Reduction to Achieve Concentration Standard	73%				

[a] To meet the WLAs for permitted MS4s, TSS loading does not need to be reduced but is not allowed to increase.

Appendix E. Individual Wastewater WLAs

Table E-1. Individual wastewater wasteload allocations

Facility	Permit	Wasteload Allocation (tons/day)	Impairment AUID [a]
ADM Corn Processing - Marshall	MN0057037	0.330	07020006-501
Alden WWTP	MNG585118	0.462	07020009-554
Altona Hutterian Brethren WWTP	MN0067610	0.0220	07020012-799
Amboy WWTP	MN0022624	0.0359	07020011-534
Anchor Glass Container Corp	MN0003042	0.00739	07020012-505
Arlington WWTP	MN0020834	0.100	07020012-800
Balaton WWTP	MN0020559	0.153	07020008-501
Belle Plaine WWTP	MN0022772	0.705	07020012-800
Belview WWTP	MNG580003	0.163	07020004-750
Benson WWTP	MN0020036	0.0978	07020005-501
Bird Island WWTP	MN0022829	0.213	07020004-750
Blomkest Svea Sewer Board WWTP	MN0069388	0.0849	07020004-587
Blue Earth WWTP	MN0020532	0.122	07020009-565
Bongards' Creameries Inc	MN0002135	0.357	07020012-506
Bricelyn WWTP	MNG585129	0.0875	07020009-553
Butterfield WWTP	MN0022977	0.519	07020010-516
CHS Mankato[b]	MN0001228	0.497	07020009-501
Clara City WWTP	MN0023035	0.0575	07020004-587
Clarkfield WWTP	MNG580093	0.550	07020004-748
Clements WWTP	MNG580094	0.0305	07020008-501
Cleveland WWTP	MNG580009	0.202	07020007-723
Clontarf WWTP	MNG580108	0.0397	07020005-501
Cold Spring Granite Co	MNG490143	0.452	07020007-720
Cologne WWTP	MN0023108	0.0407	07020012-506
Comfrey WWTP	MN0021687	0.00937	07020007-722
Community of Roseland WWTP	MN0070092	0.0694	07020004-587
Cottonwood WWTP	MNG580010	0.347	07020004-749
Dairy Farmers of America Inc - Winthrop	MN0003671	0.150 [c]	07020012-799
Danube WWTP	MNG580057	0.121	07020004-750
Danvers WWTP	MNG585119	0.0354	07020005-501
Darling International Inc - Blue Earth	MN0002313	0.069	07020009-518
De Graff WWTP [d]	MN0071234	0.054	07020005-501
Del Monte Foods Inc - Sleepy Eye Plant 114	MN0001171	0.144	07020008-501
Delavan WWTP	MNG585109	0.0764	07020011-531
Delft Sanitary District WWTP	MN0066541	0.000717	07020010-566
Delhi WWTP	MN0067008	0.0018	07020004-750

Facility	Permit	Wasteload Allocation (tons/day)	Impairment AUID [a]
Delta Air Lines Inc - Mpls/Saint Paul	MN0054194	0.00363	07020012-505
Duininck Inc	MNG490046	0.651	07020004-587
		1.14	07020004-747
		1.63	07020004-750
		0.651	07020005-501
Echo WWTP	MNG580059	0.122	07020004-749
Eden Prairie Well House 6 & 7	MNG250084	0.00125	07020012-505
Elmore WWTP	MNG585110	0.467	07020009-504
Erosion Control Plus Inc	MNG490321	0.452	07020010-510
Evan WWTP	MNG580202	0.0272	07020007-720
Evansville WWTP	MNG585074	0.141	07020005-501
Fabcon Inc	MN0068284	0.0901	07020012-505
Fairfax WWTP	MNG580060	0.791	07020007-720
Fairmont Foods Inc	MN0001996	0.00812	07020009-503
Fairmont WTP	MN0045527	0.000376	07020009-527
Fairmont WWTP	MN0030112	0.488	07020009-503
Farwell Kensington Sanitary District WWTP	MNG585220	0.107	07020005-501
Franklin WWTP	MN0021083	0.0216	07020007-720
Freeborn WWTP	MN0040908	0.0459	07020011-568
Frost WWTP	MNG585120	0.0737	07020009-553
Garvin WWTP	MNG580101	0.0317	07020008-501
Gaylord WWTP	MNG580204	0.826	07020012-799
Ghent WWTP	MNG585121	0.0485	07020006-501
Gibbon WWTP	MNG580020	0.187	07020012-799
Good Thunder WWTP	MNG580206	0.133	07020011-534
Granada WWTP	MNG585023	0.0679	07020009-503
Granite Falls Energy LLC	MN0066800	0.0165	07020004-587
Granite Falls WWTP	MN0021211	0.100	07020004-748
Granite Valley Quarry	MNG490117	0.905	07020004-750
		0.452	07020007-720
Great River Energy - Lakefield Junction Station	MN0067709	0.00113	07020009-521
Groebner Farms	MNG490270	0.452	07020008-501
Hamburg WWTP	MN0025585	0.106	07020012-800
Hancock WWTP	MNG585299	0.257	07020005-501
Hanley Falls WWTP	MNG580122	0.0459	07020004-502
Hanska WWTP	MN0052663	0.0703	07020007-722
Hartland WWTP	MNG585102	0.0743	07020011-620
Hoffman WWTP	MNG585134	0.463	07020005-501
Hopkins Well 4 WTP	MNG640045	0.0250	07020012-505

Facility	Permit	Wasteload Allocation (tons/day)	Impairment AUID [a]
Ivanhoe WWTP	MNG580103	0.104	07020004-502
Janesville WWTP	MNG580025	0.642	07020011-507
Jeffers WWTP	MNG580111	0.0642	07020008-501
Jordan Sands LLC	MN0070581	0.376	07020007-723
Jordan WWTP	MN0020869	0.161	07020012-800
Kerkhoven WWTP	MN0020583	0.0187	07020005-501
Kiester WWTP	MNG585097	0.0933	07020009-553
Kraemer Mining & Materials Burnsville	MN0002224	1.88	07020012-505
La Salle WWTP	MN0067458	0.00187	07020010-563
Lafayette WWTP	MN0023876	0.0119	07020012-799
Lake Crystal WWTP	MN0055981	0.0739	07020007-722
Laketown Community WWTP	MN0054399	0.000772	07020012-506
Lamberton WWTP	MNG580100	0.245	07020008-501
Le Center WWTP	MN0023931	0.103	07020012-799
Le Sueur Cheese Co	MN0060216	0.0250	07020012-799
Lewisville WWTP	MNG585314	0.0871	07020010-501
LifeCore Biomedical LLC	MN0060747	0.00626	07020012-506
Lincoln County Highway Department	MNG490203	0.452	07020004-502
		0.452	07020006-501
Lowry WWTP	MNG585123	0.0791	07020005-501
Lucan WWTP	MN0031348	0.0428	07020008-501
Lynd WWTP	MNG580030	0.0642	07020006-501
MA Gedney Co	MN0022446	0.254	07020012-506
Madelia WWTP	MN0024040	0.164	07020010-510
Magellan Pipeline Co LP - Marshall	MN0059838	0.0901	07020006-501
Mankato Water Resource Recovery Facility	MN0030171	1.41	07020007-723
Mapleton WWTP	MN0021172	0.672	07020011-568
Marshall WWTP	MN0022179	0.562	07020006-501
Martin Marietta Materials Yellow Medicine	MNG490195	0.626	07020004-747
Mathiowetz Construction Co	MNG490137	0.452	07020010-516
		0.452	07020011-534
Maynard WWTP	MN0056588	0.0192	07020004-587
McLaughlin Gormley King Co	MN0058033	0.000871	07020012-506
Met Council - Blue Lake WWTP	MN0029882	5.252	07020012-505
Met Council - Seneca WWTP	MN0030007	4.749	07020012-505
Metropolitan Airports Commission	MN0002101	21.5	07020012-505
MG Waldbaum Co	MN0060798	0.0688	07020012-799
Millerville WWTP	MN0054305	0.0476	07020005-501

Facility	Permit	Wasteload Allocation (tons/day)	Impairment AUID [a]
Milroy WWTP	MNG585124	0.0463	07020006-501
Minneota WWTP	MNG580033	0.336	07020004-502
Montevideo WWTP	MN0020133	0.309	07020005-501
Montgomery WWTP	MN0024210	0.121	07020012-800
Morgan WWTP[e]	MN0020443	0.434	07020007-720
Morton WWTP	MN0051292	0.0248	07020007-720
Mountain Lake WWTP	MN0021466	0.773	07020010-566
MRVPUC WWTP	MN0068195	0.230	07020012-799
Murdock WWTP	MNG585086	0.0595	07020005-501
Neuhof Hutterian Brethren	MNG580113	0.0217	07020010-547
New Prague Utilities Commission	MNG640117	0.00426	07020012-800
New Prague WWTP	MN0020150	0.229	07020012-800
New Richland WWTP	MN0021032	0.0750	07020011-620
New Ulm WWTP	MN0030066	0.847	07020008-501
Nicollet WWTP	MNG580037	0.480	07020007-722
Northern Con-Agg LLP	MNG490088	0.452	07020006-501
Northern Con-Agg LLP - Redwood Falls	MN0059331	0.0451	07020007-720
Northrop WWTP	MN0024384	0.148	07020009-502
Northstar Ethanol LLC dba Poet Biorefining - Lake Crystal	MN0067172	0.0163	07020007-722
Norwood Young America WWTP	MN0024392	0.114	07020012-800
Odin-Ormsby WWTP	MN0069442	0.0562	07020010-547
Olivia WWTP	MN0020907	0.122	07020004-750
OMG Midwest Inc/Southern MN Construction Co Inc	MNG490131	0.452	07020007-722
Pemberton WWTP	MNG585075	0.122	07020011-504
Pennock WWTP	MNG580104	0.122	07020004-587
Pepsi Beverages Co	MN0060101	0.0156	07020012-505
Polar Semiconductor LLC	MN0064661	0.0175	07020012-505
Porter WWTP	MNG580128	0.0305	07020004-502
Prinsburg WWTP	MN0063932	0.00681	07020004-587
Prior Lk/Spring Lk Ferric Chloride WTP	MN0067377	0.000626	07020012-505
Rahr Malting Co	MN0031917	0.625	07020012-506
Raymond WWTP	MN0045446	0.266	07020004-587
Redwood Falls WWTP	MN0020401	0.248	07020004-750
Renville WWTP	MN0020737	0.107	07020004-750
Revere WWTP	MNG580114	0.0281	07020008-501
Russell WWTP	MNG585062	0.110	07020006-501
Ruthton WWTP	MNG585105	0.0709	07020006-501
Sacred Heart WWTP	MN0024708	0.0297	07020004-749

Facility	Permit	Wasteload Allocation (tons/day)	Impairment AUID [a]
Saint Clair WWTP	MN0024716	0.0265	07020011-507
Saint George District Sewer System	MN0064785	0.000816	07020007-721
Saint James WWTP	MN0024759	0.370	07020010-511
Saint Leo WWTP	MN0024775	0.0265	07020004-502
Saint Peter WWTP	MN0022535	0.500	07020007-723
Sanborn WWTP	MNG580115	0.0642	07020008-501
Seagate Technology LLC - Bloomington	MN0030864	0.00376	07020012-505
Searles WWTP	MNG580080	0.0722	07020007-722
Seneca Foods Corp - Blue Earth	MN0001287	0.0182	07020009-553
Seneca Foods Corp - Montgomery	MN0001279	0.0625	07020012-800
SkyWater Technology Foundry	MN0056723	0.160	07020012-505
Sleepy Eye WWTP	MNG580041	1.21	07020008-501
Southern Minnesota Beet Sugar Coop[f]	MN0040665	0.614	07020004-750
Springfield WWTP	MN0024953	0.0977	07020008-501
Starbuck WWTP	MN0021415	0.0438	07020005-501
Starland Hutterian Brethren Inc	MN0067334	0.0298	07020012-799
Storden WWTP	MNG580106	0.0495	07020008-501
SUEZ WTS Solutions USA Inc	MN0059013	0.0249	07020012-505
Sunburg WWTP	MNG585125	0.0221	07020005-501
Superior Minerals Co	MN0063584	0.0136 [g]	07020012-505
Taunton WWTP	MNG580090	0.0367	07020004-502
Tracy WWTP[h]	MN0021725	0.656	07020008-501
Trimont WWTP	MN0022071	0.0231	07020009-521
Truman WTP	MNG640129	0.00188	07020010-524
Truman WWTP	MN0021652	0.0981	07020010-524
Tyler WWTP	MNG585116	0.205	07020006-501
Ulland Brothers Inc	MNG490069	0.452	07020011-620
Unimin Corp - Kasota Mining Project	MN0053082	2.09	07020007-723
Unimin Corp - Ottawa Plant	MN0001716	3.76	07020007-723
		3.76	07020007-799
Urbank WWTP	MNG585343	0.0150	07020005-501
Vernon Center WWTP	MN0030490	0.0110	07020009-507
Vesta WWTP	MNG580043	0.0486	07020006-501
Vetter Stone Co	MNG490173	2.71	07020007-723
Wabasso WWTP	MN0025151	0.0141	07020008-501
Waldorf WWTP	MN0021849	0.0120	07020011-504
Walnut Grove WWTP	MN0021776	0.0254	07020008-501
Walters WWTP	MNG585223	0.0274	07020009-554

Facility	Permit	Wasteload Allocation (tons/day)	Impairment AUID [a]
Wanda WWTP	MNG580126	0.0336	07020008-501
Waseca WWTP	MN0020796	0.438	07020011-620
Welcome WWTP	MN0021296	0.0325	07020009-525
Wells Public Utilities	MN0025224	2.915	07020011-535
Westbrook WWTP	MNG580127	0.305	07020008-501
Willmar WWTF	MN0025259	0.939	07020004-587
Winnebago WWTP	MN0025267	0.213	07020009-515
Winthrop WWTP	MN0051098	0.392	07020012-799
Wood Lake WWTP	MNG580107	0.0672	07020004-749
Xcel Energy - Black Dog Generating Plant	MN0000876	1.69	07020012-505
Xcel Energy - Key City/Wilmarth	MN0000914	0.0174	07020007-723

a. Only the most upstream impairment watershed is listed; each permitted facility's WLA also applies to impairments in this report that are located downstream of the indiciated impairment AUID.
b. WLA based on updated permitted flow of 3.9744 mgd.
c. The current permit limit of Dairy Farmers of America Inc–Winthrop (MN0003671) is based on 66 mg/L TSS, and the WLA is based on 65 mg/L TSS. A WQBEL will need to be considered upon permit reissuance.
d. An NPDES permit for the new De Graff WWTP is expected to be issued in summer or fall of 2018.
e. New permit and pond constructed since the WLA calculated for South Metro Mississippi TSS TMDL
f. WLA includes discharge of cooling water not accounted for in South Metro Mississippi TSS TMDL
g. The current permit limit of Superior Minerals Co (MN0063584) is based on 188 mg/L TSS, and the WLA is based on 65 mg/L TSS and flow of 0.0495 mgd. A WQBEL will need to be considered upon permit reissuance.
h. Permitted flow increased to 0.462 mgd. 45 mg/L limit remains protective of WQS.

Appendix F. List of Regulated MS4s that are Part of Categorical WLAs

Table F-1. Regulated municipal separate storm sewer systems that are part of the categorical wasteload allocations.

Permit	Regulated Entity Name	07020004-747	07020004-748	07020004-749	07020004-750	07020005-501	07020006-501	07020007-720	07020007-721	07020007-722	07020007-723	07020008-501	07020009-501	07020009-503	07020009-507	07020009-509	07020009-514	07020009-515	07020009-525	07020009-527	07020011-501	07020011-506	07020011-507	02070011-620	07020012-505	07020012-506	07020012-799	07020012-800
MS400074	Apple Valley City MS4																								✓			
– [a]	Belle Plaine City MS4																								✓	✓		✓
MS400005	Bloomington City MS4																								✓			
MS400276	Blue Earth County MS4										✓		✓			✓					✓	✓	✓		✓	✓	✓	✓
MS400076	Burnsville City MS4																								✓			
MS400077	Carver City MS4																								✓	✓		✓
MS400070	Carver County MS4																								✓	✓		
MS400079	Chanhassen City MS4																								✓	✓		
MS400080	Chaska City MS4																								✓	✓		
MS400131	Credit River Township MS4																								✓	✓		✓
MS400132	Dakota County MS4																								✓			
MS400013	Deephaven City MS4																								✓			
MS400014	Eagan City MS4																								✓			
MS400284	Eagle Lake City MS4										✓		✓								✓	✓	✓		✓	✓	✓	✓
MS400015	Eden Prairie City MS4																								✓	✓		
MS400016	Edina City MS4																								✓			

Permit	Regulated Entity Name	07020004-747	07020004-748	07020004-749	07020004-750	07020005-501	07020006-501	07020007-720	07020007-721	07020007-722	07020007-723	07020008-501	07020009-501	07020009-503	07020009-507	07020009-509	07020009-514	07020009-515	07020009-525	07020009-527	07020011-501	07020011-506	07020011-507	02070011-620	07020012-505	07020012-506	07020012-799	07020012-800
MS400237	Elko New Market City MS4																								✓	✓		✓
MS400239	Fairmont City MS4										✓		✓	✓	✓	✓	✓	✓	✓	✓					✓	✓	✓	✓
MS400138	Hennepin County MS4																								✓	✓		
MS400199	Hennepin Technical College Eden Prairie MS4																								✓			
MS400024	Hopkins City MS4																								✓			
MS400096	Inver Grove Heights City MS4																								✓			
MS400140	Jackson Township MS4																								✓	✓		✓
– [a]	Jordan City MS4																								✓	✓		✓
MS400142	Laketown Township MS4																								✓	✓		
MS400099	Lakeville City MS4																								✓			
– [a]	Le Sueur City MS4																								✓	✓	✓	✓
MS400028	Lilydale City MS4																								✓			
MS400144	Louisville Township MS4																								✓	✓		✓
MS400226	Mankato City MS4									✓	✓		✓								✓	✓	✓		✓	✓	✓	✓
MS400297	Mankato Township MS4										✓		✓								✓	✓	✓		✓	✓	✓	✓

Permit	Regulated Entity Name	07020004-747	07020004-748	07020004-749	07020004-750	07020005-501	07020006-501	07020007-720	07020007-721	07020007-722	07020007-723	07020008-501	07020009-501	07020009-503	07020009-507	07020009-509	07020009-514	07020009-515	07020009-525	07020009-527	07020011-501	07020011-506	07020011-507	02070011-620	07020012-505	07020012-506	07020012-799	07020012-800
MS400241	Marshall City MS4				✓		✓	✓	✓	✓	✓	✓													✓	✓	✓	✓
MS400033	Mendota City MS4																								✓			
MS400034	Mendota Heights City MS4																								✓			
MN0061018	Minneapolis Municipal Storm Water																								✓			
MS400035	Minnetonka City MS4																								✓			
MS400106	Minnetrista City MS4																								✓	✓		
MS400279	Minnesota State University – Mankato										✓														✓	✓	✓	✓
MS400170	Mn/DOT Metro District MS4																								✓	✓		
MS400180	Mn/DOT Outstate District MS4									✓	✓		✓			✓					✓	✓	✓		✓	✓	✓	✓
MS400261	Montevideo City MS4	✓	✓	✓	✓	✓		✓	✓	✓	✓														✓	✓	✓	✓
– [a]	New Prague City MS4																								✓	✓		✓
MS400228	New Ulm City MS4								✓	✓	✓	✓													✓	✓	✓	✓
MS400255	Normandale Community College MS4																								✓			

Permit	Regulated Entity Name	07020004-747	07020004-748	07020004-749	07020004-750	07020005-501	07020006-501	07020007-720	07020007-721	07020007-722	07020007-723	07020008-501	07020009-501	07020009-503	07020009-507	07020009-509	07020009-514	07020009-515	07020009-525	07020009-527	07020011-501	07020011-506	07020011-507	02070011-620	07020012-505	07020012-506	07020012-799	07020012-800
MS400229	North Mankato City MS4									✓	✓														✓	✓	✓	✓
MS400113	Prior Lake City MS4																								✓	✓		✓
MS400189	Prior Lake-Spring Lake WSD MS4																								✓			
MS400236	Redwood Falls City MS4				✓		✓	✓	✓	✓	✓														✓	✓	✓	✓
MS400045	Richfield City MS4																								✓			
MS400117	Rosemount City MS4																								✓			
MS400119	Savage City MS4																								✓			
MS400154	Scott County MS4																								✓	✓		
MS400120	Shakopee City MS4																								✓	✓		✓
MS400122	Shorewood City MS4																								✓			
MS400292	Skyline City MS4										✓		✓												✓	✓	✓	✓
MS400156	Spring Lake Township MS4																								✓	✓		✓
MS400299	Southbend Township MS4									✓	✓		✓			✓					✓				✓	✓	✓	✓
MS400245	St Peter City MS4										✓														✓	✓	✓	✓
MS400126	Victoria City MS4																								✓	✓		
MS400232	Waconia City MS4																								✓	✓		
MS400258	Waseca City MS4										✓		✓								✓	✓	✓	✓	✓	✓	✓	✓

Permit	Regulated Entity Name	07020004-747	07020004-748	07020004-749	07020004-750	07020005-501	07020006-501	07020007-720	07020007-721	07020007-722	07020007-723	07020008-501	07020009-501	07020009-503	07020009-507	07020009-509	07020009-514	07020009-515	07020009-525	07020009-527	07020011-501	07020011-506	07020011-507	02070011-620	07020012-505	07020012-506	07020012-799	07020012-800
MS400272	Willmar City MS4			✓	✓			✓	✓	✓	✓														✓	✓	✓	✓

The table is sorted from top to bottom alphabetically by regulated entity name.
a. Not currently regulated but expected to come under permit coverage in the next permit cycle.

Appendix G. List of Turbidity/TSS Impairments in the Minnesota River Basin below Lac qui Parle Dam and TMDL Status

Table G-1. Minnesota River basin turbidity/TSS impairments below Lac qui Parle dam.

Water body name	Water body description	Year added to List	Basin	AUID	County	HUC 8	Watershed name	Pollutant or stressor	TMDL target completion year	EPA category	AUID previously listed	Watershed TMDL	Status
Yellow Medicine River	Spring Cr to Minnesota R	2002	Minnesota River	07020004-502	Yellow Medicine	07020004	Minnesota River - Yellow Medicine River	Turbidity	2018	5		MN River	In Progress
Beaver Creek	E Fk Beaver Cr to Minnesota R	2006	Minnesota River	07020004-528	Renville	07020004	Minnesota River - Yellow Medicine River	Turbidity	2017	5		Hawk Creek	Complete
Beaver Creek, West Fork	Headwaters to E Fk Beaver Cr	2006	Minnesota River	07020004-530	Renville	07020004	Minnesota River - Yellow Medicine River	Turbidity	2017	5		Hawk Creek	Complete
Hawk Creek	Unnamed cr to Unnamed cr	2006	Minnesota River	07020004-568	Renville	07020004	Minnesota River - Yellow Medicine River	Turbidity	2017	5		Hawk Creek	Complete
Hawk Creek	Spring Cr to Minnesota R	2004	Minnesota River	07020004-587	Renville	07020004	Minnesota River - Yellow Medicine River	Turbidity	2017	5		Hawk Creek	Complete
Unnamed ditch	Chetomba Cr to Spring Cr	2006	Minnesota River	07020004-589	Renville	07020004	Minnesota River - Yellow Medicine River	Turbidity	2017	5		Hawk Creek	Complete
Minnesota River	Lac qui Parle dam to Granite Falls Dam	2002	Minnesota River	07020004-747	Chippewa	07020004	Minnesota River - Yellow Medicine River	Turbidity	2024	5	07020004-501	MN River	In Progress
Minnesota River	Granite Falls Dam to Yellow Medicine R	2008	Minnesota River	07020004-748	Yellow Medicine	07020004	Minnesota River - Yellow Medicine River	Turbidity	2024	5	07020004-515	MN River	In Progress

Water body name	Water body description	Year added to List	Basin	AUID	County	HUC 8	Watershed name	Pollutant or stressor	TMDL target completion year	EPA category	AUID previously listed	Watershed TMDL	Status
Minnesota River	Yellow Medicine R to Echo Cr	2018	Minnesota River	07020004-749	Renville	07020004	Minnesota River - Yellow Medicine River	Total suspended solids	2024	5		MN River	In Progress
Minnesota River	Echo Cr to Beaver Cr	2004	Minnesota River	07020004-750	Renville	07020004	Minnesota River - Yellow Medicine River	Turbidity	2024	5	07020004-509	MN River	In Progress
Chippewa River	Watson Sag to Minnesota R	2002	Minnesota River	07020005-501	Chippewa	07020005	Chippewa River	Turbidity	2018	5		MN River	In Progress
Redwood River	Ramsey Cr to Minnesota R	2004	Minnesota River	07020006-501	Redwood	07020006	Redwood River	Turbidity	2018	5		MN River	In Progress
Redwood River	T111 R42W S33, west line to Threemile Cr	2002	Minnesota River	07020006-502	Lyon	07020006	Redwood River	Turbidity	2021	5		Redwood River	In Progress
Redwood River	Threemile Cr to Clear Cr	2010	Minnesota River	07020006-503	Redwood	07020006	Redwood River	Turbidity	2021	5		Redwood River	In Progress
Threemile Creek	Headwaters to Redwood R	2004	Minnesota River	07020006-504	Lyon	07020006	Redwood River	Turbidity	2021	5		Redwood River	In Progress
Redwood River	Clear Cr to Redwood Lk	2002	Minnesota River	07020006-509	Redwood	07020006	Redwood River	Turbidity	2021	5		Redwood River	In Progress
Minneopa Creek	T108 R28W S23, south line to Minnesota R	2006	Minnesota River	07020007-534	Blue Earth	07020007	Minnesota River - Mankato	Turbidity	2018	5		Minnesota River - Mankato	In Progress
Sevenmile Creek	T109 R27W S4, north line to Minnesota R	2006	Minnesota River	07020007-562	Nicollet	07020007	Minnesota River - Mankato	Turbidity	2018	5		Minnesota River - Mankato	In Progress

Water body name	Water body description	Year added to List	Basin	AUID	County	HUC 8	Watershed name	Pollutant or stressor	TMDL target completion year	EPA category	AUID previously listed	Watershed TMDL	Status
Little Cottonwood River	Headwaters to T109 R31W S22, north line	2006	Minnesota River	07020007-676	Brown	07020007	Minnesota River - Mankato	Turbidity	2018	5		Minnesota River - Mankato	In Progress
Little Cottonwood River	T109 R31W S15, south line to Minnesota R	2006	Minnesota River	07020007-677	Brown	07020007	Minnesota River - Mankato	Turbidity	2018	5		Minnesota River - Mankato	In Progress
County Ditch 46A	-94.0803 44.2762 to Sevenmile Cr	2006	Minnesota River	07020007-679	Nicollet	07020007	Minnesota River - Mankato	Turbidity	2018	5		Minnesota River - Mankato	In Progress
Sevenmile Creek	MN Hwy 99 to CD 46A	2006	Minnesota River	07020007-703	Nicollet	07020007	Minnesota River - Mankato	Turbidity	2018	5		Minnesota River - Mankato	In Progress
Minnesota River	Beaver Cr to Little Rock Cr	2002	Minnesota River	07020007-720	Brown	07020007	Minnesota River - Mankato	Turbidity	2018	5	07020007-514	MN River	In Progress
Minnesota River	Little Rock Cr to Cottonwood R	2018	Minnesota River	07020007-721	Nicollet	07020007	Minnesota River - Mankato	Total suspended solids	2018	5		MN River	In Progress
Minnesota River	Cottonwood R to Blue Earth R	2002	Minnesota River	07020007-722	Nicollet	07020007	Minnesota River - Mankato	Turbidity	2018	5	07020007-503, 504; 505	MN River	In Progress
Minnesota River	Blue Earth R to Cherry Cr	2002	Minnesota River	07020007-723	Nicollet	07020007	Minnesota River - Mankato	Turbidity	2018	5	07020007-501; 502	MN River	In Progress
Cottonwood River	JD 30 to Minnesota R	2002	Minnesota River	07020008-501	Brown	07020008	Cottonwood River	Turbidity	2018	5		MN River	In Progress

Water body name	Water body description	Year added to List	Basin	AUID	County	HUC 8	Watershed name	Pollutant or stressor	TMDL target completion year	EPA category	AUID previously listed	Watershed TMDL	Status
Cottonwood River	Plum Cr to Dutch Charley Cr	2006	Minnesota River	07020008-504	Redwood	07020008	Cottonwood River	Turbidity	2021	5		Cottonwood	In Progress
Cottonwood River	Coal Mine Cr to Sleepy Eye Cr	2006	Minnesota River	07020008-508	Brown	07020008	Cottonwood River	Turbidity	2021	5		Cottonwood	In Progress
Sleepy Eye Creek	Headwaters to Cottonwood R	2006	Minnesota River	07020008-512	Redwood	07020008	Cottonwood River	Turbidity	2021	5		Cottonwood	In Progress
Plum Creek (Judicial Ditch 20A)	Headwaters to Cottonwood R	2006	Minnesota River	07020008-516	Redwood	07020008	Cottonwood River	Turbidity	2021	5		Cottonwood	In Progress
Dutch Charley Creek	Highwater Cr to Cottonwood R	2006	Minnesota River	07020008-517	Redwood	07020008	Cottonwood River	Turbidity	2021	5		Cottonwood	In Progress
Dutch Charley Creek	Headwaters to Highwater Cr	2006	Minnesota River	07020008-518	Cottonwood	07020008	Cottonwood River	Turbidity	2021	5		Cottonwood	In Progress
Pell Creek	Headwaters to T109 R38W S29, east line	2010	Minnesota River	07020008-535	Cottonwood	07020008	Cottonwood River	Turbidity	2021	5		Cottonwood	In Progress
Blue Earth River	Le Sueur R to Minnesota R	2002	Minnesota River	07020009-501	Blue Earth	07020009	Blue Earth River	Turbidity	2018	5		MN River	In Progress
Elm Creek	Cedar Cr to Blue Earth R	1996	Minnesota River	07020009-502	Martin	07020009	Blue Earth River	Turbidity	2018	5		MN River	In Progress
Center Creek	Lily Cr to Blue Earth R	2002	Minnesota River	07020009-503	Martin	07020009	Blue Earth River	Turbidity	2018	5		MN River	In Progress
Blue Earth River	W Br Blue Earth R to Coon Cr	2002	Minnesota River	07020009-504	Faribault	07020009	Blue Earth River	Turbidity	2018	5		MN River	In Progress

Water body name	Water body description	Year added to List	Basin	AUID	County	HUC 8	Watershed name	Pollutant or stressor	TMDL target completion year	EPA category	AUID previously listed	Watershed TMDL	Status
Blue Earth River	Willow Cr to Watonwan R	2008	Minnesota River	07020009-507	Blue Earth	07020009	Blue Earth River	Turbidity	2018	5		MN River	In Progress
Blue Earth River	E Br Blue Earth R to South Cr	2002	Minnesota River	07020009-508	Faribault	07020009	Blue Earth River	Turbidity	2018	5		MN River	In Progress
Blue Earth River	Rapidan Dam to Le Sueur R	2004	Minnesota River	07020009-509	Blue Earth	07020009	Blue Earth River	Turbidity	2018	5		MN River	In Progress
Blue Earth River	Center Cr to Elm Cr	2010	Minnesota River	07020009-514	Faribault	07020009	Blue Earth River	Turbidity	2018	5		MN River	In Progress
Blue Earth River	Elm Cr to Willow Cr	2002	Minnesota River	07020009-515	Blue Earth	07020009	Blue Earth River	Turbidity	2018	5		MN River	In Progress
Blue Earth River	Coon Cr to Badger Cr	2008	Minnesota River	07020009-518	Faribault	07020009	Blue Earth River	Turbidity	2018	5		MN River	In Progress
Cedar Creek (Cedar Run Creek)	Cedar Lk to Elm Cr	2006	Minnesota River	07020009-521	Martin	07020009	Blue Earth River	Turbidity	2018	5		MN River	In Progress
Elm Creek	S Fk Elm Cr to Cedar Cr	2006	Minnesota River	07020009-522	Martin	07020009	Blue Earth River	Turbidity	2018	5		MN River	In Progress
Elm Creek	Headwaters to S Fk Elm Cr	2010	Minnesota River	07020009-523	Jackson	07020009	Blue Earth River	Turbidity	2018	5		MN River	In Progress
Elm Creek, South Fork	T103 R34W S30, west line to T103 R34W S1, north line	2010	Minnesota River	07020009-524	Jackson	07020009	Blue Earth River	Turbidity	2018	5		MN River	In Progress

Water body name	Water body description	Year added to List	Basin	AUID	County	HUC 8	Watershed name	Pollutant or stressor	TMDL target completion year	EPA category	AUID previously listed	Watershed TMDL	Status
Lily Creek	Headwaters (Fox Lk 46-0109-00) to Center Cr	2006	Minnesota River	07020009-525	Martin	07020009	Blue Earth River	Turbidity	2018	5		MN River	In Progress
Dutch Creek	Headwaters to Hall Lk	2006	Minnesota River	07020009-527	Martin	07020009	Blue Earth River	Turbidity	2018	5		MN River	In Progress
Blue Earth River, East Branch	Brush Cr to Blue Earth R	2008	Minnesota River	07020009-553	Faribault	07020009	Blue Earth River	Turbidity	2018	5		MN River	In Progress
Blue Earth River, East Branch	Headwaters to Brush Cr	2008	Minnesota River	07020009-554	Faribault	07020009	Blue Earth River	Turbidity	2018	5		MN River	In Progress
Blue Earth River	Badger Cr to E Br Blue Earth R	2008	Minnesota River	07020009-565	Faribault	07020009	Blue Earth River	Turbidity	2018	5		MN River	In Progress
Watonwan River	Perch Cr to Blue Earth R	2002	Minnesota River	07020010-501	Blue Earth	07020010	Watonwan River	Turbidity	2018	5		MN River	In Progress
Watonwan River	S Fk Watonwan R to Perch Cr	2008	Minnesota River	07020010-510	Watonwan	07020010	Watonwan River	Turbidity	2018	5		MN River	In Progress
Watonwan River	Butterfield Cr to S Fk Watonwan R	2006	Minnesota River	07020010-511	Watonwan	07020010	Watonwan River	Turbidity	2018	5		MN River	In Progress
Butterfield Creek	Headwaters to St James Cr	2008	Minnesota River	07020010-516	Watonwan	07020010	Watonwan River	Turbidity	2018	5		MN River	In Progress
Watonwan River, South Fork	Willow Cr to Watonwan R	2006	Minnesota River	07020010-517	Watonwan	07020010	Watonwan River	Turbidity	2018	5		MN River	In Progress

Water body name	Water body description	Year added to List	Basin	AUID	County	HUC 8	Watershed name	Pollutant or stressor	TMDL target completion year	EPA category	AUID previously listed	Watershed TMDL	Status
Perch Creek	Headwaters (Perch Lk 46-0046-00) to Spring Cr	2006	Minnesota River	07020010-524	Watonwan	07020010	Watonwan River	Turbidity	2018	5		MN River	In Progress
St James Creek (Kansas Lake Inlet)	Headwaters to Kansas Lk	2002	Minnesota River	07020010-528	Watonwan	07020010	Watonwan River	Turbidity	2018	5		MN River	In Progress
Watonwan River, South Fork	Irish Lk to Willow Cr	2006	Minnesota River	07020010-547	Watonwan	07020010	Watonwan River	Turbidity	2018	5		MN River	In Progress
Watonwan River	N Fk Watonwan R to T107 R32W S13, east line	2006	Minnesota River	07020010-562	Watonwan	07020010	Watonwan River	Turbidity	2018	5		MN River	In Progress
Watonwan River	T107 R31W S18, west line to Butterfield Cr	2006	Minnesota River	07020010-563	Watonwan	07020010	Watonwan River	Turbidity	2018	5		MN River	In Progress
Watonwan River, North Fork	Headwaters to T107 R32W S6, east line	2006	Minnesota River	07020010-564	Cottonwood	07020010	Watonwan River	Turbidity	2018	5		MN River	In Progress
Watonwan River	Headwaters to T107 R33W S33, east line	2006	Minnesota River	07020010-566	Cottonwood	07020010	Watonwan River	Turbidity	2018	5		MN River	In Progress
Watonwan River	T107 R33W S34, west line to N Fk Watonwan R	2006	Minnesota River	07020010-567	Watonwan	07020010	Watonwan River	Turbidity	2018	5		MN River	In Progress
Le Sueur River	Maple R to Blue Earth R	2002	Minnesota River	07020011-501	Blue Earth	07020011	Le Sueur River	Turbidity	2018	5		MN River	In Progress

Water body name	Water body description	Year added to List	Basin	AUID	County	HUC 8	Watershed name	Pollutant or stressor	TMDL target completion year	EPA category	AUID previously listed	Watershed TMDL	Status
Unnamed creek (Little Beauford Ditch)	Headwaters to Cobb R	2002	Minnesota River	07020011-503	Blue Earth	07020011	Le Sueur River	Turbidity	2018	5		MN River	In Progress
Little Cobb River	Bull Run Cr to Cobb R	2002	Minnesota River	07020011-504	Blue Earth	07020011	Le Sueur River	Turbidity	2018	5		MN River	In Progress
Le Sueur River	Cobb R to Maple R	2010	Minnesota River	07020011-506	Blue Earth	07020011	Le Sueur River	Turbidity	2018	5		MN River	In Progress
Le Sueur River	CD 6 to Cobb R	2008	Minnesota River	07020011-507	Blue Earth	07020011	Le Sueur River	Turbidity	2018	5		MN River	In Progress
Rice Creek	Headwaters to Maple R	2010	Minnesota River	07020011-531	Faribault	07020011	Le Sueur River	Turbidity	2018	5		MN River	In Progress
Maple River	Rice Cr to Le Sueur R	2008	Minnesota River	07020011-534	Blue Earth	07020011	Le Sueur River	Turbidity	2018	5		MN River	In Progress
Maple River	Minnesota Lk outlet to Rice Cr	2010	Minnesota River	07020011-535	Blue Earth	07020011	Le Sueur River	Turbidity	2018	5		MN River	In Progress
County Ditch 3 (Judicial Ditch 9)	JD 9 to Maple R	2010	Minnesota River	07020011-552	Faribault	07020011	Le Sueur River	Turbidity	2018	5		MN River	In Progress
Cobb River	T107 R26W S30, west line to Le Sueur R	2008	Minnesota River	07020011-556	Blue Earth	07020011	Le Sueur River	Turbidity	2018	5		MN River	In Progress
Cobb River	T104 R23W S34, south line to Little Cobb R	2010	Minnesota River	07020011-568	Blue Earth	07020011	Le Sueur River	Turbidity	2018	5		MN River	In Progress

