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Memorandum

To:	Dr. Chuck Regan, Dave Wall (MPCA)	**Date:**	05/15/2017
From:	J. Wyss, H.I.T; J. Butcher, Ph.D., P.H.; Jennifer Olson (Tetra Tech)	**Subject:**	**Minnesota River Basin Sediment Delivery Analysis (FINAL)**
Cc:	Paul Davis, Scott MacLean (MPCA)		

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. That effort was completed in March 2016. In December 2016, MPCA contracted with Tetra Tech to characterize sediment delivery using the March 2016 models and MPCA monitoring data. This memorandum documents the characterization of sediment delivery of the Minnesota River Basin, including HSPF 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).

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2 Approach

2.1 Evaluation of Seasons and Conditions that Contribute High Sediment Loads

Using precipitation input and simulated output from the HSPF model application, Tetra Tech characterized monthly sediment loads at the mouth of each HUC8 watershed and for the Minnesota River at Jordan. The following statistics for the months of high sediment loading were determined: percent of sediment load delivered relative to the sediment load in the overall model simulation period, volume of water delivered relative to the volume in the overall model simulation period, surface runoff percent of total land outflow, interflow percent of total outflow, baseflow percent of total land outflow, water yield from the snowpack compared to total land outflow, monthly precipitation, and precipitation of the largest 24-hour storm. Additionally, for the high sediment loading months the percent contributions by sediment source were tabulated. With this information the combination of conditions (i.e., time of year, vegetative cover, and storm type) that deliver the majority of sediment to the mouth of the major watersheds and the Minnesota River at Jordan were identified.

First, Tetra Tech used monthly simulated in-stream output loading at the mouth of each HUC8 watershed and for the Minnesota River at Jordan and determined each individual month's sediment load percent contribution to the total sediment load delivered for the 18 year simulation for each location. Tetra Tech then created individual monthly sediment load percent contribution and accumulated sediment load time series plots for each location. If sediment loads were consistent throughout all 18 years of simulation each individual month would contribute approximately 0.46% of the total. Review of the time series plots indicated that any individual month contributing more than 3% of the 18 year sediment load would be classified as a high sediment loading month. With this assumption, each high sediment loading month would contribute approximately 6.5 months of sediment in an individual month if sediment loads were consistent throughout all 18 years of simulation. Tetra Tech also summarized which months in general have the largest percent contribution (e.g. summed all individual January % contributions for the 18 year simulation) to investigate overall which months contribute the majority of the sediment loads.

Second, for each high sediment loading month the volume of water delivered downstream relative to the volume delivered downstream in the overall model simulation period was determined. Additionally, the surface outflow, interflow outflow, and groundwater outflow percentages of the total land outflow were determined for each high sediment loading month. For each high sediment loading month the volume of water for each HRU (combination of land use and hydrozone) and flow path were determined individually and then summed for the entire HUC8. Therefore, the percentages reflect an area-weighted percentage by flow path of each HUC8's simulated area contributing to each analysis location [e.g. the flow path analysis for Blue Earth does not contain the upstream area from Le Sueur although in-stream values (i.e. monthly sediment and volume percent exports) do contain the contribution from upstream].

Third, for each high sediment loading month the volume of water released to the land from the snowpack was tabulated using the same approach used for surface outflow, interflow outflow, and groundwater outflow. The volume of water released by the snowpack was compared to the total volume of water leaving the land and entering streams. This percentage provides an index to the amount of snowmelt occurring for that month. If the percentage is large then it is likely that there was a rain on snow event and that land outflow was dominated by snow melt. When the percentage is zero then no snowmelt occurred that month. The index to snowmelt can be greater than 100% because it is taking the amount of water released to the land from the snowpack and dividing it by the amount of water leaving the land and entering streams. The calculation disregards the change in soil and groundwater storage due to snowmelt.

Fourth, for each high sediment loading month the monthly precipitation and also the precipitation of the largest 24-hour storm were calculated. The precipitation calculations accounted for the HRU areas and the precipitation station assigned to each HRU. Monthly precipitation represents an area-weighted monthly total precipitation amount for each HUC8. Daily maximum also represents an area-weighted precipitation amount but the largest 24-hour storms within a month can occur on different days at different precipitation stations. Therefore, the value does not pertain to any individual one day by HUC8 but instead brings together all of the largest 24-hour storms across all weather stations in each HUC8 for each high loading month.

Fifth, for each high sediment loading month the sources of sediment were tabulated. During the model calibration various sediment source budgets were used to tune the calibration so the models appropriately represented the sources of sediment on an annual average basis. The same methodology used during the calibration update was used here but instead of looking at annual average the method was adapted to look at monthly sediment loads. The sources identified below are upland, tile drain, ravine, bluff, and stream. Upland sources are tabulated as sediment washed off from all land uses except bluff and ravine. Tile drain sources are tabulated as sediment directly contributed via tile drains. Ravine sources are tabulated as sediment washed off and scoured from the ravine land use and sediment scoured from the other land uses. Bluff sources are tabulated as sediment washed off and scoured from the bluff land use and the net deposition/scour from RCHRES that contain the bluff land use in their individual drainage area. Stream sources are tabulated as net deposition/scour from RCHRES that do not contain the bluff land use in their individual drainage area.

Lastly, for the two highest sediment loading months for each HUC8 the hourly precipitation time series inputs were investigated in more detail. Each hourly precipitation time series was used to calculate the following statistics: maximum, 75th percentile, average, median, 25th percentile, and minimum. The statistical summaries were performed on hourly and daily totals for the hours and days that had measureable precipitation so the percentage of days and hours of the month with measurable precipitation was also summarized. Additionally, the total area to which each time series was supplied and the monthly total precipitation were also calculated.

Results of the analysis conducted for the evaluation of seasons and conditions that contribute high sediment loads are provided in Section 3.

2.2 EFFECTS OF INTENSE STORMS FROM MONITORED AND MODELED DAILY LOADS

Using daily sediment load estimates (from MPCA monitoring data and from HSPF modeling), Tetra Tech investigated the degree to which the very intense storms and major snowmelt events delivered sediment load to various locations scattered throughout the Minnesota River Basin. Based on the MPCA monitoring data the stations provided below were chosen as the analysis locations because they have estimates of sediment load for each day which allows for direct comparison to daily HSPF output.

- E26057001 Chippewa River near Milan, MN40
- E27035001 Redwood River near Redwood Falls, MN
- E25075001 Yellow Medicine River near Granite Falls, MN
- E29001001 Cottonwood River near New Ulm, MN68
- E31051001 Watonwan River near Garden City, CSAH13
- E32077001 Le Sueur River near Rapidan, MN66
- E30092001 Blue Earth River near Rapidan, MN

MPCA monitoring and HSPF modeling overlapped during the calendar years of 2011 and 2012 so that two-year period was used for the investigation. Additionally, to ensure that all seasons and vegetative cover conditions were included in the analysis, months were paired and redefined as seasons and intense storms were found in each season.

- LW = Late Winter (January and February)
- SP = Spring (March and April)
- ES = Early Summer (May and June)
- LS = Late Summer (July and August)
- FA = Fall (September and October)
- EW = Early Winter (November and December)

The intense storms daily sediment load analysis was conducted three different ways. First, the area-weighted largest daily precipitation total by season for the upstream area to each analysis location was found. Second, the area-weighted largest hourly precipitation total by season for the upstream area to each analysis location was found. Third, the largest observed daily sediment load by season based on the percentage each day contributed to the two year total at each analysis location was found. For each analysis location and season this provided that dates that 1) had the most daily rainfall, 2) had the most intense hourly rainfall, and 3) had the highest observed loads.

After finding the analysis dates using the three different approaches time series plots showing daily precipitation, daily observed sediment load, and daily simulated sediment load were prepared for each location and season. For the dates with the most daily rainfall and most intense hourly rainfall the sediment load for the analysis dates plus the next seven days were totaled and the percent contribution of those 8 days of the two year total were calculated. This approach assumes that all of the sediment load produced by the intense precipitation event completely passed by the analysis location within seven days of the event. Additionally, the daily total precipitation was used to calculate the percentage it contributed to the two year total precipitation at each analysis location.

For the dates with the highest observed sediment load the sediment loads for the preceding 5 days plus the analysis date plus the next two days were totaled and the percent contribution of those 8 days of the two year total were calculated. This approach captures both the rising limb and falling limb of the sediment load. Additionally, the daily precipitation for the seven days leading up to and including the maximum sediment loading day were totaled and the percent contribution of those 8 days of the two year total precipitation were calculated.

These approaches allowed for the comparison of the precipitation driven analysis dates to the sediment driven analysis dates by looking at a window of time that a storm could influence downstream sediment load and looking at the precipitation leading up to a day with high sediment load.

Results of the analysis conducted for the evaluation of seasons and conditions that contribute high sediment loads are provided in Section 4.

3 High Sediment Load Results

Results and discussion for monthly high sediment loads at the mouth of each HUC8 watershed and for the Minnesota River at Jordan are presented in the section. The results presented for each location include: percent of sediment load delivered relative to the sediment load in the overall model simulation period, volume of water delivered relative to the volume in the overall model simulation period, surface runoff percent of total land outflow, interflow percent of total outflow, baseflow percent of total land outflow, water yield from the snowpack compared to total land outflow, monthly precipitation, precipitation of the largest 24-hour storm, and the percent contributions by sediment source were tabulated for each high loading month.

For the two highest sediment loading months for each HUC8 the hourly precipitation time series inputs were investigated in more detail. The statistical summaries were performed on hourly and daily totals for the hours and days that had measureable precipitation.

3.1 CHIPPEWA (07020005)

The analysis for Chippewa was performed at two locations: Chippewa River above the Watson Sag diversion and Chippewa River at HUC8 outlet. The results at both locations are similar but the sediment loads above the diversion are much greater than at the mouth due to the diversion of high flows and associated sediment to Lac qui Parle. Both locations are discussed together.

Chippewa has four high sediment loading months. Figure 1 and Figure 3 show that for each high sediment loading month the accumulated total has a sharp upward inflection indicating a large sediment load for that month. Figure 2 and Figure 4 identify the overall highest sediment loading months as April and July with those two months contributing 50% of the sediment load during the simulation. Table 1 and Table 4 show that the individual highest sediment loading month is July 1995 and Table 2 and Table 5 show the individual monthly loads and the unit area export for the upstream drainage area. Since the highest sediment loading month is in the first year of simulation there is a possibility that initial model conditions could be causing this response. The model output was investigated and it was determined that the upland sediment storages (DETS) were stable by this point of the simulation so initial conditions did not cause this response. The four highest sediment loading months account for approximately 30% of the sediment load delivered in an 18-year period but account for only about 9% of the volume of water delivered in the same 18-year period. With the exception of April 1997 the four highest sediment loading months have surface outflow greater than approximately 15% of the total land outflow with area-weighted monthly precipitation values more than 6.8 inches/month and area-weighted largest 24-hour storms greater than 2.2 inches/day. The two high sediment month associated with the month of April have snow melt contributions but the two high sediment loading months associated with July are entirely rainfall driven.

Table 3 and Table 6 show that in July 1995 and July 2011 the sediment source is predominantly upland whereas for April 1997 the sediment source is predominantly stream. April 2001 is approximately split between upland and bluff plus stream sources. When surface runoff was greater than 15.3% (Table 1 and Table 4) then upland contributions were greater than 50% (

Table 3 and Table 6). There appears to be a strong correlation between high upland source attribution and high precipitation driven surface outflow.

Table 7 shows that monthly total precipitation for July 1995 ranges from 5.51 inches/month to 9.15 inches/month and Table 8 shows that April 2001 ranges from 5.59 inches/month to 7.73 inches/month.

Both months show high frequency of daily measurable rainfall (ranging from 53% to 74%) indicating likely high soil moisture content and reduced infiltration capacity. Both months also show large daily maxima for each station (28% to 30% of monthly total) and daily averages much greater than the daily median and occasionally above the daily 75th percentile. Additionally, hourly statistics show very intense hourly precipitation maxima (6% to 23% of monthly total) with hourly averages much greater than the hourly median. These results indicate that the rain came in infrequent (less than 2-3 times per month), short duration, but intense storms.

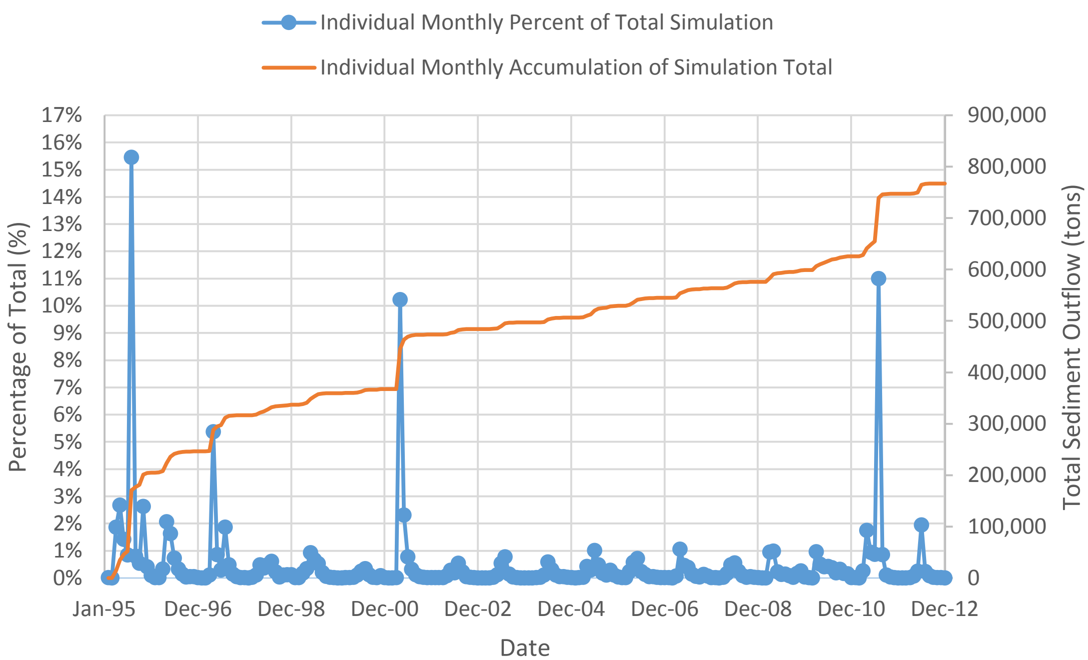

Figure 1. Monthly Sediment Export Percent of Total Simulation and Accumulation for Chippewa above Watson Sag Diversion

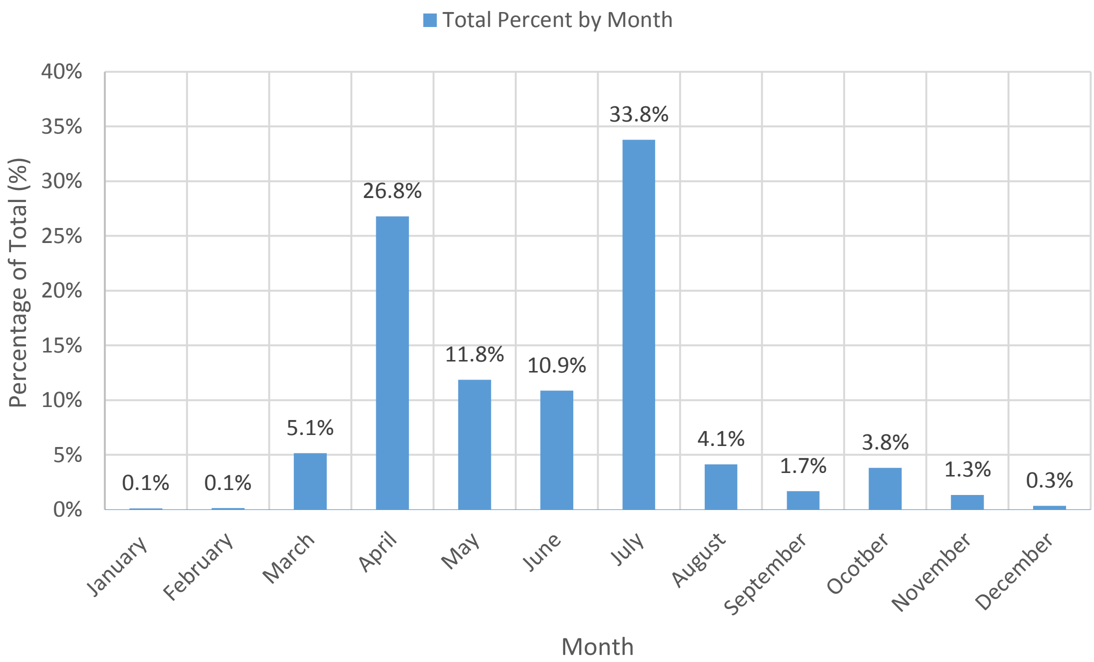

Figure 2. Total Percent by Month for Chippewa above Watson Sag Diversion

Table 1. High Sediment Loading Months Statistical Summary for Chippewa above Watson Sag Diversion