Water body name	Water body description	Year added to List	Basin	AUID	County	HUC 8	Watershed name	Pollutant or stressor	TMDL target completion year	EPA category	AUID previously listed	Watershed TMDL	Status
Le Sueur River	Headwaters to Boot Cr	2010	Minnesota River	07020011-619	Waseca	07020011	Le Sueur River	Turbidity	2018	5		MN River	In Progress
Le Sueur River	Boot Cr to CD 6	2010	Minnesota River	07020011-620	Waseca	07020011	Le Sueur River	Turbidity	2018	5		MN River	In Progress
Minnesota River	RM 22 to Mississippi R	1996	Minnesota River	07020012-505	Dakota	07020012	Lower Minnesota River	Turbidity	2018	5		MN River	In Progress
Minnesota River	Carver Cr to RM 22	1996	Minnesota River	07020012-506	Scott	07020012	Lower Minnesota River	Turbidity	2019	5		MN River	In Progress
Riley Creek	Riley Lk to Minnesota R	2002	Minnesota River	07020012-511	Hennepin	07020012	Lower Minnesota River	Turbidity	2019	5		Lower MN	In Progress
Sand Creek	Porter Cr to Minnesota R	2002	Minnesota River	07020012-513	Scott	07020012	Lower Minnesota River	Turbidity	2019	5		Lower MN	In Progress
Rush River	S Br Rush R to Minnesota R	2008	Minnesota River	07020012-521	Sibley	07020012	Lower Minnesota River	Turbidity	2019	5		Lower MN	In Progress
Sand Creek	Raven Str to Porter Cr	2010	Minnesota River	07020012-538	Scott	07020012	Lower Minnesota River	Turbidity	2019	5		Lower MN	In Progress
Rush River	M Br Rush R to S Br Rush R	2010	Minnesota River	07020012-548	Sibley	07020012	Lower Minnesota River	Turbidity	2019	5		Lower MN	In Progress

Water body name	Water body description	Year added to List	Basin	AUID	County	HUC 8	Watershed name	Pollutant or stressor	TMDL target completion year	EPA category	AUID previously listed	Watershed TMDL	Status
Robert Creek	Unnamed cr to Unnamed cr (at Belle Plaine Sewage Ponds)	2018	Minnesota River	07020012-575	Scott	07020012	Lower Minnesota River	Total suspended solids	2019	5		Lower MN	In Progress
Unnamed creek (East Creek)	Unnamed cr to Minnesota R	2008	Minnesota River	07020012-581	Carver	07020012	Lower Minnesota River	Turbidity	2019	5		Lower MN	In Progress
High Island Ditch 2	Unnamed cr to High Island Cr	2006	Minnesota River	07020012-588	Sibley	07020012	Lower Minnesota River	Turbidity	2019	5		Lower MN	In Progress
High Island Creek	JD 15 to Bakers Lk	2006	Minnesota River	07020012-653	McLeod	07020012	Lower Minnesota River	Turbidity	2019	5		Lower MN	In Progress
Minnesota River	Cherry Cr to High Island Cr	2002	Minnesota River	07020012-799	Le Sueur	07020012	Lower Minnesota River	Turbidity	2018	5	07020012-503; 507	MN River	In Progress
Minnesota River	High Island Cr to Carver Cr	1996	Minnesota River	07020012-800	Scott	07020012	Lower Minnesota River	Turbidity	2018	5	07020012-501	MN River	In Progress
Porter Creek	Fairbanks Ave to 250th St E	2010	Minnesota River	07020012-815	Scott	07020012	Lower Minnesota River	Turbidity	2019	5	07020012-540	Lower MN	In Progress
Porter Creek	Langford Rd/MN Hwy 13 to Sand Cr	2010	Minnesota River	07020012-817	Scott	07020012	Lower Minnesota River	Turbidity	2019	5	07020012-540	Lower MN	In Progress

Water body name	Water body description	Year added to List	Basin	AUID	County	HUC 8	Watershed name	Pollutant or stressor	TMDL target completion year	EPA category	AUID previously listed	Watershed TMDL	Status
Buffalo Creek	276th St /Co Rd 65 to High Island Cr	2008	Minnesota River	07020012-832	Sibley	07020012	Lower Minnesota River	Turbidity	2019	5	07020012-578	Lower MN	In Progress
High Island Creek	-94.0936 44.6181 to Minnesota R	2006	Minnesota River	07020012-834	Sibley	07020012	Lower Minnesota River	Turbidity	2019	5	07020012-589	Lower MN	In Progress
Sand Creek	T112 R23W S23, south line to -93.5454 44.5226	2010	Minnesota River	07020012-839	Le Sueur	07020012	Lower Minnesota River	Turbidity	2019	5	07020012-662	Lower MN	In Progress
Sand Creek	-93.5454 44.5226 to Raven Str	2010	Minnesota River	07020012-840	Scott	07020012	Lower Minnesota River	Turbidity	2019	5	07020012-662	Lower MN	In Progress

Appendix H. HSPF Hydrology and Sediment Calibration and Validation Reports

1 Park Drive, Suite 200 • PO Box 14409
Research Triangle Park, NC 27709
Tel 919-485-8278 • Fax 919-485-8280

TETRA TECH

Memorandum

To:	Dr. Chuck Regan, Tim Larson (MPCA)	**Date:**	03/17/2016 (Revised)
From:	J. Wyss, H.I.T; J. Butcher, Ph.D., P.H.	**Subject:**	**Minnesota River Basin HSPF Model Sediment Recalibration**
Cc:	Jennifer Olson	**Includes:**	Electronic supplement

1 Introduction

The Minnesota River basin HSPF models have a long history. Models for six of the 8-digit Hydrologic Unit Code (HUC8) basins were originally developed by MPCA in the 1990s and subsequently expanded and calibrated to include the entire basin from Lac qui Parle to Jordan, MN by Tetra Tech in 2002. Those models were used to support the development of a nutrient/dissolved oxygen TMDL and associated wasteload allocations. Tetra Tech (2008) subsequently refined these models for sediment simulation. These models were discretized at approximately the HUC10 scale. Tetra Tech later developed finer-resolution (HUC12-scale) models of the Chippewa and Hawk-Yellow Medicine HUC8 sub-models. MPCA then contracted with RESPEC to develop HUC12-scale models of the entire basin downstream of Lac qui Parle, as well as to extend the models in time through 2012. That effort was completed in 2014.

In 2015, MPCA contracted with Tetra Tech to refine the hydrologic and sediment calibrations for the Basin. The initial review of the RESPEC models provided to MPCA by Tetra Tech suggested that hydrology was fit reasonably well; however, sediment source attribution did not match up well with the evidence available from radiometric data (e.g., Schottler et al., 2010). Subsequent analysis revealed other aspects of the hydrologic calibration that potentially affect sediment calibration. Accordingly, MPCA requested review and revisions to the hydrologic calibration as part of the sediment recalibration effort. Tetra Tech completed the hydrology recalibration in November, 2015 and then used those models to complete the sediment recalibration.

The hydrologic recalibration is summarized in *Minnesota River Basin HSPF Model Hydrology Recalibration*, submitted to MPCA on November 3, 2015. This memorandum, along with accompanying electronic files, specifically documents the sediment recalibration and validation of the Minnesota River Basin HSPF modeling system, including linked models for the following HUC8 watersheds:

- Hawk-Yellow Medicine (07020004)
- Chippewa (07020005)
- Redwood (07020006)

- Middle Minnesota (07020007)
- Cottonwood (07020008)
- Blue Earth (07020009)
- Watonwan (07020010)
- Le Sueur (07020011)
- Lower Minnesota (07020012).

2 Approach

2.1 Goals and Objectives for Recalibration

The goal of this effort is to update the sediment calibration of the Minnesota River HSPF models using all relevant available sources of information including evidence on source attribution. Model performance was adjusted at all calibration gages in the watershed to meet the following objectives:

- **Formulation of sediment source attribution targets**. The MPCA was responsible for generating the first set of sediment apportionment calibration targets for Minnesota River HSPF models. The greatest amount of data is available from the detailed sediment budget study of the Le Sueur River, where estimates have been developed for sediment load deriving from upland sheet and rill erosion, ravines, channel degradation, and bluff collapse. Sediment apportionment calibration targets in the Le Sueur are based on flow and sediment measurements above and below the nick zones of active headcuts in the Le Sueur mainstem, Big Cobb River, and Maple River. Radiometric information aided in the partitioning of the field derived and channel derived sediment contributions based primarily on analysis of cores from depositional "integrator sites" (Schottler et al., 2010 plus additional ongoing work to further refine the interpretation by Schottler, as presented to Chuck Regan of MPCA, with additional information from the Le Sueur and Greater Blue Earth sediment mass balance studies of Gran et al., 2011 and Bevis, 2015).. Information from the Le Sueur Sediment Budget and other on-going work in the Greater Blue Earth watershed (Greater Blue Earth Sediment Budget) and throughout the Minnesota Basin are used to partition sediment contributions among fields, ravines, bluff, and channel incision sources. The sediment apportionment target information is summarized below in Table 1, showing the range of attributed upland loads from all sources and the current best estimate for this source.
- **Implementation of the sediment apportionment calibration targets.** The 2014 Minnesota River Basin HSPF models parameters were modified so that the amount of sediment coming from the four source categories were consistent with the calibration targets formulated in the previous task. The models were adjusted as needed to maintain acceptable levels of calibration for sediment transport.
- **Tabulation of the simulated sediment source apportionment.** For each watershed, Excel™ workbooks were created that tabulate the simulated sediment source apportionment. Each workbook is currently set up to supply simulated sediment source apportionment at instream calibration and validation stations for each watershed. They have been created in such a way that the workbooks can easily be modified to provide simulated sediment source apportionment at any pour point in each model. Each workbook uses standard model output from the HBN file so the

structure of the 2014 Minnesota River Basin HSPF models did not need to be modified to generate these results.

- **Assess the per-acre sediment loading rates for all of the pervious and impervious land classes in each model.** The 2014 Minnesota River Basin HSPF models generated per-acre upland sediment loading rates that are inconsistent with current constraining information. The models were adjusted as needed to make the sediment loading rates consistent with current constraining information.
- **Maintain acceptable fit between observed and simulated loads and concentrations** as recommended by MPCA's modeling guidance (AQUA TERRA, 2012). The existing calibration for sediment in the 2014 models appears to provide a decent fit to observations of suspended sediment concentrations, but the source apportionment is not consistent with available evidence and statistical analysis of model fit was not presented in RESPEC (2014). The objective of this work is to develop models that conform to constraining information on sediment source apportionment and annual loads while maintaining a high quality fit to instream observations of suspended sediment concentrations. The multi-objective calibration helps ensure a robust model; however, assuring an appropriate fit to source attribution information does appear to make it more difficult to match instream observations.

Table 1. Sediment Apportionment Calibration Targets

HUC8	Upland Best Estimate	Upland Range	Ravine	Bluff	Stream
Chippewa	31%	30-31%	ND	ND	ND
Redwood	23%	21-25%	ND	ND	ND
Yellow Medicine	ND	ND	ND	ND	ND
Cottonwood	21%	21-41%	ND	ND	ND
Watonwan	27%	27-41%	7%	43%	21%
Le Sueur	27%	12-27%	9%	57%	8%
Blue Earth	26%	19-28%	5%	55%	18%
Middle	27%	16-27%	ND	ND	ND
Lower/Metro	23%	14-31%	ND	ND	ND

2.2 Sediment Performance Metrics

Sediment is one of the more difficult water quality constituents to represent accurately in watershed and stream models. Important aspects of sediment behavior within a watershed system include loading and erosion sources, delivery of these eroded sediment sources to streams, drains and other pathways, and subsequent instream transport, scour and deposition processes (USEPA, 2006).

Sediment calibration for watershed models involves numerous steps in estimating model parameters and determining appropriate adjustments needed to insure a reasonable simulation of the sediment sources on the watershed, delivery to the waterbody, and transport behavior within the channel system. Rarely is there sufficient observed local data at sufficient spatial detail to obtain a unique calibration for all parameters for all land uses and each stream and waterbody reach. Consequently, model users focus the calibration on sites with observed data and review simulations in all parts of the watershed to ensure that the model results are consistent with field observations, historical reports, and expected behavior from past experience (Donigian and Love, 2003, AQUA TERRA, 2012).

The level of performance and overall quality of sediment calibration is evaluated in a weight of evidence approach that includes both visual comparisons and quantitative statistical measures. For this effort, the models were already stated to be calibrated for sediment, but did not match evidence on source attribution. Therefore, the primary focus of the model re-calibration was on approximating the source attribution evidence. We also adopted a philosophy, consistent with the RESPEC model representation, of using a parsimonious parameter set in which the parameter KSER, which controls washoff of upland sediment, were generally held constant for a given land use within a HUC8 basin. Similarly, the instream critical shear stresses for scour and deposition were held to narrow and consistent ranges. This approach leads to a robust model that is not over-fit to uncertain data and the fine-scale factors that may skew observations at individual stations; however, it also can reduce the apparent quality of fit in comparing model predictions to observations at individual stations.

The standard approach to sediment calibration focuses on the comparison of model predictions and observed total suspended solids or suspended sediment concentration data. Given the inherent errors in input and observed data and the approximate nature of model formulations, absolute criteria for watershed model performance are not generally considered appropriate by most modeling professionals. Yet, most decision makers want definitive answers to the questions—"How accurate is the model?" and "Is the model good enough for this evaluation?" Consequently, the current state of the art for model evaluation is to express model results in terms of ranges that correspond to "very good", "good", "fair", or "poor" quality of simulation fit to observed behavior. These characterizations inform appropriate uses of the model: for example, where a model achieves a good to very good fit, decision-makers often have greater confidence in having the model assume a strong role in evaluating management options. Conversely, where a model achieves only a fair or poor fit, decision makers may assign a less prominent role for the model results in the overall weight-of-evidence evaluation of management options.

For HSPF and similar watershed models, a variety of performance targets for comparison to observed suspended sediment concentrations have been documented in the literature, including Donigian et al. (1984), Lumb et al. (1994), Donigian (2000), and Moriasi et al. (2007). Based on these references and past experience, HSPF performance targets for sediment are summarized in Table 2.

Table 2. Performance Targets for HSPF Suspended Sediment Simulation (Magnitude of Annual and Seasonal Relative Mean Error (*RE)*; daily and monthly NSE)

Model Component	Very Good	Good	Fair	Poor
Sediment	≤ 20%	20 - 30%	30 - 45%	> 45%

It is important to clarify that the tolerance ranges are intended to be applied to mean values, and that individual events or observations may show larger differences and still be acceptable (Donigian, 2000).

Where model fit to observations is rated less than "good" this can be due to deficiencies in the model simulation of sediment, deficiencies in the model simulation of hydrology, deficiencies in the flow gage and water quality monitoring records, or a combination of the three. Model calibration typically assumes that the observed records are "correct" and maximizes the fit of the model to those records. It is clear in some cases, however, that uncertainty in the monitoring record itself is a major contributor to poor predictability. This is most likely to be true for stations that have short periods of record, locations that are impacted by backwater effects, and sites with unstable channels at which rating curve adjustments (which are essential to the simulation of shear stress and sediment scour and deposition) have not been frequently revised. In addition, most of the observed data consist of grab samples that represent a specific point in space and time. These are compared to model predictions that represent a daily average over a whole model reach (typically several miles in length) that is assumed to be completely mixed. An instantaneous grab sample may not be representative of an average concentration over the course of a day, and small errors in the timing of storm flows will propagate into apparent error in the fit to suspended sediment concentration. Further, observations at a specific spatial location may be affected by local conditions, such as bridge scour, that deviate from the average over the whole reach. As a result, calibration is an inexact science that must proceed by a weight-of-evidence approach.

2.3 Calibration and Validation/Corroboration

Traditional model validation is intended to provide a test of the robustness of calibrated parameters through application to a second time period. In watershed models, this is, in practice, usually an iterative process in which evaluation of model application to a validation period leads to further adjustments in the calibration. A second, and perhaps more useful constraint on model specification and performance is a spatial calibration/corroboration approach in which the model is tested at multiple gages on the stream network to ensure that the model is not over parameterized to fit any one gage or collection of gages. In particular, obtaining model fit to numerous gages at multiple spatial scales from individual headwater streams to downstream stations that integrate across the entire Minnesota River basin helps to ensure that the model calibration is robust. This is especially appropriate for the present model recalibration effort in which the full set of available data has already been used to develop the initial model calibration.

The overall model application period is 1/1/1995 – 12/31/2012. Typical sediment sampling frequencies range from once a week to once a month, but often cover only a subset of years within the overall application period. All of the sediment samples at a gage were used as a full record for that gage and no split sample calibration/validation periods were adopted. Instead a spatial distribution of calibration and validation stations was selected in which initial efforts focused on the "calibration" stations, followed by additional testing and refinement using the corroboration stations. Generally, headwater and upstream gages are considered corroboration stations, which ensures that a corroboration station is not downstream of a calibration station and thus represents a semi-independent test of the model parameterization. Note, however, that model fit to observations is likely to decline for stations with smaller drainage areas because these stations are likely to have flashier responses that amplify the potential discrepancy between grab sample observations and model daily average predictions.

2.4 Components not Adjusted

The adjustments to the sediment calibration are conditional on accepting several aspects of the RESPEC model development (RESPEC, 2014). Most of these were discussed in the hydrology recalibration memo:

- Development and assignment of meteorological forcing time series, including the calculation of potential evapotranspiration, was not adjusted. The models are forced by rainfall gauge records, which have in many instances have been shown not to be representative of areal average precipitation totals during large convective summer storm events.
- Point source discharges are accepted as specified by RESPEC.
- The RESPEC models use a degree-day method for the simulation of snow melt in which melt is estimated solely as a function of air temperature. This provided a good fit to the overall water balance at most stations, but is less adept at simulating rapid changes in the snow balance and does not account for sublimation from the snow pack.

- Hydraulic functional tables (FTables) are not altered from the RESPEC models. Lake simulation is also as set up by RESPEC. Most of the stream reach FTables appear to be specified based on regional hydraulic geometry information and do not incorporate measured channel cross section data[1]. This can bias simulation of channel shear stresses, especially during large storm events.

Also significant to the sediment recalibration are the following:

- The RESPEC models represent sediment contributions from tile drains with surface inlets through the use of GENER statements. The methodology used to generate tile drain sediment loads in this application is unchanged; however, the area factors associated with the GENER statements were updated to properly represent the modifications made to separate agricultural lands by hydrologic soil group (HSG), as described in Section 4. Examination of the approach to simulating tile drain sediment in these models indicates a much more rapid response and quick recession of sediment loads compared to those represented through Special Actions in the Tetra Tech (2008) models.
- The setup of which land uses contribute mass scour (ravine erosion) from the uplands was unchanged. The RESPEC models assign ravine erosion to agricultural lands and to the special bluff and ravine land uses. With the exception of the bluff and ravine land uses (where scour rates were increased to generate considerably more sediment from the land), the setup for ravine erosion is unchanged from what RESPEC provided; however, the results will differ due to the revisions to model hydrology.
- The partitioning from upland total sediment yield to instream sand, silt, and clay fraction loads is not modified from what RESPEC provided.
- Initial stream bed composition of sand, silt, and clay is not modified from what RESPEC provided.
- The Chippewa model received from RESPEC and adapted from the earlier Tetra Tech model is set up with an additional general quality constituent simulating sediment load independent of sheet and rill or gully erosion. This was done because suspended solids concentrations at the upstream station on the Chippewa River at Cyrus have an atypical relationship to flow. That is, high concentrations of TSS often occur at relatively low flows, while the concentration tends to decrease for higher flows. This suggests the presence of an approximately constant load of solids that is independent of flow, such as could occur from extensive animal activity in the stream or sand mining operations. This approach was not modified for the sediment recalibration.

3 Calibration Gage Sites

A total of 63 in-stream water quality stations were used for the Minnesota River Basin HSPF model sediment recalibration. All selected in-stream stations have at least 100 TSS samples during the simulation period. Additionally, with the exception of Watonwan (Watonwan has only one station with more than 100 samples) at least three stations were included for each HUC8. As previously discussed the stations were split into calibration (31 stations) and corroboration (32 stations) based on spatial

[1] The RESPEC memoranda say that for reaches where Tetra Tech previously calculated FTables using results of HEC-RAS models, those FTables "will be scaled by reach length and applied to corresponding reaches in order to maximize the use of the best available data." For reaches that did not have HEC-RAS models, the documentation implies that cross-sectional measurements at USGS gage sites will be used, and, when field information on a gage is not available, "The USGS maximum width, depth, and area data will be used to calculate cross-sections assuming a trapezoidal channel and a bank slope of 1/3."

information. The in-stream water quality stations used for sediment calibration and corroboration are listed in Table 3.

Table 3. Sediment Calibration and Corroboration Stations

Site	HUC_8	HYDSTRA ID	STORET ID	Period of Record	Type
Chippewa R at 140th St, 7 mi N of Cyrus	7020005	276033	S002-190	5/1999 - 9/2012	Calibration
Chippewa R at CSAH-22, 1 mi E of Clontarf	7020005	276036	S002-193	5/1998 - 9/2012	Calibration
Shakopee Ck, at Unn Twnshp Rd, 1 mi W Mn-29, 8 mi*	7020005	276043	S002-201	5/1998 - 9/2012	Calibration
Chippewa R, at MN-40, 5.5 mi E of Milan	7020005	276045	S002-203	5/1998 - 12/2012	Calibration
Dry Weather Creek, at 85th Ave NW, 4 mi NE of Wat*	7020005	276046	S002-204	5/1998 - 9/2012	Corroboration
Shakopee Ck S Andrew Rd at Lk Andrew Otl 4.5 mi W*	7020005	276051	S002-209	6/1996 - 10/2007	Corroboration
Little Chippewa R at MN-28, 4 mi W of Starbuck	7020005	276146	S004-705	3/2007 - 9/2009	Corroboration
Chippewa R, EB, at 15th Ave Ne, 2.5 mi N of Benson	7020005	276156	S005-364	5/1998 - 9/2012	Corroboration
W Fk Beaver Ck at CSAH-4 6.5 mi S of Olivia	7020004	275971	S000-405	6/1999 - 9/2009	Corroboration
Beaver Ck at CSAH-2 2.5 mi NE of North Redwood	7020004	275976	S000-666	6/1999 - 9/2012	Calibration
Sacred Heart Ck at CSAH-15 Br, 5 mi NW of Delhi, *	7020004	275988	S001-341	4/1999 - 9/2012	Corroboration
Hawk Ck at Cr 52 Br, 6.5 mi SE of Granite Falls	7020004	276009	S002-012	6/1999 - 12/2012	Calibration
Palmer Ck at 15th Ave Se, 2 mi NW of Granite Falls	7020004	276010	S002-136	4/1999 - 9/2012	Corroboration
Hawk Ck, at Cr-116, 1.25 mi S of MN-40, 4.2 mi SW*	7020004	276014	S002-140	6/1999 - 9/2012	Corroboration
Hawk Ck, at MN-23, 2.2 mi SW of Maynard	7020004	276022	S002-148	6/1999 - 9/2012	Calibration
Chetomba Ck, at Unnamed Twp Rd, 5 mi SE of Maynard	7020004	276026	S002-152	6/1999 - 9/2012	Corroboration
Yellow Med R, 1 1/3 mi No CSAH-18, 5 1/4 mi NE Ha*	7020004	276068	S002-316	4/2001 - 10/2012	Calibration
So Br Yellow Medicine R On CSAH-26, 4 mi N Minneo*	7020004	276071	S002-320	4/2001 - 8/2012	Corroboration
Cd-119 at CSAH-15, 5.6 mi S of Sacred Heart, Minn*	7020004	276116	S003-866	4/2005 - 8/2012	Corroboration
Timms Ck at CSAH-15, 2.8 mi NNE of Delhi, Minneso*	7020004	276117	S003-867	4/2005 - 8/2012	Corroboration
MM R 500 Ft S CSAH-13 near USGS Gage House Dwnst *	7020004	276123	S004-649	3/2007 - 12/2012	Calibration
Minnesota R, Ethanol Facility Water Supply Intake*	7020004	276349	S007-748	2/2007 - 1/2008	Calibration
Redwood R at CSAH-15 In Russell	7020006	272519	S000-696	5/2001 - 9/2012	Calibration
Redwood R at CSAH-17, 3 miles SW of Redwood Falls	7020006	272872	S001-679	3/1996 - 9/2012	Calibration
Clear Ck Cr-56, 1/3 mi upst conflu Redwd R, NE Ed*	7020006	272541	S002-311	3/1996 - 9/2012	Corroboration
Three mile Ck at Cr-67, 1 mi No of Green Valley	7020006	273019	S002-313	3/1996 - 10/2011	Corroboration
Plum Creek at CSAH 10 Br, 4.75 mi NE of Walnut Gr*	7020008	273015	S001-913	4/1997 - 7/2012	Corroboration
Cottonwood R near MN-68 And Cottonwood St In New *	7020008	273017	S001-918	4/1997 - 10/2011	Calibration
Sleepy Eye Cr at CSAH 8 Br, 2.2 mi N of Leavenwor*	7020008	272478	S001-919	4/1997 - 9/2012	Corroboration
Cottonwood R at CSAH 8 Br, 0.4 mi N of Leavenwort*	7020008	272479	S001-920	4/1997 - 9/2012	Calibration
Cottonwood R at Us-14 Brg, 1 mi NE of Lamberton	7020008	272532	S002-247	5/2000 - 9/2012	Calibration
Watonwan R Br On CSAH-13, 1 mi W of Garden City	7020010	272526	S000-163	10/1996 - 3/2012	Calibration
Le Sueur R MN-66 1.5 mi NE of Rapidan	7020011	272867	S000-340	1/2005 - 7/2012	Calibration
Unn Trib To Big Cobb R, Sh22 0.5 mi N Beauford	7020011	273013	S001-210	1/2005 - 9/2012	Corroboration
Maple R at CSAH 35 5.2 mi S of Mankato, MN	7020011	272950	S002-427	4/2003 - 8/2012	Calibration
Cobb R at CSAH-16, 4.4 mi NE of Good Thunder, MN	7020011	272629	S003-446	3/2006 - 9/2011	Calibration
Le Sueur R at CSAH 28 in Saint Clair, MN	7020011	273029	S003-448	3/2007 - 6/2012	Corroboration
Little Cobb near CSAH-16, 6.3 mi W of Pemberton, *	7020011	272962	S003-574	1/2005 - 9/2012	Corroboration
Le Sueur R at CSAH-8, 5.1 mi SSE of Mankato, MN	7020011	272617	S003-860	3/2006 - 9/2011	Calibration
Maple R at CSAH-18, 2 miles North of Sterling Cen*	7020011	272627	S004-101	4/2006 - 9/2012	Corroboration
Blue Earth River 150 Ft dwst of Rapidan Dam	7020009	272948	S001-231	1/2005 - 3/2012	Calibration
Dutch Creek at 100th St, 0.5 miles W of Fairmont	7020009	272881	S003-000	4/2000 - 10/2008	Corroboration
Center Creek at 315th Avenue - 1 mi S of Huntley	7020009	272608	S003-024	2/2002 - 10/2008	Corroboration
Elm Creek at 290th Ave - 4.5 mi NE of Granada	7020009	272609	S003-025	2/2002 - 10/2008	Calibration
Minnesota River at Mankato, MN	7020007	273053	5325000	3/1996 - 8/2007	Calibration
Minnesota R Bridge On Us-71 And MN-19 at Morton	7020007	272517	S000-145	10/2000 - 10/2011	Calibration
Minnesota R at CSAH 42 at Judson	7020007	272509	S001-759	1/2005 - 2/2012	Calibration
Sevenmile Ck dwst of MN-99, 6 mi SW of St. Peter	7020007	272646	S002-934	4/1996 - 8/2011	Corroboration
Cty Dtch 46A dwst of CSAH-13, 6 mi SW of St. Peter	7020007	272880	S002-936	4/2000 - 9/2011	Corroboration
Sevenmile Ck in Sevenmile Ck Cty Pk, 5.5 mi SW of*	7020007	273028	S002-937	4/1996 - 9/2011	Calibration
Minnesota R at MN-99 in St. Peter, MN	7020007	273031	S004-130	1/2005 - 2/2012	Calibration
Little Cottonwood R at Apple Rd, 1.6 mi S of Courtland	7020007	273033	S004-609	4/1996 - 6/2010	Corroboration
High Island Cr., CSAH-6 By Henderson	7020012	272518	S000-676	6/1998 - 9/2012	Calibration

Site	HUC_8	HYDSTRA ID	STORET ID	Period of Record	Type
Rush River, Sh-93 By Henderson	7020012	272599	S000-822	6/1998 - 9/2012	Calibration
Bevens Cr.,CSAH-41 By East Union	7020012	272871	S000-825	2/1998 - 9/2011	Calibration
Silver Cr.,CSAH-41 By East Union	7020012	272600	S000-843	6/2000 - 8/2011	Corroboration
Buffalo Ck, at 270th St, 1.5 mi NW of Henderson	7020012	272468	S001-807	5/2000 - 9/2012	Corroboration
High Island Ck at CSAH 9, 1 mi NW of Arlington	7020012	272482	S001-891	5/2000 - 9/2012	Corroboration
Carver Ck at Us-212, 2.5 mi E of Cologne, MN	7020012	273022	S002-489	5/1997 - 9/2011	Corroboration
Carver Ck at Cr-140, 2.3 mi NE of Benton, MN	7020012	272489	S002-490	5/1997 - 9/2011	Corroboration
Bevens Ck at 321st Ave, 3 mi SE of Hamburg, MN	7020012	272503	S002-516	11/1999 - 9/2011	Corroboration
Bevens Ck at Rice Ave, 3.9 mi SE of Norwood Yng America	7020012	272470	S002-539	5/1997 - 9/2011	Corroboration
W Chaska Ck, 250' W of Cty Rd 10, behind VFW, in *	7020012	272472	S002-548	4/1998 - 9/2011	Calibration

* Name truncated in RESPEC database

4 Model Updates

4.1 Model Structural Reconfiguration

After consultation with MPCA, a number of changes were made in the structure of the 2014 models. These included subdivision of agricultural land to separate hydrologic soil group (HSG) classes and separation of cropland areas receiving manure applications – both of which may be useful for development of model scenarios. The reconfiguration of the models is described below.

- **Separation of cropland into two classes based on HSG.** Most of the agricultural land in the watershed incorporates tile drainage to improve spring water balance, with intensity of tile drainage generally being greatest in the lacustrine soils of the Le Sueur watershed and adjacent parts of the Blue Earth and Middle Minnesota 8-digit HUCs. The RESPEC (2014) models (exclusive of the Chippewa and Hawk-Yellow Medicine models developed by Tetra Tech) lumped all cropland into two conventional and conservation tillage groups regardless of soil type, which precludes identification of critical areas with marginal soil characteristics. This was rectified by reprocessing the land use information and generating four cropland classes representing Cropland – Conservation Till (HSG A,B), Cropland – Conservation Till (HSG C,D), Cropland – Conventional Till (HSG A,B), and Cropland – Conventional Till (HSG C,D), where the HSG class for cropland is the designation “with drainage” for dual classification soils (i.e., B/D soils are soils that have B characteristics when drained) under the assumption that tile drainage is ubiquitous where it is necessary to improve production performance in the corn belt. This change was implemented before the completion of the hydrology recalibration but not discussed in the November 2015 memo.
- **Representation of manured lands.** For all models except Chippewa and Hawk Yellow Medicine, land receiving manure application was not explicitly represented in the RESPEC (2014) models. The models were set up with a land use called “Cropland – Reserved” for this purpose, but this land use was assigned no area in the 2014 models. The Cropland – Reserved category was changed to “Manure Application (conventional A,B)” and area from Cropland – Conventional Till (HSG A,B) was changed to the Manure Application land use to reflect the estimated acreage that receives manure application. We assumed that manure would primarily be applied to land with better drainage, as the (A,B) grouping (with drainage) is also the dominant component of the overall cropland area, and also that regular manure application is not generally consistent with conservation tillage maintenance of residue cover. The decision by MPCA to incorporate this change in the model structure occurred after the hydrology recalibration and most of the sediment recalibration was complete. To have no net impact on the hydrology and

sediment recalibrations, the manured land was reassigned solely from Cropland – Conventional Till (HSG A,B) and the hydrologic and sediment parameters for manured land were set equal to those for Cropland – Conventional Till (HSG A,B). This was the approach that used in the 2008 TMDL model as well.

- **Separation of Lower Minnesota model into two models.** The increase in the number of model pervious upland land units (PERLNDs) due to the cropland and manured area modifications increased the number of operations in the Lower Minnesota model beyond the upper limit for the current version of the HSPF model. The 2014 Lower Minnesota model was split into two separate linked models: a revised Lower Minnesota model incorporating all sub-basins upstream of and including reach 310 and a new "Metro" Minnesota that incorporates the portion of the original Lower Minnesota model downstream of reach 310.
- **Representation of bluff land area.** The RESPEC (2014) models include the land area in bluffs (as shown on a spatial coverage of bluff area developed in 2011-2012 and provided by MPCA) for all the models except for Chippewa and Hawk Yellow Medicine. There is newer work in progress to better delineate bluffs from LiDAR elevation data; however, those coverages are not yet suitable for use as they identify many small features, such as ditch banks, as bluffs, which is not consistent with the characterization of bluff areas in the model. Similarly, ravine land use has been identified as a separate coverage in the Le Sueur watershed, but work is not complete in other basins (although ravine loading is simulated as a part of the general crop land simulation). Both the bluff and ravine coverages should be updated when this ongoing work is completed. For the present round of models, bluff land use area (as shown on the 2011-12 bluff coverage) was incorporated into the Chippewa and Hawk Yellow Medicine models.
- **Representation of bluff collapse.** The RESPEC (2014) models removed the earlier models' pseudo-random process of contribution from bluff collapse that was implemented via SPECIAL ACTIONS. The old approach, where the process of bluff collapse is simulated as an increase in the bed sediment that is available for transport in stream segments, was reincorporated in the updated models. Table 5-2 (*Bluff Erosion Contribution Rates to Available Stream Bed Sediment*) from Tetra Tech (2008) was used as a starting point along with information from the Le Sueur and Greater Blue Earth sediment mass balance studies (Gran et al., 2011; Bevis, 2015). The watershed-specific estimated total bluff loads were split by area-weighting the bluff contribution based on each individual sub-watershed bluff area for each of the watersheds and then that load was supplied as a constant replenishment to the bed via SPECIAL ACTIONS. This approach maintains the watershed-specific bluff contribution loads at the mouth of each model but proportionally modifies the amount of sediment load applied to a reach containing a bluff land use by the area of bluff contributing to the reach. In the Tetra Tech (2008) report, bluff loading was not represented in the Middle Minnesota and Lower Minnesota models and no specific information on bluff loading rates has been obtained. However, there is bluff land use area in those two models. To implement the SPECIAL ACTIONS in the Middle and Lower Minnesota models, the Le Sueur bluff contribution loads were used as a proxy at the recommendation of the MPCA project manager. First, the Le Sueur bluff loading rate was converted to a yield in tons/ac relative to the specified bluff acreage. Second, the converted Le Sueur rate was applied to the bluff area in the Middle, Lower, and Metro models to develop the bluff erosion contribution rates to available stream bed sediment.
- **Creation of PLTGEN outputs for models not having those outputs.** Most of the RESPEC (2014) models provided model output at instream monitoring locations by writing to PLTGEN's. PLTGEN output was added to the Chippewa, Hawk-Yellow Medicine, Middle Minnesota, Lower Minnesota, and Metro Minnesota models. This allowed for a consistent set of tools to compare simulated and observed instream concentrations and load summaries.

4.2 UPLAND SEDIMENT SIMULATION

The RESPEC (2014) Minnesota River Basin HSPF models in most cases had upland sediment parameters similar to those calibrated in Tetra Tech (2008) and thus produce consistent loading rate estimates. This was not the case for the impervious land simulation, where the use of a high value of the washoff parameter (KEIM) resulting in extremely high loading rates from urban land, apparently accidentally set at ten times the previously calibrated value, resulted in urban impervious land generating about 1 ton per acre per year of solids and dominating total sediment load in some watersheds. Municipal Separate Storm Sewer System (MS4) monitoring results summarized by MPCA suggest that the sediment rate for urban developed land should, on average, be less than 0.1 ton/ac/yr.

The main parameters controlling upland sediment generation and transport to the stream are:

- KRER coefficient in the soil detachment equation for pervious land
- KSER coefficient in the detached sediment washoff equation for pervious land
- KEIM coefficient in the solids washoff equation for impervious land

The above parameters were the main PERLND and IMPLND parameters modified to bring consistency with the current constraining information and the simulated per acre sediment loading rates. There are other parameters that have a major influence specifically the exponential terms (JRER, JSER, and JEIM), although those were not modified from what RESPEC previously used because reasonable per acre sediment loading rates were obtained without modifying them. However, almost all sediment parameters were modified for Bluffs and Ravines. Since these land uses have small area and are large contributors of the overall sediment load in the stream, all of the parameters were set up so that the land areas have high loading rates.

Table 4 through Table 6 show the range of values used for each land use and each model for the three main parameters modified for the upland sediment simulation. KRER was calculated using the land use coverage and soils coverage and then area weighted to a value for each land use and weather station zone and was not further modified during calibration. KSER was the main parameter adjusted to control the sediment washoff and delivery. KEIM was the only parameter adjusted to control solids washoff and delivery. Table 7 provides the typical monthly erosion-related cover used for all models to provide some context to the calibrated values of KRER and KSER.