High Sediment Load Month and Year	Sediment Export Percent of simulation total (%)	Volume Export Percent of simulation total (%)	Surface Percent of monthly outflow (%)	Interflow Percent of monthly outflow (%)	Baseflow Percent of monthly outflow (%)	Snowpack water yield compared to total land outflow (%)	Area-weighted monthly precipitation (in)	Area-weighted daily maximum precipitation (in)
July 1995	15.4%	2.5%	18.2%	28.3%	53.5%	0.0%	6.72	2.19
April 1997	5.4%	4.5%	2.1%	30.6%	67.3%	105.0%	1.59	0.93
April 2001	10.2%	5.0%	15.3%	33.8%	50.9%	165.6%	6.76	2.30
July 2011	11.0%	1.7%	23.5%	18.6%	57.9%	0.0%	8.41	2.43
Average	10.5%	3.4%	14.7%	27.9%	57.4%	67.6%	5.87	1.96

Table 2. High Sediment Loading Months Load Summary for Chippewa above Watson Sag Diversion

High Sediment Load Month and Year	Sediment Load (ton/month)*	Sediment Load (ton/acre)
July 1995	118,570	0.100
April 1997	41,164	0.035
April 2001	78,456	0.066
July 2011	84,401	0.071
Average	80,648	0.068

*A majority of this sediment is diverted to Lac Qui Parle through the Watson Sag Diversion

Table 3. High Sediment Loading Months Source Attribution for Chippewa above Watson Sag Diversion

High Sediment Load Month and Year	Upland	Tile Drain	Ravine	Bluff	Stream
July 1995	88.6%	0.0%	1.2%	4.6%	5.6%
April 1997	1.1%	0.0%	0.4%	39.7%	58.8%
April 2001	51.7%	0.0%	1.8%	21.7%	24.8%
July 2011	92.7%	0.0%	0.1%	6.6%	0.6%
Average	58.5%	0.0%	0.9%	18.2%	22.5%

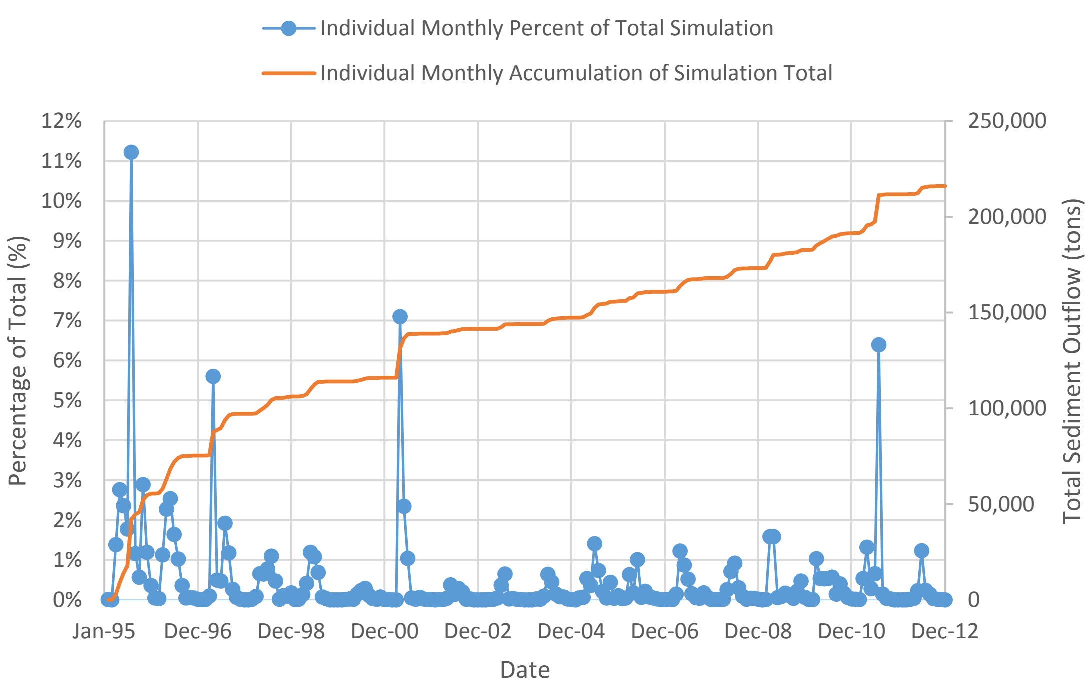

Figure 3. Monthly Sediment Export Percent of Total Simulation and Accumulation for Chippewa at HUC8 Outlet

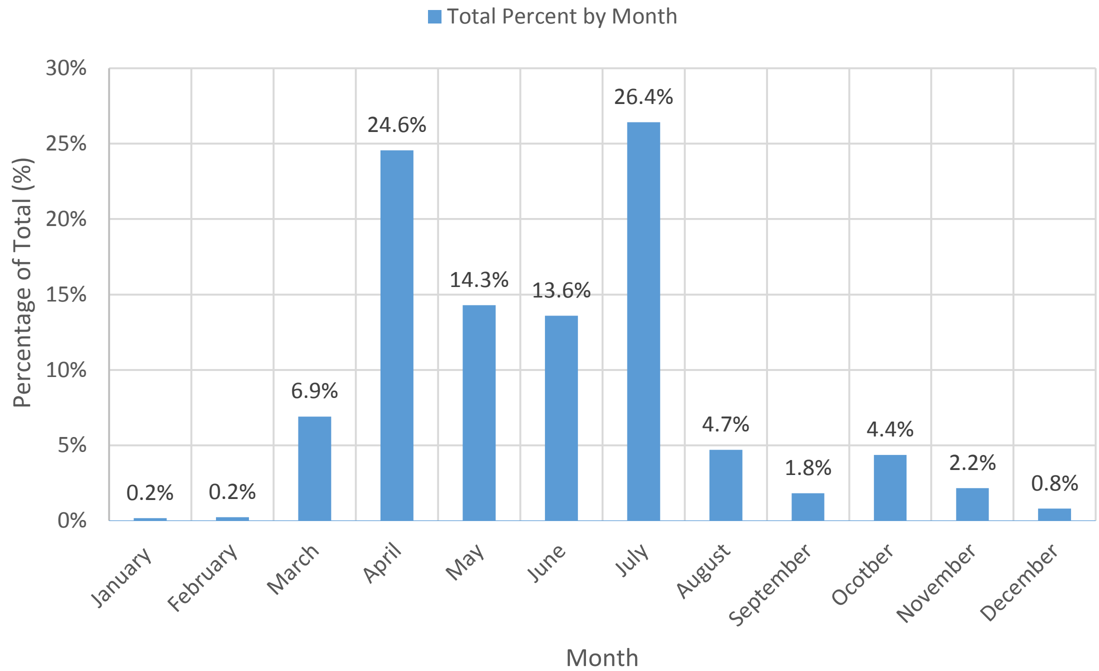

Figure 4. Total Percent by Month for Chippewa at HUC8 Outlet

Table 4. High Sediment Loading Months Statistical Summary for Chippewa at HUC8 Outlet

High Sediment Load Month and Year	Sediment Export Percent of simulation total (%)	Volume Export Percent of simulation total (%)	Surface Percent of monthly outflow (%)	Interflow Percent of monthly outflow (%)	Baseflow Percent of monthly outflow (%)	Snowpack water yield compared to total land outflow (%)	Area-weighted monthly precipitation (in)	Area-weighted daily maximum precipitation (in)
July 1995	11.2%	2.0%	20.4%	28.5%	51.0%	0.0%	6.86	2.26
April 1997	5.6%	3.4%	2.1%	30.8%	67.1%	100.7%	1.65	0.98
April 2001	7.1%	2.7%	14.8%	33.3%	51.9%	161.9%	6.83	2.34
July 2011	6.4%	1.2%	21.9%	19.7%	58.4%	0.0%	8.18	2.44
Average	7.6%	2.3%	14.8%	28.1%	57.1%	65.6%	5.88	2.00

Table 5. High Sediment Loading Months Load Summary for Chippewa at HUC8 Outlet

High Sediment Load Month and Year	Sediment Load (ton/month)	Sediment Yield (ton/acre/month)*
July 1995	24,226	0.018
April 1997	12,108	0.009
April 2001	15,327	0.012
July 2011	13,815	0.011
Average	16,369	0.012

*Calculated as total drainage area at mouth divided by sediment load at mouth which has a majority of the upstream sediment diverted to Lac Qui Parle through the Watson Sag Diversion.

Table 6. High Sediment Loading Months Source Attribution for Chippewa at HUC8 Outlet

High Sediment Load Month and Year	Upland	Tile Drain	Ravine	Bluff	Stream
July 1995	91.3%	0.0%	1.0%	1.4%	6.3%
April 1997	1.5%	0.0%	0.4%	18.2%	79.9%
April 2001	57.2%	0.0%	1.8%	8.9%	32.1%
July 2011	95.6%	0.0%	0.1%	2.1%	2.2%
Average	61.4%	0.0%	0.8%	7.7%	30.1%

Table 7. July 1995 Precipitation Analysis for Chippewa

WDM DSN ID	1	2	4	5	6
Location	SWCD_340	SWCD_317	SWCD_108	SWCD_349	SWCD_354
Acres	398,176	295,211	250,264	221,090	149,113
Monthly Total Precipitation (in)	5.51	6.52	7.05	8.00	9.15
Percent of Days with Measureable Precipitation	74%	71%	61%	55%	61%
Daily Measurable Max	1.57	2.25	2.01	2.41	3.57
Daily Measurable 75th Percentile	0.25	0.22	0.30	0.51	0.40
Daily Measurable Average	0.24	0.30	0.37	0.47	0.48
Daily Measurable Median	0.07	0.06	0.16	0.30	0.25
Daily Measurable 25th Percentile	0.02	0.04	0.05	0.05	0.05
Daily Measurable Minimum	0.00016	0.00994	0.00191	0.00013	0.000065
Percent of Hours with Measurable Precipitation	15%	12%	15%	12%	14%
Hourly Measurable Max	0.350	0.757	0.804	1.233	2.106
Hourly Measurable 75th Percentile	0.061	0.064	0.070	0.101	0.077
Hourly Measurable Average	0.049	0.073	0.064	0.088	0.090
Hourly Measurable Median	0.024	0.039	0.031	0.037	0.031
Hourly Measurable 25th Percentile	0.003	0.015	0.005	0.004	0.001
Hourly Measurable Minimum	0.00001	0.00099	0.00001	0.00013	0.000065

Table 8. April 2001 Precipitation Analysis for Chippewa

WDM DSN ID	1	2	4	5	6
Location	SWCD_340	SWCD_317	SWCD_108	SWCD_349	SWCD_354
Acres	398,176	295,211	250,264	221,090	149,113
Monthly Total Precipitation (in)	5.59	6.92	7.73	7.41	7.56
Percent of Days with Measureable Precipitation	57%	53%	63%	60%	63%
Daily Measurable Max	1.92	2.20	3.05	2.66	2.59
Daily Measurable 75th Percentile	0.30	0.47	0.36	0.49	0.46
Daily Measurable Average	0.33	0.43	0.41	0.41	0.40
Daily Measurable Median	0.05	0.11	0.10	0.09	0.05
Daily Measurable 25th Percentile	0.02	0.03	0.03	0.02	0.02
Daily Measurable Minimum	0.005	0.00992	0.00013	0.00009	0.000045
Percent of Hours with Measurable Precipitation	13%	14%	19%	18%	19%
Hourly Measurable Max	0.383	0.625	0.607	0.512	0.535
Hourly Measurable 75th Percentile	0.066	0.076	0.067	0.078	0.067
Hourly Measurable Average	0.058	0.070	0.056	0.058	0.056
Hourly Measurable Median	0.025	0.034	0.024	0.022	0.025
Acres	0.009	0.009	0.004	0.002	0.003
Monthly Total Precipitation (in)	0.00003	0.00028	0.00001	0.00001	0.000005

3.2 REDWOOD (07020006)

Redwood has ten high sediment loading months. Figure 5 shows that 40% of the high sediment loading months occur in a 14-month period between March 2010 and April 2011. Figure 6 identifies the overall highest sediment loading months as April and May with those two months contributing 53% of the sediment load during the simulation. Table 9 shows that the individual highest sediment loading month is April 2001 and Table 10 shows the individual monthly loads and the unit area export for the upstream drainage area. The ten highest sediment loading months account for approximately 52% of the sediment load delivered in an 18-year period but account for only about 29% of the volume of water delivered in the same 18-year period. Surface outflow shows high variability but when monthly precipitation is greater than about 7.5 inches then surface outflow is greater than 16% of the volume of water running off the land. Area-weighted monthly precipitation values range from about 1 inch to about 11 inches and the area-weighted monthly largest 24-hour storms range from approximately 0.5 inches to 3.38 inches. The three high sediment month associated with the month of March have extremely high snow melt contribution.

Table 11 shows that for May 2004 the sediment source is predominantly upland but for the other nine high sediment loading months the sediment source is predominantly bluff and/or stream. Generally, for months with high snowpack yield the predominant sources are bluff and stream, while for months with high total precipitation values the source appears to be pushed more towards upland but bluff and stream are still strong contributors.

Table 12 shows that monthly total precipitation for April 2001 ranges from 4.22 inches/month to 8.75 inches/month and Table 13 shows that September 2010 ranges from 8.35 inches/month to 13.05 inches/month. Both months show moderate frequency of daily measurable rainfall (ranging from 17% to 50%) indicating likely moderate soil moisture content and reduced infiltration capacity. Both months also show large daily maxima for each station (23% to 64% of monthly total) and daily averages much greater than the daily median and occasionally above the daily 75th percentile. Additionally, hourly statistics show very intense hourly precipitation maxima (7% to 23% of monthly total) with hourly averages much greater than the hourly median. These results indicate that the rain came in infrequent (less than 2-3 times per month), short duration, but intense storms.

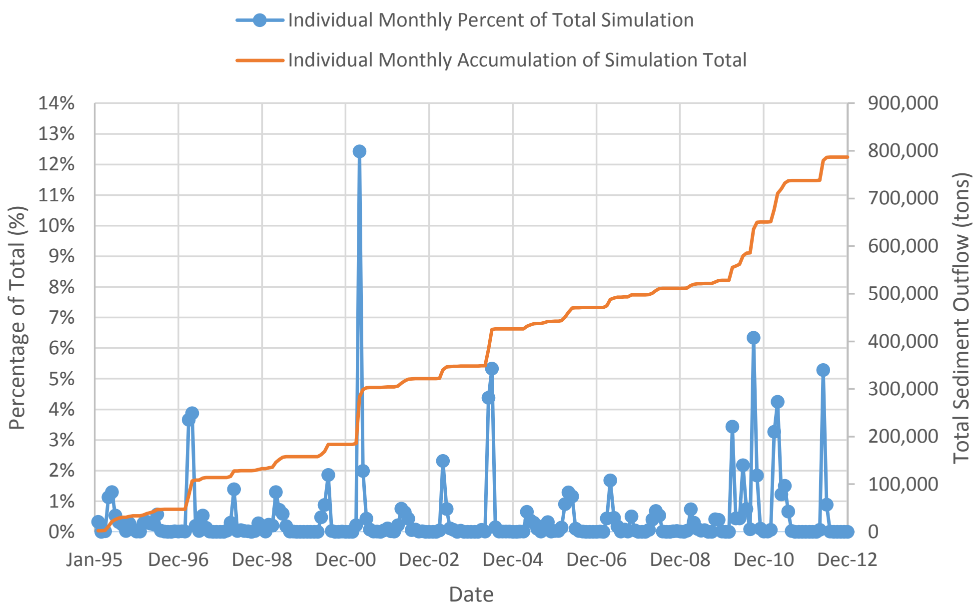

Figure 5. Monthly Sediment Export Percent of Total Simulation and Accumulation for Redwood at HUC8 Outlet

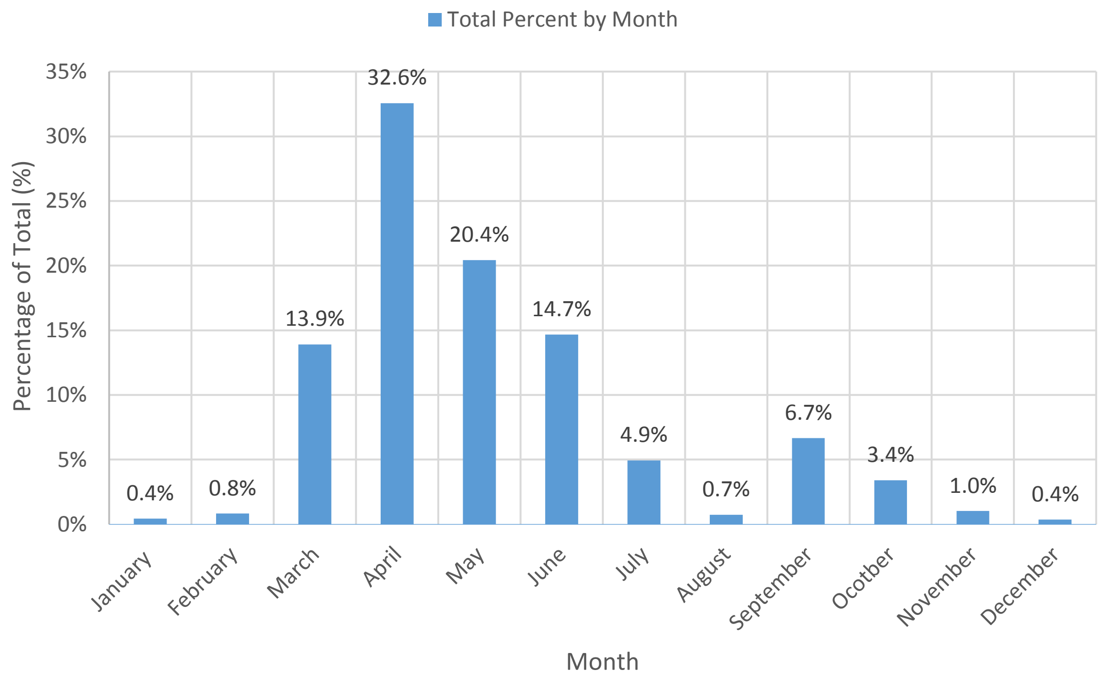

Figure 6. Total Percent by Month for Redwood at HUC8 Outlet

Table 9. High Sediment Loading Months Statistical Summary for Redwood at HUC8 Outlet

High Sediment Load Month and Year	Sediment Export Percent of simulation total (%)	Volume Export Percent of simulation total (%)	Surface Percent of monthly outflow (%)	Interflow Percent of monthly outflow (%)	Baseflow Percent of monthly outflow (%)	Snowpack water yield compared to total land outflow (%)	Area-weighted monthly precipitation (in)	Area-weighted daily maximum precipitation (in)
March 1997	3.7%	2.8%	3.2%	22.3%	74.5%	204.4%	1.04	0.54
April 1997	3.9%	2.9%	3.6%	23.4%	73.1%	21.1%	2.44	1.72
April 2001	12.4%	5.6%	16.0%	35.1%	48.9%	25.6%	7.55	3.38
May 2004	4.4%	1.1%	36.0%	26.7%	37.4%	0.2%	7.68	2.97
June 2004	5.3%	2.9%	7.2%	32.8%	60.0%	0.0%	4.56	1.70
March 2010	3.4%	2.7%	2.5%	21.1%	76.5%	189.0%	1.27	0.61
September 2010	6.3%	3.0%	19.2%	39.3%	41.6%	0.0%	10.82	2.93
March 2011	3.3%	2.5%	5.3%	24.0%	70.7%	177.5%	2.16	1.64
April 2011	4.2%	3.0%	6.4%	25.3%	68.3%	23.4%	3.28	1.33
May 2012	5.3%	2.5%	17.2%	36.5%	46.2%	0.0%	8.95	2.73
Average	5.2%	2.9%	11.6%	28.6%	59.7%	64.1%	4.98	1.95

Table 10. High Sediment Loading Months Load Summary for Redwood at HUC8 Outlet

High Sediment Load Month and Year	Sediment Load (ton/month)	Sediment Yield (ton/acre/month)
March 1997	28,824	0.065
April 1997	30,488	0.069
April 2001	97,780	0.220
May 2004	34,449	0.078
June 2004	41,947	0.095
March 2010	27,058	0.061
September 2010	49,898	0.112
March 2011	25,691	0.058
April 2011	33,419	0.075
May 2012	41,564	0.094
Average	41,112	0.093

Table 11. High Sediment Loading Months Source Attribution for Redwood at HUC8 Outlet

High Sediment Load Month and Year	Upland	Tile Drain	Ravine	Bluff	Stream
March 1997	3.7%	2.7%	0.1%	48.1%	45.4%
April 1997	5.8%	1.6%	0.2%	43.7%	48.8%
April 2001	41.5%	1.9%	3.5%	32.2%	20.8%
May 2004	109.7%	1.6%	16.6%	4.3%	-32.3%
June 2004	19.9%	1.2%	2.0%	31.3%	45.6%
March 2010	2.9%	2.4%	0.0%	47.1%	47.6%
September 2010	39.0%	1.9%	2.9%	37.0%	19.1%
March 2011	12.5%	2.8%	0.7%	43.6%	40.3%
April 2011	14.6%	1.7%	0.8%	37.1%	45.8%
May 2012	3.7%	2.7%	0.1%	48.1%	45.4%
Average	25.3%	2.1%	2.7%	37.3%	32.7%

Table 12. April 2001 Precipitation Analysis for Redwood

WDM DSN ID	110	310	510	710	910	1110	1310	1510	1710	1910	2110	2310	2510	2710
Location	SWCD 746	SWCD 502	MN218 429	SWCD4 76	SWCD 504	MN215 204	SWCD 508	MN215 482	SWCD 511	MN218 520	SWCD 838	SWCD 844	MN216 839	SWCD 837
Acres	27,315	28,834	52,064	30,131	57,792	28,175	26,469	21,556	34,223	49,371	15,324	31,037	19,560	21,721
Monthly Total Precipitation (in)	8.42	8.18	8.75	8.28	8.50	8.40	6.74	4.22	8.23	4.97	7.56	7.48	7.55	7.25
Percent of Days with Measureable Precipitation	43%	17%	43%	23%	43%	33%	23%	40%	33%	33%	37%	33%	30%	37%
Daily Measurable Max	3.60	5.25	3.79	2.66	3.64	4.13	3.50	0.99	3.97	1.82	3.87	3.32	2.75	3.26
Daily Measurable 75th Percentile	0.62	2.00	0.67	1.44	0.45	0.50	1.08	0.50	0.54	0.77	0.57	0.84	1.37	0.68
Daily Measurable Average	0.65	1.64	0.67	1.18	0.65	0.84	0.96	0.35	0.82	0.50	0.69	0.75	0.84	0.66
Daily Measurable Median	0.29	0.55	0.28	0.98	0.23	0.26	0.44	0.26	0.29	0.23	0.26	0.32	0.34	0.27
Daily Measurable 25th Percentile	0.22	0.20	0.08	0.70	0.12	0.21	0.27	0.09	0.24	0.15	0.13	0.15	0.17	0.19
Daily Measurable Minimum	0.002	0.18	0.02	0.35	0.009	0.02	0.1	0.02	0.104	0.01	0.002	0.02	0.099	0.055
Percent of Hours with Measurable Precipitation	7%	4%	8%	4%	8%	7%	4%	6%	6%	7%	7%	6%	7%	8%
Hourly Measurable Max	0.554	1.292	0.907	1.902	1.062	1.021	1.326	0.790	1.008	1.050	0.983	0.842	1.770	0.828
Hourly Measurable 75th Percentile	0.220	0.373	0.197	0.378	0.185	0.213	0.186	0.117	0.277	0.113	0.213	0.205	0.130	0.193
Hourly Measurable Average	0.159	0.282	0.148	0.276	0.149	0.162	0.217	0.103	0.206	0.104	0.154	0.163	0.142	0.129
Hourly Measurable Median	0.121	0.103	0.099	0.212	0.093	0.105	0.103	0.091	0.157	0.054	0.071	0.097	0.100	0.072
Hourly Measurable 25th Percentile	0.066	0.082	0.047	0.069	0.022	0.070	0.055	0.037	0.056	0.015	0.060	0.065	0.035	0.029
Hourly Measurable Minimum	0.002	0.005	0.01	0.006	0.002	0.011	0.007	0.006	0.011	0.004	0.002	0.002	0.008	0.006

Table 13. September 2010 Precipitation Analysis for Redwood

WDM DSN ID	**110**	**310**	**510**	**710**	**910**	**1110**	**1310**	**1510**	**1710**	**1910**	**2110**	**2310**	**2510**	**2710**
Location	**SWCD 746**	**SWCD 502**	**MN218 429**	**SWCD 476**	**SWCD 504**	**MN215 204**	**SWCD 508**	**MN215 482**	**SWCD 511**	**MN218 520**	**SWCD 838**	**SWCD 844**	**MN216 839**	**SWCD 837**
Acres	27,315	28,834	52,064	30,131	57,792	28,175	26,469	21,556	34,223	49,371	15,324	31,037	19,560	21,721
Monthly Total Precipitation (in)	11.35	13.05	12.60	9.03	9.06	12.60	11.44	12.18	11.90	10.18	9.77	10.80	8.60	8.35
Percent of Days with Measureable Precipitation	33%	23%	33%	37%	43%	33%	30%	30%	33%	40%	33%	37%	50%	40%
Daily Measurable Max	4.04	4.18	3.84	3.02	2.47	3.84	2.78	3.45	3.32	2.94	2.68	3.53	2.48	2.47
Daily Measurable 75th Percentile	1.72	2.42	1.59	1.11	1.21	1.59	2.28	1.89	1.68	1.55	1.63	1.61	0.75	1.26
Daily Measurable Average	1.14	1.86	1.26	0.82	0.70	1.26	1.27	1.35	1.19	0.85	0.98	0.98	0.57	0.70
Daily Measurable Median	0.58	2.17	0.96	0.50	0.50	0.96	1.14	1.33	0.82	0.36	0.66	0.36	0.25	0.36
Daily Measurable 25th Percentile	0.16	0.83	0.22	0.18	0.07	0.22	0.32	0.60	0.32	0.15	0.24	0.10	0.01	0.02
Daily Measurable Minimum	0.02	0.22	0.05	0.03	0.02	0.05	0.2	0.22	0.132	0.014	0.09	0.005	0.002	0.002
Percent of Hours with Measurable Precipitation	9%	8%	9%	8%	12%	9%	9%	8%	9%	12%	9%	11%	16%	11%
Hourly Measurable Max	1.828	1.891	1.100	1.785	0.726	1.100	1.317	1.055	1.288	0.775	1.279	1.155	0.710	0.706
Hourly Measurable 75th Percentile	0.236	0.246	0.210	0.160	0.132	0.210	0.235	0.261	0.194	0.154	0.175	0.180	0.110	0.149
Hourly Measurable Average	0.177	0.218	0.188	0.153	0.105	0.188	0.176	0.200	0.175	0.121	0.144	0.135	0.077	0.103
Hourly Measurable Median	0.070	0.092	0.100	0.047	0.040	0.100	0.071	0.110	0.100	0.051	0.070	0.052	0.020	0.047
Hourly Measurable 25th Percentile	0.018	0.021	0.025	0.009	0.010	0.025	0.032	0.033	0.030	0.015	0.021	0.008	0.002	0.011
Hourly Measurable Minimum	0.001	0.002	0.01	0.003	0.002	0.01	0.006	0.007	0.005	0.001	0.001	0.001	0.002	0.002

3.3 HAWK-YELLOW MEDICINE (07020004)

Hawk-Yellow Medicine has six high sediment loading months. Figure 7 shows that 66% of the high sediment loading months occur in a 14-month period between March 2010 and April 2011. Figure 8 identifies the overall highest sediment loading months as April and May with those two months contributing nearly 48% of the sediment load during the simulation.

Table 14 shows that the individual highest sediment loading month is April 2001and Table 15 shows the individual monthly loads and the unit area export for the upstream drainage area. The six highest sediment loading months account for approximately 30% of the sediment load delivered in an 18-year period but account for only about 18% of the volume of water delivered in the same 18-year period. Surface outflow shows high variability but when monthly precipitation is greater than about 7 inches then surface outflow is greater than 14% of the volume of water running off the land. Area-weighted monthly precipitation values range from about 1.3 inches to about 9 inches and the area-weighted monthly largest 24-hour storms range from approximately 0.5 inches to 3 inches. The high sediment loading months associated with March and April have snowmelt released to the land with March 2010 having significant amounts of snowmelt.

Table 16 shows that April 2001, August 2010, and September 2010 (monthly precipitation greater than about 7 inches and surface outflow greater than 14%) sediment is predominantly from the upland. The other three high sediment loading months are predominantly bluff and stream and are associated with low rainfall totals and high snowmelt contributions.

Table 17 shows that monthly total precipitation for April 2001 ranges from 4.22 inches/month to 8.88 inches/month and Table 18 shows that September 2010 ranges from 5.47 inches/month to 13.05 inches/month. Both months show moderate frequency of daily measurable rainfall (ranging from 30% to 57%) indicating likely moderate soil moisture content and reduced infiltration capacity. Both months also show large daily maxima for each station (23% to 55% of monthly total) and daily averages much greater than the daily median and occasionally above the daily 75th percentile. Additionally, hourly statistics show very intense hourly precipitation maxima (5% to 27% of monthly total) with hourly averages much greater than the hourly median. These results indicate that the rain came in infrequent (less than 2-3 times per month), short duration, but intense storms.