Table 4. KRER Values Used for Updated Models

Land Use	Redwood	Cottonwood	Watonwan	Le Sueur	Blue Earth	Middle	Lower	Metro
Urban	0.241 - 0.287	0.233 - 0.27	0.233 - 0.266	0.237 - 0.278	0.239 - 0.289	0.228 - 0.268	0.229 - 0.271	0.207 - 0.281
Forest	0.24 - 0.281	0.234 - 0.273	0.211 - 0.253	0.209 - 0.287	0.24 - 0.292	0.165 - 0.269	0.2 - 0.274	0.177 - 0.261
Cropland - Conservation Till (HSG A,B)	0.243 - 0.277	0.233 - 0.27	0.232 - 0.265	0.225 - 0.272	0.217 - 0.284	0.23 - 0.251	0.217 - 0.256	0.04 - 0.305
Cropland - Conservation Till (HSG C,D)	0.314 - 0.363	0.312 - 0.362	0.127 - 0.331	0.106 - 0.286	0.15 - 0.336	0.192 - 0.339	0.219 - 0.357	0.02 - 0.313
Cropland - Conventional Till (HSG A,B)	0.243 - 0.277	0.233 - 0.27	0.232 - 0.265	0.225 - 0.272	0.217 - 0.284	0.23 - 0.251	0.217 - 0.256	0.04 - 0.305
Cropland - Conventional Till (HSG C,D)	0.314 - 0.363	0.312 - 0.362	0.127 - 0.331	0.106 - 0.286	0.15 - 0.336	0.192 - 0.339	0.219 - 0.357	0.02 - 0.313
Cropland - Manure Application (conv A,B)	0.243 - 0.277	0.233 - 0.27	0.232 - 0.265	0.225 - 0.272	0.217 - 0.284	0.23 - 0.251	0.217 - 0.256	0.04 - 0.305
Grassland	0.249 - 0.28	0.212 - 0.277	0.217 - 0.287	0.209 - 0.264	0.214 - 0.274	0.204 - 0265	0.21 - 0.275	0.171 - 0.276
Pasture	0.211 - 0.288	0.22 - 0.284	0.211 0.261	0.192 - 0.282	0.227 - 0.279	0.208 - 0.27	0.217 - 0.268	0.113 - 0.274
Wetland	0.254 - 0.313	0.227 - 0.278	0.155 - 0.244	0.042 - 0.249	0.104 - 0.276	0.066 - 0.311	0.072 - 0.264	0.049 - 0.236
Feedlot	0.25	0.25	0.25	0.23 - 0.27	0.246	0.245	0.244	0.244
Bluff	0.24	0.24	0.24	0.23 - 0.27	0.243	0.243	0.174	0.174
Ravine	0.28	0.28	0.28	0.23	0.278	0.278	0.278	0.278

Notes: KRER estimates are derived from soil survey data on the Universal Soil Loss Equation erodibility (K) factor. Values for Chippewa and Hawk Yellow Medicine not presented here due to different PERLND configurations. Refer to their UCI files for their parameterization

Table 5. KSER Values Used for Updated Models

Land Use	Redwood	Cottonwood	Watonwan	Le Sueur	Blue Earth	Middle	Lower	Metro
Urban	0.08	0.08	0.07	0.08	0.08	0.08	0.08	0.08
Forest	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Cropland - Conservation Till (HSG A,B)	0.2	0.3	0.08	0.2 & 0.05	0.25	0.3	0.15	0.15
Cropland - Conservation Till (HSG C,D)	0.15	0.3	0.08	0.2 & 0.05	0.1	0.3	0.15	0.15
Cropland - Conventional Till (HSG A,B)	0.25	0.4	0.11	0.3 & 0.1	0.3	0.4	0.2	0.2
Cropland - Conventional Till (HSG C,D)	0.2	0.4	0.11	0.3 & 0.1	0.15	0.4	0.2	0.2
Cropland - Manure Application (conv A,B)	0.25	0.4	0.09	0.3 & 0.1	0.3	0.4	0.2	0.2
Grassland	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04
Pasture	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07
Wetland	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Feedlot	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14
Bluff	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75
Ravine	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5

Note: Values for Chippewa and Hawk Yellow Medicine not presented here due to different PERLND configurations. Refer to their UCI files for their parameterization

Table 6. KEIM Values Used for Updated Models

Land Use	Chippewa	HYM	Redwood	Cottonwood	Watonwan	Le Sueur	Blue Earth	Middle	Lower	Metro
Urban Impervious	0.03	0.02	0.015	0.015	0.015	0.015	0.015	0.015	0.015	0.015

Table 7. Typical Monthly Cover Values Used for Updated Models

Land Use	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
Urban	0.85	0.85	0.85	0.88	0.88	0.88	0.88	0.88	0.88	0.86	0.85	0.85
Forest	0.85	0.85	0.85	0.9	0.95	0.95	0.95	0.95	0.95	0.95	0.85	0.85
Cropland - Conservation Till A,B	0.2	0.2	0.2	0.35	0.35	0.3	0.4	0.85	0.85	0.7	0.55	0.35
Cropland - Conservation Till C,D	0.2	0.2	0.2	0.35	0.35	0.3	0.4	0.85	0.85	0.7	0.55	0.35
Cropland - Conventional Till A,B	0.05	0.05	0.05	0.15	0.15	0.2	0.4	0.85	0.85	0.6	0.4	0.15
Cropland - Conventional Till C,D	0.05	0.05	0.05	0.15	0.15	0.2	0.4	0.85	0.85	0.6	0.4	0.15
Cropland - Manure Application (conv A,B)	0.05	0.05	0.05	0.15	0.15	0.2	0.4	0.85	0.85	0.6	0.4	0.15
Grassland	0.75	0.75	0.75	0.8	0.85	0.9	0.9	0.9	0.9	0.9	0.85	0.8
Pasture	0.75	0.75	0.75	0.8	0.85	0.9	0.9	0.9	0.9	0.9	0.85	0.8
Wetland	0.9	0.9	0.9	0.92	0.97	0.97	0.97	0.97	0.97	0.97	0.92	0.9
Feedlot	0.1	0.1	0.1	0.03	0.03	0.1	0.6	0.85	0.85	0.7	0.2	0.15
Bluff	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Ravine	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2

4.3 INSTREAM SEDIMENT SIMULATION

As previously discussed the 2014 Minnesota River Basin HSPF models had sediment source apportionment results that were inconsistent with the current constraining information. For example, the 2014 models of the Blue Earth and Le Sueur watersheds attributed over 70 percent of the total sediment load to upland sources compared to less than 30 percent based on radiometric analysis (see Table 1 above). This fact, along with the updated hydrology calibration, required adjustment of the instream simulation of sediment.

There are two types and three classes of sediment simulated in HSPF non-cohesive (sand) and cohesive (silt and clay). The three sediment classes are simulated independently of one another in the stream. Load delivered from the land surface is simulated as total sediment and partitioned into sand, silt, and clay factions at the stream edge. As previously stated, the upland to instream partitioning of sediment was not modified from what was provided by RESPEC.

In HSPF, sand can be simulated by one of three approaches: 1) Toffaletti equation, 2) Colby method, or 3) power function of velocity. For the Minnesota River Basin HSPF the selected sand method is 3) power function of velocity. This was the method that RESPEC used and was unmodified for the recalibration.

The main parameters controlling the cohesive instream sediment simulation are listed below. These values are contained in the SILT-CLAY-PM block of the UCI and the data block is repeated twice. The first set in the UCI pertains to silt and the second set in the UCI pertains to clay.

- D effective diameter of the particles
- W particle fall velocity in still water
- RHO particle density
- TAUCD critical bed shear stress for deposition
- TAUCS critical bed shear stress for scour
- M erodibility coefficient of the sediment

D, W, and RHO were parameterized with values in range with those outlined in US EPA (2006) and following the approach laid out for MPCA One Water projects by AQUA TERRA (2012). Values for TAUCD, TAUCS, and M were calibrated by first outputting the hourly TAU (bed shear stress) for the simulation period. Second, the percentile ranges of TAU for each simulated reach were tabulated. Third, initial values TAUCD, TAUCS, were input by selecting a percentile used in previous model calibrations and finding each reaches TAU value corresponding to that percentile. Lastly, after the upland simulation was completed, TAUCD, TAUCS, and M were adjusted through an iterative process until an acceptable match was achieved between observed instream concentrations and loads and simulated concentrations and loads, and sediment source apportionment (percent and estimated load where available) were consistent with the current constraining information.

As noted above, the representation of sediment load associated with mass wasting of bluffs was reverted to the prior approach (Tetra Tech, 2008) where the process of bluff collapse is simulated as an increase in the bed sediment that is available for transport in stream segments. Table 8 shows the bluff erosion contribution rates to available stream bed sediment as a total rate above each models pour point or end point. The watershed-specific bluff contribution loads were split among identified bluff land uses based on the bluff area by sub-basin. That load was then supplied as a constant replenishment rate to the bed for the reaches containing upland bluff area via SPECIAL ACTIONS. The added sediment was then mobilized when higher flows occur (i.e., TAU values greater than TAUCS). The bluff reaches had higher values of the erodibility coefficient M specified to maintain proper stream bed balance.

Table 8. Total Sediment Loading to Stream Bed Storage from Bluff Mass Wasting Processes

Watershed	Bluff Contribution (tons/hr)
Blue Earth River	28
Chippewa River	0.1
Cottonwood River	2.1
Hawk Creek	0.97
Le Sueur River	11.2
Lower Minnesota River	0.05
Middle Minnesota River	0.13
Redwood River	1.6
Watonwan River	2.1
Yellow Medicine River	1.5

In the initial calibration the simulated TSS concentrations were generally lower than those observed at base flow conditions. To improve the baseflow simulation, a clay load associated with groundwater was supplied as a surrogate for a combination of fine material in actual groundwater discharges, and activity of fish, animals, and humans in the streams. The added clay load equated to 5 mg/L for all models except Hawk-Yellow Medicine, and Chippewa, which were assigned 1 mg/L.

Table 9 provides the range of values used in the SILT- and CLAY-PM blocks. Values for D, W, RHO, and M in this table are the actual values input into the UCI, while entries for TAUCD and TAUCS provide the percentile range of simulated TAU. Since each reach has its own model derived value for TAU providing the percentile range of TAU provides much more insight into the parameterization of TAUCD and TAUCS. For each basin, parameters other than the critical shear stresses were specified separately for stream, lake, and bluff-area reaches but otherwise held constant or varied only slightly (in the case of M) across the basin. The erodibility and critical shear stress parameters were varied within relatively constrained ranges to improve the calibration fit.

Table 9. SILT-CLAY-PM Block Values Used for Updated Models

Constituent	RCHRES Type	Parameter	Chippewa	HYM	Redwood	Cottonwood	Watonwan	Le Sueur	Blue Earth	Middle	Lower	Metro
Silt	Stream	D	0.0006	0.0006	0.0006	0.0006	0.0006	0.0006	0.0006	0.0006	0.0006	0.0006
		W	0.0039	0.0039	0.0039	0.0039	0.0039	0.0039	0.0039	0.0039	0.0039	0.0039
		RHO	2.3	2.3	2.3	2.3	2.3	2.3	2.3	2.3	2.3	2.3
		TAUCD*	1-50	4-7	1-18	4-6	1-10	4-10	1-13	1-18	1-13	1-16
		TAUCS*	80-85	80-81	75-76	75-76	66-78	65-92	65-80	73-91	74-78	68-80
		M	0.004	0.004	0.015	0.015-0.025	0.01	0.006-0.03	0.025	0.01	0.02	0.02
	Bluff	D	0.0006	0.0006	0.0006	0.0006	0.0006	0.0006	0.0006	0.0006	0.0006	0.0006
		W	0.0039	0.0039	0.0039	0.0039	0.0039	0.0039	0.0039	0.0039	0.0039	0.0039
		RHO	2.3	2.3	2.3	2.3	2.3	2.3	2.3	2.3	2.3	2.3
		TAUCD*	6	5-6	6	5-6	5-6	4-11	5-6	5-6	5-6	5-6
		TAUCS*	80-81	81	76	75-76	66-78	65-92	65-75	85-86	75-76	75-76
		M	0.01	0.07	0.1	0.05-0.1	0.03-0.05	0.008-0.07	0.1	0.1	0.1	0.1
	Lake	D	0.0006	0.0006	0.0006	0.0006	0.0006	0.0006	0.0006	0.0006	0.0006	0.0006
		W	0.0039	0.0039	0.0039	0.0039	0.0039	0.0039	0.0039	0.0039	0.0039	0.0039
		RHO	2.3	2.3	2.3	2.3	2.3	2.3	2.3	2.3	2.3	2.3
		TAUCD*	97-99.9	97-98	97-99.9	97-99.9	98-99	97-99	95-99	97-99	97-99	97-99
		TAUCS*	99-99.9	99	99-99.9	97-99.9	99-99.9	99-99.9	96-99.9	99-99.9	99-99.9	99-99.9
		M	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005
Clay	Stream	D	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001
		W	0.00001	0.00001	0.00001	0.00001	0.00001	0.00001	0.00001	0.00001	0.00001	0.00001
		RHO	2	2	2	2	2	2	2	2	2	2
		TAUCD*	1-47	3-4	1-18	3-4	1-10	1-9	1-13	1-16	1-12	1-13
		TAUCS*	75-85	75-76	70-71	70-72	60-73	60-87	65-80	60-89	68-75	64-73
		M	0.004	0.004	0.015	0.015-0.025	0.01	0.006-0.03	0.025	0.01	0.02	0.02
	Bluff	D	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001
		W	0.00001	0.00001	0.00001	0.00001	0.00001	0.00001	0.00001	0.00001	0.00001	0.00001
		RHO	2	2	2	2	2	2	2	2	2	2
		TAUCD*	3-4	3-4	3-4	3-4	3-4	1-5	3-4	3-4	3-4	3-4
		TAUCS*	76	75-76	70	70-71	60-73	60-87	60-70	80-81	70-71	70-71
		M	0.01	0.07	0.1	0.05-0.1	0.03-0.05	0.008-0.07	0.1	0.1	0.1	0.1
	Lake	D	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001
		W	0.00001	0.00001	0.00001	0.00001	0.00001	0.00001	0.00001	0.00001	0.00001	0.00001
		RHO	2	2	2	2	2	2	2	2	2	2
		TAUCD*	97-99.9	97-98	97-99.9	97-99.9	98-99	97-99	95-99	97-99	97-99	97-99
		TAUCS*	99-99.9	99	99-99.9	97-99.9	99-99.9	99-99.9	96-99.9	99-99.9	99-99.9	99-99.9
		M	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005

* Value in table provided as a percentile of the hourly simulated TAU range

4.4 SEDIMENT SOURCE APPORTIONMENT

Sediment source data is primarily based on interpretation of radiometric data (^{210}Pb and ^{137}Cs) that provides an estimate of the fraction of sediment that has recently been in contact with the atmosphere (Schottler et al., 2010). To a first approximation, the percentage of "new" sediment is interpreted as the fraction of stream sediment load that derives from upland surface erosion, as opposed to load from channel erosion, ravine erosion, or bluffs. That interpretation is not exact, however, as each source contains some mixture of older, buried soil and exposed surface sediment. Another problem for interpretation is that upland sediment load may be temporarily stored and then re-scoured from the stream bed, so model output of channel scour does not necessarily represent only "old" sediment. A unique set of upland loading rates, bed erosion rates, and downstream sediment transport measures is thus not readily interpretable from the model output and the ratio of old to new sediment is not directly extractable from the model because individual sediment particles are not tracked as they move in and out of bed storage.

This issue was explored in some detail in Tetra Tech (2008), from which the following text is summarized:

Consider a case in which there is an external (upland) sediment load of *X* and a bank and bluff erosion load of *B*. The processes can be conceptually represented by a simple box model (Figure 1).

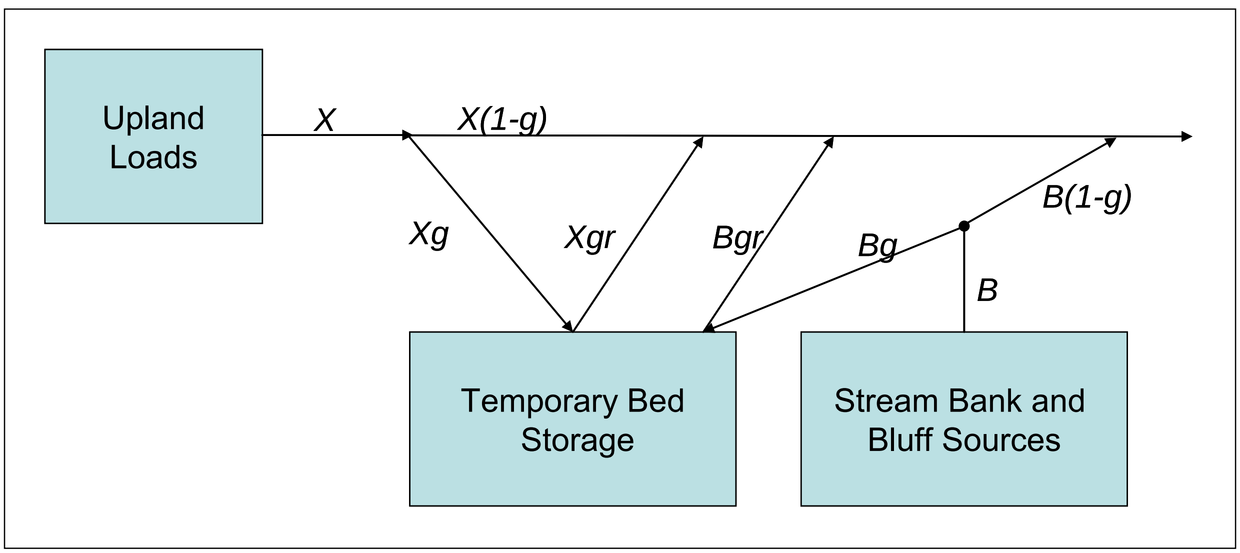


Figure 1. Conceptual Representation of Stream Sediment Processing

For an external sediment load *X*, a fraction *g* goes into temporary bed or floodplain storage. A fraction of this (*r*) is in turn resuspended and transported downstream as *Xgr*. Similarly, erosion of established stream banks and bluffs yields a total load *B*. This is assumed to be subject to the same physical processes as the upland load, *X*: A fraction *g* goes into temporary storage, of which a further fraction *r* is transported downstream. (The factor *r* may be thought of as a recycle rate. The total sediment load transported downstream, *Y*, is then:

$$Y = (X + B)(1 - g + gr).$$

The model output provides information on both gross bed scour (*GS*, resuspension flux only) and net bed scour (*NS*, balance of scour and deposition). Two additional equations can be written for *GS* and *NS* based on the simple box model:

$$GS = Xgr + B + Bgr$$
$$NS = X\left(gr - g\right) + B\left(1 + gr - g\right).$$

Given X, this appears to yield three equations in three unknowns. However, the system of equations is indeterminate, as the output, Y, is simply equal to the net scour (NS) + X. Therefore, there is not a unique solution unless additional constraints are imposed regarding the recycle rate, r.

Tetra Tech (2008) explored this issue further and concluded that the net effect of scour plus deposition was that the true upland-derived fraction at the outlet was likely to be about 95% of the simulated upland load divided by the downstream output load. Conducting the analysis is, however, difficult because the gross scour and net scour components need to be separated based on analysis of hourly simulation results and the results, in the end, remain uncertain because a value for r must be assumed.

To address these issues, a new approximate methodology was developed to generate simulated source apportionments in an efficient manner. For this purpose, Excel™ "Sediment Sources" workbooks were created with live equations that tabulate the simulated sediment source apportionment. The workbooks are provided for further investigation. The following discusses how to update the workbooks and the calculations that are being performed in the workbooks.

To use/update the workbook for any of the watershed models in the Minnesota River Basin HSPF the user must first generate yearly reach.HBN and wshd.HBN files for sediment. To do this the user must specify a flag of 5 for SED, SLD, and SED in the BINARY-INFO blocks for PERLND, IMPLND, and RCHRES respectively and then run the model. The needed HBN files can be found in the PLTGEN folder for the model that you are working with. Data for certain constituents contained in the reach.HBN and wshd.HBN are used to update the reachHBN and wshdHBN tabs in the EXCEL workbook. To access the data the user must open the reach.HBN and wshd.HBN files with the SARA Timeseries Utility. The reach.HBN file is populated with ISED-TOT (inflow of total sediment to each RCHRES by year), ROSED-TOT (outflow of total sediment from each RCHRES by year), and RSED-BED-TOT (average bed storage mass of sediment for each RCHRES by year). The wshd.HBN is populated with WSSD (washoff of detached sediment for each PERLND by year), SCRSD (scour of matrix soil for each PERLND by year), and SOSLD (washoff of solids for surface for each IMPLND per year). The user must select each constituent individually and also be sure to select the location attribute otherwise the workbook will not function properly. Copy/Paste the created list from SARA to the appropriate location in the attribution workbook and the pertinent information should be updated.

The All_Reach_Summary worksheet performs a series of tabulations that calculate the necessary information to determine the source apportionment. The workbook has comments associate with cells A4:A21 to provide the user with information about what is actually being calculated. The calculations use the information in the reachHBN and wshdHBN along with information in the SchemPLS_All, SchemPLS_RAV, SchemPLS_BLF, SchemPLS_OTH, SchemILS, and SchemRch tabs. All of the tabs listed in this paragraph contain live equations so please be very cautious about inserting, deleting, or modifying anything in all of the listed tabs.

The results of the All_Reach_Summary are then used to populate the Source_Attribution tab. For each workbook the Source_Attribution tab varies in the number of locations where source attributions are currently calculated, and the number of upstream reaches that are used to develop the source attribution. Basically, the source attribution is calculated by using the full 18 year simulation for all reaches upstream and including the reach pour point of interest. For each reach the sediment load of WSSD and SCOUR for Ravine, Bluff, and all other PERLND's are found in the All_Reach_Summary tab. Also found for each reach is the amount of sediment coming from IMPLND's as well as the deposition (positive value) or scour (negative value) from the instream simulation. Upland, Ravine, Bluff, and Stream mass are then approximated using the following calculations:

- Upland = Sum of WSSD Other, SCRSD Other, and SOSLD

- Ravine = Sum of WSSD Ravine and SCRSD Ravine
- Bluff = Sum of WSSD Bluff , SCRSD Bluff, and (-1* Deposition/Scour from Bluff Reaches)
- Stream = Sum of -1* Deposition/Scour from Non-Bluff Reaches (as scour is negative in the output).

Sediment source apportionments from upstream models are copy/pasted into the downstream model workbooks. For instance, for the Blue Earth at the mouth the workbook is theoretically only calculating the input from the Blue Earth model itself (the local drainage); however, when the Watonwan and Le Sueur source apportionment results are incorporated you can calculate the source apportionment at the mouth for the entire drainage basin. Additionally, the Chippewa model accounts for the Watson Sag Diversion to the Lac Qui Parle. The source apportionment calculations do not explicitly account for the sediment lost due to the diversion. Instead the apportionment is calculated on a percentage basis as though the diversion did not exist and then the calculated source fractions are applied to the Chippewa ROSED value at the mouth to calculate the source apportionment going into the Hawk Yellow Medicine model. That same source apportionment is applied to the Lac qui Parle input to the Hawk-Yellow Medicine model as simulation model results are not yet available for Lac qui Parle and its upstream watershed.

Based on comparison to a detailed (hourly) analysis of the Le Sueur River basin, this method, which includes only annual totals of scour and/or deposition, provides a close approximation to a more complex analysis using hourly data. However, as noted above, complete attribution of surface sediment sources would require correction for net storage/resuspension within the stream network, which would be expected to result in a small reduction in the estimated surface-derived fraction.

5 Results

5.1 Upland Unit Area Loads

As described above, some of the existing (2014) models provided unrealistic results for the amount of sediment being generated from upland sources, especially from developed land. Table 10 displays the simulated upland sediment loading rates by basin and land use for the revised model. HSPF simulates urban pervious and impervious lands separately, so a combination result for 25 percent impervious (and 75 percent developed pervious) land is shown for comparison with MS4 loading rates. These results were calculated by taking the wshd.HBN outputs of WSSD, SCRSD, and SOSLD (discussed in section 4.4) and 1) calculating the average annual sediment load for each PERLND/IMPLND (combination of weather station zone and land use) and 2) averaging the PERLND/IMPLND average annual sediment load across all weather station zones to find the average annual sediment load for each land use. Note, the loads are not area weighted but are simply a tabulation of unit area load as provided by the wshd.HBN output.

Excel™ workbooks for each watershed model were created and are provided as a supplement to this memorandum to allow for further investigation.

Le Sueur, Blue Earth, and Watonwan watersheds had much more constraining information for the apportionment of sediment mass and percent contribution due to the Le Sueur sediment budget and Greater Blue Earth sediment budget efforts (Gran et al., 2011; Bevis, 2015). That information along with results of Schottler et al. (2010) as further updated in presentations by the investigators to MPCA (personal communication from Chuck Regan, MPCA) was used to constrain the upland sediment source apportionment.

A goal for the upland sediment simulation was to supply largely homogeneous parameterization throughout the entire suite of Minnesota River Basin HSPF. Simulated upland unit area loading rates are in general roughly consistent between basins, but differ according to the local meteorological forcing, soil characteristics, and hydrologic simulation. Some deviations between basins are intentional: Specifically, for the Watonwan basin, the unit area loadings were reduced to obtain a better match between simulated and observed upland source mass as provided in the Greater Blue Earth sediment budget (Bevis, 2015). Additionally, for the Blue Earth the unit area loading was increased to get a better match between simulated upland source mass and observed upland source mass provided in the Greater Blue Earth sediment budget. It is also worth noting that the Hawk-Yellow Medicine model shows less distinction between HSG A,B and C,D soils for agriculture. This basin contains primarily B and B/D (B when drained) soils so the difference is not of great practical importance for total load simulation. The similarity between loading rates for different soil groups appears to be due to the hydrology set up of the model, which specifies only a small difference in infiltration rates between the different HSG classes.

Table 10. Revised Annual Average Unit Area Sediment Loads, 1995-2012 pound/acre/year

Land Use	Chippewa	HawkYM	Redwood	Cottonwood	Watonwan	Le Sueur	Blue Earth	Middle	Lower	Metro
Urban Pervious	31.3	129.6	72.1	86.1	89.6	195.7	147.2	46.1	38.4	70.5
Urban Impervious	325.7	285.3	292.9	304.9	338.1	364.4	361.0	318.5	318.9	349.9
Urban Combo (75% Pervious 25% Impervious)	104.9	168.5	127.3	140.8	151.7	238.9	200.7	114.2	108.5	140.4
Forest	0.6	7.5	6.0	6.8	14.2	13.6	16.5	4.4	3.7	7.0
Cropland - Conservation Till (HSG A,B)	61.3	47.5	36.8	55.6	31.0	85.3	77.4	107.0	45.3	81.4
Cropland - Conservation Till (HSG C,D)	126.4	52.5	247.1	375.8	198.1	350.0	266.1	244.3	283.4	347.7
Cropland - Conventional Till (HSG A,B)	63.5	71.2	51.0	79.2	48.2	138.9	104.4	150.8	67.4	115.5
Cropland - Conventional Till (HSG C,D)	160.3	77.4	312.6	497.7	260.5	512.1	359.0	301.1	355.2	426.9
Cropland - Manure Application (conv A,B)	148.3	77.1	51.0	79.1	48.2	138.4	104.4	150.3	67.4	114.5
Grassland	1.6	13.7	8.7	8.7	22.3	26.1	25.7	3.4	1.1	2.3
Pasture	28.2	NA	16.5	17.2	36.4	47.5	39.4	6.1	2.3	4.8
Wetland	0.6	0.0	0.5	0.3	2.9	1.5	1.2	0.6	0.5	0.9
Feedlot	NA	NA	233.5	294.8	367.5	570.8	563.7	167.7	129.7	239.4
Bluff	271	25	2,276	3,124	5,696	6,262	10,550	1,202	516	1,053
Ravine	NA	NA	7,827	16,369	95,117	31,237	393,722	8,996	1,097	2,198

Note: For Chippewa, results shown for Forest, Grass, and Pasture are for D soils. For Hawk-Yellow Medicine, results shown for Forest, Grass, and Pasture are for D soils on low slopes. Feedlot and Ravine land uses are not specified separately in the Chippewa and Hawk-Yellow Medicine models.

5.2 INSTREAM CALIBRATION AND VALIDATION

As previously discussed, separate calibration and validation tests were conducted based on a spatial and temporal distribution of stations (Table 3). These are summarized in electronic spreadsheets provided as a supplement to this memorandum. The statistical results below are reported according to the two groups of gages (calibration and validation) in the next two sub-sections. A representative station was selected for each group and graphical results are provided for those stations for example purposes. Comprehensive graphics for each gage are provided in the electronic files.

The summary statistics include concentration average error, concentration median error, load average error and load median error. All of the statistics are performed on paired comparisons of simulated daily average and observed instream instantaneous grab measurements. Also provided is the number of paired comparisons for each station.

5.2.1 Calibration Stations

Table 11 (in five parts) shows the statistical results for the calibration gages. The calibration strategy focused foremost on sediment source attribution and used harmonized parameter estimates instead of over-fitting individual gages, resulting in some relatively large errors, especially at some of the stations where there are limited data for accurate hydrologic calibration. The quality of fit for suspended sediment is generally in the good to very good range for concentration and load median errors. The quality of fit ranges from very good to poor for concentration and load average errors. Average errors are more susceptible to large deviations because they can be heavily influenced by extreme events and slight shifts in timing. Additionally, the stations that show large differences in the average error have a much more favorable comparison when looking at the graphical comparisons. It is advised to look at both the statistical comparison and graphical comparison when assessing the overall model fit to instream monitoring data.

Graphical examples of the calibration for Le Sueur River at MN-66 1.5 miles NE of Rapidan are provided in Figure 2 through Figure 6. Results for all other calibration gages are contained in the electronic files.

Table 11. Summary Statistics for Calibration Stations

Site	Chippewa R at 140th St, 7 mi N of Cyrus	Chippewa R at CSAH-22, 1 mi E Of Clontarf	Shakopee Ck, at Unn Twnshp Rd, 1 mi W MN-29	Chippewa R, at MN-40, 5.5 mi E of Milan	Beaver Ck at CSAH-2 2.5 mi NE of North Redwood	Hawk Ck at CR 52 Br, 6.5 mi SE off Granite Falls	Hawk Ck, at MN-23, 2.2 mi SW of Maynard
STORET Code	S002-190	S002-193	S002-201	S002-203	S000-666	S002-012	S002-148
Count	243	322	314	367	374	408	375
Conc Ave Error	68.7%	-129.9%	-33.9%	-141.7%	-428.6%	-76.6%	-3.89074
Conc Median Error	1.6%	-26.3%	-52.5%	-26.9%	20.0%	14.1%	-1.0%
Load Ave Error	340.3%	39.1%	-62.1%	-23.3%	3.8%	62.0%	44.6%
Load Median Error	5.9%	-14.4%	-33.9%	-10.2%	0.2%	0.5%	-0.4%

(Table 11. Continued)

Site	Yellow Med R, 1 1/3 mi N CSAH-18	MN R 500 Ft S CSAH-13 near USGS Gage	Minnesota R, Ethanol Facility WS Intake*	Redwood R at CSAH-15 in Russell	Redwood R at CSAH-17, 3 Miles SW of Redwood Falls	Cottonwood R near MN-68 In New Ulm	Cottonwood R at CSAH 8 Br, 0.4 mi N Leavenworth
STORET Code	S002-316	S004-649	S007-748	S000-696	S001-679	S001-918	S001-920
Count	-7.7%	-59.8%	61.1%	47.1%	-21.0%	-37.8%	-18.7%
Conc Ave Error	7.7%	22.7%	8.7%	3.1%	-6.9%	0.2%	-1.6%
Conc Median Error	136.5%	-2.3%	-27.5%	-35.3%	76.2%	-3.2%	62.8%
Load Ave Error	0.4%	5.2%	1.7%	0.1%	-1.5%	0.0%	-0.1%
Load Median Error	-7.7%	-59.8%	61.1%	47.1%	-21.0%	-37.8%	-18.7%

(Table 11. Continued)

Site	Cottonwood R at US-14 Brg, 1 mi NE Lamberton	Watonwan R Br on CSH-13, 1 mi W of Garden City	Le Sueur R Mn-66 1.5 mi NE of Rapidan	Maple R At CSAH 35 5.2 mi S of Mankato	Cobb R at CSAH-16, 4.4 mi NE of Good Thunder	Le Sueur R at CSAH-8, 5.1 mi SSE of Mankato	Blue Earth R 150 Ft dnst of Rapidan Dam
STORET Code	S002-247	S000-163	S000-340	S002-427	S003-446	S003-860	S001-231
Count	210	502	251	378	210	205	240
Conc Ave Error	17.5%	-423.8%	39.2%	14.6%	-162.7%	164.7%	-18.9%
Conc Median Error	5.7%	-13.5%	11.5%	-0.2%	51.0%	2.9%	4.9%
Load Ave Error	123.3%	15.6%	12.2%	19.0%	161.7%	-25.1%	-4.3%
Load Median Error	0.1%	-1.3%	0.6%	0.1%	15.3%	0.0%	0.7%

(Table 11. Continued)

Site	Elm Creek at 290th Ave - 4.5 mi NE of Granada	Minnesota River at Mankato	Minnesota R Bridge on US-71 and MN-19 at Morton	Minnesota R at CSAH 42 at Judson	Sevenmile Ck In Sevenmile Ck Cty Pk	Minnesota R at MN-99 in St. Peter	High Island Cr., CSAH-6, Henderson
STORET Code	213	45	165	199	261	239	297
Count	213	45	165	199	261	239	297
Conc Ave Error	-31.7%	77.6%	-43.1%	-58.8%	-710.8%	-39.3%	16.6%
Conc Median Error	-3.5%	9.6%	-1.5%	5.7%	2.5%	6.4%	1.3%
Load Ave Error	126.7%	34.7%	92.3%	66.8%	-43.5%	42.6%	-55.6%
Load Median Error	0.5%	0.6%	-0.5%	0.3%	0.0%	1.8%	-0.1%

(Table 11. Continued)

Site	Rush River, SH-93 by Henderson	Bevens Cr.,CSAH-41 by East Union	W Chaska Ck, 250' W of Cty Rd 10
STORET Code	S000-822	S000-825	S002-548
Count	266	135	129
Conc Ave Error	1.1%	27.1%	-4.4%
Conc Median Error	-7.2%	-14.0%	3.0%
Load Ave Error	-81.5%	-34.4%	-56.0%
Load Median Error	-2.3%	-3.5%	0.2%

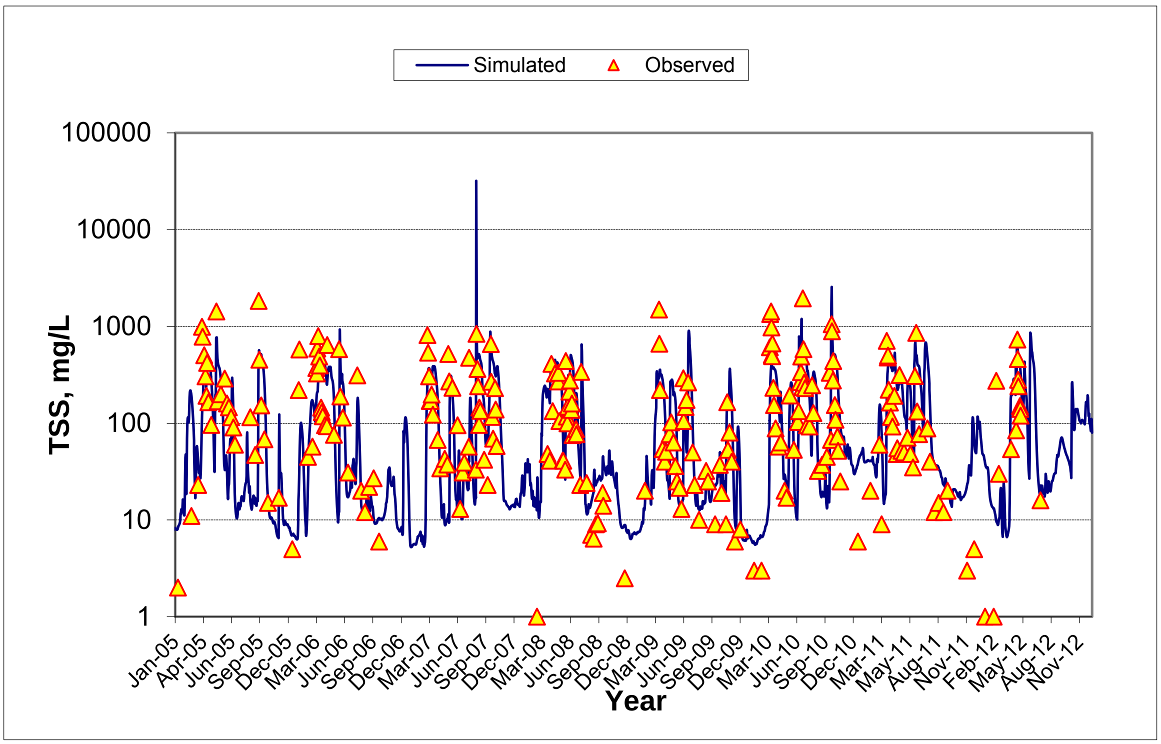


Figure 2. Timeseries Plot of Simulated and Observed TSS Concentration for Le Sueur River at MN-66 1.5 miles NE of Rapidan for 2005-2012

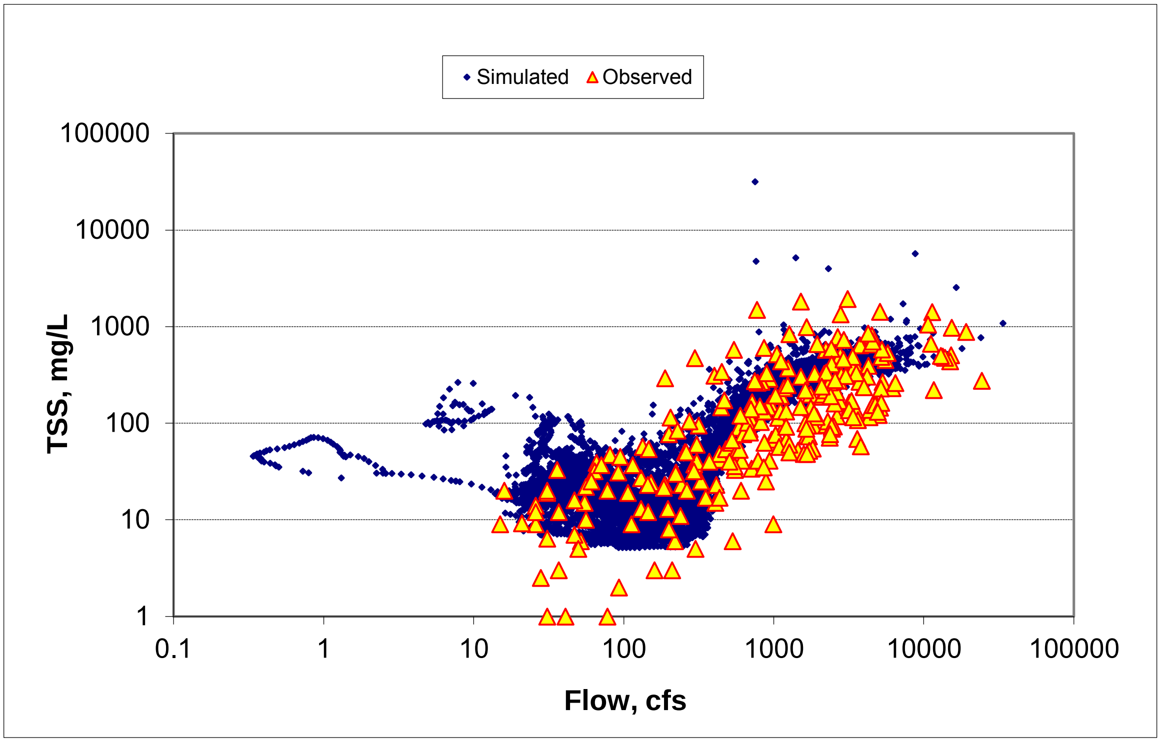


Figure 3. Concentration vs Flow Plot of Simulated and Observed TSS Concentration for Le Sueur River at MN-66 1.5 miles NE of Rapidan for 2005-2012

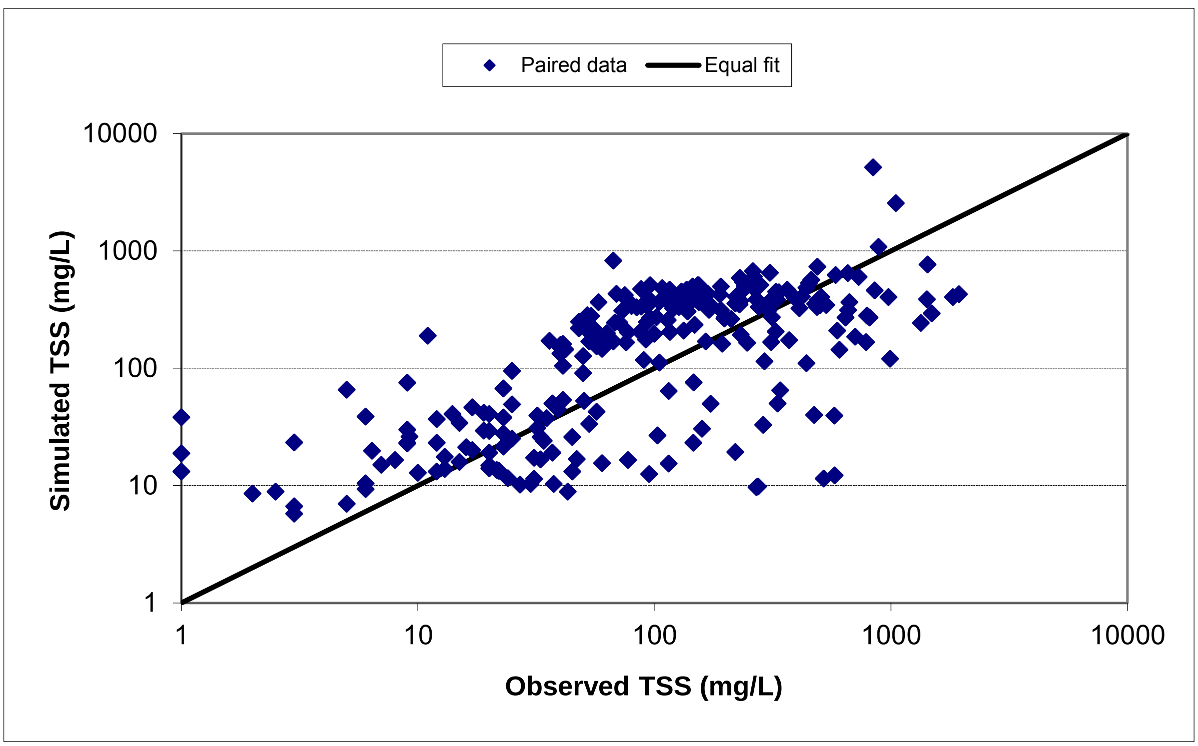


Figure 4. Simulated and Observed TSS Concentration Paired Regression Plot for Le Sueur River at MN-66 1.5 miles NE of Rapidan for 2005-2012

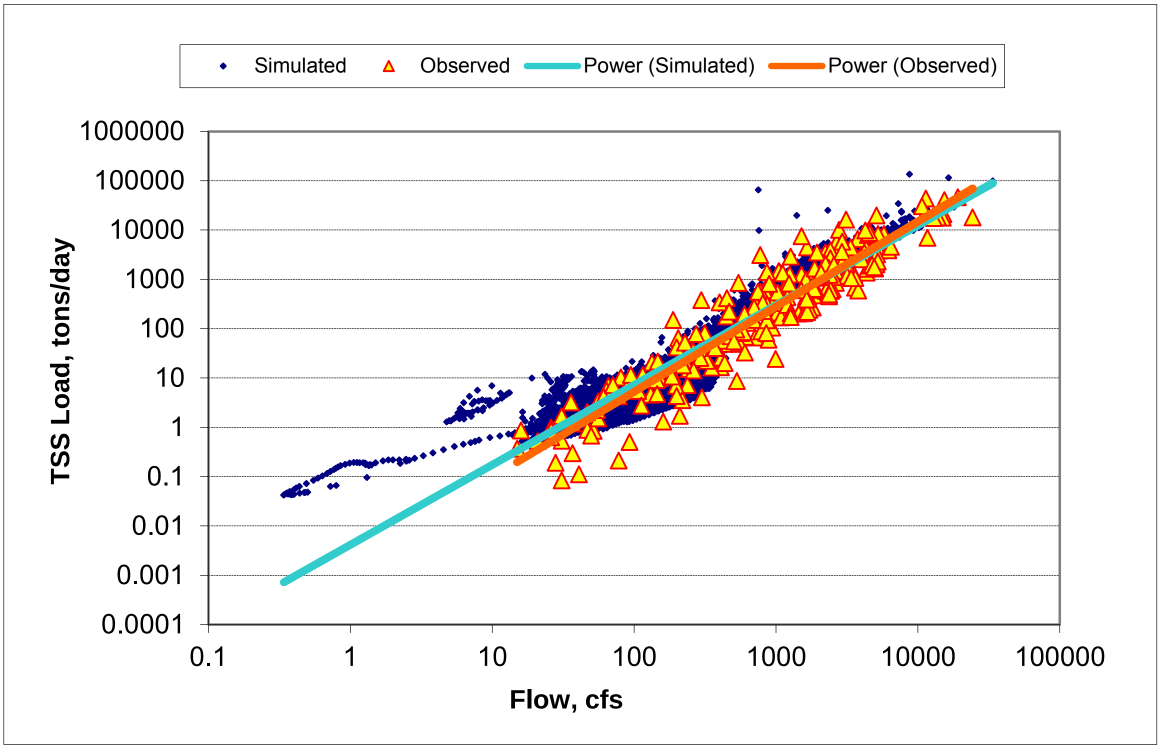


Figure 5. Load vs Flow Plot of Simulated and Observed TSS Load for Le Sueur River at MN-66 1.5 miles NE of Rapidan for 2005-2012

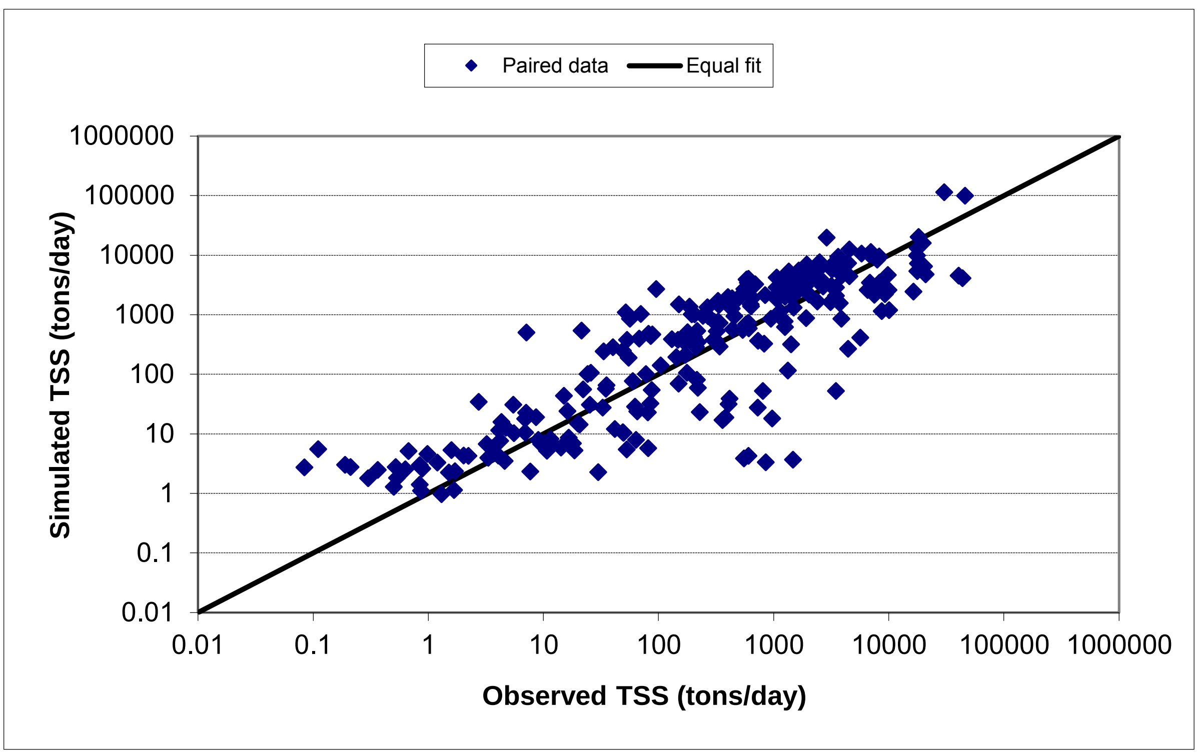


Figure 6. Simulated and Observed TSS Load Paired Regression Plot for Le Sueur River at MN-66 1.5 miles NE of Rapidan for 2005-2012

5.2.2 Validation Stations

The parameters developed during calibration were applied without modification to the validation stations. Table 12 (in five parts) shows the statistical results for the validation gages. Similar to the calibration stations the quality of fit is generally in the good to very good range for concentration and load median errors but from very good to poor for concentration and load average errors. There are a few validation stations that have poor fit for both averages and medians (e.g., Shakopee Creek S002-209 and High Island Creek S001-891). Model performance could likely be improved at individual stations; however, the parameters were not modified due to the desire to maintain spatial homogeneity across all models in the upland parameters and maintain reach homogeneity within each individual model.

Graphical examples of the calibration for Little Cottonwood River at Apple Road are provided in Figure 7 through Figure 11. While fit is reasonable at this station, the model appears to under-estimate suspended sediment concentrations observed at high flows Results for all other validation gages are contained in the electronic files.

Table 12. Summary Statistics for Validation Stations

Site	Dry Weather Creek, at 85th Ave NW, 4 mi NE of Watson	Shakopee Ck ,S Andrew Rd at Lk Andrew Otl	Little Chippewa R at Mn-28, 4 mi W of Starbuck	Chippewa R, EB, at 15th Ave NE, 2.5 mi N of Benson	W Fk Beaver Ck at CSAH-4 6.5 mi S of Olivia	Sacred Heart Ck at CSAH-15 Br, 5 mi NW of Delhi	Palmer Ck at 15th Ave SE, 2 mi NW of Granite Falls
STORET Code	S002-204	S002-209	S004-705	S005-364	S000-405	S001-341	S002-136
Count	322	116	64	307	234	131	126
Conc Ave Error	17.8%	715.2%	-96.4%	-4.0%	-189.5%	-321.7%	107.9%
Conc Median Error	-2.5%	258.1%	37.9%	1.0%	-14.9%	19.5%	6.9%
Load Ave Error	-63.0%	474.3%	-21.0%	25.2%	418.1%	-52.1%	-25.5%
Load Median Error	0.0%	182.3%	8.7%	0.3%	0.5%	0.4%	0.4%

(Table 12. Continued)

Site	Hawk Ck, at CR-116, 1.25 mi S of MN-40	Chetomba Ck, 5 mi SE of Maynard	S Br Yellow Medicine R on CSAH-26	CD-119 at CSAG-15, 5.6 mi S of Sacred Heart	Timms Ck at CSAG-15, 2.8 mi NNE of Delhi	Clear Ck Cr, 1/3 mi upst confl Redwd R	Three Mile Ck at CR-67, 1 mi N Green Valley
STORET Code	S002-140	S002-152	S002-320	S003-866	S003-867	S002-311	S002-313
Count	368	374	105	96	124	208	209
Conc Ave Error	-141.1%	35.7%	89.6%	33.2%	34.6%	-7.9%	-47.9%
Conc Median Error	-8.7%	17.0%	20.6%	8.2%	7.9%	-6.5%	-14.4%
Load Ave Error	60.7%	61.4%	36.8%	-69.3%	-62.6%	150.3%	-18.3%
Load Median Error	-2.1%	0.2%	0.8%	0.4%	0.1%	-0.1%	-0.4%

(Table 12. Continued)

Site	Plum Creek At CSAH 10 Br	Sleepy Eye Cr at CSAH 8 Br, 2.2 mi N of Leavenworth	Unn Trib To Big Cobb R, 0.5 mi N Beauford	Le Sueur R at CSAH 28 In Saint Clair	Little Cobb nr CSAH-16, 6.3 mi W of Pemberton	Maple R at CSAH-18, 2 mi N of Sterling Center	Dutch Creek at 100th St, 0.5 mi W of Fairmont
STORET Code	S001-913	S001-919	S001-210	S003-448	S003-574	S004-101	S003-000
Count	193	221	201	181	250	232	202
Conc Ave Error	-993.4%	-84.9%	-22.3%	-97.4%	-223.6%	-118.1%	-367.7%
Conc Median Error	-1.6%	1.5%	-1.2%	-5.2%	-19.4%	-11.6%	6.1%
Load Ave Error	-10.4%	20.4%	102.4%	84.1%	210.4%	280.2%	23.5%
Load Median Error	0.0%	0.1%	-0.1%	-0.3%	-0.8%	-0.5%	0.1%

(Table 12. Continued)

Site	Center Creek at 315th Avenue - 1 mi S of Huntley	Sevenmile Ck dwst of MN-99, 6 mi SW of St. Peter	CD 46A dwst of CSAH-13, 6 mi SW of St. Peter	Little Cottonwood R at Apple Rd, 1.6 mi S of Courtland*	Silver Cr.,CSAH-41 by East Union	Buffalo Ck, at 270th St, 1.5 mi NW of Henderson	High Island Ck at CSAH 9, 1 mi NW of Arlington
STORET Code	S003-024	S002-934	S002-936	S004-609	S000-843	S001-807	S001-891
Count	220	197	188	212	113	276	274
Conc Ave Error	-39.4%	118.0%	474.9%	35.5%	17.0%	24.6%	987.1%
Conc Median Error	-15.2%	27.7%	5.7%	-0.6%	2.3%	3.0%	131.7%
Load Ave Error	28.0%	288.3%	15.3%	-9.9%	-15.0%	-91.1%	551.2%
Load Median Error	-1.1%	3.8%	0.1%	0.0%	0.3%	0.0%	75.3%

(Table 12. Continued)

Site	Carver Ck at US-212, 2.5 mi E of Cologne	Carver Ck at Cr-140, 2.3 mi NE of Benton	Bevens Ck at 321st Ave, 3 mi SE of Hamburg	Bevens Ck at Rice Ave, 3.9 mi SE of Norwood Yng America
STORET Code	S002-489	S002-490	S002-516	S002-539
Count	165	164	116	153
Conc Ave Error	-40.1%	-98.3%	41.2%	-73.0%
Conc Median Error	-16.2%	153.4%	3.2%	-5.4%
Load Ave Error	-47.8%	499.4%	-42.9%	3.3%
Load Median Error	-4.7%	42.0%	0.5%	-0.6%

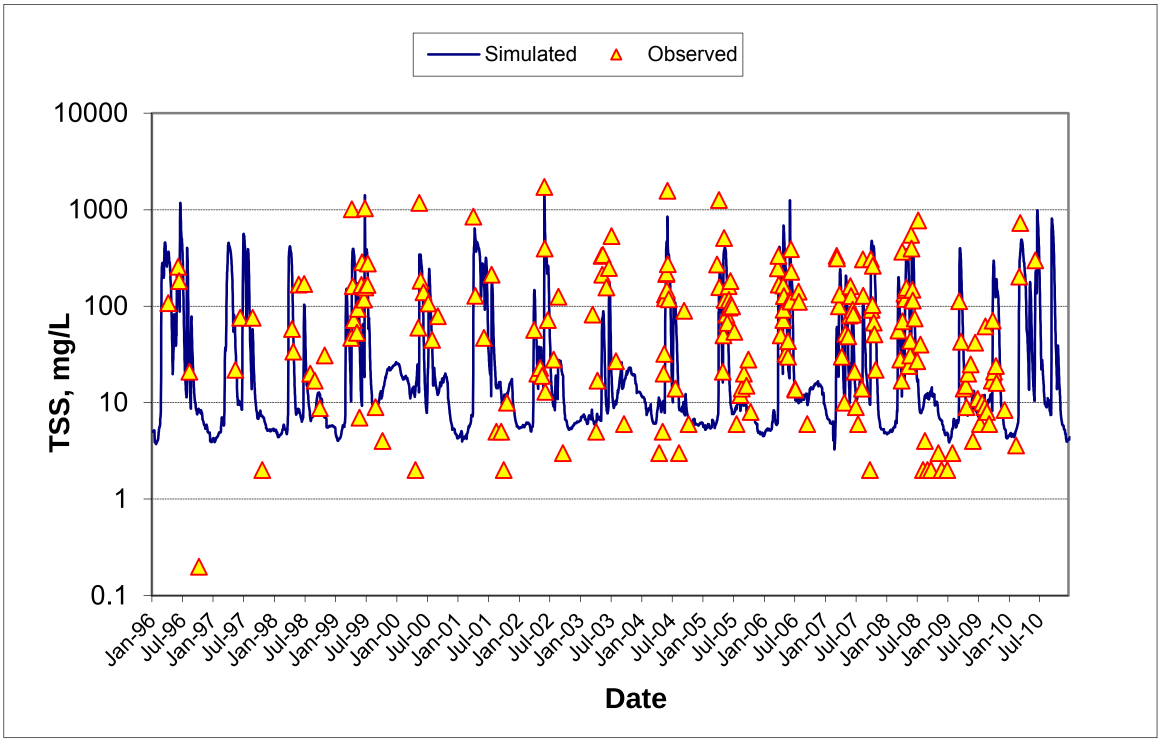


Figure 7. Timeseries Plot of Simulated and Observed TSS Concentration for Little Cottonwood River at Apple Road for 1996-2010

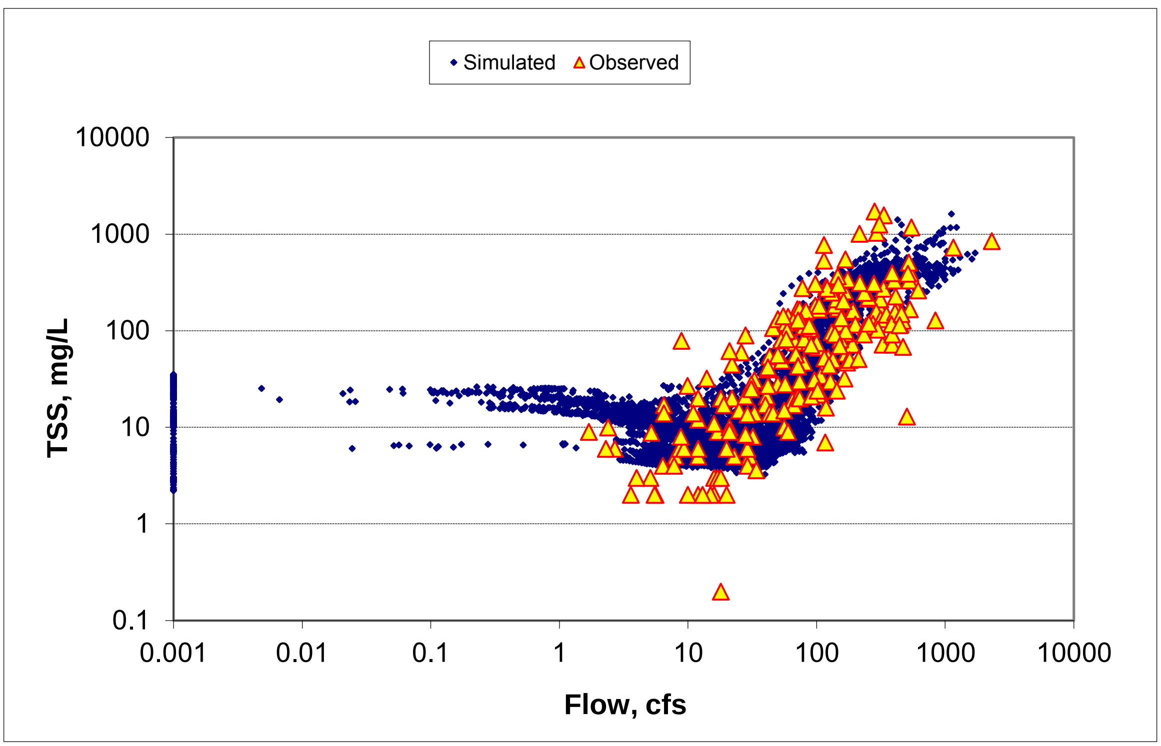


Figure 8. Concentration vs Flow Plot of Simulated and Observed TSS Concentration for Little Cottonwood River at Apple Road for 1996-2010

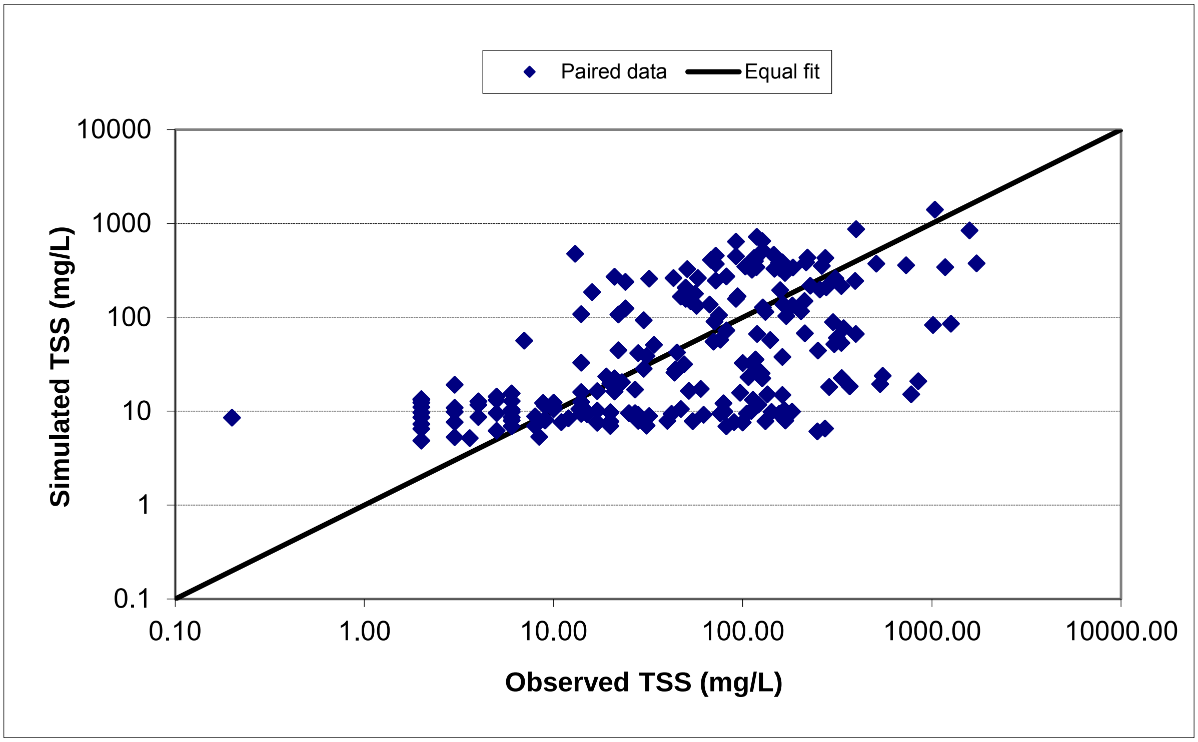


Figure 9. Simulated and Observed TSS Concentration Paired Regression Plot for Little Cottonwood River at Apple Road for 1996-2010

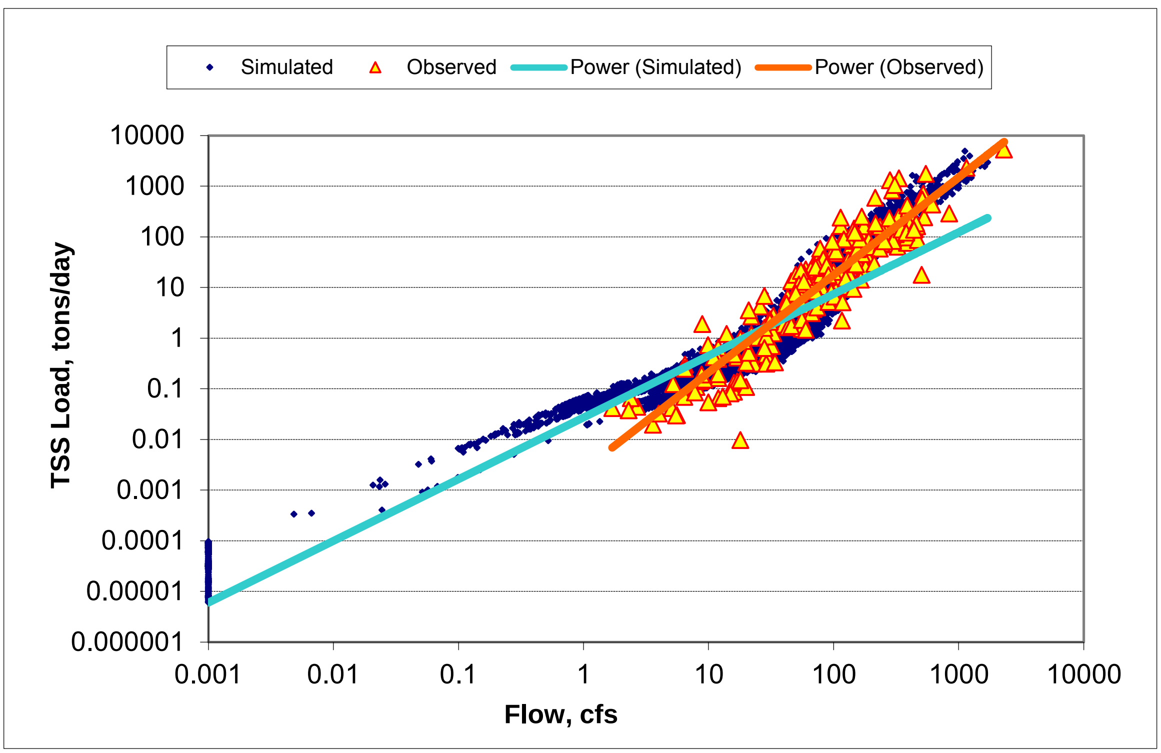


Figure 10. Load vs Flow Plot of Simulated and Observed TSS Load for Little Cottonwood River at Apple Road for 1996-2010

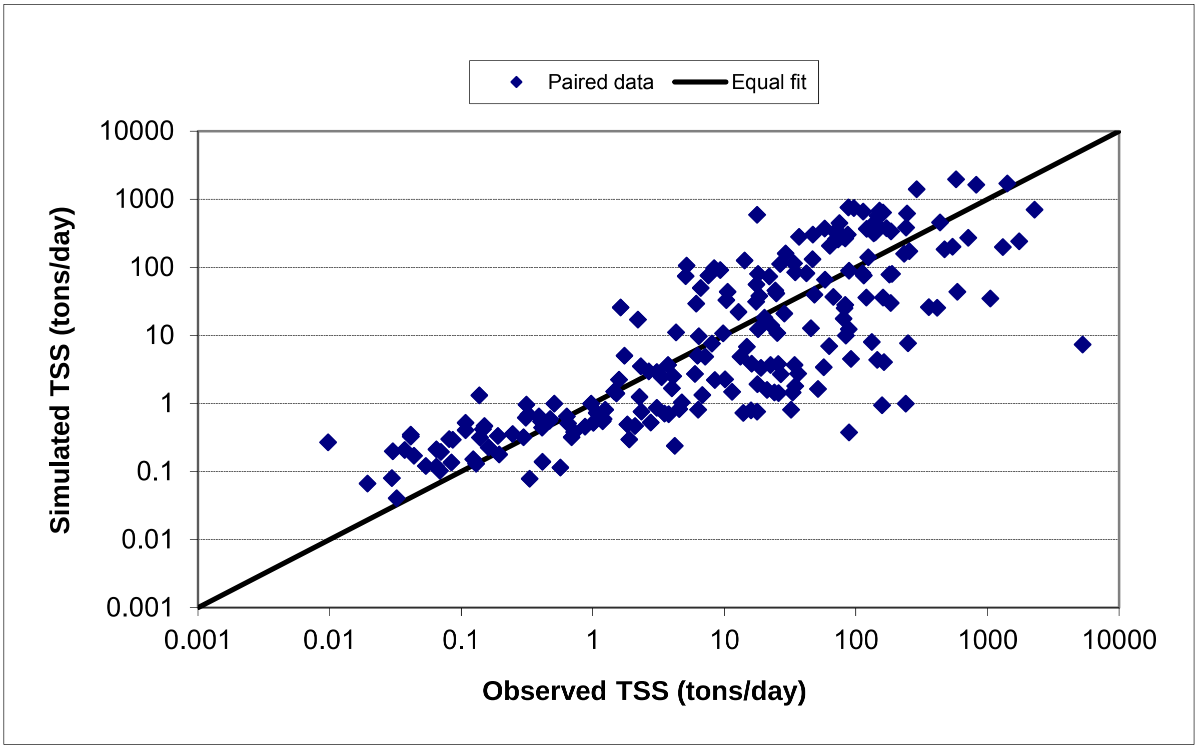


Figure 11. Simulated and Observed TSS Load Paired Regression Plot for Little Cottonwood River at Apple Road for 1996-2010

5.3 Comparison to FLUX Loads

MPCA's Watershed Pollutant Load Monitoring Network (WPLMN) is designed to obtain spatial and temporal pollutant load information from Minnesota's rivers and streams and track water quality trends. As part of this program, MPCA releases estimates of annual pollutant loads for each 8-digit hydrologic unit code basin. These "observed" monthly loads are estimated using the USACE FLUX32 program (a Windows-based update of the FLUX program developed by Walker, 1996; available at https://www.pca.state.mn.us/water/watershed-pollutant-load-monitoring-network#flux32-8f1620f5), and are themselves subject to significant uncertainty.

MPCA estimates at the downstream gage station on each of the HUC-8 watersheds within the Minnesota River basin are currently available for calendar years 2007 – 2011. The model and FLUX estimates are compared in Figure 12. While the fit is generally close, there are some discrepancies at individual stations during 2011 and 2012 where FLUX estimates are higher than loads produced by the model.

Figure 12. Comparison of Model and FLUX TSS Load Estimates, Calendar Years 2007 - 2011

5.4 Sediment Source Apportionment

Provided below are results for simulated source apportionment at the mouth of each 8-digit (HUC). Results at the mouth include the influence of upstream model(s) if one or more exist. As previously stated each model had its own unique processing workbook created and those are provided in electronic format as a supplement to this memorandum. Each electronic workbook contains source apportionment at additional locations in each watershed. Also include are the incremental or local drainage area contributions for those locations that receive influence of upstream model(s). Specifically for Le Sueur, the between stations (between upper and lower stations) source apportionment has been calculated. This allows you to see the proportion and amount of sediment generated in the nick zone area for each drainage basin. Table 13 provides the average annual sediment load and source percentage at the mouth of each model.

Figure 13 (in two parts) shows the source percentage as pie charts which are similar to how source apportionment was shown in the Le Sueur and Greater Blue Earth sediment budgets. The Le Sueur and greater Blue Earth produce sediment source apportionment (mass and percentage) that are consistent with the full sediment budgets, while the other basins approximately replicate the upland source fraction attribution provided in Table 1 (see Figure 13). An exact match is not expected because the model results are for 1995 – 2012, while the radiometric source data are primarily depositional sediment cores collected in 2007 and 2008 that integrate over an uncertain time period.

Also provided in Table 14 and Figure 15 is an apportionment of the annual average sediment load at the mouth of the Metro model for each HUC8 watershed contributing to that point. Note, the Lac Qui Parle is not explicitly modeled as part of the Minnesota River Basin HSPF model suite but it is represented like a point source input to the Hawk Yellow Medicine model.

Table 13. Summary of Source Apportionment at the Mouth of each HUC8

HUC8	Metric	Upland	Ravine	Bluff	Stream	Total
Chippewa	Mass (ton/year)	4,309	66	2,107	5,518	12,000
	Source Percentage	36%	1%	18%	46%	100%
Redwood	Mass (ton/year)	11,438	937	17,180	12,572	42,127
	Source Percentage	27%	2%	41%	30%	100%
Hawk Yellow Medicine	Mass (ton/year)	71,513	2,564	64,997	67,262	206,336
	Source Percentage	35%	1%	32%	33%	100%
Cottonwood	Mass (ton/year)	31,846	1,492	75,227	50,067	158,633
	Source Percentage	20%	1%	47%	32%	100%
Watonwan	Mass (ton/year)	12,602	2,283	21,451	8,483	44,819
	Source Percentage	28%	5%	48%	19%	100%
Le Sueur	Mass (ton/year)	59,352	32,103	135,185	18,837	245,477
	Source Percentage	24%	13%	55%	8%	100%
Blue Earth	Mass (ton/year)	127,406	40,968	284,940	93,384	546,698
	Source Percentage	23%	7%	52%	17%	100%
Middle	Mass (ton/year)	289,417	48,976	482,842	297,839	1,119,074
	Source Percentage	26%	4%	43%	27%	100%
Lower/Metro	Mass (ton/year)	331,411	53,414	624,074	354,566	1,363,464
	Source Percentage	24%	4%	46%	26%	100%

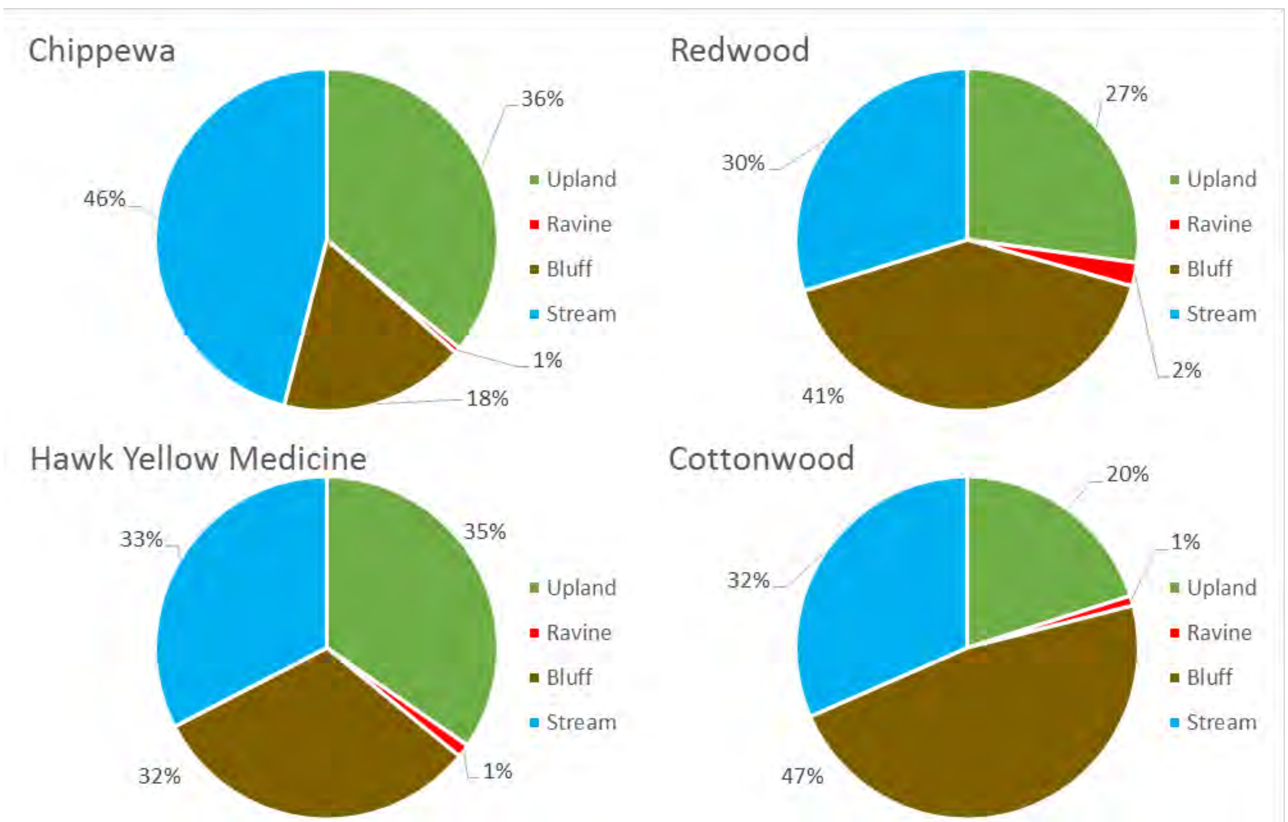
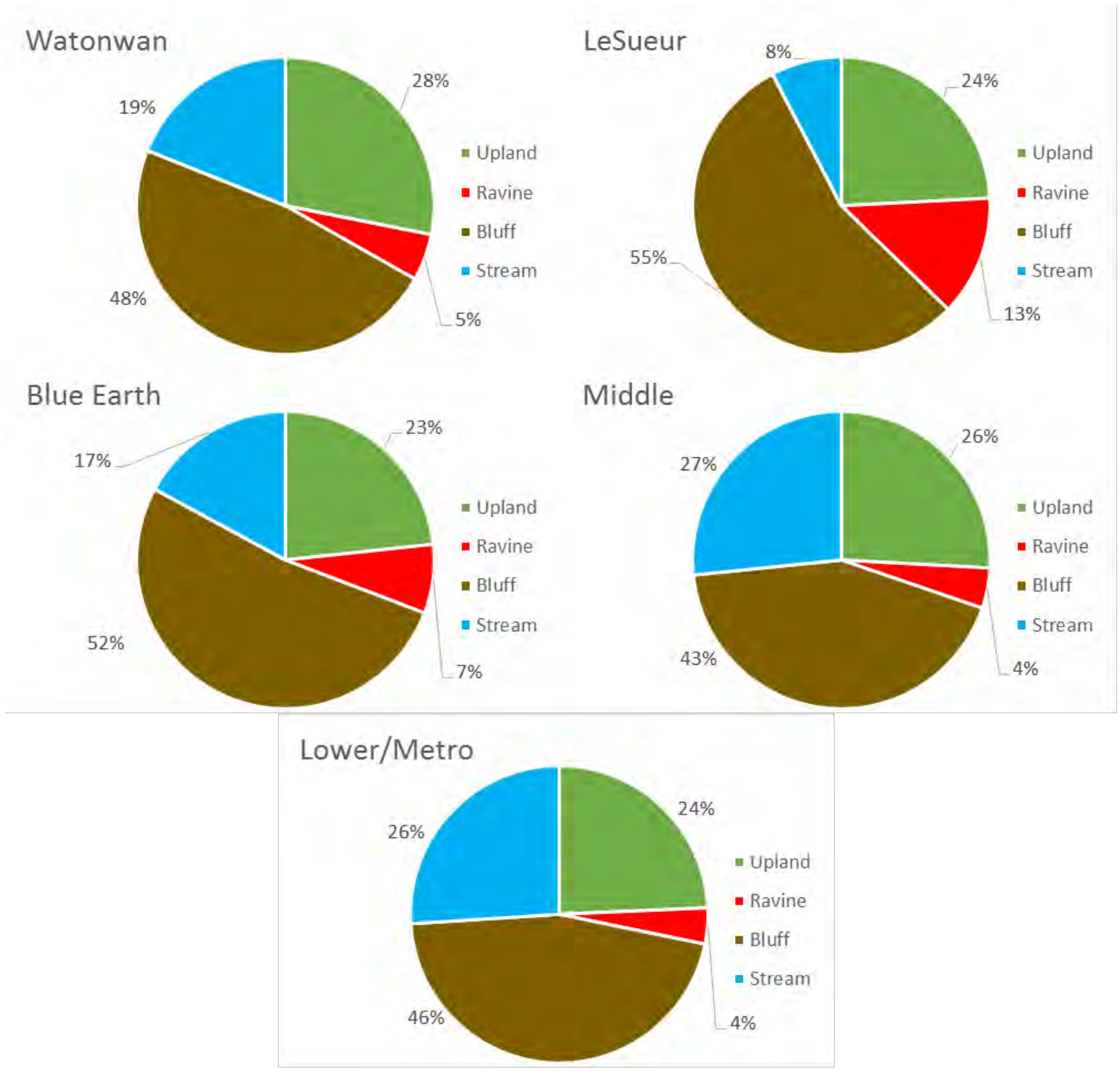


Figure 13. Instream Sediment Source Apportionment at HUC8 Outlets



(Figure 13 Continued, Instream Sediment Source Apportionment at HUC8 Outlets)

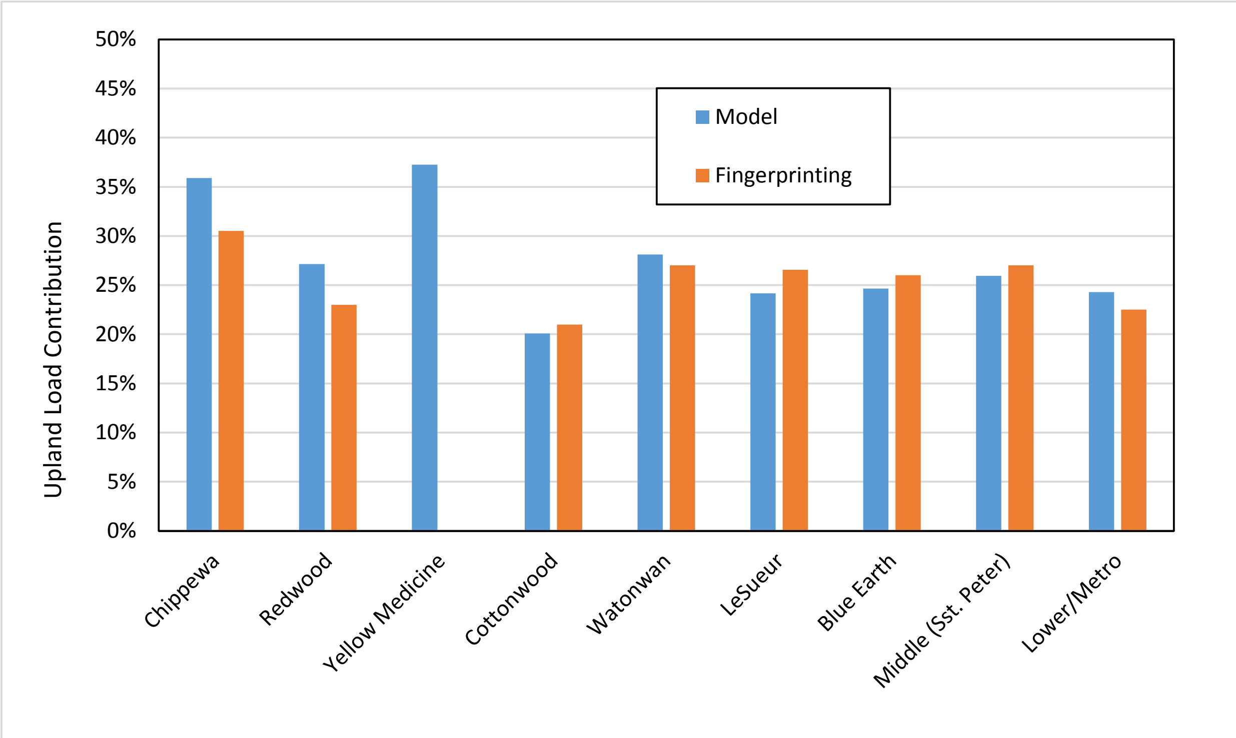


Figure 14. Comparison of Simulated Surface Washoff Loading to Surface Source Fraction from Sediment Fingerprinting Analysis

Note: Refer to Table 1 for sediment source attribution targets.