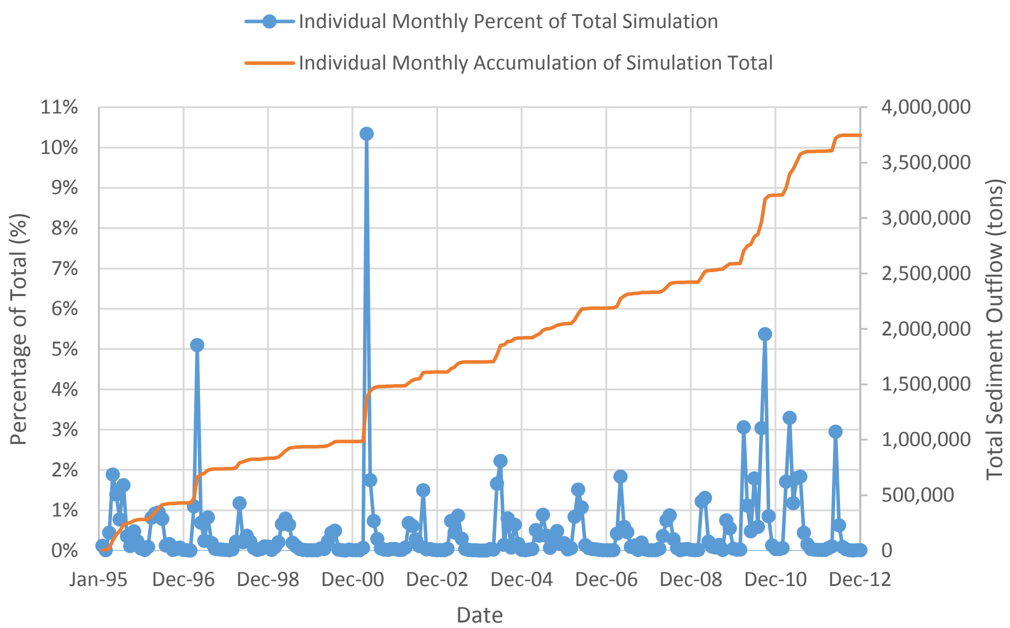

Figure 7. Monthly Sediment Export Percent of Total Simulation and Accumulation for Hawk-Yellow Medicine at HUC8 Outlet

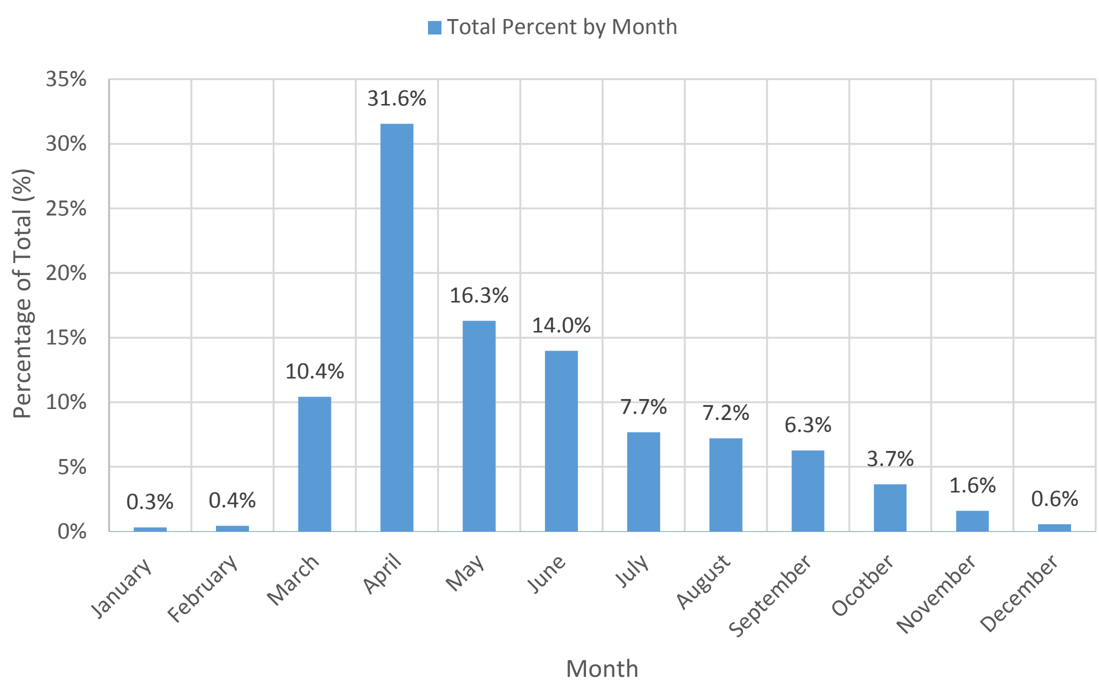

Figure 8. Total Percent by Month for Hawk-Yellow Medicine at HUC8 Outlet

Table 14. High Sediment Loading Months Statistical Summary for Hawk-Yellow Medicine at HUC8 Outlet

High Sediment Load Month and Year	Sediment Export Percent of simulation total (%)	Volume Export Percent of simulation total (%)	Surface Percent of monthly outflow (%)	Interflow Percent of monthly outflow (%)	Baseflow Percent of monthly outflow (%)	Snowpack water yield compared to total land outflow (%)	Area-weighted monthly precipitation (in)	Area-weighted daily maximum precipitation (in)
April 1997	5.1%	5.0%	3.4%	24.5%	72.1%	25.2%	1.92	1.40
April 2001	10.3%	4.8%	14.2%	36.4%	49.4%	49.9%	7.14	2.97
March 2010	3.1%	2.7%	2.1%	22.4%	75.5%	196.2%	1.35	0.62
August 2010	3.0%	0.5%	33.5%	43.5%	22.9%	0.0%	6.96	2.69
September 2010	5.4%	1.5%	19.0%	47.6%	33.5%	0.0%	8.70	2.69
April 2011	3.3%	3.8%	2.5%	26.0%	71.4%	72.4%	1.98	0.44
Average	5.0%	3.0%	12.5%	33.4%	54.1%	57.3%	4.68	1.80

Table 15. High Sediment Loading Months Load Summary for Hawk-Yellow Medicine at HUC8 Outlet

High Sediment Load Month and Year	Sediment Load (ton/month)*	Sediment Yield (ton/acre/month)**
April 1997	191,030	0.144
April 2001	387,750	0.293
March 2010	114,580	0.087
August 2010	113,850	0.086
September 2010	201,320	0.152
April 2011	123,560	0.093
Average	188,682	0.142

*Includes load from Lac Qui Parle
**Does not include area of Lac Qui Parle

Table 16. High Sediment Loading Months Source Attribution for Hawk-Yellow Medicine at HUC8 Outlet

High Sediment Load Month and Year	Upland	Tile Drain	Ravine	Bluff	Stream
April 1997	7.9%	0.4%	0.4%	36.2%	55.1%
April 2001	51.0%	0.4%	2.4%	27.0%	19.2%
March 2010	1.2%	0.9%	0.1%	51.0%	46.9%
August 2010	81.8%	0.0%	3.0%	12.5%	2.6%
September 2010	67.1%	0.3%	2.9%	16.3%	13.4%
April 2011	4.6%	0.8%	0.3%	28.3%	66.0%
Average	35.6%	0.5%	1.5%	28.6%	33.9%

Table 17. April 2001 Precipitation Analysis for Hawk-Yellow Medicine

WDM DSN ID	21	22	23	24	25	27	71
Location	**S270**	**S297**	**S302**	**S329**	**S253**	**S341**	**MN213311**
Acres	69,095	67,750	57,672	172,395	138,845	142,410	214,692
Monthly Total Precipitation (in)	5.97	7.54	8.88	7.90	7.36	6.57	7.45
Percent of Days with Measureable Precipitation	40%	37%	33%	37%	40%	53%	33%
Daily Measurable Max	2.27	2.92	4.59	4.11	2.76	3.61	2.26
Daily Measurable 75th Percentile	0.49	0.74	1.02	0.68	0.50	0.39	1.13
Daily Measurable Average	0.50	0.69	0.89	0.72	0.61	0.41	0.74
Daily Measurable Median	0.15	0.21	0.29	0.26	0.26	0.09	0.27
Daily Measurable 25th Percentile	0.03	0.14	0.21	0.14	0.10	0.02	0.13
Daily Measurable Minimum	0.02	0.07	0.051	0.044	0.04	0.01	0.09846
Percent of Hours with Measurable Precipitation	8%	9%	7%	8%	9%	9%	5%
Hourly Measurable Max	0.395	0.684	1.132	1.042	0.594	0.916	0.886
Hourly Measurable 75th Percentile	0.177	0.130	0.205	0.191	0.125	0.122	0.213
Hourly Measurable Average	0.109	0.122	0.171	0.144	0.112	0.097	0.191
Hourly Measurable Median	0.074	0.053	0.072	0.081	0.066	0.031	0.114
Hourly Measurable 25th Percentile	0.017	0.012	0.014	0.033	0.017	0.010	0.098
Hourly Measurable Minimum	0.007	0.005	0.006	0.006	0.005	0.006	0.09846
WDM DSN ID	**81**	**91**	**101**	**111**	**121**	**139**	**141**
Location	**MN215204**	**MN215482**	**MN215563**	**MN216152**	**MN218429**	**MN219004**	**SD390422**
Acres	55,179	78,973	102,274	57,466	41,619	83,951	42,123
Monthly Total Precipitation (in)	8.40	4.22	6.69	6.35	8.75	7.05	7.30
Percent of Days with Measureable Precipitation	33%	40%	43%	30%	43%	40%	33%
Daily Measurable Max	4.13	0.99	2.32	3.06	3.79	2.92	2.51
Daily Measurable 75th Percentile	0.50	0.50	0.59	0.45	0.67	0.45	1.20
Daily Measurable Average	0.84	0.35	0.51	0.71	0.67	0.59	0.73
Daily Measurable Median	0.26	0.26	0.20	0.41	0.28	0.30	0.26
Daily Measurable 25th Percentile	0.21	0.09	0.12	0.11	0.08	0.10	0.10
Daily Measurable Minimum	0.02	0.02	0.02	0.03	0.02	0.01	0.02

WDM DSN ID	**81**	**91**	**101**	**111**	**121**	**139**	**141**
Location	**MN215204**	**MN215482**	**MN215563**	**MN216152**	**MN218429**	**MN219004**	**SD390422**
Percent of Hours with Measurable Precipitation	7%	6%	8%	9%	8%	8%	7%
Hourly Measurable Max	1.021	0.790	0.361	0.533	0.907	0.705	0.539
Hourly Measurable 75th Percentile	0.213	0.117	0.179	0.113	0.197	0.135	0.201
Hourly Measurable Average	0.162	0.103	0.124	0.101	0.148	0.128	0.152
Hourly Measurable Median	0.105	0.091	0.104	0.052	0.099	0.100	0.108
Hourly Measurable 25th Percentile	0.070	0.037	0.062	0.016	0.047	0.067	0.099
Hourly Measurable Minimum	0.011	0.006	0.01	0.007	0.01	0.01	0.005

Table 18. September 2010 Precipitation Analysis for Hawk-Yellow Medicine

WDM DSN ID	**21**	**22**	**23**	**24**	**25**	**27**	**71**
Location	**S270**	**S297**	**S302**	**S329**	**S253**	**S341**	**MN213311**
Acres	69,095	67,750	57,672	172,395	138,845	142,410	214,692
Monthly Total Precipitation (in)	8.01	8.17	10.24	7.30	9.54	6.87	8.77
Percent of Days with Measureable Precipitation	47%	37%	33%	30%	47%	33%	30%
Daily Measurable Max	1.85	3.26	2.94	2.43	2.35	1.98	2.49
Daily Measurable 75th Percentile	0.90	0.76	1.64	1.37	1.16	1.12	0.88
Daily Measurable Average	0.57	0.74	1.02	0.81	0.68	0.69	0.97
Daily Measurable Median	0.44	0.44	0.59	0.20	0.32	0.33	0.74
Daily Measurable 25th Percentile	0.21	0.31	0.35	0.20	0.06	0.20	0.50
Daily Measurable Minimum	0.014	0.14	0.145	0.087	0.015	0.003	0.19
Percent of Hours with Measurable Precipitation	13%	9%	7%	5%	10%	7%	7%
Hourly Measurable Max	0.745	0.812	1.655	0.958	1.750	1.873	2.355
Hourly Measurable 75th Percentile	0.070	0.116	0.179	0.251	0.140	0.125	0.155
Hourly Measurable Average	0.085	0.120	0.197	0.187	0.136	0.146	0.165
Hourly Measurable Median	0.037	0.050	0.081	0.087	0.050	0.057	0.065
Hourly Measurable 25th Percentile	0.019	0.017	0.030	0.032	0.015	0.015	0.026
Hourly Measurable Minimum	0.007	0.003	0.004	0.006	0.006	0.003	0.006

WDM DSN ID	**81**	**91**	**101**	**111**	**121**	**139**	**141**
Location	**MN215204**	**MN215482**	**MN215563**	**MN216152**	**MN218429**	**MN219004**	**SD390422**
Acres	55,179	78,973	102,274	57,466	41,619	83,951	42,123
Monthly Total Precipitation (in)	13.05	12.18	7.64	8.11	10.72	5.47	13.04
Percent of Days with Measureable Precipitation	50%	33%	47%	40%	40%	57%	33%
Daily Measurable Max	3.61	3.45	2.30	2.95	2.63	1.99	5.40
Daily Measurable 75th Percentile	1.69	1.84	0.74	0.66	1.92	0.29	1.18
Daily Measurable Average	0.87	1.22	0.55	0.68	0.89	0.32	1.30
Daily Measurable Median	0.17	0.97	0.28	0.18	0.45	0.04	0.63
Daily Measurable 25th Percentile	0.06	0.36	0.03	0.11	0.10	0.01	0.19
Daily Measurable Minimum	0.002	0.016	0.002	0.002	0.007	0.002	0.043
WDM DSN ID	**81**	**91**	**101**	**111**	**121**	**139**	**141**
Location	**MN215204**	**MN215482**	**MN215563**	**MN216152**	**MN218429**	**MN219004**	**SD390422**
Percent of Hours with Measurable Precipitation	12%	8%	11%	10%	12%	15%	9%
Hourly Measurable Max	2.688	1.898	1.237	0.952	1.255	0.619	2.576
Hourly Measurable 75th Percentile	0.168	0.183	0.068	0.129	0.179	0.054	0.187
Hourly Measurable Average	0.150	0.221	0.099	0.113	0.128	0.051	0.195
Hourly Measurable Median	0.059	0.072	0.046	0.042	0.041	0.009	0.062
Hourly Measurable 25th Percentile	0.015	0.034	0.023	0.014	0.018	0.002	0.029
Hourly Measurable Minimum	0.002	0.007	0.002	0.002	0.006	0.001	0.002

3.4 COTTONWOOD (07020008)

Cottonwood has eight high sediment loading months. Figure 9 shows that 50% of the high sediment loading months occur in a 16-month period between March 2010 and June 2011. Figure 10 identifies the overall highest sediment loading months as April through June with those three months contributing 71% of the sediment load during the simulation.

Table 19 shows that the individual highest sediment loading month is April 2001 and Table 20 shows the individual monthly loads and the unit area export for the upstream drainage area. The eight highest sediment loading months account for approximately 42% of the sediment load delivered in an 18-year period but account for only about 24% of the volume of water delivered in the same 18-year period. Surface outflow shows high variability but when monthly precipitation is greater than about 6 inches then surface outflow is greater than 11% of the volume of water running off the land. Area-weighted monthly precipitation values range from about 1.5 inches to about 11 inches and the area-weighted monthly largest 24-hour storms range from approximately 0.6 inches to 3.8 inches. The high sediment loading months associated with March and April have snowmelt released to the land with March 2010 and March 2011 having significant amounts of snowmelt.

Table 21 shows that April 2001, September 2010, June 2011, and May 2012 (monthly precipitation greater than about 6 inches and surface outflow greater than 11%) have upland contributions around 30% from the upland but the sediment sources are still primarily bluff and stream.

Table 22 shows that monthly total precipitation for April 2001 ranges from 6.13 inches/month to 9.03 inches/month and Table 23 shows that June 2004 ranges from 2.76 inches/month to 5.88 inches/month. Both months show moderate frequency of daily measurable rainfall (ranging from 17% to 60%) indicating likely moderate soil moisture content and reduced infiltration capacity. Both months also show large daily maxima for each station (18% to 64% of monthly total) and daily averages much greater than the daily median and occasionally above the daily 75th percentile. Additionally, hourly statistics show very intense hourly precipitation maxima (5% to 43% of monthly total) with hourly averages much greater than the hourly median. These results indicate that the rain came in infrequent (less than 2-3 times per month), short duration, but intense storms.

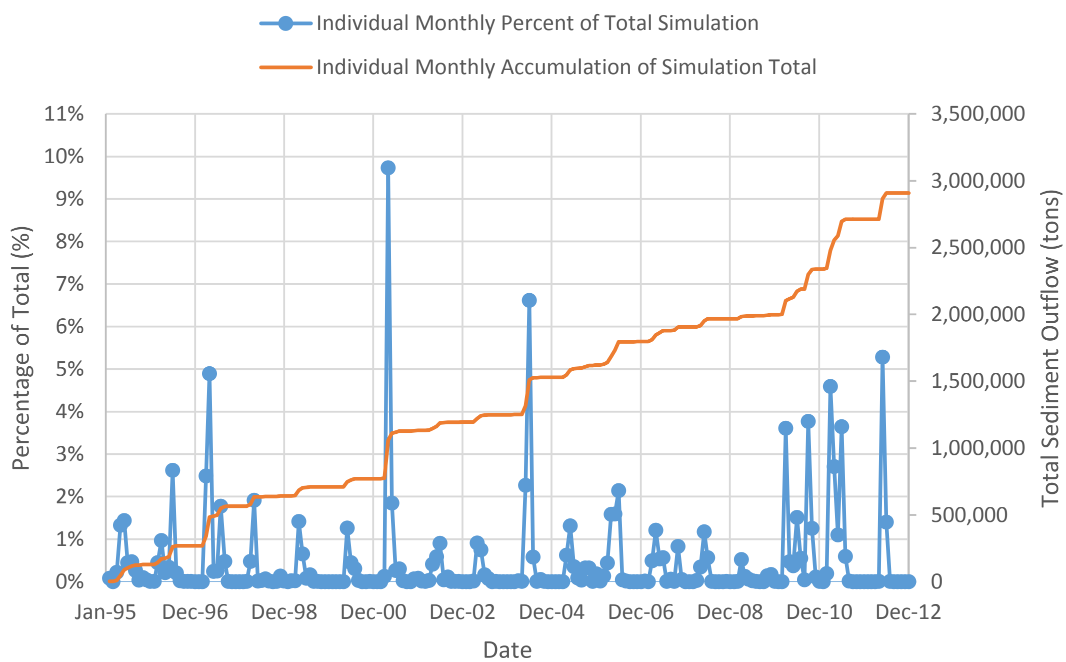

Figure 9. Monthly Sediment Export Percent of Total Simulation and Accumulation for Cottonwood at HUC8 Outlet

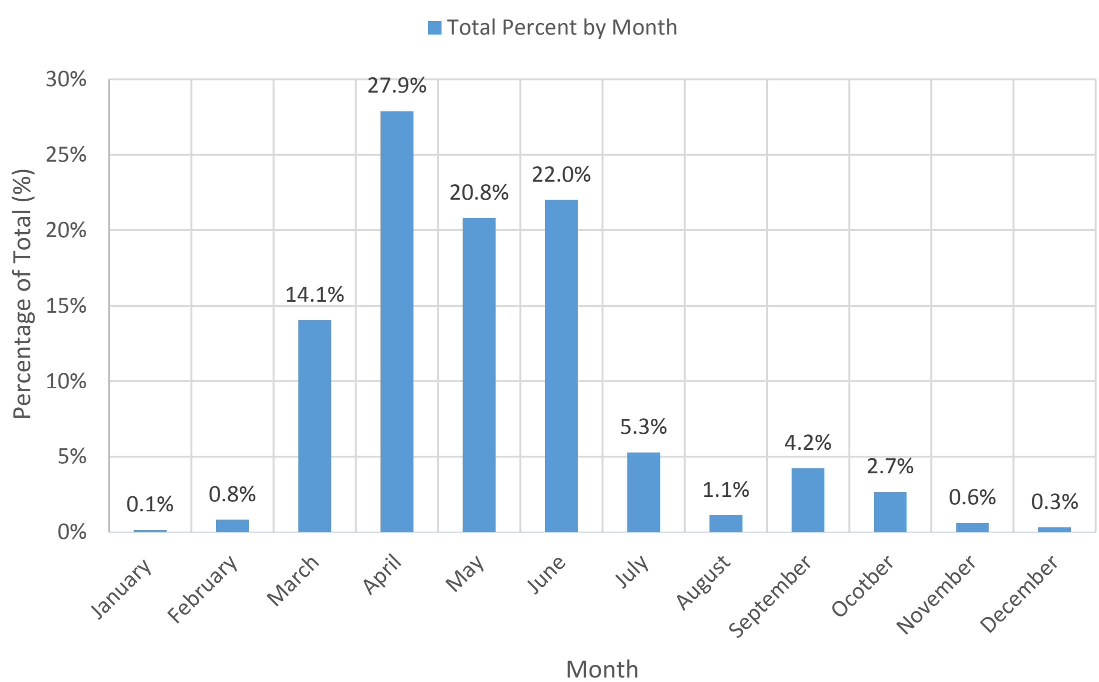

Figure 10. Total Percent by Month for Cottonwood at HUC8 Outlet

Table 19. High Sediment Loading Months Statistical Summary for Cottonwood at HUC8 Outlet

High Sediment Load Month and Year	Sediment Export Percent of simulation total (%)	Volume Export Percent of simulation total (%)	Surface Percent of monthly outflow (%)	Interflow Percent of monthly outflow (%)	Baseflow Percent of monthly outflow (%)	Snowpack water yield compared to total land outflow (%)	Area-weighted monthly precipitation (in)	Area-weighted daily maximum precipitation (in)
April 1997	4.9%	3.3%	1.1%	25.9%	73.0%	21.1%	1.99	1.10
April 2001	9.7%	5.3%	11.4%	41.1%	47.5%	48.2%	7.76	3.19
June 2004	6.6%	2.8%	6.9%	31.7%	61.3%	0.0%	4.68	1.91
March 2010	3.6%	2.6%	2.6%	28.8%	68.6%	197.9%	1.40	0.67
September 2010	3.8%	1.9%	19.0%	45.9%	35.1%	0.0%	10.59	3.80
March 2011	4.6%	3.3%	4.0%	34.6%	61.4%	147.6%	2.12	1.47
June 2011	3.6%	2.1%	11.4%	43.0%	45.6%	0.0%	6.05	3.07
May 2012	5.3%	2.6%	16.3%	43.2%	40.5%	0.0%	10.14	2.16
Average	5.3%	3.0%	9.1%	36.8%	54.1%	51.8%	5.59	2.17

Table 20. High Sediment Loading Months Load Summary for Cottonwood at HUC8 Outlet

High Sediment Load Month and Year	Sediment Load (ton/month)	Sediment Yield (ton/acre/month)
April 1997	142,270	0.169
April 2001	282,920	0.337
June 2004	192,360	0.229
March 2010	104,950	0.125
September 2010	109,640	0.131
March 2011	133,450	0.159
June 2011	106,080	0.126
May 2012	153,620	0.183
Average	153,161	0.182

Table 21. High Sediment Loading Months Source Attribution for Cottonwood at HUC8 Outlet

High Sediment Load Month and Year	Upland	Tile Drain	Ravine	Bluff	Stream
April 1997	0.7%	0.7%	0.0%	59.6%	39.0%
April 2001	26.2%	1.7%	0.9%	43.1%	28.1%
June 2004	11.3%	0.5%	0.6%	47.9%	39.8%
March 2010	3.3%	1.1%	0.0%	55.2%	40.3%
September 2010	38.9%	1.6%	1.3%	33.6%	24.5%
March 2011	5.6%	1.3%	0.1%	52.6%	40.5%

High Sediment Load Month and Year	Upland	Tile Drain	Ravine	Bluff	Stream
June 2011	30.4%	1.9%	0.7%	43.1%	24.0%
May 2012	47.1%	1.5%	2.1%	32.7%	16.7%
Average	20.4%	1.3%	0.7%	46.0%	31.6%

Table 22. April 2001 Precipitation Analysis for Cottonwood

WDM DSN ID	110	310	510	710	910	1310	1510
Location	MN216835	SWCD502	MN218232	SWCD100	SWCD78	SWCD508	MN214546
Acres	17,420	15,725	80,536	43,117	50,587	26,727	56,246
Monthly Total Precipitation (in)	7.55	8.18	9.03	7.69	7.44	6.74	8.88
Percent of Days with Measureable Precipitation	43%	17%	40%	37%	47%	23%	47%
Daily Measurable Max	3.25	5.25	4.57	3.55	3.53	3.50	3.41
Daily Measurable 75th Percentile	0.31	2.00	0.52	0.57	0.59	1.08	0.75
Daily Measurable Average	0.58	1.64	0.75	0.70	0.53	0.96	0.63
Daily Measurable Median	0.17	0.55	0.20	0.25	0.18	0.44	0.27
Daily Measurable 25th Percentile	0.10	0.20	0.19	0.24	0.06	0.27	0.19
Daily Measurable Minimum	0.01	0.18	0.079	0.176	0.002	0.1	0.03
Percent of Hours with Measurable Precipitation	7%	4%	6%	7%	6%	4%	9%
Hourly Measurable Max	0.825	1.292	0.943	0.880	0.876	1.326	0.930
Hourly Measurable 75th Percentile	0.216	0.256	0.291	0.183	0.292	0.186	0.187
Hourly Measurable Average	0.148	0.264	0.220	0.151	0.165	0.217	0.139
Hourly Measurable Median	0.102	0.113	0.115	0.098	0.117	0.103	0.095
Hourly Measurable 25th Percentile	0.052	0.088	0.097	0.078	0.020	0.055	0.030
Hourly Measurable Minimum	0.005	0.005	0.02	0.01	0.002	0.007	0.006
WDM DSN ID	**1710**	**1910**	**2110**	**2310**	**2510**	**2710**	**2910**
Location	**SWCD94**	**SWCD101**	**SWCD838**	**SWCD1184**	**SWCD1182**	**SWCD837**	**SWCD506**
Acres	31,065	39,659	38,531	20,434	16,903	31,761	70,126
Monthly Total Precipitation (in)	6.89	7.11	7.56	6.75	7.58	7.25	8.18
Percent of Days with Measureable Precipitation	40%	40%	37%	47%	40%	37%	37%
Daily Measurable Max	3.31	3.31	3.87	2.50	2.23	3.26	3.60
Daily Measurable 75th Percentile	0.60	0.62	0.57	0.59	0.71	0.68	0.76
Daily Measurable Average	0.57	0.59	0.69	0.48	0.63	0.66	0.74
Daily Measurable Median	0.22	0.33	0.26	0.16	0.39	0.27	0.23
Daily Measurable 25th Percentile	0.15	0.15	0.13	0.06	0.24	0.19	0.13
Daily Measurable Minimum	0.009	0.042	0.002	0.002	0.081	0.055	0.024

WDM DSN ID	1710	1910	2110	2310	2510	2710	2910
Location	**SWCD94**	**SWCD101**	**SWCD838**	**SWCD1184**	**SWCD1182**	**SWCD837**	**SWCD506**
Percent of Hours with Measurable Precipitation	8%	8%	7%	7%	7%	8%	7%
Hourly Measurable Max	0.499	0.953	0.983	0.480	0.560	0.828	0.883
Hourly Measurable 75th Percentile	0.182	0.150	0.213	0.194	0.214	0.193	0.221
Hourly Measurable Average	0.123	0.125	0.154	0.141	0.158	0.129	0.154
Hourly Measurable Median	0.097	0.081	0.071	0.112	0.112	0.072	0.113
Hourly Measurable 25th Percentile	0.036	0.030	0.060	0.077	0.089	0.029	0.080
Hourly Measurable Minimum	0.007	0.006	0.002	0.002	0.009	0.006	0.008
WDM DSN ID	**3310**	**3510**	**3910**	**4110**	**4310**	**4510**	**4910**
Location	**MN215887**	**SWCD1179**	**SWCD1169**	**MN217907**	**SWCD831**	**SWCD1166**	**SWCD95**
Acres	17,520	12,192	47,076	91,564	52,087	2,362	78,146
Monthly Total Precipitation (in)	7.24	8.56	7.23	8.39	6.13	6.78	7.81
Percent of Days with Measureable Precipitation	43%	53%	60%	43%	47%	37%	43%
Daily Measurable Max	1.63	1.58	1.71	2.24	3.16	1.61	3.67
Daily Measurable 75th Percentile	0.84	0.81	0.60	0.86	0.28	1.00	0.62
Daily Measurable Average	0.56	0.53	0.40	0.65	0.44	0.62	0.60
Daily Measurable Median	0.41	0.31	0.23	0.28	0.13	0.39	0.20
Daily Measurable 25th Percentile	0.24	0.15	0.03	0.12	0.05	0.16	0.05
Daily Measurable Minimum	0.02	0.002	0.002	0.01	0.001	0.056	0.02
Percent of Hours with Measurable Precipitation	7%	11%	9%	8%	8%	7%	7%
Hourly Measurable Max	0.532	1.120	0.433	0.460	0.801	0.675	0.930
Hourly Measurable 75th Percentile	0.211	0.100	0.173	0.195	0.120	0.174	0.224
Hourly Measurable Average	0.151	0.107	0.113	0.140	0.114	0.136	0.147
Hourly Measurable Median	0.106	0.029	0.089	0.098	0.060	0.096	0.070
Hourly Measurable 25th Percentile	0.097	0.010	0.033	0.083	0.031	0.087	0.015
Hourly Measurable Minimum	0.01	0.002	0.002	0.006	0.001	0.01	0.002

Table 23. June 2004 Precipitation Analysis for Cottonwood

WDM DSN ID	110	310	510	710	910	1310	1510
Location	MN216835	SWCD502	MN218232	SWCD100	SWCD78	SWCD508	MN214546
Acres	17,420	15,725	80,536	43,117	50,587	26,727	56,246
Monthly Total Precipitation (in)	4.23	5.52	5.65	4.71	4.60	4.75	3.45
Percent of Days with Measureable Precipitation	47%	20%	37%	33%	43%	37%	30%
Daily Measurable Max	2.13	2.10	2.70	1.34	1.91	2.06	1.64
Daily Measurable 75th Percentile	0.09	1.38	0.49	0.46	0.49	0.57	0.47
Daily Measurable Average	0.30	0.92	0.51	0.47	0.35	0.43	0.38
Daily Measurable Median	0.06	0.70	0.42	0.43	0.12	0.15	0.24
Daily Measurable 25th Percentile	0.04	0.34	0.14	0.30	0.03	0.07	0.08
Daily Measurable Minimum	0.01	0.2	0.019	0.06	0.002	0.035	0.01
Percent of Hours with Measurable Precipitation	4%	5%	4%	3%	5%	4%	3%
Hourly Measurable Max	1.253	1.260	1.700	0.700	0.522	2.064	0.684
Hourly Measurable 75th Percentile	0.091	0.141	0.168	0.212	0.206	0.203	0.153
Hourly Measurable Average	0.137	0.162	0.182	0.196	0.124	0.183	0.138
Hourly Measurable Median	0.030	0.088	0.100	0.135	0.089	0.046	0.094
Hourly Measurable 25th Percentile	0.010	0.031	0.060	0.110	0.018	0.023	0.073
Hourly Measurable Minimum	0.003	0.006	0.01	0.06	0.002	0.006	0.005
WDM DSN ID	**1710**	**1910**	**2110**	**2310**	**2510**	**2710**	**2910**
Location	**SWCD94**	**SWCD101**	**SWCD838**	**SWCD1184**	**SWCD1182**	**SWCD837**	**SWCD506**
Acres	31,065	39,659	38,531	20,434	16,903	31,761	70,126
Monthly Total Precipitation (in)	4.00	5.63	3.59	5.88	4.65	5.61	5.56
Percent of Days with Measureable Precipitation	43%	43%	33%	37%	33%	30%	40%
Daily Measurable Max	0.88	2.31	1.63	2.51	2.89	2.46	2.22
Daily Measurable 75th Percentile	0.51	0.46	0.36	0.66	0.33	0.46	0.51
Daily Measurable Average	0.31	0.43	0.36	0.53	0.47	0.62	0.46
Daily Measurable Median	0.20	0.26	0.18	0.10	0.08	0.27	0.31
Daily Measurable 25th Percentile	0.03	0.02	0.06	0.02	0.03	0.16	0.10
Daily Measurable Minimum	0.012	0.006	0.002	0.002	0.005	0.03	0.02

WDM DSN ID	**1710**	**1910**	**2110**	**2310**	**2510**	**2710**	**2910**
Location	**SWCD94**	**SWCD101**	**SWCD838**	**SWCD1184**	**SWCD1182**	**SWCD837**	**SWCD506**
Percent of Hours with Measurable Precipitation	5%	8%	4%	3%	4%	3%	5%
Hourly Measurable Max	0.537	0.634	0.703	1.500	0.891	1.680	1.309
Hourly Measurable 75th Percentile	0.133	0.123	0.120	0.220	0.290	0.270	0.143
Hourly Measurable Average	0.114	0.101	0.133	0.235	0.179	0.224	0.163
Hourly Measurable Median	0.098	0.048	0.062	0.107	0.088	0.153	0.100
Hourly Measurable 25th Percentile	0.024	0.010	0.029	0.034	0.019	0.030	0.043
Hourly Measurable Minimum	0.005	0.006	0.002	0.002	0.003	0.008	0.01
WDM DSN ID	**3310**	**3510**	**3910**	**4110**	**4310**	**4510**	**4910**
Location	**MN215887**	**SWCD1179**	**SWCD1169**	**MN217907**	**SWCD831**	**SWCD1166**	**SWCD95**
Acres	17,520	12,192	47,076	91,564	52,087	2,362	78,146
Monthly Total Precipitation (in)	3.45	4.57	4.35	3.20	3.03	2.76	2.89
Percent of Days with Measureable Precipitation	40%	33%	37%	37%	33%	33%	33%
Daily Measurable Max	1.38	2.99	1.65	1.36	1.52	1.29	1.13
Daily Measurable 75th Percentile	0.39	0.29	0.56	0.32	0.22	0.33	0.33
Daily Measurable Average	0.29	0.46	0.40	0.29	0.30	0.28	0.29
Daily Measurable Median	0.06	0.10	0.15	0.15	0.16	0.14	0.14
Daily Measurable 25th Percentile	0.02	0.04	0.03	0.07	0.12	0.06	0.09
Daily Measurable Minimum	0.003	0.006	0.002	0.01	0.01	0.01	0.032
Percent of Hours with Measurable Precipitation	4%	5%	5%	4%	3%	3%	4%
Hourly Measurable Max	0.774	0.738	0.929	0.406	0.474	0.369	0.453
Hourly Measurable 75th Percentile	0.090	0.204	0.145	0.139	0.151	0.190	0.118
Hourly Measurable Average	0.119	0.138	0.124	0.118	0.121	0.145	0.103
Hourly Measurable Median	0.059	0.053	0.048	0.090	0.098	0.097	0.092
Hourly Measurable 25th Percentile	0.012	0.014	0.021	0.036	0.021	0.064	0.033
Hourly Measurable Minimum	0.001	0.006	0.002	0.005	0.005	0.01	0.008

3.5 WATONWAN (07020010)

Watonwan has six high sediment loading months. Figure 11 shows that 50% of the high sediment loading months occur in a six-month period between March 2010 and September 2010. Figure 12 identifies the overall highest sediment loading months as April and June with those two months contributing about 45% of the sediment load during the simulation. Table 24 shows that the individual highest sediment loading month is September 2010 and Table 25 shows the individual monthly loads and the unit area export for the upstream drainage area. The six highest sediment loading months account for approximately 31% of the sediment load delivered in an 18-year period but account for only about 17% of the volume of water delivered in the same 18-year period. With the exception of March 2010 the six highest sediment loading months have surface outflow greater than approximately 7% of the total land outflow with area-weighted monthly precipitation values more than 7 inches/month and area-weighted largest 24-hour storms greater than 1.9 inches/day. The high sediment loading months associated with March and April have snowmelt released to the land.