Table 14. HUC8 Contributions to Sediment Load at the Mouth of the Metro Model

Watershed	Sediment Ton/year	Percent of Total
Chippewa	12,000	0.9%
Redwood	42,127	3.1%
Hawk Yellow Medicine	104,604	7.7%
Lac Qui Parle	54,269	4.0%
Cottonwood	158,633	11.6%
Watonwan	44,819	3.3%
LeSueur	245,477	18.0%
Blue Earth	256,370	18.8%
Middle	200,776	14.7%
Lower	127,446	9.3%
Metro	116,948	8.6%
Total at Metro Mouth	1,363,464	100.0%

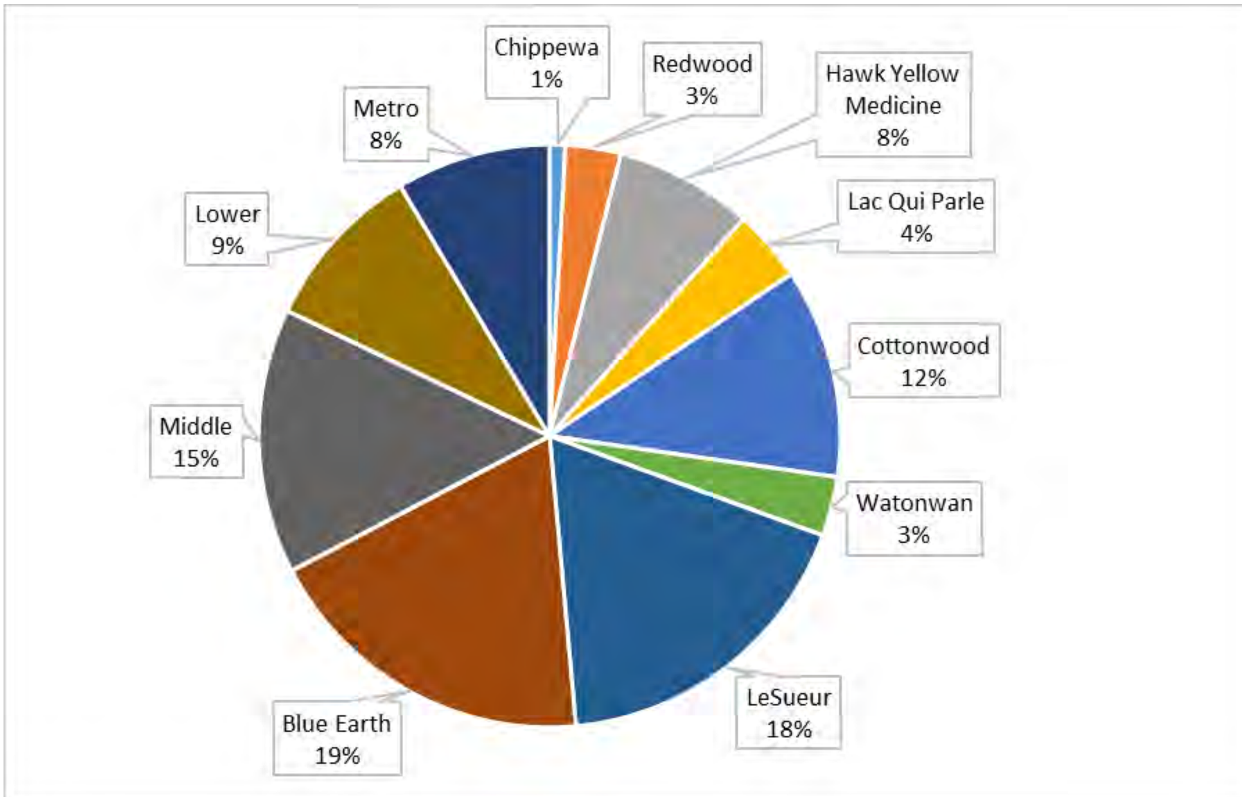


Figure 15. HUC8 Contributions to Sediment Load at the Mouth of the Metro Model

6 Summary and Potential Enhancements

The primary motivation for the sediment recalibration for the Minnesota River Basin was to better represent the source attribution information available from radiometric data and the detailed sediment source budgets for the Greater Blue Earth basin. Adjustments to the calibration to better simulate observed suspended sediment concentration data was also pursued, but under a constraint to use a relatively parsimonious parameter set that kept sediment parameters that are not based on observed soils and geological data at values that are generally constant across a basin for a given land use or waterbody type. Better fits to observed data could likely be obtained at many observation sites if more site-specific calibration with local parameter adjustments was pursued. While such an approach is likely to provide better model fit statistics it also raises the danger of over-calibration. Before taking such an approach it would be wise to consider several other factors that may be contributing to model uncertainty and potential enhancements that might improve overall model performance. Among other issues, the following items should be considered if the models are further developed:

1. **Meteorological Data**: The current model refinements make use of the meteorological time series developed by RESPEC (2014). These are based on point rainfall measurements and are often derived from volunteer daily total observations that have been disaggregated based on nearest available hourly station templates. We have seen through previous model applications that point gauges can be un-representative of the areal average precipitation depth over a model sub-basin, especially during summer convective storms, which often have local variability. The switch back to point gauge measurements appears to have resulted in a significant decline in hydrologic calibration performance in the model Chippewa basin, which has strong precipitation gradients but rather limited precipitation gauging. Further, temporal disaggregation to a template station that is some distance away can incorporate significant biases in the timing of major rainfall events, which in turn translates into apparent mismatches between model simulation and observed sediment concentrations. The newest generation of PRISM gridded precipitation products (which incorporate gage data, NEXRAD radar precipitation intensity information, and regressions against topographic characteristics) provide a potentially stronger approach to estimate the average precipitation characteristics on a reach. Downscaling to an hourly scale in the absence of nearby hourly template stations may be better achieved by using a fractal simulation approach to assign random intra-day intensities rather than assuming timing is synchronized with the template station. Potential evapotranspiration time series construction is also an issue as the energy inputs (e.g., solar radiation, dew point, wind) are often not available for rural areas and are translated from distant airport stations. The gridded NLDAS evapotranspiration estimates may provide a better means of estimation for areas far from first-order airport meteorological stations. Improvements in the representation of storm hydrology would lead directly to improvements in the simulation of sediment washoff and channel erosion during large storm events, which typically move the majority of sediment in a given year.
2. **Hydraulics**: The current models incorporate only limited information on channel hydraulics. RESPEC (2014) created much finer-scale models than the earlier Tetra Tech (2008) models. This required the development of new hydraulic functional tables (FTables), expressing the relationship between reach storage volume, outflow, surface area, and depth. These calculations in turn determine the shear stress exerted on the channel. As channel erosion has been identified as a major contributor to the total sediment load in the basin this component of the model is critical. The RESPEC memoranda say that for reaches where Tetra Tech previously calculated FTables using results of HEC-RAS models, those FTables “will be scaled by reach length and applied to corresponding reaches in order to maximize the use of the best available data.” For reaches that did not have HEC-RAS models, the documentation implies that cross-sectional measurements at USGS gage sites will be used, and, when field information on a gage is not

available, "the USGS maximum width, depth, and area data will be used to calculate cross-sections assuming a trapezoidal channel and a bank slope of 1/3." Exact details of how FTables were developed for individual reaches are not provided. It is clear, however, that a scaling approach related to gage data can introduce problems because gage rating curves are often developed at constrictions, such as bridge crossings. Similarly, FTables derived from HEC models should be re-calculated based on new reach lengths (not scaled relative to coarser determinations) to incorporate the information available in the HEC models. Re-evaluation of HEC model output plus analysis of measured cross-sections would likely improve the hydraulic performance – and thus the channel sediment scour performance – of the models. Related to this topic, we noted that the 2014 models omit representation of Rapidan Dam on the Blue Earth River. While the pool behind Rapidan Dam is largely silted up, the dam does have an effect on hydraulics and sediment transport in the lower Blue Earth, which is a major source of sediment load to the lower Minnesota River. Therefore it should be important to incorporate the effects of this structure into the models.

3. **Ravine and Bluff Areas**: At the start of this work assignment it was anticipated that new information on the extent of ravine and bluff land use areas would be provided for each HUC8 watershed. Those coverages have not been finalized (and the current bluff coverage based on LiDAR appears to delineate features such as ditch banks as "bluffs," which is not particularly useful to basin-scale modeling). When these delineation efforts are completed the models should be updated to incorporate the information.

4. **Parameters for Manured Land**: It required a considerable amount of time to reach an agreement with MPCA on the appropriate approach to determine the land area that received manure applications. Manure applications have impacts on nutrient loading, but also change the soil structure in somewhat subtle ways that can change runoff and sediment loading impacts. Due to the delay in resolving the manured land area representation, the definition of manured area was not finalized until after the hydrologic recalibration had been completed. To avoid disturbing the hydrologic calibration, the manure application areas were specified (and area shifted from) as equal to existing conventional tillage on A/B soils. In fact, evidence (summarized in Tetra Tech, 2008) suggests that land receiving manure application should have somewhat greater upper zone storage capacity (UZSN), which in turn affects runoff sediment transport capacity. This refinement should be incorporated into any revised models.

5. **Tile Drain Sediment**: RESPEC (2014) adopted a modified approach to the simulation of sediment transport through surface tile inlets that was much simpler and more efficient than the SPECIAL ACTIONS approach implemented by Tetra Tech (2008). The revised approach gives a similar estimate of total sediment load transported by this pathway, but the pollutograph is very different, with the load transmitted to the stream much more quickly. At this point it is not clear which representation is correct, although the approach earlier use by Tetra Tech did result in a good match between observed and simulated sediment concentrations. This topic appears worthy of further investigation.

7 References

AQUA TERRA. 2012. Modeling Guidance for BASINS/HSPF Applications under the MPCA One Water Program. Prepared for Minnesota Pollution Control Agency by AQUA TERRA Consultants, Mountain View, CA.

Bevis, M. 2015. Sediment Budgets Indicate Pleistocene Base Level Fall Drives Erosion in Minnesota's Greater Blue Earth River Basin. A thesis submitted to the Faculty of the University of Minnesota in partial fulfillment of the requirements for the degree of Master of Science, Dr. Karen Gran, Advisor.

Donigian, A.S., J.C. Imhoff, B.R. Bicknell, and J.L. Kittle. 1984. Application Guide for the Hydrologic Simulation Program - FORTRAN. EPA 600/3-84-066. U.S. Environmental Protection Agency, Athens, GA.

Donigian, A.S. Jr. 2000. *HSPF Training Workshop Handbook and CD*. Lecture #19. Calibration and Verification Issues, Slides #L19-22. U.S. Environmental Protection Agency, Washington Information Center, January 10–14, 2000. Prepared for U.S. Environmental Protection Agency, Office of Water, Office of Science and Technology, Washington, DC.

Donigian, A.S. Jr., and J.T. Love. 2003. Sediment Calibration Procedures and Guidelines for Watershed Modeling. Presented at the Water Environment Federation Total Maximum Daily Load Conference, November 16–19, 2003, Chicago, IL.

Gran, K., P. Belmont, S. Day, C. Jennings, J.W. Lauer, E. Viparelli, P. Wilcock, and G. Parker. 2011. An Integrated Sediment Budget for the Le Sueur River Basin, Final Report. National Center for Earth Systems Dynamics.

Lumb, A.M., R.B. McCammon, and J.L. Kittle, Jr. 1994. Users Manual for an Expert System (HSPEXP) for Calibration of the Hydrological Simulation Program – FORTRAN. Water-Resources Investigation Report 94-4168. U.S. Geological Survey, Reston, VA.

Moriasi, D.N., J.G. Arnold, M.W. Van Liew, R.L. Bingner, R.D. Harmel, and T.L. Veith. 2007. Model evaluation guidelines for systematic quantification of accuracy in watershed simulations. *Transactions of the ASABE*, 50(3): 885-900.

RESPEC. 2014. Hydrology and Water Quality Calibration and Validation of Minnesota River Watershed Modeling Applications. Memorandum to Dr. Charles Regan, Minnesota Pollution Control Agency.

Schottler, S., D. Engstrom, and D. Blumentritt. 2010. Fingerptinting Sources of Sediment in Large Agricultural River Systems. St. Croix Watershed Research Station, Marine, MN.

Tetra Tech. 2008. Minnesota River Basin Turbidity TMDL and Lake Pepin Excessive Nutrient TMDL, Model Calibration and Validation Report. Prepared for Minnesota Pollution Control Agency by Tetra Tech, Inc., Research Triangle Park, NC.

US EPA. 2006. BASINS Technical Note 8: Sediment Parameter and Calibration Guidance for HSPF. Office of Water, U.S. Environmental Protection Agency, Washington, DC.

Walker, W.W. 1996. Simplified Procedures for Eutrophication Assessment and Prediction: User Manual. Instruction Report W-96-2. U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS.

1Park Drive, Suite 200 • PO Box 14409
Research Triangle Park, NC 27709
Tel 919-485-8278 • Fax 919-485-8280

TETRA TECH

Memorandum

To:	Chuck Regan, Tim Larson (MPCA)	**Date:**	11/3/2015
From:	J. Butcher, P.H.	**Subject:**	**Minnesota River Basin HSPF Model Hydrology Recalibration**

1 Introduction

The MPCA has been working for many years on development and refinement of HSPF models for the Minnesota River Basin (010200). In 2015, MPCA contracted with Tetra Tech to refine the hydrologic and sediment calibrations for the Basin.

This memorandum specifically documents the hydrology recalibration and validation of the Minnesota River Basin HSPF modeling system, including the following 8-digit Hydrologic Unit Code (HUC) watersheds:

- Chippewa (07020005)
- Redwood (07020006)
- Middle Minnesota (07020007)
- Cottonwood (07020008)
- Blue Earth (07020009)
- Watonwan (07020010)
- LeSueur (07020011)
- Lower Minnesota (07020012).

The Hawk-Yellow Medicine basin (07020004) is also a HUC 8 watershed within the Minnesota River Basin. RESPEC committed to and provided an update to MPCA of the Hawk-Yellow Medicine model. Tetra Tech provided input to RESPEC as part of this effort; however, the status of the revised Hawk-Yellow Medicine HSPF model is not documented in this memorandum.

2 Approach

The Minnesota River basin HSPF models have a long history. Models for six of the HUC8 basins were originally developed by MPCA and subsequently expanded and calibrated to include the entire basin from

Lac qui Parle to Jordan, MN by Tetra Tech in 2002. Tetra Tech (2008) subsequently refined these models for sediment simulation. These models were discretized at approximately the HUC10 scale. Tetra Tech later developed finer-resolution (HUC12-scale) models of the Chippewa and Hawk-Yellow Medicine HUC8 sub-models. MPCA then contracted with RESPEC to develop HUC12-scale models of the entire basin downstream of Lac qui Parle, as well as to extend the models in time through 2012. This effort was completed in 2014.

The initial review of the RESPEC models provided to MPCA by Tetra Tech suggested that hydrology was fit reasonably well; however, sediment source attribution did not match up well with the evidence available from cosmogenic radionuclide data (e.g., Schottler et al., 2010). Subsequent analysis revealed other aspects of the hydrologic calibration that potentially affect sediment calibration. Accordingly, MPCA requested review and revisions to the hydrologic calibration as part of the sediment recalibration effort.

2.1 OBJECTIVES FOR RECALIBRATION

The RESPEC models provide an excellent starting point for the current hydrology revisions. Model performance was adjusted at all calibration gages in the watershed to meet the following objectives:

- **Achieve high values of the NSE while also minimizing standard measures of volumetric error** (percent error on total volume, 10% high flows, 50% low flows, seasonal flows, and storm flows) as recommended by MPCA's modeling guidance (AQUA TERRA, 2012). The existing calibration appears to be focused more on achieving high NSE, which indicates a situation in which the model tracks the variability in observations well. It is possible to achieve a relatively high NSE while also incurring high volumetric errors, which indicates an undesirable situation where the model is relatively precise, but biased.
- **Adjust the ET simulation to better represent the seasonal pattern in MODIS data.** Comparison of modeled evapotranspiration (ET) to MODIS satellite-estimated ET showed that the model was simulating the peak of ET in June, whereas the MODIS estimates peak in July-August. (See further discussion below in Section 4.2.)
- **Control water balance components.** The consensus of MPCA staff was that the models tended to under-estimate direct surface runoff, which is important to sediment simulation. In general, the surface runoff fraction should be greater than 4 percent of total flow and higher in the lacustrine soils of the LeSueur watershed. To ensure better representation of surface runoff, tile flow, and shallow groundwater discharges, the focus was on achieving a good match between simulated and observed baseflow fraction using the sliding windows method for baseflow separation (Sloto and Crouse, 1996). Because tile flow is simulated as a mix of interflow and groundwater discharge, the baseflow fraction is judged to be the best measure of water balance components.
- **Examine and attempt to fit gage records at smaller watersheds to the extent possible.** Calibration of the existing models focused on downstream gages at the outlet of HUC8 watersheds and especially on the Nash-Sutcliffe coefficient of model fit efficiency (NSE). Average volumetric errors on total flow, high and low flows, and seasonal flows were sometimes larger than desirable for gage records on smaller watersheds. Accordingly, the hydrologic calibration was adjusted to better represent these gage records. Several caveats are necessary here. Many of the gages on smaller records are seasonal gages operated by MDNR with limited field adjustments to rating curves. Some gages have very short periods of record as well. Therefore, it is important to consider the record length and be aware of potential problems in some gage records. A cautionary example is provided by the gages on the Rush River. The Rush River mainstem is formed from four approximately equal tributaries shortly upstream of the mouth (North Branch Rush River, Middle Branch Rush River, South Branch Rush River, and

Nicollet-Sibley Judicial Ditch 1A). There is a gage at the mouth of the Rush River, and each of the tributaries has been gaged for several years. It is clear, however, that the gaged flows reported at the mouth of the Rush River are substantially greater than the sum of the four upstream gages and the intervening drainage area is not sufficiently large to explain the discrepancy. There may be some longer-range groundwater pathways that discharge into the incised channel of the lower Rush River, but the discrepancy is also present at high flows. Examination of annual hydrologist's notes suggest that the gage records themselves are at issue here. The upstream gages are generally rated as fair to poor quality, but the largest issues appear to be associated with the gage at the mouth. The hydrologist notes for 2012 (available on HYDSTRA) state "This is not a stable site. This is a constantly changing sand channel and high flows are affected by backwater from [the Minnesota River] during high flows. Rating changes most years and all rating points are coded as poor. This is due to constantly changing sand channel for lower flows and backwater effects during higher flows." Obviously, the model calibration cannot fully resolve these data issues and the calibration must attempt to provide as good a fit as possible to the four gages, while accepting that significant unresolvable discrepancies will remain.

2.2 Performance Metrics

Hydrologic calibration is performed by comparing time-series of model results to gaged flows and other water balance measures. Key considerations in the hydrology calibration are the overall water balance, the high-flow to low-flow distribution, storm flows, seasonal variation in flows, and evapotranspiration.

The level of performance and overall quality of hydrologic calibration is evaluated in a weight of evidence approach that includes both visual comparisons and quantitative statistical measures. Given the inherent errors in input and observed data and the approximate nature of model formulations, absolute criteria for watershed model acceptance or rejection are not generally considered appropriate by most modeling professionals. And yet, most decision makers want definitive answers to the questions—"How accurate is the model?" and "Is the model good enough for this evaluation?" Consequently, the current state of the art for model evaluation is to express model results in terms of ranges that correspond to "very good", "good", "fair", or "poor" quality of simulation fit to observed behavior. These characterizations inform appropriate uses of the model: for example, where a model achieves a good to very good fit, decision-makers often have greater confidence in having the model assume a strong role in evaluating management options. Conversely, where a model achieves only a fair or poor fit, decision makers may assign a less prominent role for the model results in the overall weight-of-evidence evaluation of management options.

Quantitative measures of model performance will be constructed based on relative error and the Nash-Sutcliffe coefficient of model fit efficiency (NSE; Nash and Sutcliffe, 1970). Relative error is calculated as:

$$E_{rel} = \frac{\sum |O - P|}{\sum O} \cdot 100 ,$$

where E_{rel}= relative error in percent. The relative error is the ratio of the absolute mean error to the mean of the observations and is expressed as a percent. A relative error of zero is ideal. NSE is calculated (at both the daily and monthly time scale) as:

$$NSE = 1 - \frac{\sum (O-P)^2}{\sum (O-\bar{O})^2},$$

in which the overbar indicates the average.

Unlike relative error, NSE is a measure of the ability of the model to explain the variance in the observed data. Values may vary from -∞ to 1.0. A value of NSE = 1.0 indicates a perfect fit between modeled and observed data, while values equal to or less than 0 indicate the model's predictions of temporal variability in observed flows are no better than using the average of observed data. The accuracy of a model increases as the value approaches 1.0.

For HSPF, LSPC, and similar watershed models, a variety of performance targets have been documented in the literature, including Donigian et al. (1984), Lumb et al. (1994), Donigian (2000), and Moriasi et al. (2007). Based on these references and past experience, HSPF performance targets are summarized in Table 1.

Model performance is generally deemed fully acceptable where a performance evaluation of "good" or "very good" is attained. It is important to clarify that the tolerance ranges are intended to be applied to mean values, and that individual events or observations may show larger differences and still be acceptable (Donigian, 2000). Moriasi et al. (2007) suggest that achieving a relative error on total volume of 10 percent or better and an NSE of 0.75 or more on *monthly* flows constitutes a good modeling fit for watershed applications.

Table 1. Performance targets for HSPF/LSPC hydrologic simulation (magnitude of annual and seasonal Relative mean error (*RE)*; daily and monthly NSE)

Model Component	Very Good	Good	Fair	Poor
1. Error in total volume	≤ 5%	5 - 10%	10 - 15%	> 15%
2. Error in 50% lowest flow volumes	≤ 10%	10 - 15%	15 - 25%	> 25%
3. Error in 10% highest flow volumes	≤ 10%	10 - 15%	15 - 25%	> 25%
4. Error in storm volume	≤ 10%	10 - 15%	15 - 25%	> 25%
5. Winter volume error (JFM)	≤ 15%	15 - 30%	30 - 50%	> 50%
6. Spring volume error (AMJ)	≤ 15%	15 - 30%	30 - 50%	> 50%
7. Summer volume error (JAS)	≤ 15%	15 - 30%	30 - 50%	> 50%
8. Fall volume error (OND)	≤ 15%	15 - 30%	30 - 50%	> 50%
9. NSE on daily values	> 0.80	> 0.70	> 0.60	≤ 0.60
10. NSE on monthly values	> 0.85	> 0.75	> 0.65	≤ 0.65

Where model fit to observations is found to be less than "good" this can be due to deficiencies in the model, deficiencies in the gage record, or a combination of the two. Calibration typically assumes that gage records are "correct" and maximizes the fit of the model to those records. It is clear in some cases, however, that uncertainty in the gage record itself is a major contributor to poor predictability. This is most likely to be true for gages that have short periods of record, locations that are impacted by backwater effects, and sites with unstable channels at which rating curve adjustments have not been frequently revised.

2.3 Calibration and Validation/Corroboration

Traditional model validation is intended to provide a test of the robustness of calibrated parameters through application to a second time period. In watershed models, this is, in practice, usually an iterative process in which evaluation of model application to a validation period leads to further adjustments in the calibration. A second, and perhaps more useful constraint, on model specification and performance is provided by the multi-objective approach described above in which the model is tested at multiple gages on the stream network in relation to multiple measures relative to both flow and other components of the water balance. In particular, obtaining model fit to numerous gages at multiple spatial scales from individual headwater streams to downstream stations that integrate across the entire Minnesota River basin helps to ensure that the model calibration is robust.

The overall model application period is 1/1/1995 – 12/31/2012. For gages with longer periods of record (primarily the HUC8 scale gages), this extended time period was segmented into calibration and validation periods, which are from 1/1/2003 – 12/31/2012 and 1/1/1995 – 1/1/2002, respectively. Separate calibration and validation period results are provided electronically. This summary memorandum focuses on model statistics over the entire available gage record coincident with the model application period.

2.4 Components not Adjusted

The adjustments to the hydrologic calibration are conditional on several aspects of the RESPEC model development (RESPEC, 2014). Most importantly, the development and assignment of meteorological variables, including the calculation of potential evapotranspiration, is left intact and not adjusted. In some cases, the assignment of single gage records to broad areas can lead to bias in simulation of adjacent areas, as in the Shakopee Creek area of the Chippewa model where NEXRAD data shows a relatively strong precipitation gradient that is not captured by the meteorological stations selected by RESPEC. Point source discharges are also accepted as specified by RESPEC.

The RESPEC models use a degree-day method for the simulation of snow melt. In general, energy-balance methods of snow simulation are preferred (AQUA TERRA, 2012); however, energy-balance simulations of snow accumulation and melt are highly dependent on the accuracy and applicability of meteorological data to local conditions. We examined the LeSueur model in detail and determined that it did not appear to be feasible to attain any significant improvements in model performance through switching to an energy-balance method.

The RESPEC (2014) models were calibrated for snow through comparison of observed and simulated snowfall and snow depth at meteorological stations. These comparisons are of necessity approximate due to wind drift and other factors that influence snow at specific gage sites. The current recalibration did not introduce any significant changes into the snow simulation. Therefore, we checked and confirmed that the snow simulation provided results similar to those reported by RESPEC, but did not redo a detailed statistical evaluation of observed versus simulated snow depth. Figure 1 shows a typical plot for snow depth, comparable to Figure 3 in RESPEC (2014).

Hydraulic functional tables (FTables) are not altered from the RESPEC models. Lake simulation is also as set up by RESPEC. Hydrologic balance for lakes is determined by the interaction of the overall water balance (total flow volume and evaporative losses) with lake FTables. As the FTables are unaltered and the total flow volumes are well simulated, detailed recalibration analyses for lakes is also not presented here.

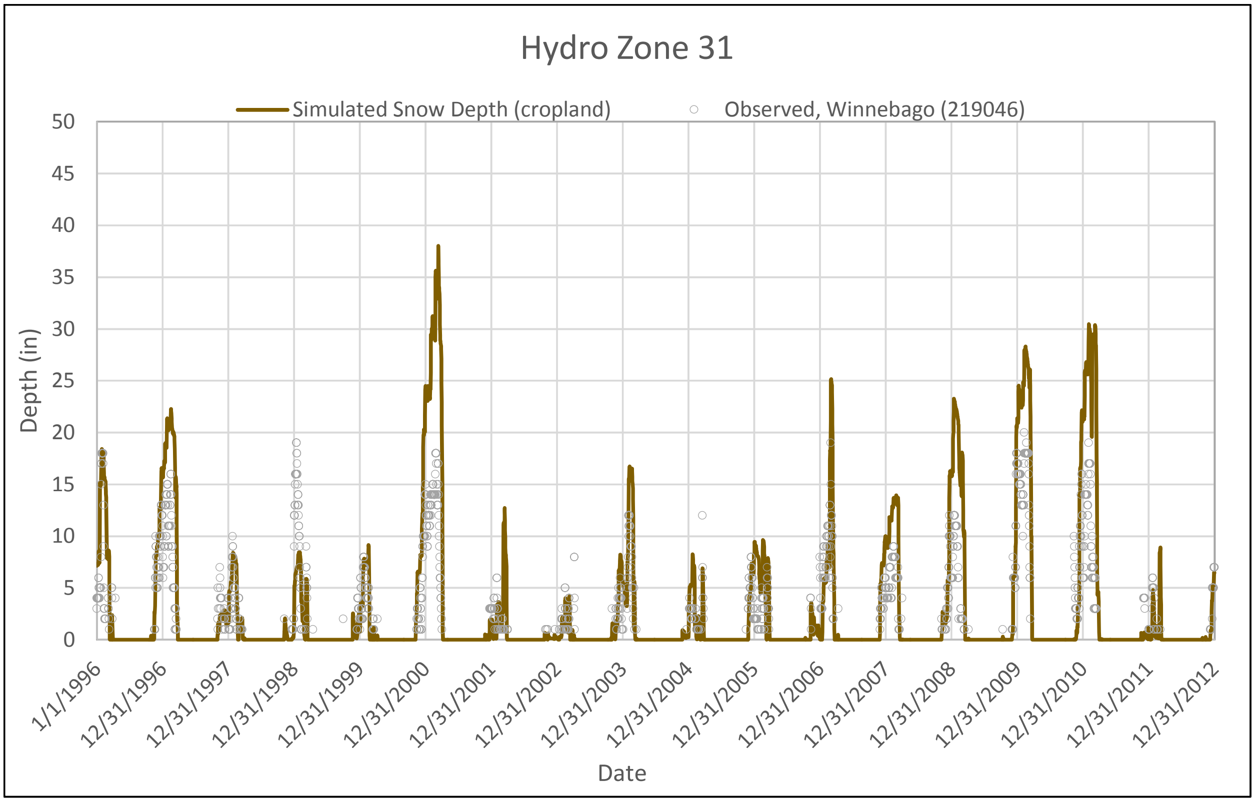


Figure 1. Observed and Simulated Snow Depth at Winnebago, MN

3 Calibration Gage Sites

A total of 57 stream gage stations were used for the Minnesota River Basin HSPF model hydrology recalibration. At least three gage sites were included for each HUC8.

The sites fall into three categories with different levels of importance for calibration. These are, in order of importance:

1. Gages with long-term, continuous flow records. These are primarily USGS gages and include the gages at the mouth of HUC8s and on the Minnesota River mainstem. Most of these gages have rating curves that are regularly updated using standard protocols; however, winter ice period records are often estimated and of poorer quality.

2. Seasonal gages with longer term records. Many of these gages are operated by MDNR and records are maintained for the non-winter period only. Spring gaging often starts in the middle of snowmelt, and small differences in timing of snowmelt between the gage and model may bias estimates of flow volume. Quality of records may vary due to the stability of the stream channel, the frequency at which adjustments to rating curves are made based on field observations, and other factors.

3. Gages with short-term, seasonal flow records are of lesser importance. Not only are these gages potentially subject to uncertainties associated with seasonal operation and potentially poor rating curves, but short periods of record are also prone to yield misleading statistics due to one or a few anomalous rainfall events that are not captured in the meteorological series.

The three categories of stream gages used in calibration are presented in Tables 2 through 4.

Table 2. Hydrology Calibration Gage Sites with Long-term, Continuous Flow Records

Site	HUC8	HYDSTRA ID	STORET ID	USGS ID	Calibration Start Date	Calibration End Date
Chippewa River near Milan, MN	07020005	26057001	S002-203	05304500	1/1/1996	12/31/2012
Redwood River near Marshall, MN	07020006	27043002	--	05315000	1/1/1996	12/31/2012
Redwood River near Redwood Falls, MN	07020006	27035001	S001-679	05316500	1/1/1996	12/31/2012
Minnesota River at Morton, MN	07020007	28012001	S000-145	05316580	10/1/2000	12/31/2012
Little Cottonwood River near Courtland, MN	07020007	28057001	S001-377	05317200	1/1/1996	6/8/2010
Minnesota River at Mankato, MN	07020007	28042001	--	05325000	1/1/1996	12/31/2012
Cottonwood River near New Ulm, MN	07020008	29001001	S001-918	05317000	1/1/1996	12/31/2012
Blue Earth River near Rapidan, MN	07020009	30092001	S001-231	05320000	1/1/1996	12/31/2012
Watonwan River near Garden City, MN	07020010	31051001	S000-163	05319500	1/1/1996	12/31/2012
Little Cobb River near Beauford, MN	07020011	32069001	S003-574	05320270	4/1/1996	10/15/2012
LeSueur River near Rapidan	07020011	32077001	S000-340	05320500	1/1/1996	12/31/2012
High Island Creek near Henderson, CSAH6	07020012	33091001	S000-676	05327000	1/1/1996	12/4/2012
Minnesota River near Jordan, MN	07020012	33145001	S000-039	05330000	1/1/1996	12/31/2012
Minnesota River at Fort Snelling State Park, MN	07020012	33143004	--	05330920	1/21/2004	12/31/2012

Table 3. Hydrology Calibration Gage Sites with Long-term, Seasonal Flow Records

Site	HUC 8	HYDSTRA ID	STORET ID	USGS ID	Calibration Start Date	Calibration End Date
Chippewa River at Cyrus	07020005	26003001	S002-190	05301930	3/25/2003	12/31/2012
Chippewa River at Benson, MN	07020005	26037001	--	05303500	6/26/1998	11/11/2012
Shakopee Creek near Benson	07020005	26038001	S002-201	--	3/19/2004	10/7/2012
Dry Weather Creek near Watson	07020005	26078001	S002-204	05304800	3/30/2004	10/7/2012
East Branch Chippewa River near Benson	07020005	26088001	S002-196	05303470	3/28/2003	10/7/2012
Redwood River at Russell CR15	07020006	27043001	S000-696	05314973	10/1/1998	12/31/2012
Threemile Creek near Green Valley, CR 67	07020006	27039001	S002-313	--	4/9/2004	10/2/2012
Clear Creek near Seaforth, CR56	07020006	27030001	S002-311	--	4/8/2004	10/2/2012
Nicollet CD46A near North Star, CSAH13	07020007	28066001	S002-936	--	4/3/2002	7/14/2012
Seven Mile Creek near North Star	07020007	28063001	S002-937	--	4/3/2002	12/17/2012
Nicollet CD13A near North Star, MN99	07020007	28062001	S002-934	--	4/2/2002	7/11/2012
Cottonwood River near Lamberton, US14	07020008	29062002	S002-247	--	6/15/1998	11/23/2012
Cottonwood River near Springfield, CR2	07020008	29015001	--	05316950	10/1/1999	11/12/2012
Cottonwood River near Leavenworth CR8	07020008	29022001	S001-920	05316970	4/15/2004	10/8/2012
Sleepy Eye Creek near Cobden, CR8	07020008	29011001	S001-919	05316992	3/19/2004	10/8/2012
Center Creek near Huntley, CR1	07020009	30028001	S003-024	--	4/1/2004	10/1/2008
Elm Creek near Huntley, CR159	07020009	30051001	S003-025	--	4/1/2004	10/1/2008
Maple River near Rapidan, CR35	07020011	32072001	S002-427	05320408	4/24/2003	10/16/2012
Little Beauford Ditch near Beauford, MN22	07020011	32073001	S001-210	--	3/21/1996	11/30/2007
High Island Creek near Arlington, CR9	07020012	33075001	S001-891	05326700	4/9/2001	9/27/2012
Buffalo Creek near Jessenland, 270th St.	07020012	33092001	S001-807	05326900	4/9/2001	9/30/2012
Rush River near Henderson, MN93	07020012	33096001	S000-822	05326400	3/15/2003	9/30/2012

Table 4. Hydrology Calibration Gage Sites with Short-term, Seasonal Flow Records

Site	HUC 8	HYDSTRA ID	STORET ID	USGS ID	Calibration Start Date	Calibration End Date
Minnesota River at Judson, CSAH42	07020007	28054001	S001-759	05317500	1/1/2008	12/31/2012
Crow Creek near Morton, Noble Ave	07020007	28098001	S005-628	--	4/2/2009	10/25/2010
Wabasha Creek near Franklin, CSAH11	07020007	28102001	S005-627	--	4/2/2009	10/25/2010
North Eden Creek near Franklin, CSAH10	07020007	28095001	S005-626	--	4/2/2009	10/25/2010
Nicollet CD24 near North Star, Timber Ln	07020007	28063002	S002-464	--	3/31/2006	11/1/2009
Plum Creek near Walnut Grove, CSAH10	07020008	29048001	S001-913	--	4/2/2005	10/27/2009
North Fork Watonwan River near Sveadahl, MN	07020010	31030001	--	--	4/1/2000	11/6/2002
Watonwan River near La Salle, CSAH16	07020010	31040001	S002-253	--	4/1/2000	9/30/2002
Watonwan River near La Salle, CSAH3	07020010	31028001	S002-254	--	4/1/2000	11/7/2002
South Fork Watonwan River near Madelia, CSAH13	07020010	31021001	S002-251	--	4/1/2000	11/7/2002
Maple River near Sterling Center, CR18	07020011	32062001	S004-101	05320450	3/30/2006	10/16/2012
Big Cobb River near Beauford, CR16	07020011	32071001	S003-446	05320330	3/29/2006	10/2/2012
LeSueur River at St. Clair, CSAH28	07020011	32079001	S003-448	--	3/26/2007	10/2/2012
LeSueur River near Rapidan, CR8	07020011	32076001	S003-860	--	3/29/2006	10/2/2012
High Island Creek near Fernando, CSAH7	07020012	33010001	S001-629	--	4/9/2001	7/15/2002
High Island Creek near New Auburn, CSAH13	07020012	33003001	S001-626	--	4/9/2001	7/15/2002
Buffalo Creek (County Ditch 59) near New Rome, CSAH17	07020012	33092002	S002-306	--	4/9/2001	7/15/2002
North Branch Rush River near New Rome, CSAH9	07020012	33071001	S002-930	--	3/15/2003	10/26/2005
Middle Branch Rush River near New Sweden, CR63	07020012	33069001	S002-931	--	3/20/2003	10/26/2005
South Branch Rush River near Norseland, CR63	07020012	33065001	S002-932	05326189	4/30/2003	10/7/2008
Nicollet Sibley JD1A near Norseland, CSAH3	07020012	33068001	S002-933	05326205	3/15/2003	10/26/2005

4 Model Updates

4.1 Modifications to Land Use Representation

Several adjustments were made to the representation of land use developed by RESPEC (2014) at the request of MPCA. Most significantly, the categories for conventional and conservation tillage cropland were split according to hydrologic soil group using SSURGO soil coverages (using the drained designation for dual classification soils). This is important to identify marginal crop areas that may contribute disproportionately large amounts of runoff and solids. Two groups were used: A+B and C+D soils. Conservation and conventional tillage area totals by subbasin were preserved in this splitting process.