Table 26 shows that June 2010 and September 2010 (monthly precipitation greater than about 8 inches and surface outflow greater than 25%) have upland contributions above 65%. The other high sediment loading months have bluff and stream as their primary source of sediment.

Table 27 shows that monthly total precipitation for September 2010 ranges from 8.79 inches/month to 14.17 inches/month and Table 28 shows that April 2001 ranges from 6.48 inches/month to 8.16 inches/month. Both months show moderate to high frequency of daily measurable rainfall (ranging from 29% to 83%) indicating likely moderate to high soil moisture content and reduced infiltration capacity. Both months also show large daily maxima for each station (28% to 30% of monthly total) and daily averages much greater than the daily median and occasionally above the daily 75th percentile. Additionally, hourly statistics show very intense hourly precipitation maxima (6% to 29% of monthly total) with hourly averages much greater than the hourly median. These results indicate that the rain came in infrequent (less than 2-3 times per month), short duration, but intense storms.

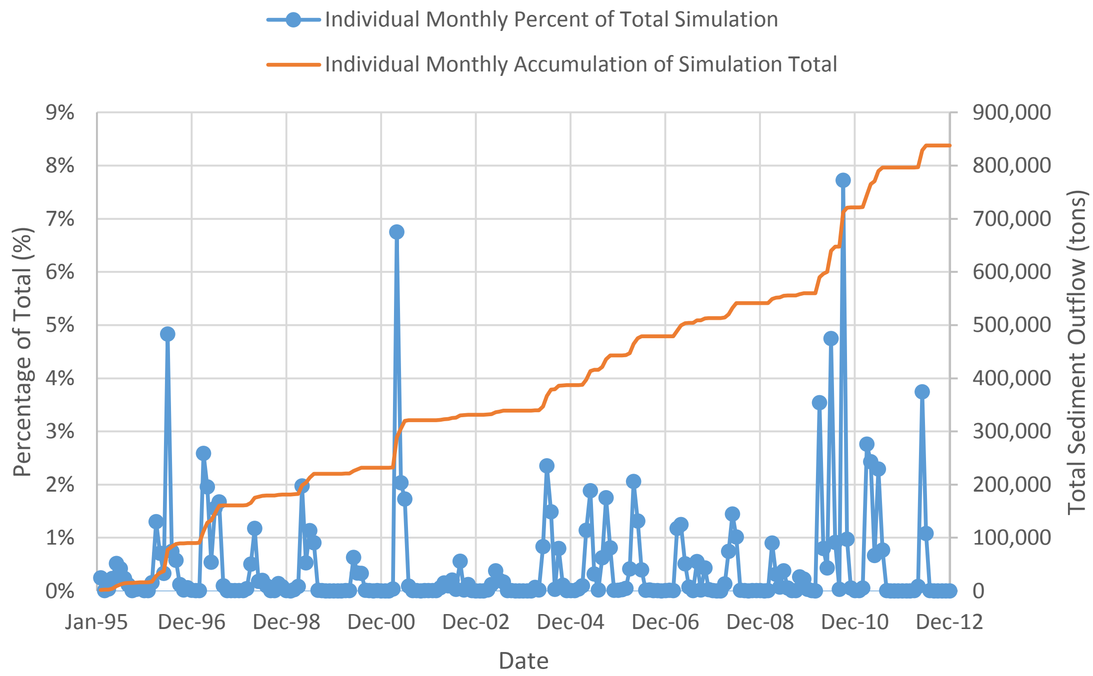

Figure 11. Monthly Sediment Export Percent of Total Simulation and Accumulation for Watonwan at HUC8 Outlet

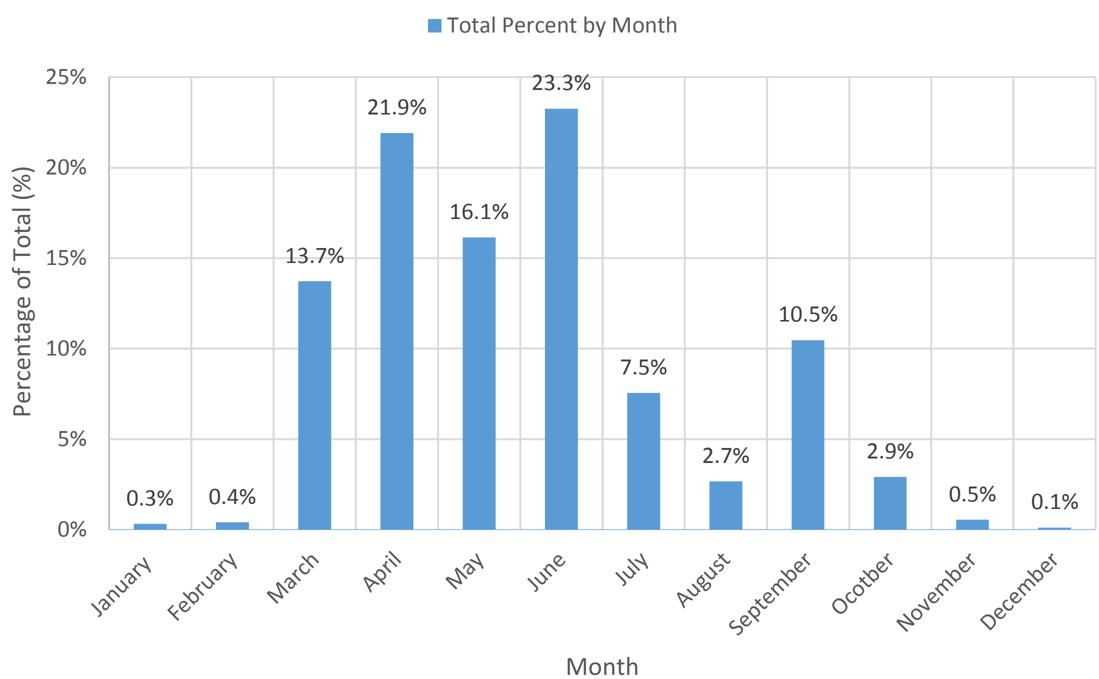

Figure 12. Total Percent by Month for Watonwan at HUC8 Outlet

Table 24. High Sediment Loading Months Statistical Summary for Watonwan at HUC8 Outlet

High Sediment Load Month and Year	Sediment Export Percent of simulation total (%)	Volume Export Percent of simulation total (%)	Surface Percent of monthly outflow (%)	Interflow Percent of monthly outflow (%)	Baseflow Percent of monthly outflow (%)	Snowpack water yield compared to total land outflow (%)	Area-weighted monthly precipitation (in)	Area-weighted daily maximum precipitation (in)
June 1996	4.8%	2.4%	16.6%	49.3%	34.1%	0.0%	6.11	2.89
April 2001	6.8%	4.7%	7.2%	43.9%	48.9%	55.4%	7.13	2.15
March 2010	3.5%	3.0%	2.0%	25.9%	72.1%	188.4%	1.62	0.82
June 2010	4.7%	1.9%	27.8%	39.0%	33.2%	0.0%	8.00	1.89
September 2010	7.7%	3.0%	28.1%	52.8%	19.1%	0.0%	11.43	5.67
May 2012	3.7%	2.4%	11.9%	53.1%	35.0%	0.0%	9.81	2.00
Average	5.2%	2.9%	15.6%	44.0%	40.4%	40.6%	7.35	2.57

Table 25. High Sediment Loading Months Load Summary for Watonwan at HUC8 Outlet

High Sediment Load Month and Year	Sediment Load (ton/month)	Sediment Yield (ton/acre/month)
June 1996	40,494	0.073
April 2001	56,578	0.102
March 2010	29,665	0.053
June 2010	39,749	0.072
Sep 2010	64,725	0.117
May 2012	31,353	0.056
Average	43,761	0.079

Table 26. High Sediment Loading Months Source Attribution for Watonwan at HUC8 Outlet

High Sediment Load Month and Year	Upland	Tile Drain	Ravine	Bluff	Stream
June 1996	44.9%	2.2%	13.6%	33.0%	6.3%
April 2001	13.5%	2.5%	0.5%	55.3%	28.2%
March 2010	1.6%	3.0%	0.0%	59.7%	35.7%
June 2010	75.0%	3.1%	18.3%	23.0%	-19.4%
September 2010	63.0%	2.3%	23.3%	18.4%	-7.1%
May 2012	33.2%	2.8%	2.7%	45.2%	16.1%
Average	38.5%	2.7%	9.7%	39.1%	10.0%

Table 27. September 2010 Precipitation Analysis for Watonwan

WDM DSN ID	**110**	**310**	**510**	**710**	**910**	**1110**	**1310**
Location	**SWCD71**	**SWCD47**	**SWCD1265**	**SWCD1258**	**SWCD604**	**NWS1245**	**SWCD1225**
Acres	45,027	38,141	70,014	32,255	25,522	59,982	32,525
Monthly Total Precipitation (in)	11.99	9.14	10.07	10.53	13.49	13.40	14.17
Percent of Days with Measureable Precipitation	43%	13%	37%	27%	40%	37%	30%
Daily Measurable Max	5.70	7.58	3.29	4.07	8.32	7.48	8.40
Daily Measurable 75th Percentile	0.71	2.91	1.15	1.71	0.64	0.84	1.39
Daily Measurable Average	0.92	2.29	0.92	1.32	1.12	1.22	1.57
Daily Measurable Median	0.17	0.78	0.23	0.73	0.51	0.28	0.21
Daily Measurable 25th Percentile	0.07	0.15	0.11	0.23	0.05	0.06	0.18
Daily Measurable Minimum	0.002	0.007	0.002	0.05	0.002	0.001	0.01
Percent of Hours with Measurable Precipitation	10%	4%	10%	7%	11%	8%	7%
Hourly Measurable Max	1.782	1.868	1.328	2.768	2.004	2.512	2.570
Hourly Measurable 75th Percentile	0.160	0.333	0.153	0.156	0.117	0.246	0.281
Hourly Measurable Average	0.174	0.352	0.146	0.215	0.175	0.220	0.295
Hourly Measurable Median	0.079	0.075	0.075	0.092	0.051	0.086	0.095
Hourly Measurable 25th Percentile	0.011	0.031	0.020	0.019	0.009	0.031	0.044
Hourly Measurable Minimum	0.002	0.005	0.001	0.002	0.001	0.001	0.004
WDM DSN ID	**1510**	**1710**	**1910**	**2110**	**2310**	**2510**	
Location	**SWCD82**	**SWCD1259**	**SWCD598**	**SWCD1228**	**SWCD591**	**SWCD912**	
Acres	16,896	48,332	43,578	99,528	4,515	39,062	
Monthly Total Precipitation (in)	10.85	8.79	9.82	12.00	13.20	13.24	
Percent of Days with Measureable Precipitation	33%	47%	40%	33%	47%	33%	
Daily Measurable Max	7.02	3.69	2.87	7.48	4.90	5.56	
Daily Measurable 75th Percentile	0.90	0.78	1.76	0.59	1.62	0.88	
Daily Measurable Average	1.09	0.63	0.82	1.20	0.94	1.32	
Daily Measurable Median	0.37	0.12	0.19	0.43	0.13	0.56	
Daily Measurable 25th Percentile	0.04	0.01	0.03	0.19	0.02	0.09	
Daily Measurable Minimum	0.006	0.002	0.018	0.02	0.01	0.002	

WDM DSN ID	1510	1710	1910	2110	2310	2510
Location	SWCD82	SWCD1259	SWCD598	SWCD1228	SWCD591	SWCD912
Percent of Hours with Measurable Precipitation	8%	10%	9%	9%	11%	7%
Hourly Measurable Max	1.648	1.931	1.554	3.067	1.502	3.903
Hourly Measurable 75th Percentile	0.197	0.136	0.148	0.186	0.184	0.196
Hourly Measurable Average	0.190	0.120	0.144	0.190	0.163	0.265
Hourly Measurable Median	0.053	0.050	0.060	0.088	0.067	0.075
Hourly Measurable 25th Percentile	0.009	0.010	0.011	0.038	0.012	0.030
Hourly Measurable Minimum	0.001	0.001	0.003	0.007	0.001	0.002

Table 28. April 2001 Precipitation Analysis for Watonwan

WDM DSN ID	110	310	510	710	910	1110	1310
Location	SWCD71	SWCD47	SWCD1265	SWCD1258	SWCD604	NWS1245	SWCD1225
Acres	45,026.6	38,141.2	70,014.4	32,255.3	25,522.3	59,982.1	32,524.8
Monthly Total Precipitation (in)	6.63	7.61	7.98	6.48	7.384	7.21	6.92
Percent of Days with Measureable Precipitation	47%	43%	37%	57%	43%	47%	40%
Daily Measurable Max	2.04	2.52	2.72	1.53	2.47	1.71	2.40
Daily Measurable 75th Percentile	0.54	0.75	0.85	0.58	0.71	0.72	0.79
Daily Measurable Average	0.47	0.59	0.73	0.38	0.57	0.52	0.58
Daily Measurable Median	0.21	0.23	0.42	0.23	0.35	0.26	0.22
Daily Measurable 25th Percentile	0.12	0.18	0.25	0.05	0.18	0.14	0.07
Daily Measurable Minimum	0.03	0.05	0.15	0.00	0.00	0.05	0.00
Percent of Hours with Measurable Precipitation	9%	7%	8%	8%	7%	9%	7%
Hourly Measurable Max	0.42	0.54	0.83	0.51	0.48	0.43	0.53
Hourly Measurable 75th Percentile	0.15	0.21	0.22	0.15	0.21	0.12	0.18
Hourly Measurable Average	0.10	0.15	0.15	0.11	0.14	0.11	0.14
Hourly Measurable Median	0.08	0.11	0.10	0.08	0.10	0.08	0.09
Hourly Measurable 25th Percentile	0.03	0.08	0.04	0.03	0.06	0.03	0.01
Hourly Measurable Minimum	0.00	0.01	0.01	0.00	0.00	0.01	0.00