MPCA also requested separate representation of lands receiving manure applications. The RESPEC models contain a placeholder for this category, but no area is assigned. This modification has not been accomplished as MPCA is still debating the best means of calculation of this area. Effects on hydrology are expected to be small.

The RESPEC models specify bluffs and major ravines as separate pervious land areas, but did not do this for the Chippewa and Hawk-Yellow Medicine models where the land cover was originally developed by Tetra Tech. Bluff areas were added to these models based on the bluff coverage provided by MPCA. Full coverage of ravine areas is not yet available.

4.2 Evapotranspiration

Evapotranspiration is the sum of evaporation from soil, water, and leaf surfaces and transpiration of soil water by plants. Actual evapotranspiration predicted by the RESPEC models tended to peak in June with a fall-off over the remainder of the summer.

Data gathered by remote sensing technology can be used to check and improve the representation of evapotranspiration in watershed models. Evapotranspiration data is calculated from remote sensing data collected by the Moderate Resolution Imaging Spectroradiometer (MODIS) aboard NASA’s Terra and Aqua satellites. Monthly evapotranspiration data was extracted from the global MOD16 dataset at a resolution of 1 km^2 for the Minnesota River Basin to identify seasonal evapotranspiration patterns.

It is important to recognize that MODIS does not directly measure evapotranspiration. Rather, an algorithm that considers MODIS land cover, albedo, leaf area index, and enhanced vegetation index is combined with daily meteorological data from NASA’s Global Modeling and Assimilation Office reanalysis datasets using a Penman-Monteith type of approach (Mu et al., 2011). A validation study (Velpuri et al., 2013) showed that MODIS was able to estimate monthly ET within about 25 percent based on comparison to FLUXNET studies. For Köppen climatic zone Dfb (which includes the Minnesota Corn Belt) MODIS was shown to have a positive bias during warmer months with an overall root mean squared error of 31 mm/mo. Nonetheless, it is anticipated that MODIS should correctly identify the annual peak ET pattern.

Seasonal patterns of actual ET simulated by HSPF depend on both the calculated PET and the assignment of monthly lower zone evapotranspiration parameters (MON-LZETPARM). We conducted experiments with the LeSueur model and found that modification to the seasonal pattern of this parameter can successfully move the simulated ET peak to July and maintain a good match to MODIS estimates of ET through the fall, as shown for example from the Middle Minnesota basin in Figure 2. It was not possible, however, to maintain a complete match over the early summer without throwing off the summer low flow simulation. Essentially, MODIS predicts a slower ramp up of summer ET than is necessary to predict summer flows. This may be because the MODIS algorithm relies on leaf area whereas a significant portion of the total evaporation during early periods of crop growth may come directly from the soil surface. Simulated evaporation in winter is less than predicted by MODIS, in part because the degree-day approach to snow simulation does not allow for direct sublimation of snow. However, it also appears likely that MODIS over-estimates winter evaporation in this climate zone.

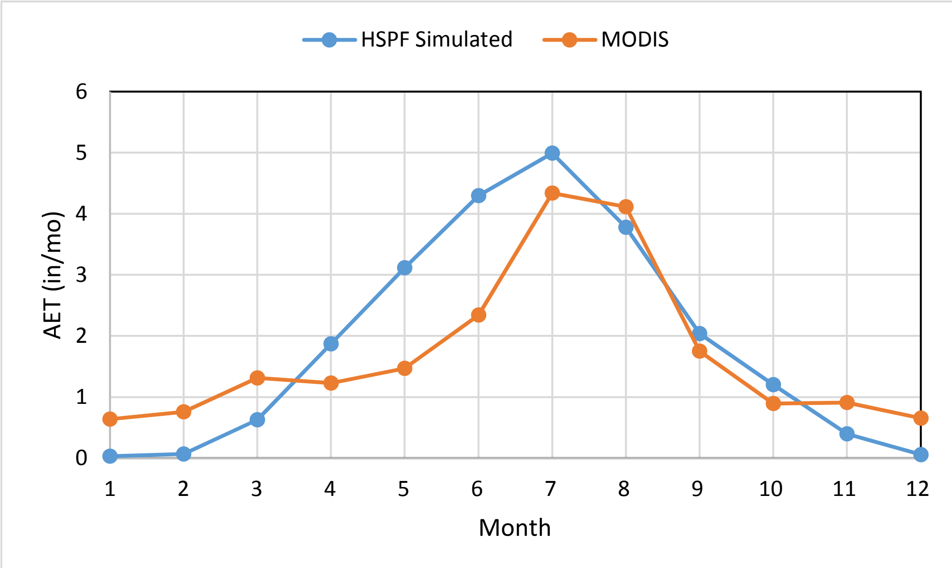


Figure 2. Comparison of MODIS ET and Revised HSPF Actual ET for the Middle Minnesota River Basin Model

MODIS was also used as a guide to shape the monthly ET pattern of individual land cover types. The evapotranspiration patterns were applied to update the monthly variable lower zone evapotranspiration parameter for all of the HUC 8 watersheds discussed in this memorandum. The remote sensing-based lower zone evapotranspiration parameter values for the Cottonwood watershed are provided as an example in Table 5.

Table 5. Monthly Values of the Lower Zone Evapotranspiration Parameter (MON-LZETPARM) for the Cottonwood Watershed

Land Use/ Land Cover	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
Urban	0.1	0.1	0.1	0.2	0.6	0.57	0.64	0.7	0.64	0.51	0.33	0.1
Forest	0.1	0.1	0.1	0.2	0.6	0.69	0.74	0.74	0.71	0.57	0.33	0.1
Cropland	0.1	0.1	0.1	0.1	0.05	0.15	0.45	1.05	0.85	0.4	0.15	0.1
Grassland	0.1	0.1	0.1	0.2	0.6	0.57	0.75	0.7	0.64	0.51	0.33	0.1
Pasture	0.1	0.1	0.1	0.2	0.6	0.57	0.75	0.7	0.64	0.51	0.33	0.1
Wetland	0.1	0.1	0.1	0.2	0.4	0.44	0.64	0.7	0.64	0.51	0.33	0.1
Feedlot	0.1	0.1	0.1	0.2	0.6	0.57	0.75	0.7	0.64	0.51	0.33	0.1
Bluff	0.1	0.1	0.1	0.2	0.6	0.69	0.74	0.74	0.71	0.57	0.33	0.1
Ravine	0.1	0.1	0.1	0.2	0.6	0.69	0.74	0.74	0.71	0.57	0.33	0.1

4.3 Interception

Interception of moisture by vegetation is another important contributor to total evapotranspiration and is generally determined by leaf area index. Vegetative cover patterns are also important to the estimation of surface erosion. As noted above, remote sensing data can be used to identify the seasonal pattern of vegetative cover in the watershed. MODIS surveys global vegetative cover at 16-day intervals and the data can be aggregated and downloaded at varied spatial scales. MODIS vegetative cover data was retrieved for the entire Minnesota River Basin. Seasonal vegetative cover patterns, which vary spatially across the Minnesota River Basin, were analyzed. The results from this analysis directed the selection of monthly variable interception parameters for all of the HUC 8s. The interception parameters assigned to the Cottonwood watershed are shown for example in Table 6.

Table 6. Monthly Values of the Vegetative Interception Parameter (MON-INTERCEP) for the Cottonwood Watershed

Land Use/ Land Cover	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.
Urban	0.09	0.09	0.09	0.09	0.1	0.1	0.1	0.1	0.1	0.09	0.09	0.09
Forest	0.06	0.06	0.06	0.1	0.16	0.18	0.19	0.19	0.17	0.1	0.06	0.06
Cropland (Conservation Till)	0.03	0.03	0.03	0.06	0.07	0.12	0.15	0.13	0.14	0.08	0.05	0.04
Cropland (Conventional Till)	0.01	0.01	0.01	0.03	0.06	0.12	0.15	0.13	0.14	0.06	0.03	0.02
Grassland	0.06	0.06	0.07	0.08	0.12	0.13	0.15	0.13	0.13	0.08	0.07	0.07
Pasture	0.06	0.06	0.07	0.08	0.12	0.13	0.15	0.13	0.13	0.08	0.07	0.07
Wetland	0.04	0.04	0.04	0.04	0.05	0.08	0.12	0.14	0.15	0.11	0.07	0.05
Feedlot	0.02	0.02	0.03	0.04	0.05	0.1	0.07	0.09	0.09	0.06	0.04	0.03
Bluff	0.06	0.06	0.06	0.1	0.16	0.18	0.19	0.19	0.17	0.1	0.06	0.06
Ravine	0.06	0.06	0.06	0.1	0.16	0.18	0.19	0.19	0.17	0.1	0.06	0.06

4.4 Interflow Inflow

Under-prediction of surface runoff in the existing models occurred primarily because the vast majority of potential direct runoff was being diverted to interflow as a representation of tile drainage. Tile drainage is certainly a key aspect of the water balance in these basins, but was likely over-represented in some basins. The monthly interflow inflow parameter for agricultural lands ranged up to 8 in Watonwan and up to 7.5 in Cottonwood and Redwood, both much higher than the maximum value of 5.5 used for LeSueur, which is generally characterized as the basin with the greatest tiling density. Therefore, this parameter was scaled back in accordance with the analysis of tiling density done for the 2002 models, which was found to be generally consistent with specifications for field drainage rates, and set so that the values generally decline from LeSueur and Middle Minnesota basins to the Chippewa. For example, the revised maximum monthly interflow inflow parameter for Cottonwood is revised to be 4.0.

4.5 Additional Updates

Model goodness of fit was evaluated at each calibration gage following the implementation of the updated evapotranspiration, vegetative interception, and tile drainage parameters. Additional parameters were adjusted as necessary to improve the hydrologic simulation. The main processes that were modified during the hydrology recalibration include interflow and groundwater recession, infiltration rates, and nominal soil storage capacities in the upper and lower soil zones.

5 Results

5.1 Water Balance Components

As described above, the RESPEC models are believed to generally under-estimate the surface runoff component of flow. The updated models predict a slightly higher surface fraction of total flow, ranging from a high of about 12 percent in the lacustrine soils of the LeSueur watershed to a low of about 4 percent in the Chippewa when expressed as a weighted average across whole watersheds. Figure 3 compares the current results to those from RESPEC (2014) and earlier Tetra Tech (2008) models. The flow components for the revised simulation are summarized in Table 7 and shown graphically in Figure 4.

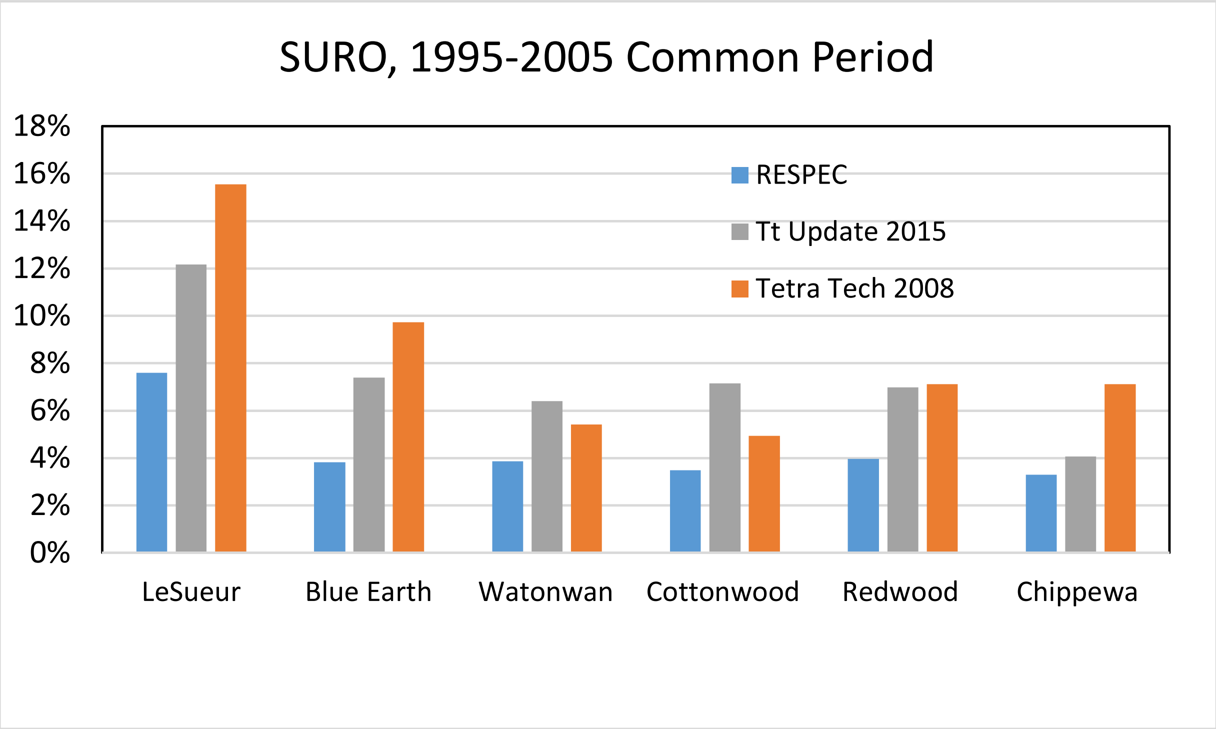


Figure 3. Surface Runoff (SURO) as an Area-Weighted Fraction of Total Flow; Current Recalibration Compared to RESPEC (2014) and Tetra Tech (2008) Results
Note: Results are shown for the period of 1995-2005 common to all three modeling efforts.

Table 7. Flow Components for Revised Models, 1995-2012

	LeSueur	Blue Earth	Watonwan	Cottonwood	Redwood	Chippewa
Surface	12.59%	7.45%	7.06%	7.76%	6.94%	4.31%
Interflow	40.61%	28.41%	26.08%	21.92%	16.61%	9.37%
Groundwater	46.81%	64.13%	66.86%	70.32%	76.45%	86.33%

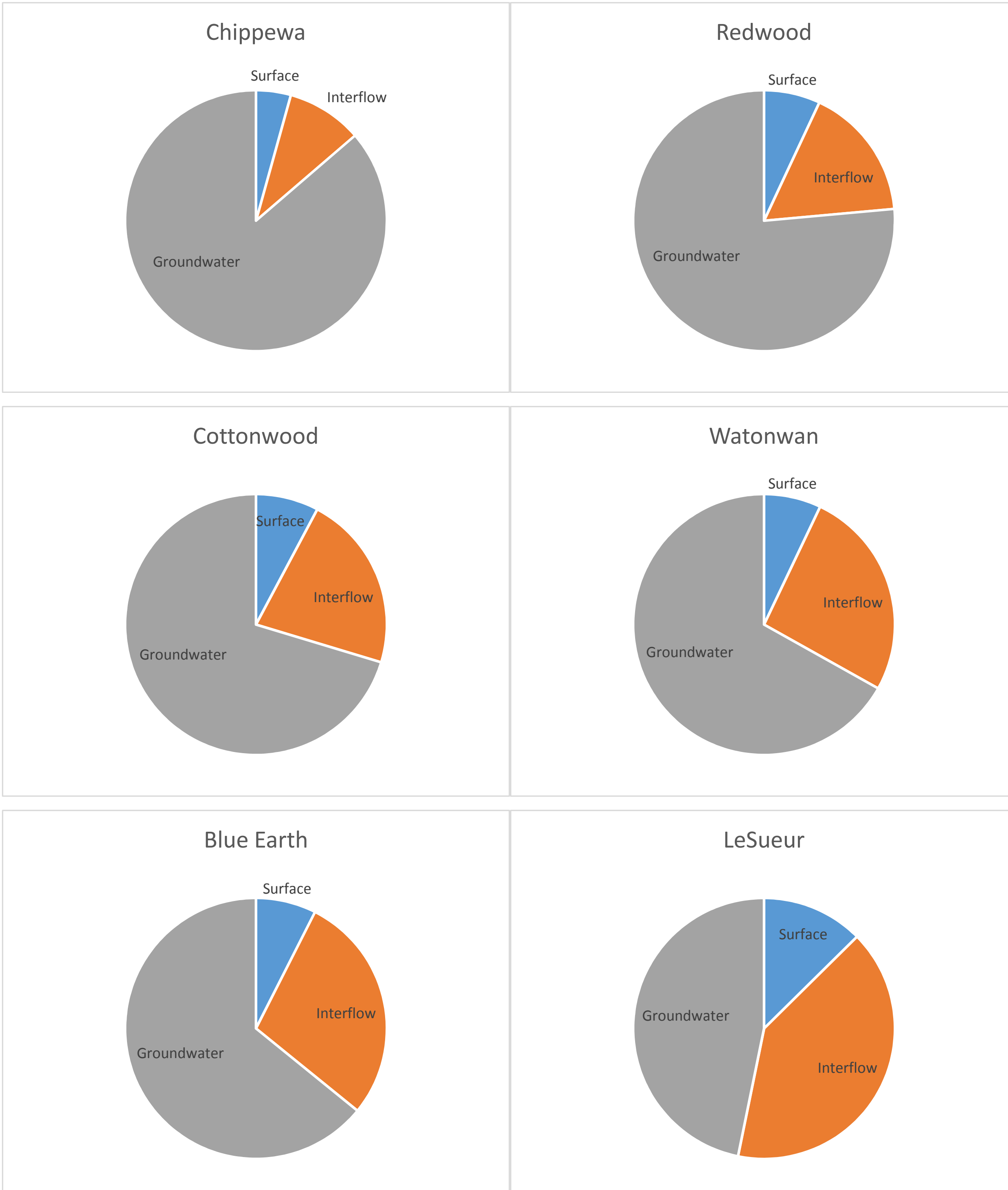


Figure 4. Water Balance Components, 1995-2012

5.2 Hydrologic Calibration

Separate calibration and validation tests were conducted for a number of stations with longer periods of record. These are summarized in electronic spreadsheets provided as a supplement to this memorandum. Final results are summarized in this section for the full period in which the gage data coincides with the model for each calibration site. Period-of-record calibration spreadsheets are also provided electronically.

Results are reported according to the three groups of gages (continuous gages with long periods of records, seasonal gages with long periods of record, and seasonal gages with short periods of record) in the next three sub-sections. A representative calibration site was selected for each group and graphical results are provided for those stations for example. Comprehensive graphics for each gage are provided in the electronic files.

The summary statistics include the annual, seasonal, and flow regime-based volumetric errors. Three versions of the NSE are reported: daily and monthly standard NSE (based on squared error) and Garrick's adjusted NSE, which is based on absolute errors and thus is more robust against the influence of outliers. Simulated and observed baseflow fractions are also compared as an indicator of the model's ability to reproduce flow components.

5.2.1 Gage Sites with Long-term, Continuous Flow Records

Table 8 (in two parts) shows the results for the highest priority gages. The quality of fit is generally in the good to very good range. Flows below the median appear to be under-estimated for Little Cottonwood River and over-estimated for High Island Creek – possibly due to estimated flow records in winter. For Minnesota River at Fort Snelling State Park the USGS summary states "discharges less than 2,000 cfs are poor", due to backwater from the Mississippi River. The baseflow fraction is matched within a few percent with the exception of the mainstem stations. For these, which integrate large upstream areas, the baseflow fraction is not a very direct indicator of the water balance, but instead is dominated by the specification of upstream boundary flows and the hydraulic response within the channel.

Graphical examples of the calibration for Minnesota River at Morton are provided in Figure 5 through Figure 11. Results for all other gages are contained in the electronic files.

Table 8. Summary Statistics for Gage Sites with Long-term, Continuous Flow Records

	Chippewa River near Milan, MN	Redwood River near Marshall, MN	Redwood River near Redwood Falls, MN	Minnesota River at Morton, MN	Little Cottonwood River near Courtland, MN	Minnesota River at Mankato, MN	Cottonwood River near New Ulm, MN
HYDSTRA ID	26057001	27043002	27035001	28012001	28057001	28042001	29001001
USGS ID	05304500	05315000	05316500	05316580	05317200	05325000	05317000
Error in total volume (%):	0.40	-4.19	1.75	0.86	-8.55	-2.10	-4.15
Error in 50% lowest flows (%):	-9.86	-8.45	9.63	1.43	-25.29	-0.71	7.77
Error in 10% highest flows (%):	6.01	-5.96	-0.89	4.94	-4.15	-2.00	-7.76
Seasonal error – Summer (%):	4.80	-4.24	-3.35	-6.80	10.35	-2.15	0.30
Seasonal error – Fall (%):	-7.20	-11.97	-3.06	1.98	-20.23	-7.86	-9.47
Seasonal error – Winter (%):	-17.92	-9.42	6.83	11.19	-19.02	2.29	-10.91
Seasonal error – Spring (%):	5.83	-1.07	2.30	-0.03	-6.54	-2.12	-2.08
Error in storm volumes (%):	12.98	-2.61	2.97	24.66	-7.31	11.58	-7.64
Error in summer storm volumes (%):	12.75	-8.20	-7.39	19.59	11.68	3.22	-26.31
Nash-Sutcliffe Coefficient of Efficiency, E:	0.805	0.772	0.789	0.907	0.694	0.920	0.815
Baseline adjusted coefficient (Garrick), E':	0.627	0.627	0.622	0.785	0.636	0.772	0.659
Monthly NSE	0.901	0.876	0.860	0.960	0.895	0.953	0.888
Observed Baseflow Fraction	77.57%	71.6%	72.4%	77.4%	79.3%	74.4%	64.0%
Simulated Baseflow Fraction	80.07%	71.1%	72.1%	72.0%	79.1%	70.8%	65.3%

Note: Summer = Jun, Jul, Aug; Fall = Oct, Nov, Dec, Winter = Jan, Feb, Mar; Spring = Apr, May Jun

(Table 8 continued)

	Blue Earth River near Rapidan, MN	Watonwan River near Garden City, MN	Little Cobb River near Beauford, MN	LeSueur River near Rapidan	High Island Creek near Henderson, CSAH6	Minnesota River near Jordan, MN	Minnesota River at Fort Snelling State Park, MN
HYDSTRA ID	30092001	31051001	32069001	32077001	33091001	33145001	33143004
USGS ID	05320000	05319500	05320270	05320500	05327000	05330000	05330920
Error in total volume (%):	-5.20	-9.38	-10.39	-5.95	-8.65	-4.32	-5.43
Error in 50% lowest flows (%):	6.82	9.88	11.98	-3.97	30.42	-8.67	-11.24
Error in 10% highest flows (%):	-3.47	-7.70	-8.48	-5.19	-9.73	-3.43	-3.80
Seasonal error – Summer (%):	4.49	-4.16	-10.24	-6.94	-21.85	-4.40	0.01
Seasonal error – Fall (%):	-20.74	-29.05	-34.09	-17.45	-19.38	-13.44	-16.39
Seasonal error – Winter (%):	-7.39	0.91	-9.40	0.05	-1.64	-2.40	-9.56
Seasonal error – Spring (%):	-3.96	-10.27	-4.23	-5.06	-5.03	-2.80	-2.31
Error in storm volumes (%):	-3.31	0.39	3.77	0.96	-6.54	9.21	9.18
Error in summer storm volumes (%):	-7.31	-6.38	-10.17	-9.96	-32.84	2.97	22.48
Nash-Sutcliffe Coefficient of Efficiency, E:	0.862	0.764	0.483	0.802	0.712	0.894	0.846
Baseline adjusted coefficient (Garrick), E':	0.701	0.619	0.530	0.667	0.652	0.743	0.700
Monthly NSE	0.924	0.882	0.808	0.895	0.879	0.941	0.908
Observed Baseflow Fraction	66.9%	69.4%	73.2%	58.8%	76.5%	75.6%	76.6%
Simulated Baseflow Fraction	66.2%	66.1%	69.0%	55.7%	75.9%	72.2%	73.0%

Note: Summer = Jun, Jul, Aug; Fall = Oct, Nov, Dec, Winter = Jan, Feb, Mar; Spring = Apr, May Jun

USGS 05316580 Minnesota River at Morton, MN

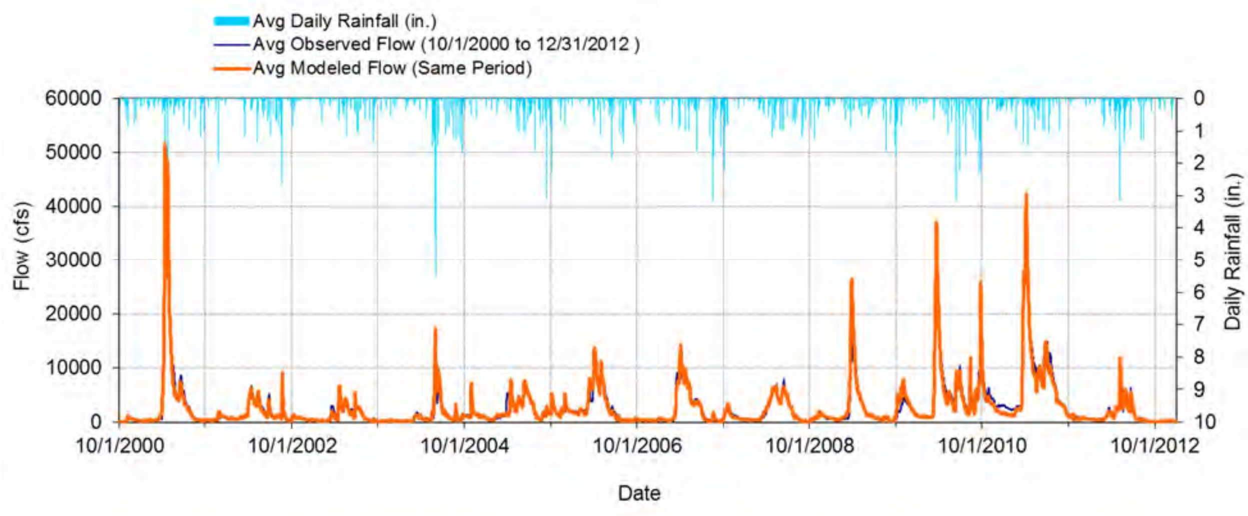


Figure 5. Mean daily flow at USGS 05316580 Minnesota River at Morton, MN

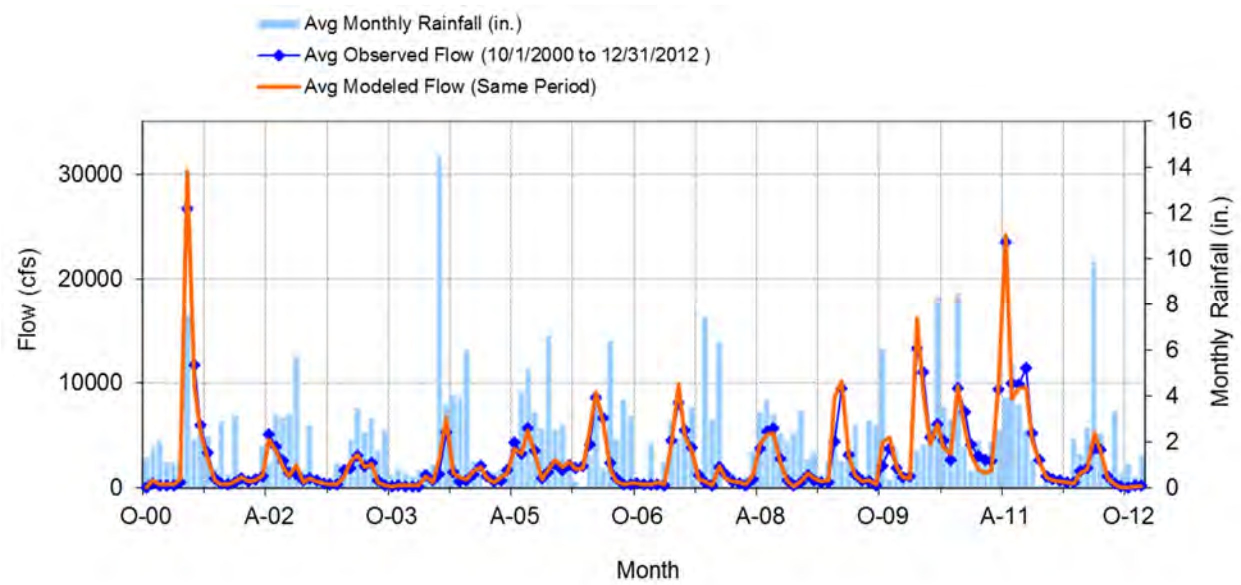


Figure 6. Mean monthly flow at USGS 05316580 Minnesota River at Morton, MN

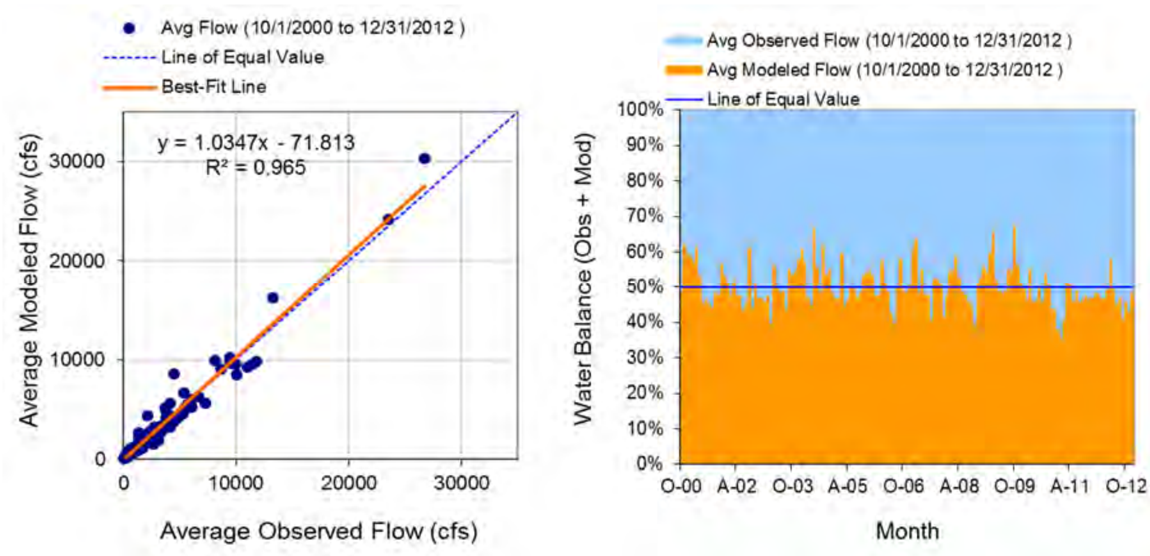


Figure 7. Monthly flow regression and temporal variation at USGS 05316580 Minnesota River at Morton, MN

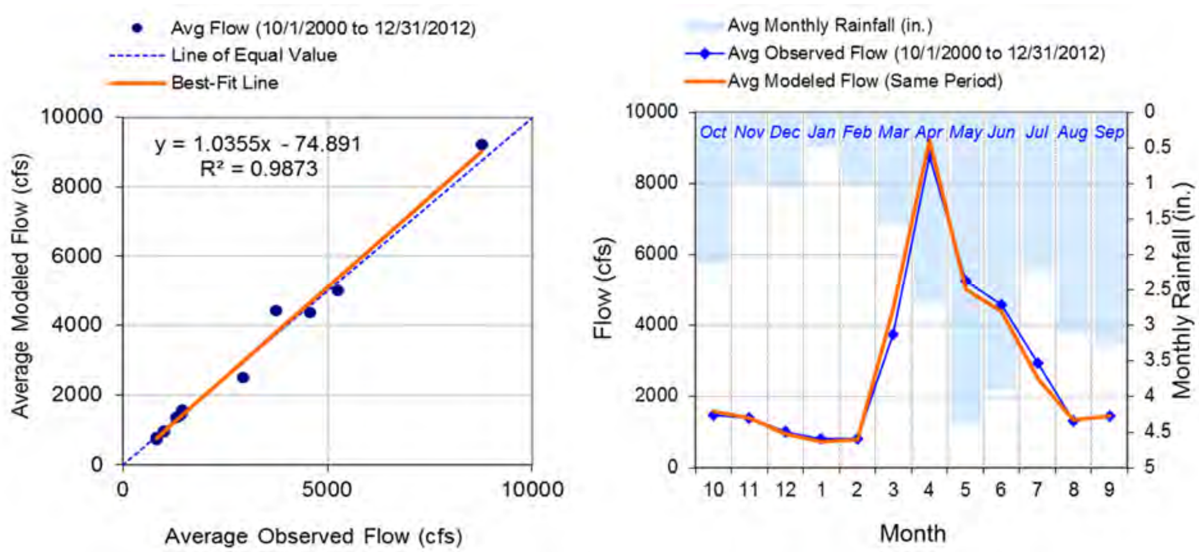


Figure 8. Seasonal regression and temporal aggregate at USGS 05316580 Minnesota River at Morton, MN

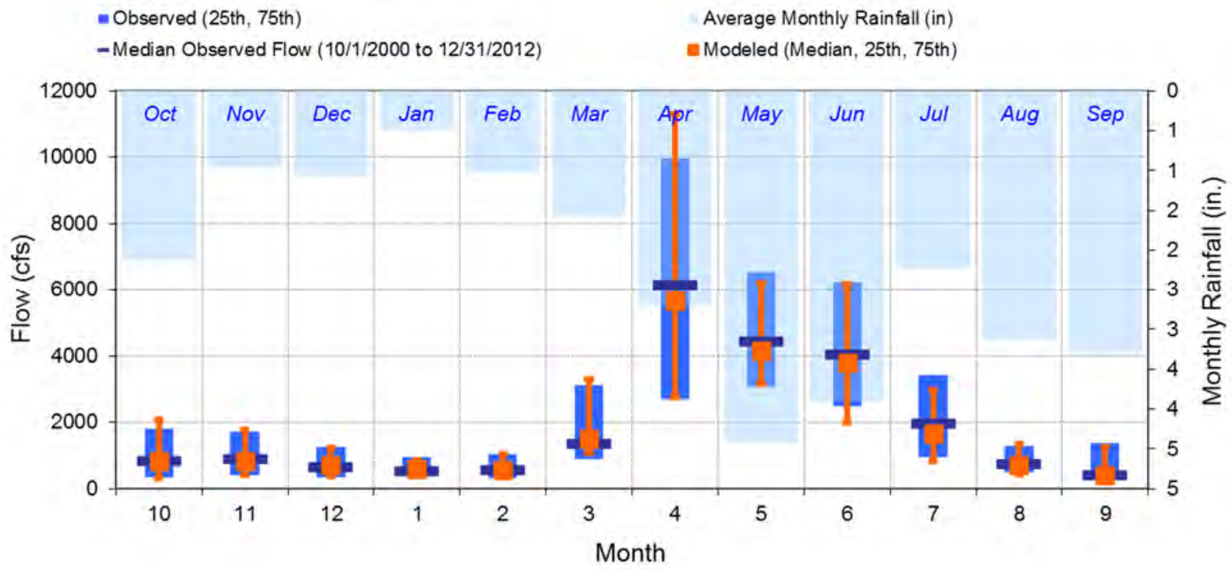


Figure 9. Seasonal medians and ranges at USGS 05316580 Minnesota River at Morton, MN

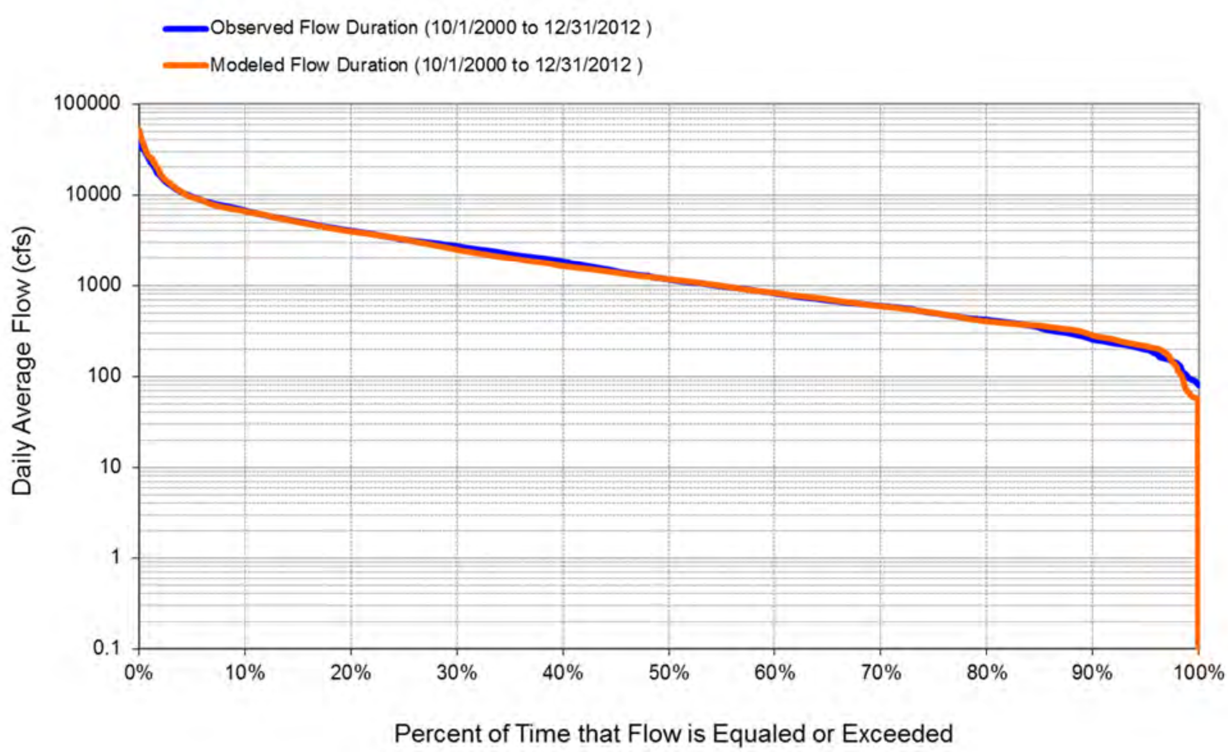


Figure 10. Flow Exceedance at USGS 05316580 Minnesota River at Morton, MN

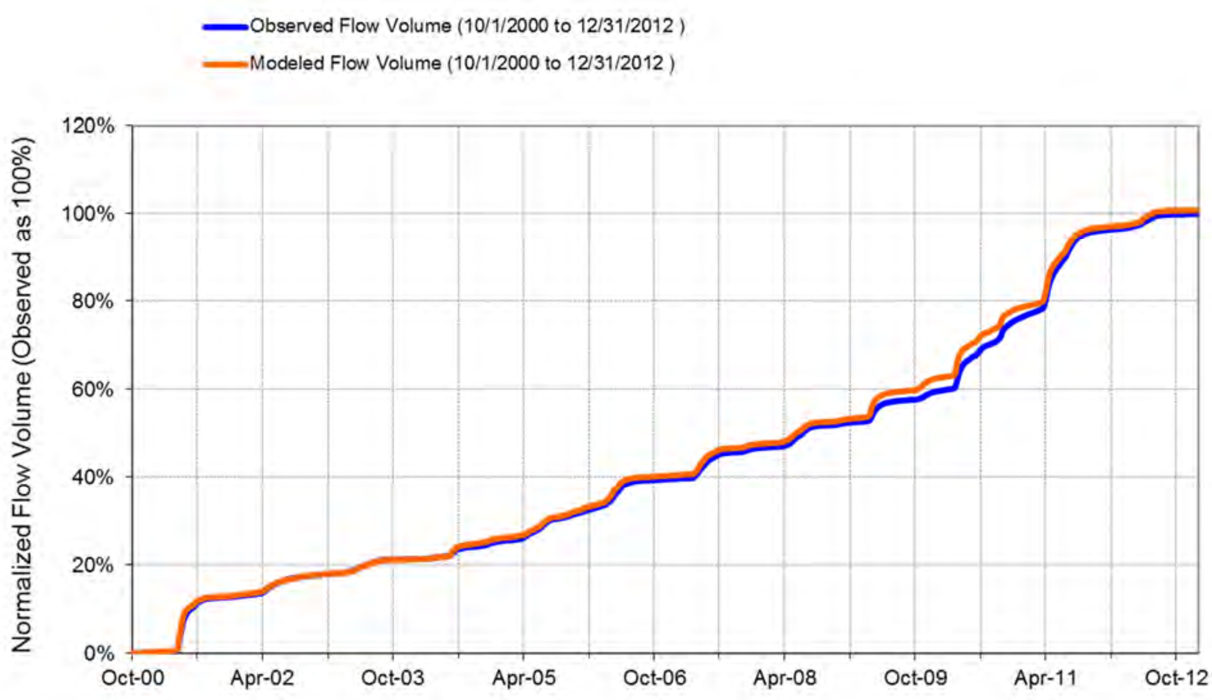


Figure 11. Flow accumulation at USGS 05316580 Minnesota River at Morton, MN

5.2.2 Gage Sites with Long-term, Seasonal Flow Records

The second tier of sites have long-term records, but do not report winter results. Many of these stream gages are operated by MDNR and several have generally poor quality results due to unstable, shifting channels that make calibration difficult. Seasonal statistics for fall (Oct.-Dec.) and winter (Jan.-Mar.) should be discounted as gaging generally stops in October and does not resume until late March. Summary results are provided in Table 9.

The upper Chippewa River gages at Cyrus and Benson were especially challenging, with negative NSE values despite efforts at calibration. Both these gages do not have a fixed control and the channel is noted as not stable with rating curves that are not well developed. Vegetation has an important effect on stage at Cyrus, which may explain the discrepancy between observed and simulated baseflow. Logger malfunctions are also noted, which may result in errors in storm volumes. Garrick's adjusted coefficient is much higher than the NSE, indicating that outliers have an important effect on statistics. Other gages with poor fit statistics also often have poor quality rating curves. Many of these are on smaller streams (e.g., Nicollet CD 13A), where vegetation in the channel has an important effect on flow estimates. Shifting sand also affects the upstream gages on the Cottonwood River. Challenges with the Rush River gages were discussed above in Section 2.

Detailed graphical results are provided, for example, for Cottonwood River near Leavenworth, a site where there is a relatively large volumetric error for 50 percent lowest flows, but a high NSE and a good match on baseflow fraction.

Table 9. Summary Statistics for Gage Sites with Long-term, Seasonal Flow Records

	Chippewa River at Cyrus	Chippewa River at Benson, MN	Shakopee Creek near Benson	Dry Weather Creek near Watson	East Branch Chippewa River near Benson	Redwood River at Russell CR15	Threemile Creek near Green Valley, CR67
HYDSTRA ID	26003001	26037001	26038001	26078001	26088001	27043001	27039001
USGS ID	05301930	05303500	NA	05304800	05303470	05314973	NA
Error in total volume (%):	-7.14	-10.95	-9.88	3.72	5.58	-5.99	5.56
Error in 50% lowest flows (%):	9.46	-17.48	9.33	5.06	17.13	7.54	28.31
Error in 10% highest flows (%):	-6.69	7.57	-14.12	-14.08	6.30	-10.01	-6.41
Seasonal error – Summer (%):	-11.47	-25.30	-20.43	-20.70	2.11	-10.96	-33.94
Seasonal error – Fall (%):	53.91	-23.73	0.45	49.18	23.29	-25.66	12.60
Seasonal error – Winter (%):	3.25	-25.61	-23.08	-41.57	-14.13	-35.70	-24.69
Seasonal error – Spring (%):	-10.45	3.81	-6.41	19.82	7.85	5.55	40.25
Error in storm volumes:	65.56	-0.62	-5.03	5.75	9.18	-5.85	4.77
Error in summer storm volumes:	58.02	-25.79	-21.97	-31.92	-16.64	-13.06	-46.98
Nash-Sutcliffe Coefficient of Efficiency, E:	-0.230	-0.295	0.730	0.610	0.618	0.714	0.533
Baseline adjusted coefficient (Garrick), E':	0.424	0.354	0.594	0.454	0.514	0.608	0.461
Monthly NSE	0.647	0.145	0.789	0.722	0.835	0.851	0.664
Observed Baseflow Fraction	81.87%	80.68%	76.80%	63.13%	82.63%	75.5%	67.3%
Simulated Baseflow Fraction	89.83%	82.69%	77.99%	63.84%	83.21%	75.5%	67.5%

Note: Summer = Jun, Jul, Aug; Fall = Oct, Nov, Dec, Winter = Jan, Feb, Mar; Spring = Apr, May Jun. Seasonal gages typically report only a few days at the beginning of October for Fall and a few days at the end of March for Spring, so statistics for these seasons should be discounted.

(Table 9 continued, part 2)

	Clear Creek near Seaforth, CR56	Nicollet CD46A near North Star, CSAH13	Seven Mile Creek near North Star	Nicollet CD13A near North Star, MN99	Cottonwood River near Lamberton, US14	Cottonwood River near Springfield, CR2	Cottonwood River near Leavenworth, CR8
HYDSTRA ID	27030001	28066001	28063001	28062001	29062002	29015001	29022001
USGS ID	NA	NA	NA	NA	NA	05316950	05316970
Error in total volume (%):	-9.86	-34.12	-16.69	19.46	-15.90	-0.39	-7.34
Error in 50% lowest flows (%):	8.16	-13.88	23.42	186.60	45.69	42.14	38.59
Error in 10% highest flows (%):	-9.39	-30.51	-30.36	3.53	-18.09	0.38	-11.42
Seasonal error – Summer (%):	-33.91	-42.36	-10.05	7.39	-7.12	-3.04	-9.67
Seasonal error – Fall (%):	-12.47	-70.10	-44.29	-22.36	-11.33	-6.10	-5.41
Seasonal error – Winter (%):	-18.48	-34.14	-45.06	49.59	-24.73	-18.48	-17.39
Seasonal error – Spring (%):	0.31	-29.59	-4.71	22.02	-17.03	5.22	-4.49
Error in storm volumes:	-11.54	-28.84	-21.33	3.37	-12.38	1.12	-8.86
Error in summer storm volumes:	-43.96	-45.88	-10.49	4.26	-29.23	-18.94	-27.66
Nash-Sutcliffe Coefficient of Efficiency, E:	0.623	0.336	0.552	0.560	0.719	0.752	0.839
Baseline adjusted coefficient (Garrick), E':	0.568	0.353	0.528	0.388	0.630	0.612	0.671
Monthly NSE	0.722	0.677	0.604	0.658	0.848	0.671	0.838
Observed Baseflow Fraction	66.2%	82.9%	66.9%	78.2%	66.6%	66.7%	68.4%
Simulated Baseflow Fraction	66.8%	81.5%	68.9%	81.5%	65.2%	66.2%	68.9%

Note: Summer = Jun, Jul, Aug; Fall = Oct, Nov, Dec, Winter = Jan, Feb, Mar; Spring = Apr, May Jun. Seasonal gages typically report only a few days at the beginning of October for Fall and a few days at the end of March for Spring, so statistics for these seasons should be discounted.

(Table 9 continued, part 3)

	Sleepy Eye Creek near Cobden, CR8	Center Creek near Huntley, CR1	Elm Creek near Huntley, CR159	Maple River near Rapidan, CR35	Little Beauford Ditch near Beauford, MN22	High Island Creek near Arlington, CR9	Buffalo Creek near Jessenland, 270th St.	Rush River near Henderson, MN93
HYDSTRA ID	29011001	30028001	30051001	32072001	32073001	33075001	33092001	33096001
USGS ID	05316992	NA	NA	05320408	NA	05326700	05326900	05326400
Error in total volume (%):	-8.41	-9.49	-6.37	-10.39	-13.95	-8.41	-11.17	-41.91
Error in 50% lowest flows (%):	58.93	8.92	37.62	-2.23	-53.23	25.48	4.36	18.32
Error in 10% highest flows (%):	-14.50	-7.82	-11.80	-10.32	-10.99	-3.09	-9.43	-52.38
Seasonal error – Summer (%):	-19.37	8.79	18.38	-13.00	-28.04	-28.13	-51.47	-58.54
Seasonal error – Fall (%):	-24.41	3.33	-27.03	-25.56	-28.34	-26.83	-40.00	-55.66
Seasonal error – Winter (%):	-23.83	-12.48	-46.80	-18.09	-10.28	-31.21	-29.55	-59.03
Seasonal error – Spring (%):	0.10	-16.42	-4.60	-3.82	-8.72	0.69	2.32	-32.06
Error in storm volumes (%):	-23.08	-2.27	1.81	-1.42	-17.52	12.73	-19.69	-42.26
Error in summer storm volumes (%):	-48.92	8.96	19.04	-14.09	-37.79	-36.26	-69.65	-70.11
Nash-Sutcliffe Coefficient of Efficiency, E:	0.757	0.840	0.803	0.771	0.066	0.560	0.638	0.413
Baseline adjusted coefficient (Garrick), E':	0.627	0.649	0.647	0.638	0.433	0.571	0.553	0.525
Monthly NSE	0.788	0.871	0.875	0.885	0.806	0.812	0.787	0.429
Observed Baseflow Fraction	60.3%	77.8%	72.4%	57.9%	60.0%	83.4%	68.8%	63.8%
Simulated Baseflow Fraction	66.6%	76.0%	69.9%	53.7%	61.6%	79.1%	71.4%	63.6%

Note: Summer = Jun, Jul, Aug; Fall = Oct, Nov, Dec, Winter = Jan, Feb, Mar; Spring = Apr, May Jun. Seasonal gages typically report only a few days at the beginning of October for Fall and a few days at the end of March for Spring, so statistics for these seasons should be discounted.

USGS 05316970 Cottonwood River near Leavenworth, CR8

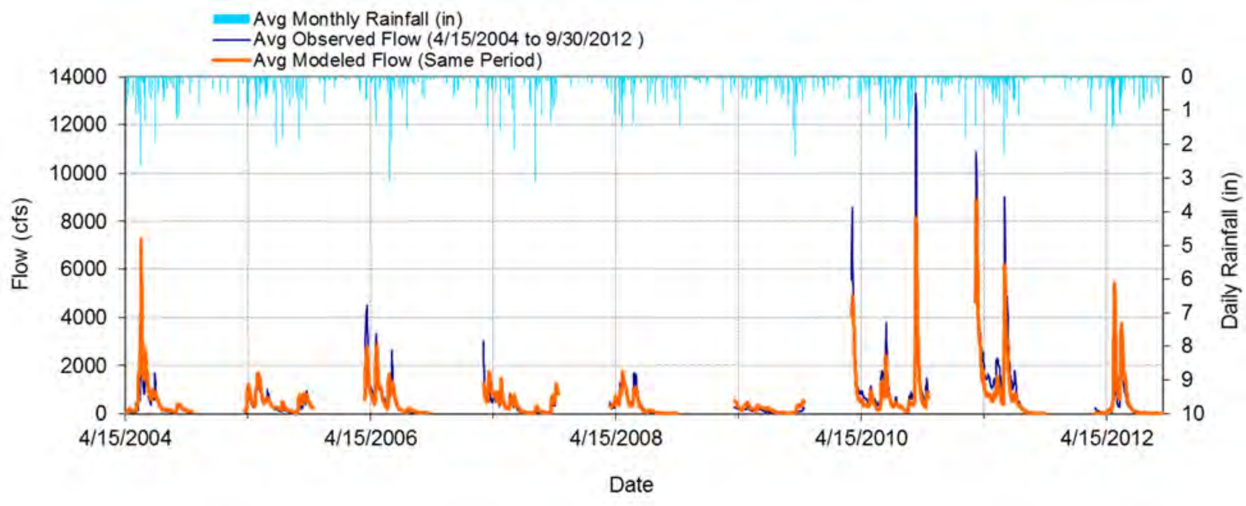


Figure 12. Mean daily flow at USGS 05316970 Cottonwood River near Leavenworth, CR8

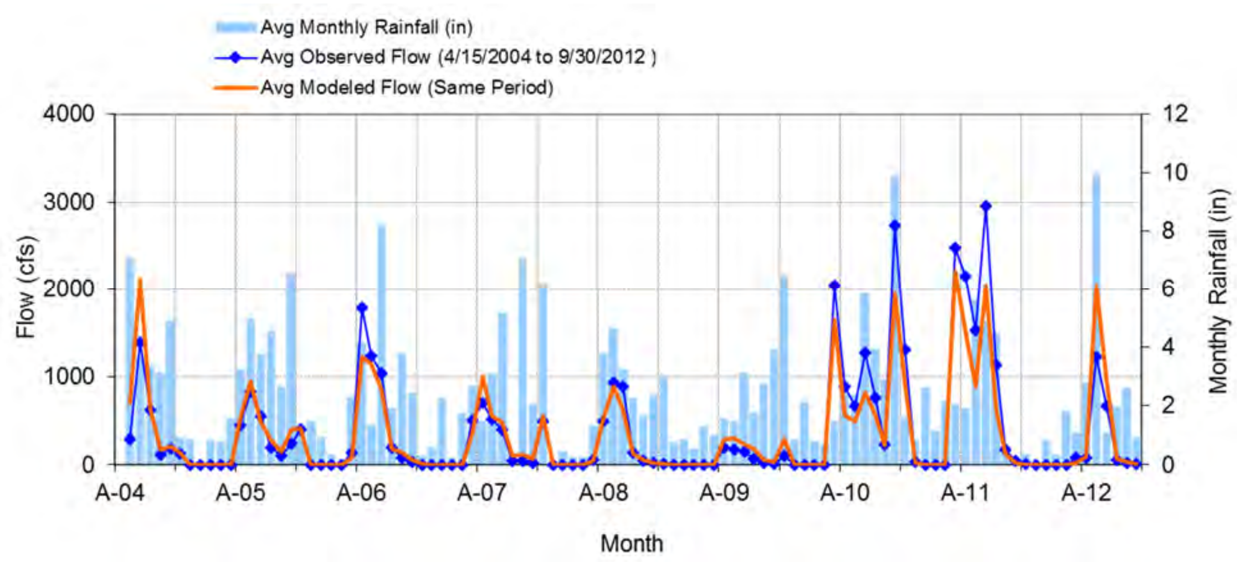


Figure 13. Mean monthly flow at USGS 05316970 Cottonwood River near Leavenworth, CR8

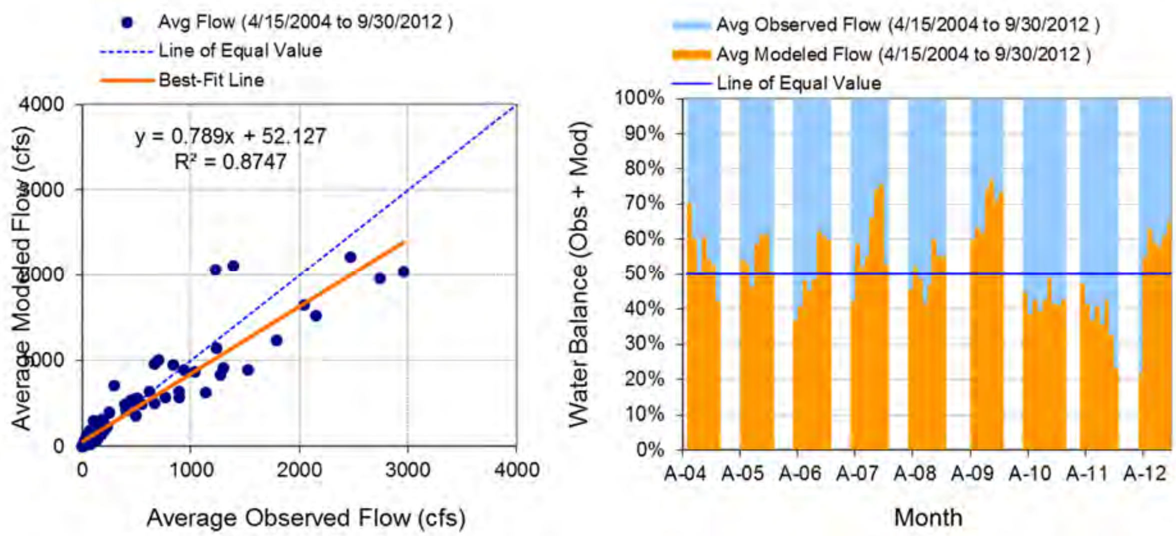


Figure 14. Monthly flow regression and temporal variation at USGS 05316970 Cottonwood River near Leavenworth, CR8

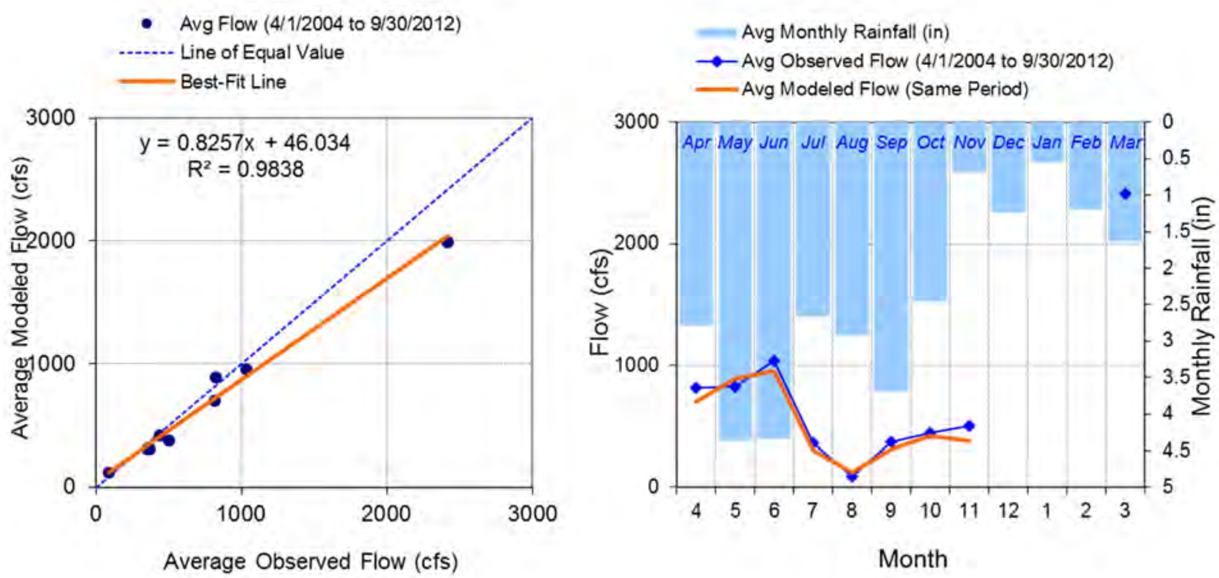


Figure 15. Seasonal regression and temporal aggregate at USGS 05316970 Cottonwood River near Leavenworth, CR8

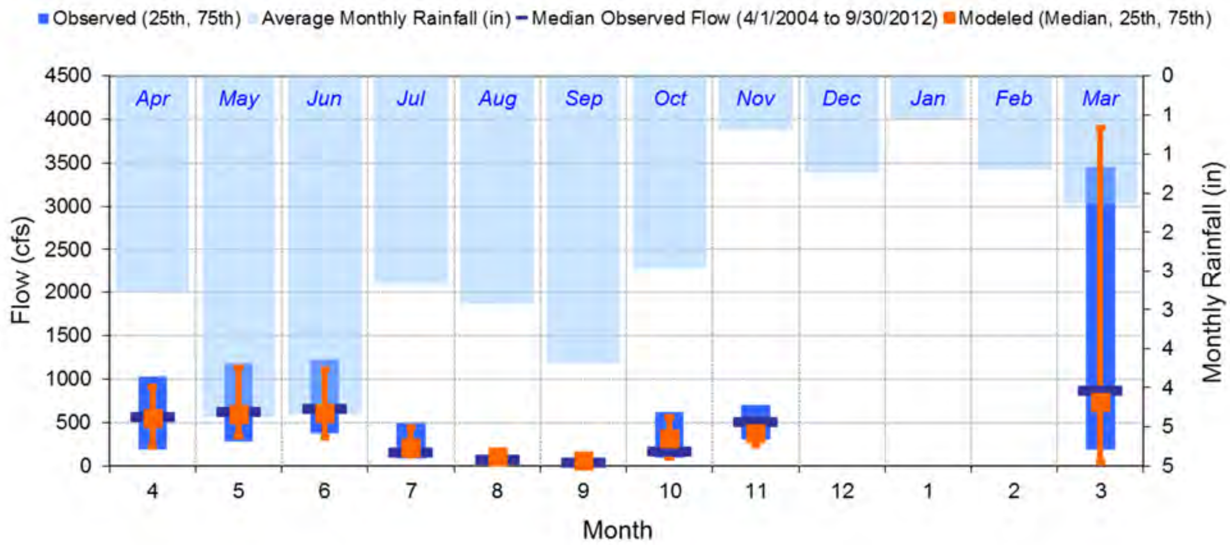


Figure 16. Seasonal medians and ranges at USGS 05316970 Cottonwood River near Leavenworth, CR8

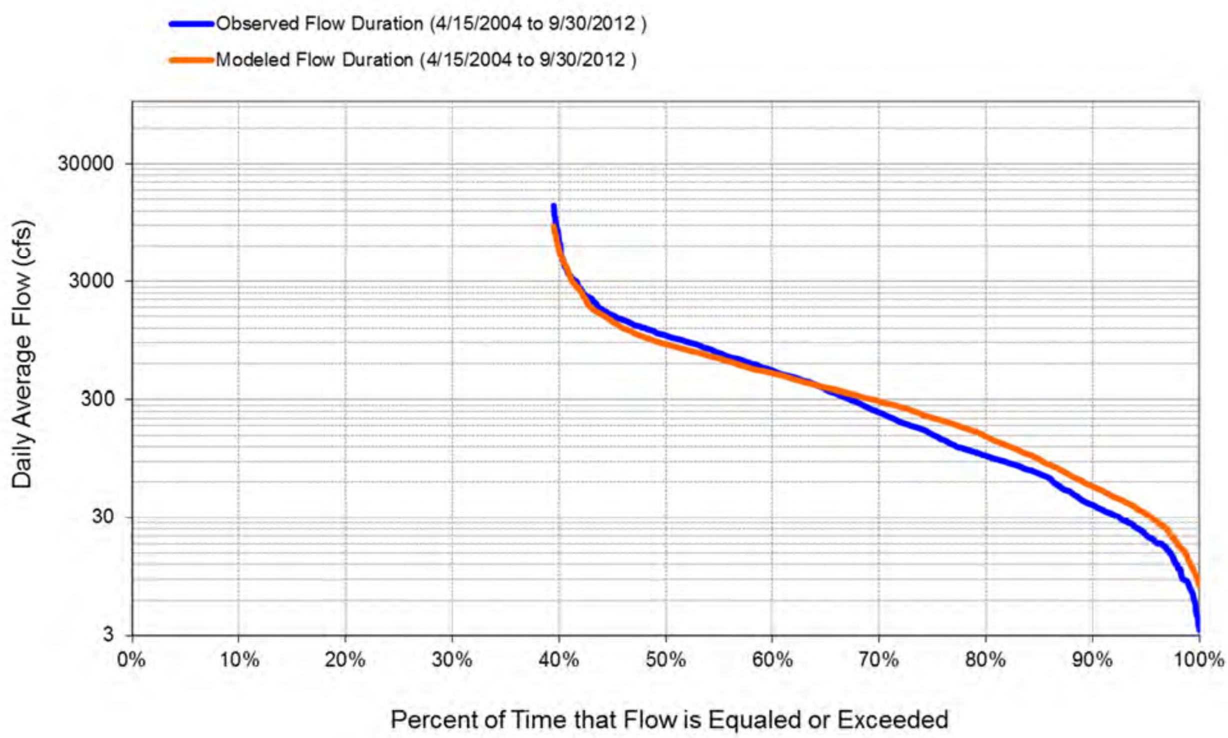


Figure 17. Flow Exceedance at USGS 05316970 Cottonwood River near Leavenworth, CR8

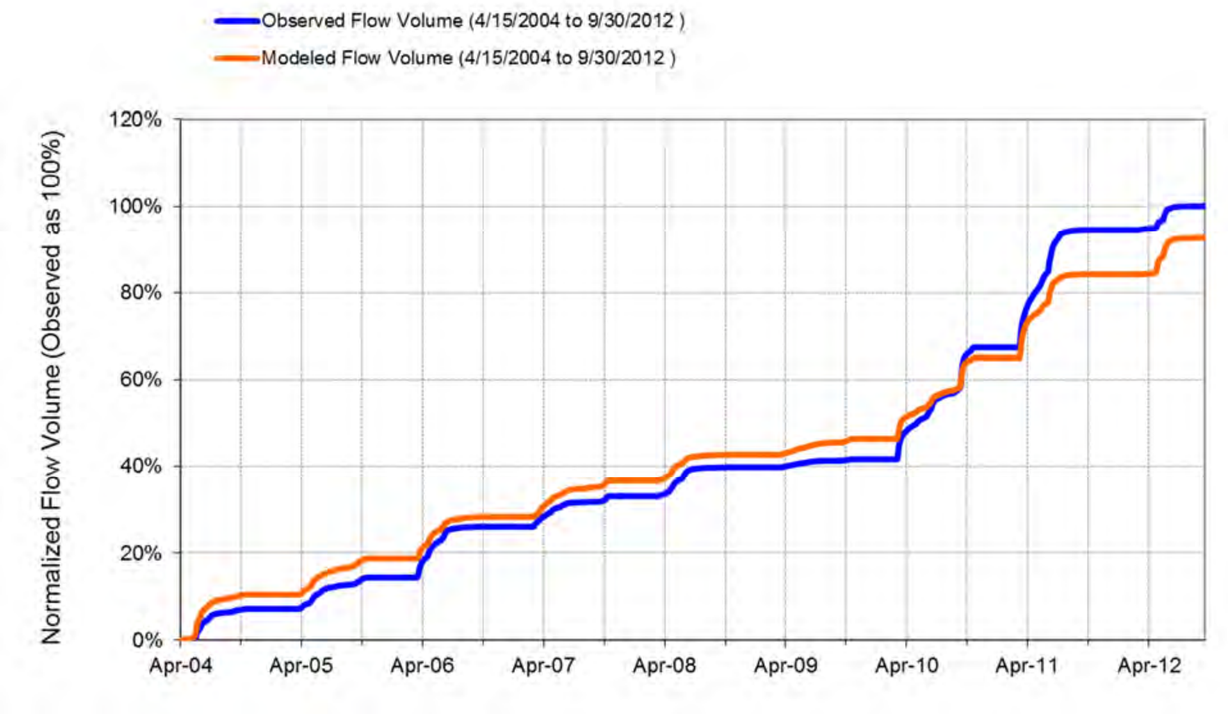


Figure 18. Flow accumulation at USGS 05316970 Cottonwood River near Leavenworth, CR

5.2.3 Gage Sites with Short-term, Seasonal Flow Records

The third tier of sites are also seasonal, but have only one to six years of monitoring. The shorter periods of record present several challenges. The model fit statistics are likely to be influenced by anomalies in the recorded precipitation record, and one poorly fit event will have a major effect on the apparent degree of fit. In addition, short records do not provide enough evidence for reliable site-specific calibration. Finally, the fact that these sites were in use for only a few years increases the degree of uncertainty that is likely to be present in rating curves that convert stage to flow estimates. Results for the short-term gages are summarized in Table 10. Example graphical calibration results are provided in the following figures for Watonwan River at La Salle. As before, complete calibration results are provided in the accompanying electronic files.

Table 10. Summary Statistics for Gage Sites with Short-term, Seasonal Flow Records

	Minnesota River at Judson, CSAH42	Crow Creek near Morton, Noble Ave	Wabasha Creek near Franklin, CSAH11	North Eden Creek near Franklin, CSAH10	Nicollet CD24 near North Star, Timber Ln	Plum Creek near Walnut Grove, CSAH10	North Fork Watonwan River near Sveadahl, MN
HYDSTRA ID	28054001	28098001	28102001	28095001	28063002	29048001	31030001
USGS ID	05317500	NA	NA	NA	NA	NA	NA
Error in total volume (%):	-5.18	1.54	-77.10	-13.40	-35.29	3.79	-3.06
Error in 50% lowest flows (%):	-11.00	-10.72	-6.13	2.85	24.52	86.05	85.58
Error in 10% highest flows (%):	-2.63	-5.41	-83.87	-27.13	-58.54	-9.11	-1.15
Seasonal error – Summer (%):	-10.63	-23.91	-61.39	-20.53	-1.27	69.10	-3.18
Seasonal error – Fall (%):	-7.94	-22.47	4.53	56.76	-86.80	13.36	-0.67
Seasonal error – Winter (%):	0.97	2.16	-88.92	-46.05	-1.83	-29.54	ND
Seasonal error – Spring (%):	-4.67	18.87	-71.16	6.86	-21.48	-2.90	-3.09
Error in storm volumes (%):	19.79	-8.84	-75.13	-19.58	-63.63	-2.27	-1.87
Error in summer storm volumes (%):	9.28	-36.04	-63.71	-22.50	-25.56	36.55	-43.92
Nash-Sutcliffe Coefficient of Efficiency, E:	0.914	0.689	0.069	0.688	0.063	0.866	0.726
Baseline adjusted coefficient (Garrick), E':	0.764	0.608	0.403	0.503	0.255	0.679	0.637
Monthly NSE	0.940	0.908	0.030	0.663	0.347	0.904	0.873
Observed Baseflow Fraction	79.3%	67.2%	71.6%	77.3%	66.2%	71.7%	72.1%
Simulated Baseflow Fraction	73.9%	66.7%	71.7%	76.1%	84.6%	73.4%	71.8%

Note: Summer = Jun, Jul, Aug; Fall = Oct, Nov, Dec, Winter = Jan, Feb, Mar; Spring = Apr, May Jun. Seasonal gages typically report only a few days at the beginning of October for Fall and a few days at the end of March for Spring, so statistics for these seasons should be discounted.

(Table 10 continued, part 2)

	Watonwan River near La Salle, CSAH16	Watonwan River near La Salle, CSAH3	South Fork Watonwan River near Madelia, CSAH13	Maple River near Sterling Center, CR18	Big Cobb River near Beauford, CR16	LeSueur River at St. Clair, CSAH28	LeSueur River near Rapidan, CR8
HYDSTRA ID	31040001	31028001	31021001	32062001	32071001	32079001	32076001
USGS ID	NA	NA	NA	05320450	05320330	NA	NA
Error in total volume (%):	-8.59	9.24	7.36	-14.67	-1.13	0.10	-2.81
Error in 50% lowest flows (%):	57.04	36.74	99.73	-6.08	34.30	12.89	2.45
Error in 10% highest flows (%):	-6.08	16.10	-3.29	-15.06	-3.14	-5.77	-5.78
Seasonal error – Summer (%):	-4.38	1.66	87.22	-10.66	12.19	-0.17	-3.01
Seasonal error – Fall (%):	129.40	-17.66	-13.63	-17.92	-18.32	-14.10	-14.45
Seasonal error – Winter (%):	ND	-3.49	-4.87	-23.00	-17.94	-8.24	-14.10
Seasonal error – Spring (%):	-9.66	11.63	0.95	-12.89	2.00	6.95	3.19
Error in storm volumes (%):	-1.92	8.51	8.41	-6.87	12.08	-0.90	-2.25
Error in summer storm volumes (%):	-31.04	-29.20	26.42	-10.53	7.50	-2.98	-7.03
Nash-Sutcliffe Coefficient of Efficiency, E:	0.877	0.901	0.907	0.735	0.731	0.698	0.739
Baseline adjusted coefficient (Garrick), E':	0.715	0.702	0.702	0.641	0.610	0.582	0.609
Monthly NSE	0.967	0.940	0.968	0.893	0.872	0.899	0.898
Observed Baseflow Fraction	71.0%	62.1%	71.0%	58.0%	67.7%	59.2%	64.6%
Simulated Baseflow Fraction	68.9%	62.4%	70.7%	54.2%	63.3%	59.6%	64.4%

Note: Summer = Jun, Jul, Aug; Fall = Oct, Nov, Dec, Winter = Jan, Feb, Mar; Spring = Apr, May Jun. Seasonal gages typically report only a few days at the beginning of October for Fall and a few days at the end of March for Spring, so statistics for these seasons should be discounted.

(Table 10 continued, part 3)

	High Island Creek near Fernando, CSAH7	High Island Creek near New Auburn, CSAH13	Buffalo Creek (County Ditch 59) near New Rome, CSAH17	North Branch Rush River near New Rome, CSAH9	Middle Branch Rush River near New Sweden, CR63	South Branch Rush River near Norseland, CR63	Nicollet Sibley JD1A near Norseland, CSAH3
HYDSTRA ID	33010001	33003001	33092002	33071001	33069001	33065001	33068001
USGS ID	NA	NA	NA	NA	NA	05326189	05326205
Error in total volume (%):	2.51	12.51	16.01	22.46	-5.88	-3.89	-2.81
Error in 50% lowest flows (%):	206.19	275.40	-47.33	84.56	64.03	37.91	24.67
Error in 10% highest flows (%):	-38.02	-31.98	7.91	18.11	-5.74	-1.38	-6.58
Seasonal error – Summer (%):	8.68	41.19	-77.65	28.96	-16.43	-18.15	-28.69
Seasonal error – Fall (%):	ND	ND	ND	62.17	-71.33	-42.62	-26.71
Seasonal error – Winter (%):	ND	ND	ND	-5.39	-13.30	13.87	6.98
Seasonal error – Spring (%):	2.43	12.23	19.02	20.52	2.50	4.69	5.13
Error in storm volumes:	-36.42	-34.16	-10.04	5.97	-25.54	-4.25	-19.51
Error in summer storm volumes:	2.92	85.69	53.20	2.76	-48.03	-21.58	-53.95
Nash-Sutcliffe Coefficient of Efficiency, E:	0.641	0.755	0.827	0.753	0.698	0.624	0.693
Baseline adjusted coefficient (Garrick), E':	0.490	0.507	0.560	0.588	0.545	0.533	0.557
Monthly NSE	0.811	0.827	0.902	0.828	0.709	0.731	0.823
Observed Baseflow Fraction	63.2%	65.2%	57.7%	69.8%	58.4%	63.1%	57.8%
Simulated Baseflow Fraction	78.2%	80.4%	67.2%	73.7%	67.0%	63.1%	64.9%

Note: Summer = Jun, Jul, Aug; Fall = Oct, Nov, Dec, Winter = Jan, Feb, Mar; Spring = Apr, May Jun. Seasonal gages typically report only a few days at the beginning of October for Fall and a few days at the end of March for Spring, so statistics for these seasons should be discounted.