WDM DSN ID	1510	1710	1910	2110	2310	2510
Location	**SWCD82**	**SWCD1259**	**SWCD598**	**SWCD1228**	**SWCD591**	**SWCD912**
Acres	16,895.8	48,332.2	43,577.6	99,527.7	4,515.1	39,061.9
Monthly Total Precipitation (in)	8.16	7.266	6.835	6.5	6.77	7.131
Percent of Days with Measureable Precipitation	37%	57%	33%	30%	47%	33%
Daily Measurable Max	3.00	2.41	2.14	2.14	2.22	1.57
Daily Measurable 75th Percentile	0.66	0.35	1.00	1.30	0.59	1.06
Daily Measurable Average	0.74	0.43	0.68	0.72	0.48	0.71
Daily Measurable Median	0.39	0.26	0.51	0.46	0.26	0.74
Daily Measurable 25th Percentile	0.24	0.02	0.17	0.16	0.11	0.14
Daily Measurable Minimum	0.10	0.00	0.05	0.06	0.01	0.05
WDM DSN ID	**1510**	**1710**	**1910**	**2110**	**2310**	**2510**
Location	**SWCD82**	**SWCD1259**	**SWCD598**	**SWCD1228**	**SWCD591**	**SWCD912**
Percent of Hours with Measurable Precipitation	7%	9%	6%	8%	7%	9%
Hourly Measurable Max	0.57	0.44	0.85	0.55	0.61	0.50
Hourly Measurable 75th Percentile	0.21	0.15	0.21	0.16	0.16	0.17
Hourly Measurable Average	0.16	0.11	0.16	0.11	0.13	0.12
Hourly Measurable Median	0.10	0.09	0.10	0.06	0.10	0.05
Hourly Measurable 25th Percentile	0.06	0.03	0.04	0.02	0.04	0.02
Hourly Measurable Minimum	0.00	0.00	0.01	0.01	0.01	0.01

3.6 LE SUEUR (07020011)

Le Sueur has six high sediment loading months. Figure 13 shows that 33% of the high sediment loading months occur in a three-month period between April 2001 and June 2001. Figure 14 identifies the overall highest sediment loading months as April through June with those three months contributing 58% of the sediment load during the simulation. Table 29 shows that the individual highest sediment loading month is September 2010 and Table 30 shows the individual monthly loads and the unit area export for the upstream drainage area. The six highest sediment loading months account for approximately 27% of the sediment load delivered in an 18-year period but account for only about 14% of the volume of water delivered in the same 18-year period. With the exception of April 2001 the six highest sediment loading months have surface outflow greater than approximately 16% of the total land outflow with area-weighted monthly precipitation values more than 5 inches/month and area-weighted largest 24-hour storms greater than 2.1 inches/day. Additionally, April 2001 has area-weighted monthly precipitation more than 5.5 inches but area-weighted largest 24-hour storms at 1.6 inches/day which resulted in only 9.4% surface runoff. The high sediment loading months associated with April have snowmelt released to the land.

Table 31 shows that ravine, bluff, and/or stream is the primary source of sediment for the LeSueur watershed. Note that ravines are defined as a distinct land use only in the LeSueur model, although the other models do account for some ravine erosion from crop land.

Table 32 shows that monthly total precipitation for September 2010 ranges from 5.93 inches/month to 14.84 inches/month and Table 33 shows that April 2001 ranges from 1.6 inches/month to 8.3 inches/month. Both months show moderate to high frequency of daily measurable rainfall (ranging from 26% to 80%) indicating likely moderate to high soil moisture content and reduced infiltration capacity. Both months also show large daily maxima for each station (6% to 33% of monthly total) and daily averages much greater than the daily median and occasionally above the daily 75th percentile. Additionally, hourly statistics show very intense hourly precipitation maxima (6% to 23% of monthly total) with hourly averages much greater than the hourly median. These results indicate that the rain came in infrequent (less than 2-3 times per month), short duration, but intense storms.

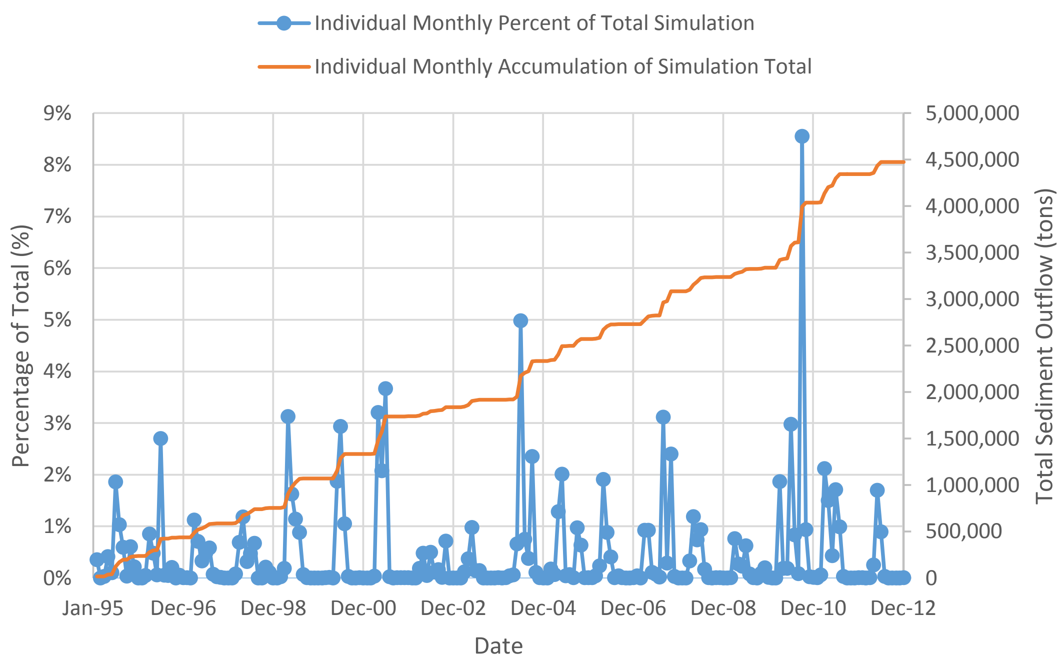

Figure 13. Monthly Sediment Export Percent of Total Simulation and Accumulation for Le Sueur at HUC8 Outlet

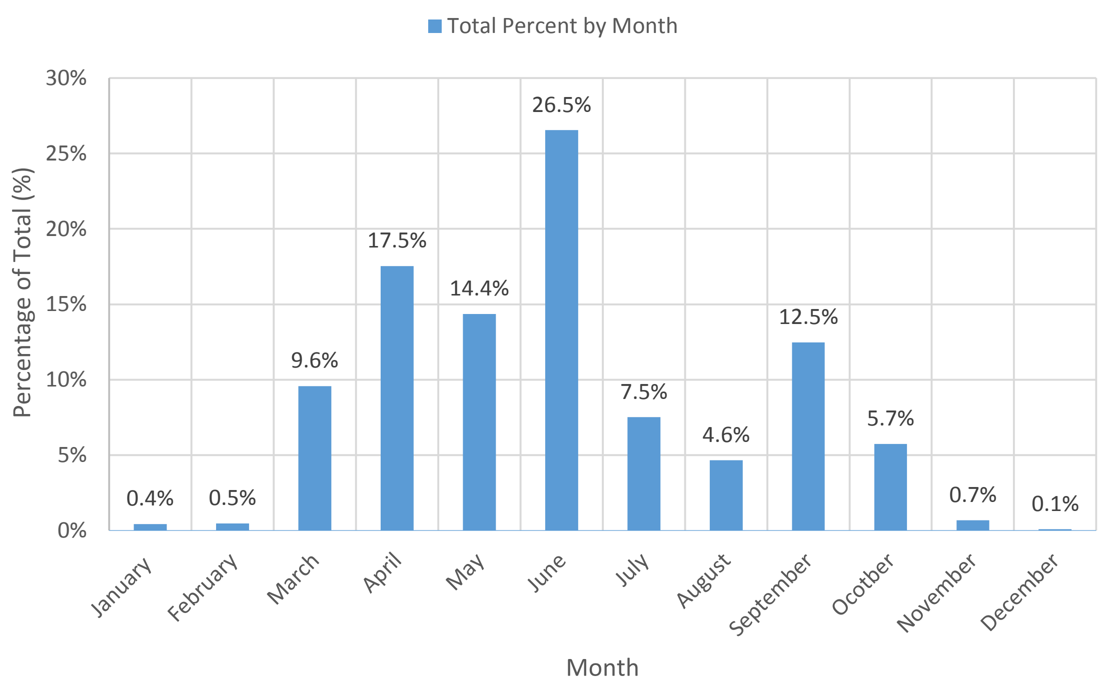

Figure 14. Total Percent by Month for Le Sueur at HUC8 Outlet

Table 29. High Sediment Loading Months Statistical Summary for Le Sueur at HUC8 Outlet

High Sediment Load Month and Year	Sediment Export Percent of simulation total (%)	Volume Export Percent of simulation total (%)	Surface Percent of monthly outflow (%)	Interflow Percent of monthly outflow (%)	Baseflow Percent of monthly outflow (%)	Snowpack water yield compared to total land outflow (%)	Area-weighted monthly precipitation (in)	Area-weighted daily maximum precipitation (in)
April 1999	3.1%	2.5%	16.1%	55.7%	28.2%	0.8%	6.95	2.10
April 2001	3.2%	3.0%	9.4%	49.7%	40.9%	50.9%	5.52	1.60
June 2001	3.7%	2.2%	29.0%	48.4%	22.6%	0.0%	6.13	2.85
June 2004	5.0%	1.8%	26.8%	46.2%	27.0%	0.0%	5.11	2.65
August 2007	3.1%	1.1%	15.9%	46.6%	37.5%	0.0%	9.80	4.38
September 2010	8.6%	3.3%	35.7%	47.5%	16.8%	0.0%	12.32	5.75
Average	4.4%	2.3%	22.2%	49.0%	28.8%	8.6%	7.64	3.22

Table 30. High Sediment Loading Months Load Summary for Le Sueur at HUC8 Outlet

High Sediment Load Month and Year	Sediment Load (ton/month)	Sediment Yield (ton/acre/month)
April 1999	139,830	0.200
April 2001	143,370	0.205
June 2001	164,180	0.235
June 2004	223,000	0.319
August 2007	139,460	0.200
September 2010	382,800	0.548
Average	198,773	0.284

Table 31. High Sediment Loading Months Source Attribution for Le Sueur at HUC8 Outlet

High Sediment Load Month and Year	Upland	Tile Drain	Ravine	Bluff	Stream
April 1999	25.2%	1.1%	2.0%	61.6%	10.0%
April 2001	13.3%	1.1%	0.7%	71.9%	12.9%
June 2001	39.2%	0.9%	6.5%	49.3%	4.2%
June 2004	31.8%	0.9%	52.0%	16.9%	-1.6%
August 2007	6.8%	0.2%	65.6%	20.9%	6.5%
September 2010	31.2%	1.4%	41.2%	25.4%	0.9%
Average	24.6%	0.9%	28.0%	41.0%	5.5%

Table 32. September 2010 Precipitation Analysis for Le Sueur

WDM DSN ID	**110**	**310**	**510**	**710**	**910**	**1110**	**1310**
Location	**SWCD246**	**SWCD1124**	**MN218692**	**SWCD1200**	**SWCD1211**	**SWCD1214**	**SWCD966**
Acres	60,421.6	34,928.2	22,596.4	86,552.8	45,772.7	13,974.6	31,578.3
Monthly Total Precipitation (in)	12.75	12.892	11.741	13.174	14.84	12.463	12.37
Percent of Days with Measureable Precipitation	30%	50%	50%	47%	43%	47%	43%
Daily Measurable Max	8.67	4.58	3.97	5.55	5.00	3.76	3.24
Daily Measurable 75th Percentile	0.76	0.54	0.72	0.63	1.95	1.16	1.38
Daily Measurable Average	1.42	0.86	0.78	0.94	1.14	0.89	0.95
Daily Measurable Median	0.52	0.14	0.17	0.22	0.60	0.42	0.20
Daily Measurable 25th Percentile	0.13	0.03	0.02	0.02	0.35	0.02	0.07
Daily Measurable Minimum	0.02	0.00	0.00	0.01	0.06	0.00	0.00
Percent of Hours with Measurable Precipitation	7%	11%	11%	10%	13%	10%	9%
Hourly Measurable Max	3.63	1.40	1.08	1.51	0.89	0.84	1.37
Hourly Measurable 75th Percentile	0.12	0.22	0.21	0.26	0.21	0.22	0.23
Hourly Measurable Average	0.27	0.17	0.15	0.19	0.16	0.17	0.18
Hourly Measurable Median	0.05	0.06	0.06	0.09	0.07	0.13	0.06
Hourly Measurable 25th Percentile	0.01	0.02	0.02	0.02	0.03	0.03	0.03
Hourly Measurable Minimum	0.00	0.00	0.00	0.01	0.01	0.00	0.00
WDM DSN ID	**1510**	**1710**	**1910**	**2110**	**2310**	**2510**	
Location	**MN218808**	**SWCD179**	**SWCD253**	**SWCD967**	**SWCD906**	**SWCD199**	
Acres	27,947.9	22,636.0	44,610.9	6,313.3	69,239.3	48,187.2	
Monthly Total Precipitation (in)	11.294	10.45	12.684	8.95	12.624	13.398	
Percent of Days with Measureable Precipitation	40%	37%	37%	40%	40%	33%	
Daily Measurable Max	5.04	5.88	5.38	2.51	6.38	7.13	
Daily Measurable 75th Percentile	0.98	0.85	0.95	1.18	0.60	0.83	
Daily Measurable Average	0.94	0.95	1.15	0.75	1.05	1.34	
Daily Measurable Median	0.50	0.41	0.36	0.35	0.36	0.47	
Daily Measurable 25th Percentile	0.07	0.17	0.09	0.06	0.04	0.06	
Daily Measurable Minimum	0.00	0.02	0.00	0.01	0.00	0.01	

WDM DSN ID	**1510**	**1710**	**1910**	**2110**	**2310**	**2510**
Location	**MN218808**	**SWCD179**	**SWCD253**	**SWCD967**	**SWCD906**	**SWCD199**
Percent of Hours with Measurable Precipitation	9%	9%	9%	10%	9%	9%
Hourly Measurable Max	2.05	2.41	1.46	0.68	2.88	3.03
Hourly Measurable 75th Percentile	0.21	0.16	0.23	0.16	0.16	0.19
Hourly Measurable Average	0.18	0.16	0.20	0.13	0.19	0.21
Hourly Measurable Median	0.10	0.07	0.11	0.07	0.09	0.05
Hourly Measurable 25th Percentile	0.02	0.04	0.03	0.03	0.02	0.01
Hourly Measurable Minimum	0.00	0.01	0.00	0.01	0.00	0.00
WDM DSN ID	**2710**	**2910**	**3110**	**3310**	**3510**	**3710**
Location	**SWCD929**	**MN215073**	**SWCD185**	**SWCD183**	**SWCD922**	**NWS910**
Acres	76,192.7	27,847.4	13,824.1	27,357.7	21,551.6	17,372.6
Monthly Total Precipitation (in)	12.706	5.93	9.8	10.93	11.302	13.85
Percent of Days with Measureable Precipitation	43%	23%	57%	37%	37%	33%
Daily Measurable Max	7.02	2.16	4.20	4.97	5.48	7.94
Daily Measurable 75th Percentile	0.64	1.28	0.48	0.63	0.57	0.73
Daily Measurable Average	0.98	0.85	0.58	0.99	1.03	1.39
Daily Measurable Median	0.41	0.75	0.18	0.48	0.43	0.47
Daily Measurable 25th Percentile	0.19	0.22	0.01	0.30	0.10	0.30
Daily Measurable Minimum	0.01	0.03	0.01	0.01	0.03	0.11
Percent of Hours with Measurable Precipitation	10%	6%	12%	8%	8%	8%
Hourly Measurable Max	1.73	0.93	1.93	2.02	2.60	3.24
Hourly Measurable 75th Percentile	0.14	0.15	0.10	0.24	0.19	0.24
Hourly Measurable Average	0.17	0.13	0.12	0.20	0.20	0.25
Hourly Measurable Median	0.06	0.07	0.04	0.09	0.07	0.10
Hourly Measurable 25th Percentile	0.01	0.02	0.01	0.03	0.04	0.04
Hourly Measurable Minimum	0.01	0.01	0.00	0.00	0.01	0.00