MN 31040001 Watonwan River near La Salle, CSAH16

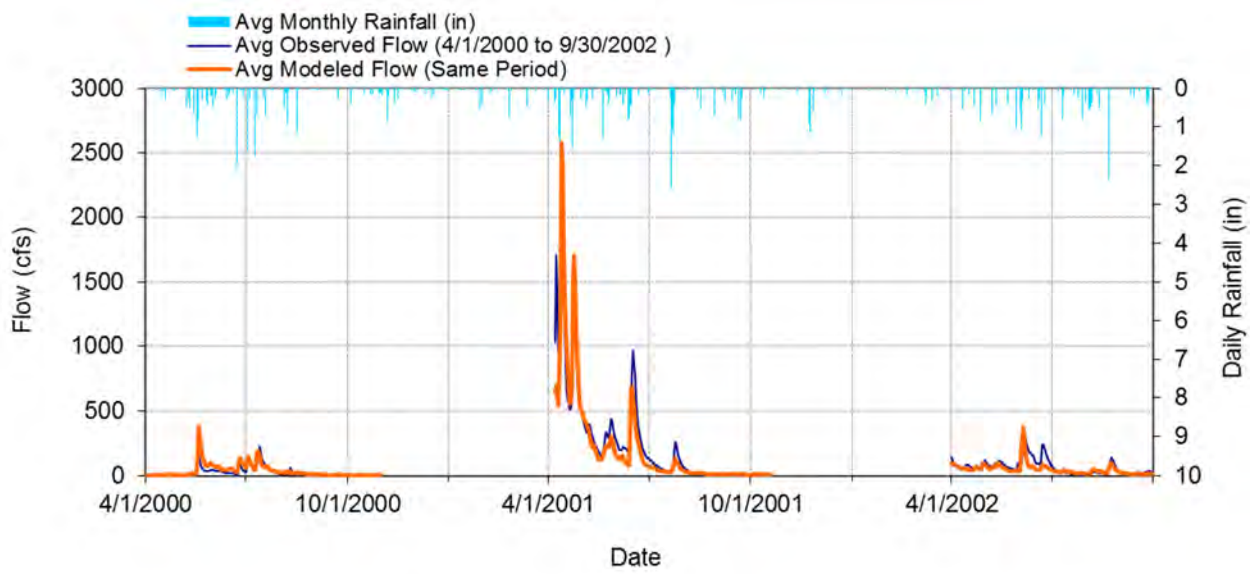


Figure 19. Mean daily flow at MN 31040001 Watonwan River near La Salle, CSAH16

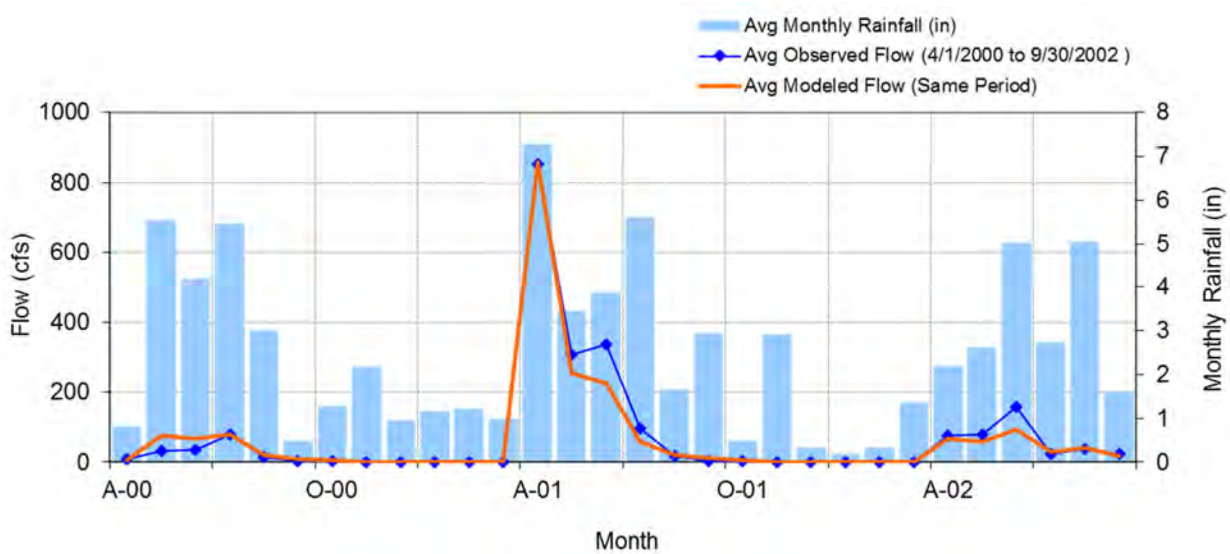


Figure 20. Mean monthly flow at MN 31040001 Watonwan River near La Salle, CSAH16

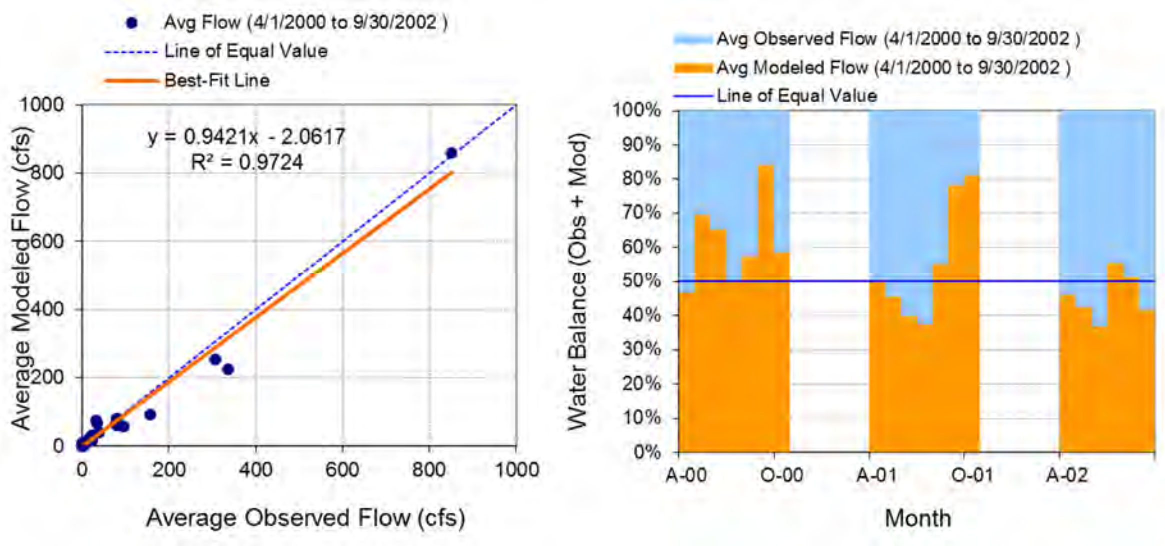


Figure 21. Monthly flow regression and temporal variation at MN 31040001 Watonwan River near La Salle, CSAH16

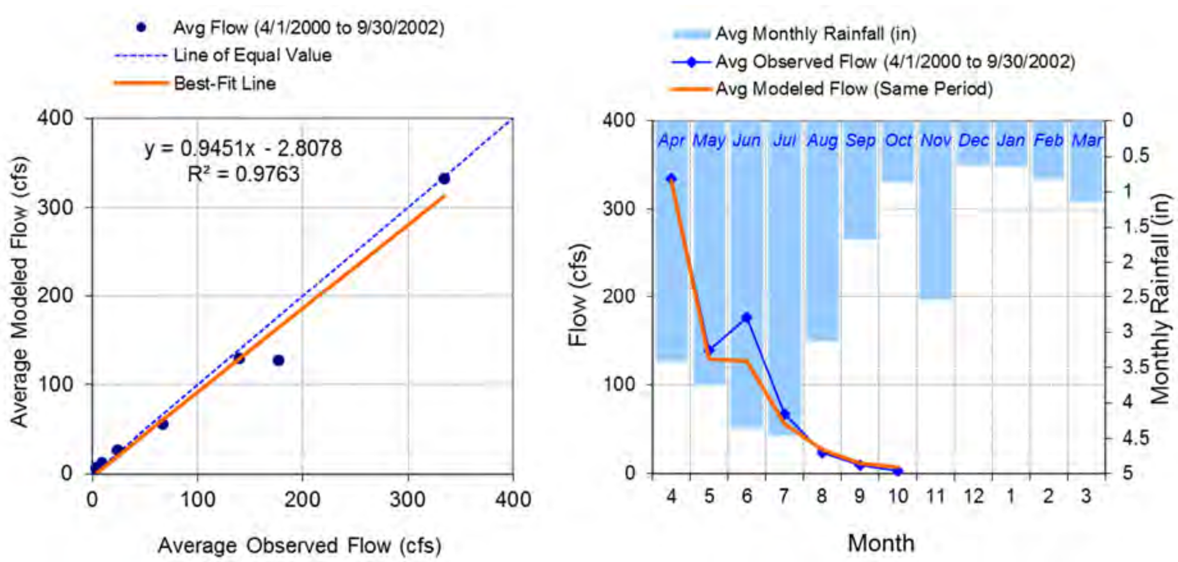


Figure 22. Seasonal regression and temporal aggregate at MN 31040001 Watonwan River near La Salle, CSAH16

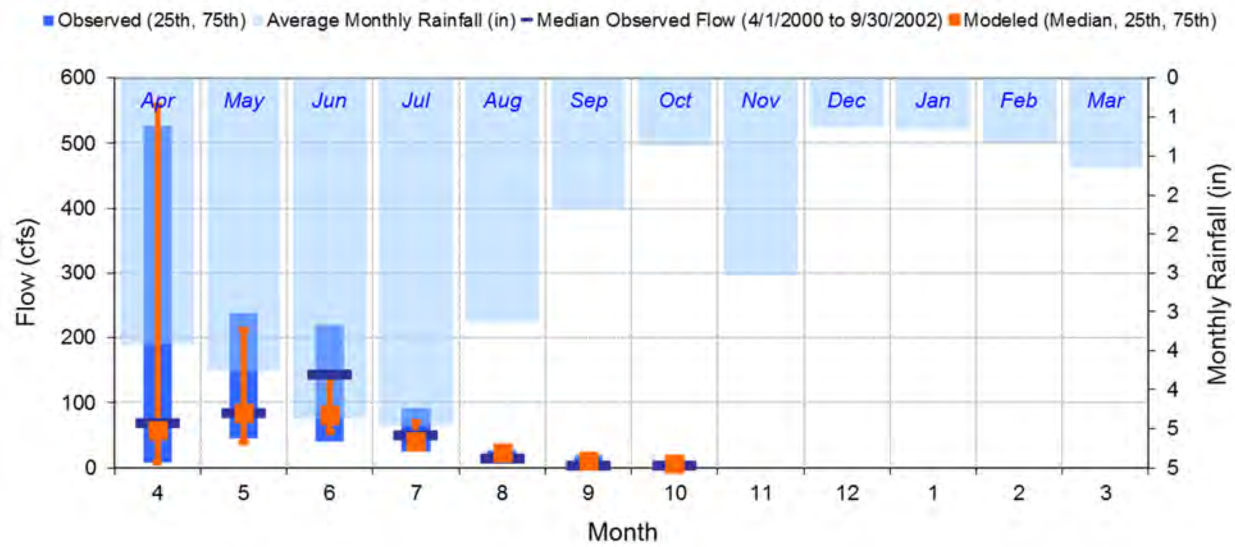


Figure 23. Seasonal medians and ranges at MN 31040001 Watonwan River near La Salle, CSAH16

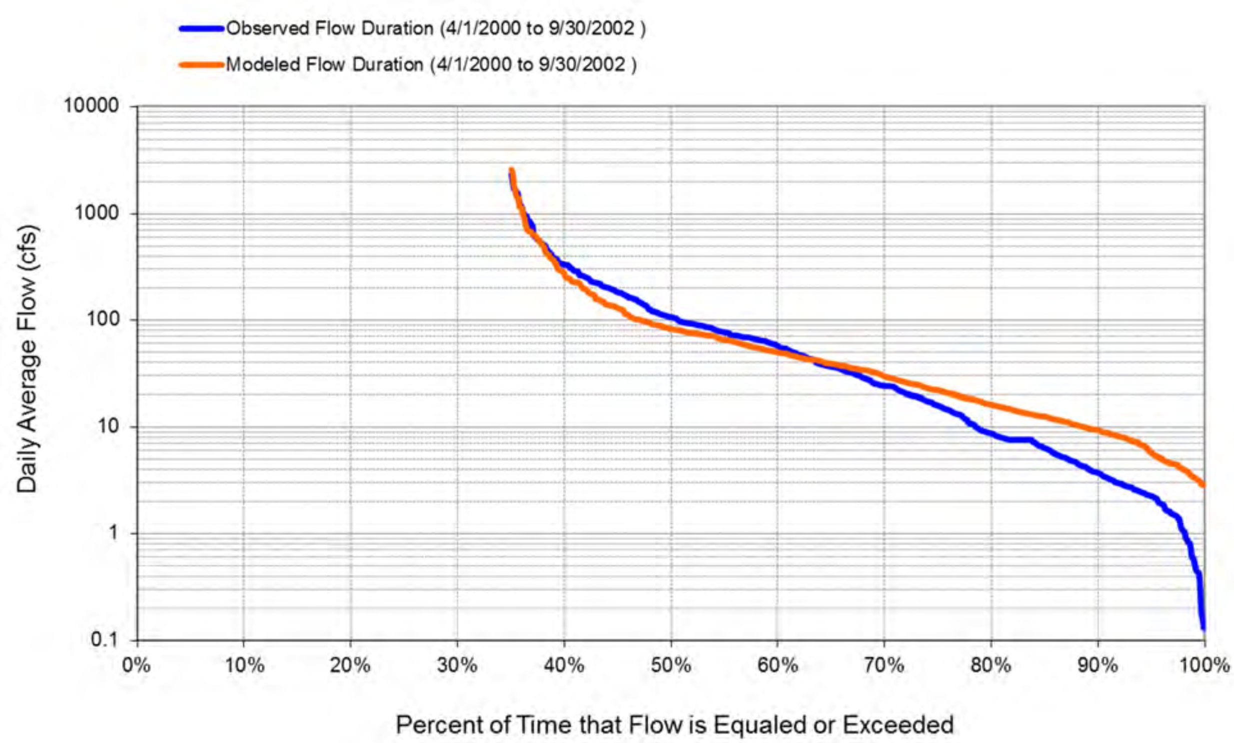


Figure 24. Flow Exceedance at MN 31040001 Watonwan River near La Salle, CSAH16

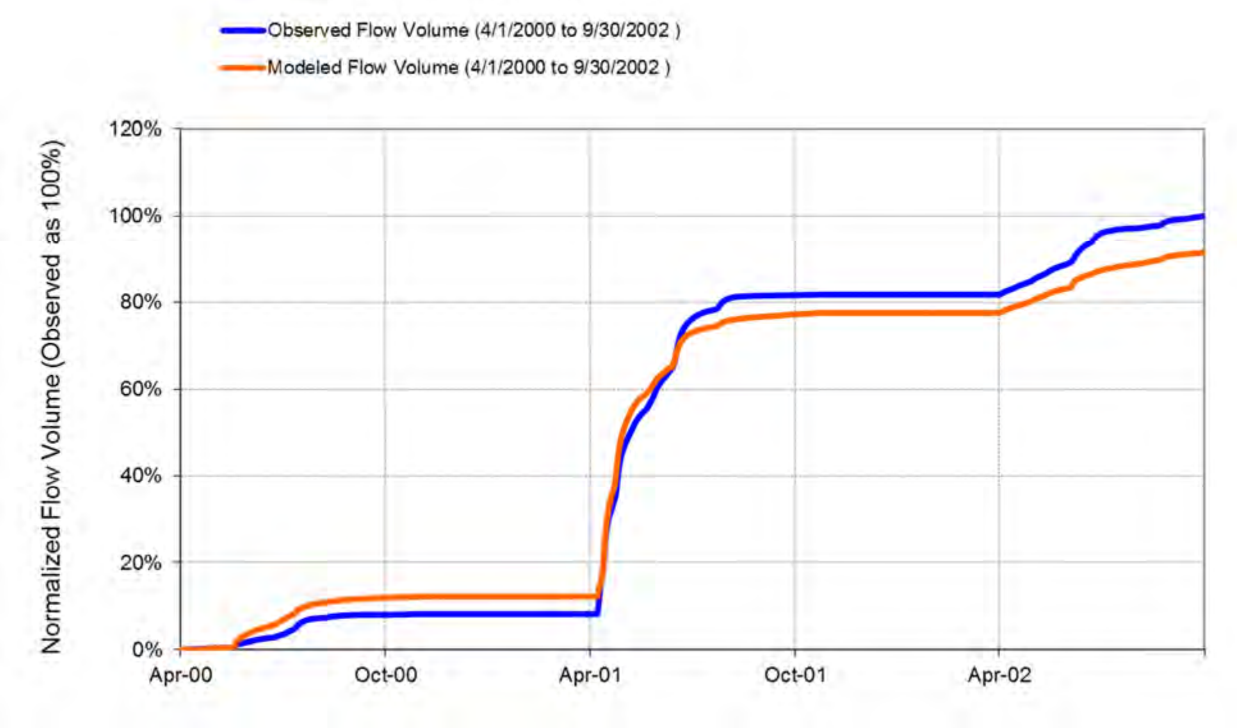


Figure 25. **Flow accumulation at MN 31040001 Watonwan River near La Salle, CSAH16**

6 References

AQUA TERRA. 2012. Modeling Guidance for BASINS/HSPF Applications under the MPCA One Water Program. Prepared for Minnesota Pollution Control Agency by AQUA TERRA Consultants, Mountain View, CA.

Donigian, A.S., J.C. Imhoff, B.R. Bicknell, and J.L. Kittle. 1984. Application Guide for the Hydrologic Simulation Program - FORTRAN. EPA 600/3-84-066. U.S. Environmental Protection Agency, Athens, GA.

Donigian, A.S. Jr. 2000. *HSPF Training Workshop Handbook and CD*. Lecture #19. Calibration and Verification Issues, Slide #L19-22. U.S. Environmental Protection Agency, Washington Information Center, January 10–14, 2000. Presented to and prepared for U.S. Environmental Protection Agency, Office of Water, Office of Science and Technology, Washington, DC.

Do8nigian, A.S. Jr., and J.T. Love. 2003. Sediment Calibration Procedures and Guidelines for Watershed Modeling. Presented at the Water Environment Federation Total Maximum Daily Load Conference, November 16–19, 2003, Chicago, IL.

Lumb, A.M., R.B. McCammon, and J.L. Kittle, Jr. 1994. Users Manual for an Expert System (HSPEXP) for Calibration of the Hydrological Simulation Program – FORTRAN. Water-Resources Investigation Report 94-4168. U.S. Geological Survey, Reston, VA.

Moriasi, D.N., J.G. Arnold, M.W. Van Liew, R.L. Bingner, R.D. Harmel, and T.L. Veith. 2007. Model evaluation guidelines for systematic quantification of accuracy in watershed simulations. *Transactions of the ASABE,* 50(3): 885-900.

Mu, Q., M. Zhao, and S.W. Running. 2011. Improvements to a MODIS global terrestrial evapotranspiration algorithm. *Remote Sensing of Environment*, 115:1781-1800.

Nash, J. E., and J. V. Sutcliffe. 1970. River flow forecasting through conceptual models: Part 1: A discussion of principles. *Journal of Hydrology*, 10(3): 282-290.

RESPEC. 2014. Hydrology and Water Quality Calibration and Validation of Minnesota River Watershed Modeling Applications. Memorandum to Dr. Charles Regan, Minnesota Pollution Control Agency.

Schottler, S., D. Engstrom, and D. Blumentritt. 2010. Fingerptinting Sources of Sediment in Large Agricultural River Systems. St. Croix Watershed Research Station, Marine, MN.

Sloto, R.A. and M.Y. Crouse. 1996. HYSEP: A Computer Program for Streamflow Hydrograph Separation and Analysis. Water-Resources Investigations Report 96-4040. U.S. Geological Survey, Lemoyne, PA.

Tetra Tech. 2008. Minnesota River Basin Turbidity TMDL and Lake Pepin Excessive Nutrient TMDL, Model Calibration and Validation Report. Prepared for Minnesota Pollution Control Agency by Tetra Tech, Inc., Research Triangle Park, NC.

Velpuri, N.M., G.B. Senay, R.K. Singh, S. Bohms, and J.P. Verdin. 2013. A comprehensive evaluation of two MODIS evapotranspiration products over the conterminous United States: Using point and gridded FLUXNET and water balance ET. *Remote Sensing of Environment*, 139: 35-49.

Appendix I. CAFOs by HUC12

Facilty Name	Permit	AU	HUC8 Name	HUC12 Name
Obermeyer Farms	MN0070084	1215.4	Blue Earth R.	Upper E Br Blue Earth R.
Sahrside Dairy LLP	MN0071153	1996	Blue Earth R.	Upper E Br Blue Earth R.
Richters Hog Site	MNG440329	1200	Blue Earth R.	Upper E Br Blue Earth R.
Pleasant View Hogs	MNG440439	1200	Blue Earth R.	Upper E Br Blue Earth R.
David Murra Farm	MNG440184	988.4	Blue Earth R.	Middle E Br Blue Earth R.
Dueck Diversified	MNG440365	1994.4	Blue Earth R.	Middle E Br Blue Earth R.
Diamond Pork LLC	MNG441238	1200	Blue Earth R.	Middle E Br Blue Earth R.
Hawkeye Three LLP	MNG440007	1462.4	Blue Earth R.	Lily Crk
HQ Finishing	MNG440312	1560	Blue Earth R.	Lily Crk
Lily Crk Farm c/o Daryl Bartz	MNG440420	1350	Blue Earth R.	Lily Crk
Camalot Breeders LLP	MNG440507	1223.8	Blue Earth R.	Lily Crk
Camalot Breeders LLP	MNG440507	1223.8	Blue Earth R.	Lily Crk
Christensen Farms Site F013	MNG440581	936	Blue Earth R.	Lily Crk
Myron Moeller Farm - Sec 26	MNG440727	1440	Blue Earth R.	Lily Crk
Eisenmenger Finisher	MNG441066	900	Blue Earth R.	Lily Crk
DAI-2	MNG440167	1440	Blue Earth R.	Center Crk
Chad Thate Finisher	MNG440223	1470	Blue Earth R.	Center Crk
Andrew Dahl Farm - Huntley Site	MNG440385	1200	Blue Earth R.	Center Crk
S & L Pork Farm	MNG440984	780	Blue Earth R.	Center Crk
JL Pork Farm	MNG441081	900	Blue Earth R.	Center Crk
WelCam	MNG441701	1659.8	Blue Earth R.	Center Crk
Wood Site	MNG442013	960	Blue Earth R.	Center Crk
Brian & Jean Millmann Farm	MNG440185	1320	Blue Earth R.	Cty of Blue Earth-Blue Earth R.
DAI-1	MNG440186	1440	Blue Earth R.	Cty of Blue Earth-Blue Earth R.
Pork Plus Inc Unit 3	MNG440051	1440	Blue Earth R.	Headwaters Elm Crk
New Fashion Pork - Farm 150-Crissinger	MNG440568	990	Blue Earth R.	Headwaters Elm Crk
New Fashion Pork - Farm 175-Kimball	MNG440890	990	Blue Earth R.	Headwaters Elm Crk
Pork Plus Inc Unit 11	MNG441242	900	Blue Earth R.	Headwaters Elm Crk
John Regier Farm - Pork Royal	MNG440011	1000	Blue Earth R.	S Fork Elm Crk
Steen Site	MNG440050	1152	Blue Earth R.	S Fork Elm Crk
Lennie Varilek Farm	MNG440715	990	Blue Earth R.	S Fork Elm Crk
Pork Plus Inc Unit 10	MNG440819	900	Blue Earth R.	S Fork Elm Crk
Tumbleson Finisher	MNG440364	1200	Blue Earth R.	Big Twin Lake-Elm Crk
Christensen Farms Site F052	MNG440579	936	Blue Earth R.	Big Twin Lake-Elm Crk
Watkins Acres - NFP 164	MNG440588	990	Blue Earth R.	Big Twin Lake-Elm Crk
Jay Moore Farm - NFP 170 Goldencrown	MNG440622	990	Blue Earth R.	Big Twin Lake-Elm Crk
Trent Tumbleson Barns	MNG440752	900	Blue Earth R.	Big Twin Lake-Elm Crk
Wing Farm	MNG440874	990	Blue Earth R.	Big Twin Lake-Elm Crk
Walnut Pork Cory Sinn	MNG440943	945	Blue Earth R.	Big Twin Lake-Elm Crk
Roger and Rita Matejka Finishers	MNG440957	1152	Blue Earth R.	Big Twin Lake-Elm Crk
Old Acres LLC - NFP 205 Ahrens	MNG440962	990	Blue Earth R.	Big Twin Lake-Elm Crk
DWN LLP Site F130	MNG441018	990	Blue Earth R.	Big Twin Lake-Elm Crk

Tracy Melson Farm - NFP 136	MNG440560	837	Blue Earth R.	Cedar Crk
Tracy & Troy Melson Farm - NFP 139	MNG440560	990	Blue Earth R.	Cedar Crk
Troy Melson Farm - NFP 140	MNG440560	990	Blue Earth R.	Cedar Crk
Farm 156 - Dykstra/Melson	MNG440587	990	Blue Earth R.	Cedar Crk
New Fashion Pork - Farm 161-Malone	MNG440589	990	Blue Earth R.	Cedar Crk
Farm 160 - Lyons	MNG440591	990	Blue Earth R.	Cedar Crk
Farm 165 - Burkhart	MNG440621	990	Blue Earth R.	Cedar Crk
Stone Lake Pork - North	MNG440959	990	Blue Earth R.	Cedar Crk
Stone Lake Pork - South	MNG440959	990	Blue Earth R.	Cedar Crk
Farm 240 - Anderson	MNG441202	990	Blue Earth R.	Cedar Crk
Carlson Finishers	MNG441212	945	Blue Earth R.	Cedar Crk
Bergemann Fraser 4	MNG441788	900	Blue Earth R.	Cedar Crk
West Ridge Pork	MNG440442	2105.2	Blue Earth R.	Martin Lake-Elm Crk
Pork Behrens Mill Farm	MNG440635	1200	Blue Earth R.	Martin Lake-Elm Crk
Glenn Moeller Farm - Rutland 30	MNG441037	945	Blue Earth R.	Martin Lake-Elm Crk
Tim Steuber Pork - Site 5	MNG441216	1414	Blue Earth R.	Martin Lake-Elm Crk
Multi-Site - Bicknase Sites 1 & 2	MNG441786	990	Blue Earth R.	Martin Lake-Elm Crk
Darren Schweiger Farm	MNG441971	1488	Blue Earth R.	Martin Lake-Elm Crk
Fraser Pork	MNG442015	900	Blue Earth R.	Martin Lake-Elm Crk
Richison Family Farms	MNG440572	1890	Blue Earth R.	Elm Crk
Vogt's Hog Finishing LLC	MNG440630	1440	Blue Earth R.	Elm Crk
Center Crk Pork Inc - Sec 7	MNG440645	1920	Blue Earth R.	Elm Crk
Wolter Brothers - Nashville 32	MNG440899	900	Blue Earth R.	Elm Crk
Haroldson Farm	MNG440026	1440	Blue Earth R.	Cty of Vernon Center-Blue Earth R.
Wakefield - Noy Site	MNG440173	1440	Blue Earth R.	Cty of Vernon Center-Blue Earth R.
Matzke Farms Inc - Sec 20	MNG440576	906	Blue Earth R.	Cty of Vernon Center-Blue Earth R.
Brandts Farm Partnership - Vernon Center	MNG440708	864	Blue Earth R.	Cty of Vernon Center-Blue Earth R.
Klimmek Hog Finishing	MNG440946	900	Le Sueur R.	Headwaters Le Sueur R.
Jensen Family Farms LLC	MNG441279	1440	Le Sueur R.	Headwaters Le Sueur R.
Zion Barns	MNG440095	1260	Le Sueur R.	Co. Ditch No 27-Le Sueur R.
Michael & Julie Moen Hogs	MNG440202	1200	Le Sueur R.	Co. Ditch No 27-Le Sueur R.
John Krause Sec 26	MNG441111	1233.6	Le Sueur R.	Co. Ditch No 27-Le Sueur R.
Paul Johnson Farms	MNG441290	1440	Le Sueur R.	Co. Ditch No 27-Le Sueur R.
Hi-Way 30 Hogs LLC	MNG441941	1440	Le Sueur R.	Co. Ditch No 27-Le Sueur R.
Klemmensen Brothers	MNG441981	1440	Le Sueur R.	Co. Ditch No 27-Le Sueur R.
Strobel Farms - McPherson 23 Site	MNG440170	1488	Le Sueur R.	Co. Ditch No 35-Le Sueur R.
TDL Farms - Guse Site	MNG440195	1680	Le Sueur R.	Co. Ditch No 35-Le Sueur R.
Keith Krause Farm - Sec 14	MNG440438	1850.4	Le Sueur R.	Co. Ditch No 35-Le Sueur R.
TDL Farms - Home Site	MNG441138	1500	Le Sueur R.	Co. Ditch No 35-Le Sueur R.
Roger Haley Farm - Sec 26	MNG441309	1080	Le Sueur R.	Co. Ditch No 35-Le Sueur R.
Strobel Farms - Alton 30 Site	MNG441441	1440	Le Sueur R.	Co. Ditch No 35-Le Sueur R.
Buffalo Lake - South	MNG441964	1440	Le Sueur R.	Co. Ditch No 35-Le Sueur R.

Michael L Anderson Farm	MNG440014	1185	Le Sueur R.	Little Cobb R.
Strobel Farms - McPherson 36 Site	MNG441103	1440	Le Sueur R.	Little Cobb R.
Vaubel - Medo Finishing Site	MNG441715	1284	Le Sueur R.	Little Cobb R.
Strobel Farms - McPherson 34 Site	MNG441778	1440	Le Sueur R.	Little Cobb R.
Green Power Acres	MNG440207	1200	Le Sueur R.	Freeborn Lake-Cobb R.
Terry Traynor Farm	MNG440200	1200	Le Sueur R.	JD No 51-Cobb R.
Drager Boys Finisher 1	MNG440362	1200	Le Sueur R.	JD No 51-Cobb R.
Peter Sonnek Farm	MNG440389	1248	Le Sueur R.	JD No 51-Cobb R.
Taylor Holland Pork	MNG441020	990	Le Sueur R.	JD No 51-Cobb R.
KMB Inc	MNG442004	1104	Le Sueur R.	JD No 51-Cobb R.
Nienow Acres, LLC	MNG440017	1900	Le Sueur R.	Cottonwood Lake-Cobb R.
Vaubel - Home Site	MNG440377	1455	Le Sueur R.	Cottonwood Lake-Cobb R.
Marian Moore Farm	MNG440578	1590	Le Sueur R.	Cottonwood Lake-Cobb R.
Will Farms	MNG441232	1500	Le Sueur R.	Cottonwood Lake-Cobb R.
Vaubel - Pig Sty Site	MNG441714	1080	Le Sueur R.	Cottonwood Lake-Cobb R.
Maurer Finisher	MN0070793	864	Le Sueur R.	Cobb R.
David & Dennis Sohre Farm	MNG440382	1320	Le Sueur R.	Cobb R.
Hislop Finishing Site	MNG440501	1200	Le Sueur R.	Cobb R.
Harlan and Elaine Marble Farm	MNG440625	900	Le Sueur R.	Cobb R.
Cords Finisher	MNG441376	990	Le Sueur R.	Cobb R.
Becker Farms - Sec 21	MNG440764	1430	Le Sueur R.	Upper Rice Crk
Schaible Finisher	MN0071129	1152	Le Sueur R.	Lower Rice Crk
John Covey Jr Farm - Sec 22	MNG440374	1200	Le Sueur R.	Lower Rice Crk
Susan Covey Farm - Sec 23	MNG441485	1200	Le Sueur R.	Lower Rice Crk
Maple Valley Pork	MNG441337	1207.2	Le Sueur R.	Minnesota Lake-Maple R.
Karl's 39 Site	MNG440367	864	Le Sueur R.	Co. Ditch No 95-Maple R.
McGregor Farms	MNG440775	900	Le Sueur R.	Co. Ditch No 95-Maple R.
Mark's Farms Inc	MNG441713	435	Le Sueur R.	Co. Ditch No 95-Maple R.
Wingen Farms - Farm 2	MNG440164	1248	Le Sueur R.	Maple R.
Patrick Duncanson Farm - Mountain Site	MNG440367	1152	Le Sueur R.	Maple R.
Troy Phillips Farm - Sec 29	MNG441297	1440	Le Sueur R.	Cty of St. Clair-Le Sueur R.
MG Waldbaum/Michael Foods - Lake Prairie	MNG441044	5760	Lower MN R.	Cty of Le Sueur-MN R.
Multi-Site - Loewe Brothers Inc	MNG440326	1500	Lower MN R.	Cty of Henderson-MN R.
Multi-Site - Loewe Brothers Inc	MNG440326	960	Lower MN R.	Cty of Henderson-MN R.
Koepp Hog Farm	MNG440509	815	Lower MN R.	Cty of Henderson-MN R.
Mark Koepp Hog Barn	MNG441176	1547.5	Lower MN R.	Cty of Henderson-MN R.
Willmar Poultry Farms - Wilson	MNG441118	1190	MN R. - Mankato	Cty of Morton-MN R.
Lee Farms Inc	MNG440503	1300	MN R. - Mankato	Threemile Crk-MN R.
Patrick Krzmarzick Farm 1	MNG440158	1560	MN R. - Mankato	Co. Ditch No 10-MN R.
John Hillesheim Site F024	MNG440577	936	MN R. - Mankato	Co. Ditch No 10-MN R.
Randy Reinhart Farm - Sec 26	MNG440193	1900.8	MN R. - Mankato	Cty of New Ulm-MN R.
Tim Harmening Farm	MNG440518	1314	MN R. - Mankato	Cty of New Ulm-MN R.
PJM Pork	MNG440546	1500	MN R. - Mankato	Cty of New Ulm-MN R.

Jonathan R Rewitzer Farm	MNG440774	923.1	MN R. - Mankato	Cty of New Ulm-MN R.
Jason Enter - Site 2	MNG441170	900	MN R. - Mankato	Cty of New Ulm-MN R.
Jason Enter - Site 1	MNG441171	900	MN R. - Mankato	Cty of New Ulm-MN R.
Martens Family Farm	MNG441251	1191.6	MN R. - Mankato	Cty of New Ulm-MN R.
Randy Reinhart Farm - Sec 21	MNG441890	1923	MN R. - Mankato	Cty of New Ulm-MN R.
Timothy A. Waibel Farm	MNG440327	1650	MN R. - Mankato	Cty of Courtland-MN R.
Courtland Dairy LLC	MNG441235	1680	MN R. - Mankato	Cty of Courtland-MN R.
Rebco Pork II	MNG441328	1440	MN R. - Mankato	Cty of Courtland-MN R.
Belgrade Pullets, LLC	MNG440817	960	MN R. - Mankato	Co. Ditch No 3-MN R.
Svin Hus Inc	MNG440908	1080	MN R. - Mankato	Cty of Mankato-MN R.
Hoppe Finisher	MNG441766	990	MN R. - Mankato	Cty of Mankato-MN R.
R. Ridge Farms Inc	MNG441930	990	Redwood R.	Redwood R.
SFI - Carlson 12	MNG440802	900	Watonwan R.	Headwaters Watonwan R.
Schwartz Farms Inc - Immer	MNG440903	900	Watonwan R.	Headwaters Watonwan R.
Michael Pearson Farm	MNG440623	900	Watonwan R.	E Sveadahl Church-Watonwan R.
North Branch Pork	MNG440697	840	Watonwan R.	E Sveadahl Church-Watonwan R.
Schwartz Farms Inc - CLF-1	MNG441173	1960	Watonwan R.	E Sveadahl Church-Watonwan R.
Lange Finisher	MNG441221	990	Watonwan R.	E Sveadahl Church-Watonwan R.
Schwartz Farms Inc - PAP	MNG440286	2758.9	Watonwan R.	Upper N Fork Watonwan R.
Christensen Farms Site N012	MNG440825	860	Watonwan R.	Upper N Fork Watonwan R.
Schwartz Farms Inc - Delton Site	MNG440977	900	Watonwan R.	Upper N Fork Watonwan R.
Schwartz Farms Inc - Hesse Site	MNG441267	990	Watonwan R.	Upper N Fork Watonwan R.
Oeltjenbruns Finishing Site	MNG441277	990	Watonwan R.	Upper N Fork Watonwan R.
Christensen Farms Site C009	MNG440061	1200	Watonwan R.	Middle N Fork Watonwan R.
Christensen Farms Site N008	MNG440651	645	Watonwan R.	Lower N Fork Watonwan R.
David Englin Farm - Sec 1	MNG440766	1556	Watonwan R.	Lower N Fork Watonwan R.
Menken Farms	MN0071251	250	Watonwan R.	Upper Butterfield Crk
Elwood Heldt Farm	MNG440402	1230	Watonwan R.	Upper Butterfield Crk
Braaten Home Site	MNG441255	1440	Watonwan R.	Upper Butterfield Crk
Mike Brandts Farm 1	MNG440147	888	Watonwan R.	Lower Butterfield Crk
HK Pork, LLC	MNG441253	990	Watonwan R.	Lower Butterfield Crk
Dickens Pigs Inc	MNG440020	1152	Watonwan R.	Upper St. James Crk
Romsdahl Long Lake Finisher	MNG441004	900	Watonwan R.	Upper St. James Crk
CK Pork LLC Finisher	MNG441021	900	Watonwan R.	Upper St. James Crk
All Four Pork	MNG441304	945	Watonwan R.	Upper St. James Crk
Robert Cunningham Farm 3	MNG440082	990	Watonwan R.	Middle S Fork Watonwan R.
Dennis Coleman Farm - Sites 1-3	MNG440372	2599.2	Watonwan R.	Middle S Fork Watonwan R.
Matt & Jeff Romsdahl Farm	MNG441083	1200	Watonwan R.	Middle S Fork Watonwan R.
Schwartz Farms Inc - South View Site	MNG441239	990	Watonwan R.	Middle S Fork Watonwan R.
Coleman Chops	MNG441994	995.2	Watonwan R.	Middle S Fork Watonwan R.
Harbitz Finisher	MNG440086	1200	Watonwan R.	Lower S Fork Watonwan R.
Aaron Eberhart Site 1	MNG441010	900	Watonwan R.	Lower S Fork Watonwan R.
Schwartz Farms Inc - Urevig Site	MNG441281	990	Watonwan R.	Lower S Fork Watonwan R.

Tilney Pork LLP	MNG440084	2206.8	Watonwan R.	Upper Perch Crk
Flitter Site	MNG440171	1200	Watonwan R.	Lower Perch Crk
Macho-Eckstein Co LLC	MNG440019	1224.9	Watonwan R.	Cty of La Salle-Watonwan R.
Mike Brandts Farm 1	MNG440147	872	Watonwan R.	Cty of La Salle-Watonwan R.
Bottem Farms Inc	MNG440634	2750	Watonwan R.	Cty of La Salle-Watonwan R.
Aaron Eberhart Farm	MNG441313	990	Watonwan R.	Cty of Madelia-Watonwan R.
Grover Barn 1	MNG441318	990	Watonwan R.	Cty of Madelia-Watonwan R.
Aaron Eberhart Farm	MNG441794	1440	Watonwan R.	Cty of Madelia-Watonwan R.
G & A Wendinger Farms LLC	MNG441940	1710	Watonwan R.	Cty of Madelia-Watonwan R.
Sundlee Pork Inc	MNG440970	1778.4	Yellow Medicine R.	Co. Ditch No 90-MN R.
Paul Kvistad Poultry	MNG441052	920	Yellow Medicine R.	Co. Ditch No 104-MN R.
Pederson Pork Farm	MNG441085	1350	Yellow Medicine R.	Co. Ditch No 2-MN R.
Hentges Family Farm - Site 2	MNG441285	990	Yellow Medicine R.	Middle Crk-MN R.
The Pullet Connection Inc	MNG440474	2772	Yellow Medicine R.	Smith Crk-MN R.
Kevin's Site	MNG440478	1440	Yellow Medicine R.	Smith Crk-MN R.
Randall Dolezal Farm	MNG440913	840	Yellow Medicine R.	Smith Crk-MN R.