Table 33. June 2004 Precipitation Analysis for Le Sueur

WDM DSN ID	110	310	510	710	910	1110	1310
Location	**SWCD246**	**SWCD1124**	**MN218692**	**SWCD1200**	**SWCD1211**	**SWCD1214**	**SWCD966**
Acres	60,421.6	34,928.2	22,596.4	86,552.8	45,772.7	13,974.6	31,578.3
Monthly Total Precipitation (in)	5.072	7.99	6.393	3.86	7.097	7.432	7.094
Percent of Days with Measureable Precipitation	37%	37%	33%	33%	27%	40%	47%
Daily Measurable Max	3.10	5.17	2.36	1.91	5.70	4.46	4.34
Daily Measurable 75th Percentile	0.39	0.35	0.74	0.32	0.38	0.41	0.23
Daily Measurable Average	0.46	0.73	0.64	0.39	0.89	0.62	0.51
Daily Measurable Median	0.22	0.26	0.26	0.16	0.22	0.20	0.08
Daily Measurable 25th Percentile	0.04	0.08	0.10	0.11	0.09	0.12	0.04
Daily Measurable Minimum	0.01	0.02	0.01	0.01	0.02	0.00	0.02
Percent of Hours with Measurable Precipitation	6%	6%	5%	5%	4%	5%	6%
Hourly Measurable Max	0.90	1.09	0.79	0.49	1.79	1.06	1.12
Hourly Measurable 75th Percentile	0.09	0.19	0.22	0.14	0.19	0.25	0.14
Hourly Measurable Average	0.12	0.18	0.17	0.11	0.25	0.20	0.16
Hourly Measurable Median	0.05	0.09	0.10	0.08	0.07	0.13	0.04
Hourly Measurable 25th Percentile	0.02	0.02	0.04	0.04	0.03	0.07	0.01
Hourly Measurable Minimum	0.00	0.01	0.01	0.01	0.00	0.00	0.00
WDM DSN ID	**1510**	**1710**	**1910**	**2110**	**2310**	**2510**	
Location	**MN218808**	**SWCD179**	**SWCD253**	**SWCD967**	**SWCD906**	**SWCD199**	
Acres	27,947.9	22,636.0	44,610.9	6,313.3	69,239.3	48,187.2	
Monthly Total Precipitation (in)	3.116	1.618	4.356	8.229	3.104	4.494	
Percent of Days with Measureable Precipitation	33%	27%	47%	40%	33%	40%	
Daily Measurable Max	1.43	0.53	2.41	5.68	1.29	1.78	
Daily Measurable 75th Percentile	0.24	0.25	0.24	0.37	0.31	0.22	
Daily Measurable Average	0.31	0.20	0.31	0.69	0.31	0.37	
Daily Measurable Median	0.20	0.20	0.15	0.18	0.17	0.13	
Daily Measurable 25th Percentile	0.11	0.07	0.07	0.03	0.12	0.10	
Daily Measurable Minimum	0.03	0.00	0.00	0.01	0.06	0.03	

WDM DSN ID	1510	1710	1910	2110	2310	2510
Location	**MN218808**	**SWCD179**	**SWCD253**	**SWCD967**	**SWCD906**	**SWCD199**
Percent of Hours with Measurable Precipitation	4%	2%	4%	5%	4%	4%
Hourly Measurable Max	0.35	0.53	0.74	1.72	0.30	0.93
Hourly Measurable 75th Percentile	0.14	0.13	0.20	0.22	0.15	0.20
Hourly Measurable Average	0.10	0.12	0.16	0.23	0.11	0.14
Hourly Measurable Median	0.09	0.09	0.10	0.09	0.10	0.09
Hourly Measurable 25th Percentile	0.06	0.04	0.03	0.04	0.03	0.05
Hourly Measurable Minimum	0.01	0.00	0.00	0.01	0.01	0.01
WDM DSN ID	**2710**	**2910**	**3110**	**3310**	**3510**	**3710**
Location	**SWCD929**	**MN215073**	**SWCD185**	**SWCD183**	**SWCD922**	**NWS910**
Acres	76,192.7	27,847.4	13,824.1	27,357.7	21,551.6	17,372.6
Monthly Total Precipitation (in)	5.18	8.334	2.522	2.48	6.14	3.11
Percent of Days with Measureable Precipitation	30%	43%	50%	23%	40%	37%
Daily Measurable Max	2.02	6.36	0.74	0.88	4.06	1.64
Daily Measurable 75th Percentile	0.56	0.25	0.22	0.48	0.22	0.20
Daily Measurable Average	0.58	0.64	0.17	0.35	0.51	0.28
Daily Measurable Median	0.31	0.10	0.06	0.19	0.14	0.13
Daily Measurable 25th Percentile	0.17	0.06	0.04	0.17	0.08	0.09
Daily Measurable Minimum	0.10	0.01	0.00	0.11	0.00	0.05
Percent of Hours with Measurable Precipitation	6%	4%	5%	3%	5%	5%
Hourly Measurable Max	0.55	1.99	0.48	0.55	1.34	0.81
Hourly Measurable 75th Percentile	0.19	0.24	0.09	0.10	0.14	0.09
Hourly Measurable Average	0.13	0.29	0.08	0.11	0.18	0.09
Hourly Measurable Median	0.06	0.10	0.03	0.08	0.05	0.04
Hourly Measurable 25th Percentile	0.03	0.06	0.01	0.02	0.02	0.02
Hourly Measurable Minimum	0.01	0.01	0.00	0.01	0.00	0.01

3.7 BLUE EARTH (07020009)

Blue Earth has five high sediment loading months. Figure 15 shows that 33% of the high sediment loading months occur in a three-month period between April 2001 and June 2001 and another 33% occur in a four-month period between June 2010 and September 2010. Figure 16 identifies the overall highest sediment loading months as April through June with those three months contributing 60.5% of the sediment load during the simulation. Table 34 shows that the individual highest sediment loading month is September 2010 and Table 35 shows the individual monthly loads and the unit area export for the upstream drainage area. With the exception of April 2001 and June 2004 the five highest sediment loading months have surface outflow greater than approximately 16% of the total land outflow with area-weighted monthly precipitation values more than 5.4 inches/month and area-weighted largest 24-hour storms greater than 2.0 inches/day. Additionally, April 2001 has area-weighted monthly precipitation more than 5.5 inches but area-weighted largest 24-hour storms at 2.1 inches/day which resulted in only 6% surface runoff. The high sediment loading months associated with April have snowmelt released to the land.

Table 36 April 2001 has the lowest upland percent source attribution (10.7%). The other 5 months have upland source percentages greater than 25%. June 2010 has the highest upland source percentage (54.9%) but only the second highest surface outflow percentage (21.4%). The results for Blue Earth suggest that high surface percent in June produces more sediment than high surface percent in September.

Table 37 shows that monthly total precipitation for September 2010 ranges from 3.99 inches/month to 14.85 inches/month and Table 38 shows that April 2001 ranges from 3.96 inches/month to 7.38 inches/month. Both months show moderate to high frequency of daily measurable rainfall (ranging from 23% to 57%) indicating likely moderate to high soil moisture content and reduced infiltration capacity. Both months also show large daily maximum for each station (25% to 62% of monthly total) and daily averages much greater than the daily median and occasionally above the daily 75th percentile. Additionally, hourly statistics show very intense hourly precipitation maximum (5% to 29% of monthly total) with hourly averages much greater than the hourly median. These results indicate that the rain came in infrequent (less than 2-3 times per month), short duration, but intense storms.

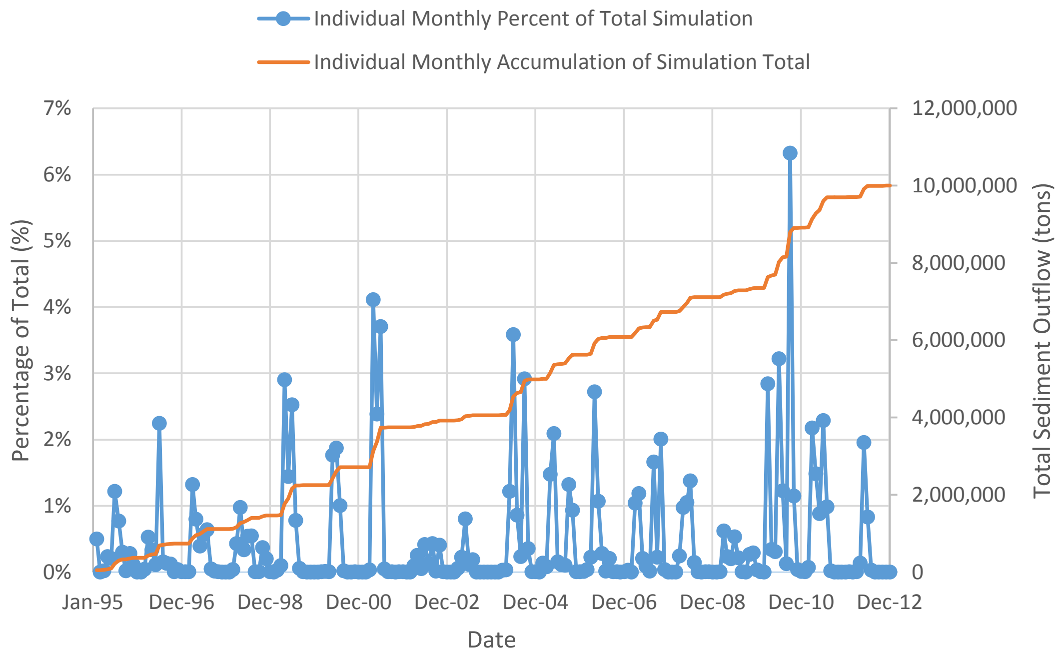

Figure 15. Monthly Sediment Export Percent of Total Simulation and Accumulation for Blue Earth at HUC8 Outlet

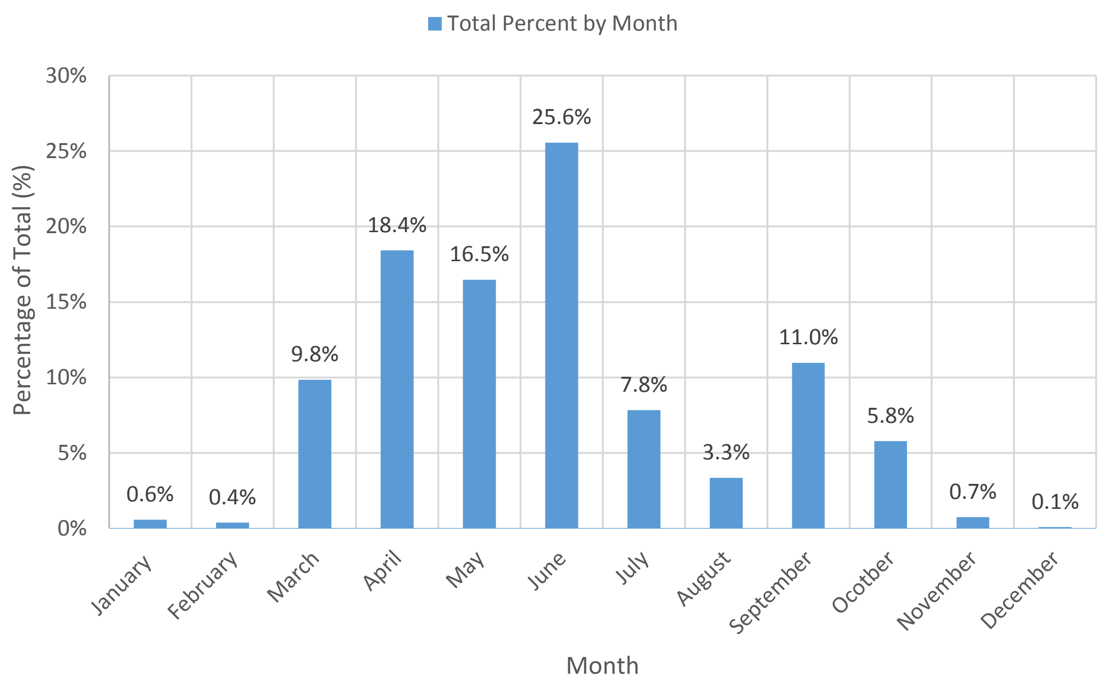

Figure 16. Total Percent by Month for Blue Earth at HUC8 Outlet

Table 34. High Sediment Loading Months Statistical Summary for Blue Earth at HUC8 Outlet

High Sediment Load Month and Year	Sediment Export Percent of simulation total (%)	Volume Export Percent of simulation total (%)	Surface Percent of monthly outflow (%)	Interflow Percent of monthly outflow (%)	Baseflow Percent of monthly outflow (%)	Snowpack water yield compared to total land outflow (%)	Area-weighted monthly precipitation (in)	Area-weighted daily maximum precipitation (in)
April 2001	4.1%	3.5%	6.0%	34.7%	59.4%	40.5%	6.22	2.01
June 2001	3.7%	2.0%	16.1%	42.0%	41.8%	0.0%	5.40	2.36
June 2004	3.6%	1.7%	7.6%	35.6%	56.8%	0.0%	2.87	1.21
June 2010	3.2%	1.7%	21.4%	38.8%	39.8%	0.0%	8.06	2.04
September 2010	6.3%	2.4%	26.5%	42.6%	30.9%	0.0%	9.76	3.75
Average	4.2%	2.3%	15.5%	38.7%	45.8%	8.1%	6.46	2.27

Table 35. High Sediment Loading Months Load Summary for Blue Earth at HUC8 Outlet

High Sediment Load Month and Year	Sediment Load (ton/month)	Sediment Yield (ton/acre/month)
April 2001	411,320	0.183
June 2001	370,450	0.165
June 2004	358,410	0.159
June 2010	321,860	0.143
September 2010	632,220	0.281
Average	418,852	0.186

Table 36. High Sediment Loading Months Source Attribution for Blue Earth at HUC8 Outlet

High Sediment Load Month and Year	Upland	Tile Drain	Ravine	Bluff	Stream
April 2001	10.7%	1.3%	0.5%	62.9%	24.6%
June 2001	38.6%	0.4%	5.4%	44.8%	10.9%
June 2004	27.4%	0.9%	33.5%	30.6%	7.6%
June 2010	54.9%	1.3%	10.5%	31.2%	2.1%
September 2010	39.2%	1.2%	31.8%	25.2%	2.5%
Average	34.2%	1.0%	16.3%	38.9%	9.5%

Table 37. September 2010 Precipitation Analysis for Blue Earth

WDM DSN ID	110	310	510	710	910	1110	1310	1510
Location	**IA138270**	**SWCD151**	**IA138026**	**SWCD172**	**SWCD604**	**MN210852**	**SWCD571**	**MN218808**
Acres	52,919.3	94,209.3	48,033.1	55,870.3	25,291.0	43,495.1	58,557.5	44,748.5
Monthly Total Precipitation (in)	3.99	10.52	5.046	9.84	13.492	10.42	9.736	11.294
Percent of Days with Measureable Precipitation	37%	37%	37%	33%	40%	37%	47%	40%
Daily Measurable Max	1.80	3.18	1.83	3.87	8.32	4.48	3.94	5.04
Daily Measurable 75th Percentile	0.36	1.04	0.56	1.09	0.64	0.74	0.86	0.98
Daily Measurable Average	0.36	0.96	0.46	0.98	1.12	0.95	0.70	0.94
Daily Measurable Median	0.26	0.55	0.44	0.67	0.51	0.57	0.25	0.50
Daily Measurable 25th Percentile	0.02	0.25	0.10	0.28	0.05	0.18	0.07	0.07
Daily Measurable Minimum	0.01	0.05	0.00	0.01	0.00	0.03	0.02	0.00
Percent of Hours with Measurable Precipitation	7%	9%	9%	9%	11%	9%	11%	9%
Hourly Measurable Max	0.46	0.91	0.44	1.40	2.00	1.87	1.42	2.05
Hourly Measurable 75th Percentile	0.11	0.18	0.11	0.18	0.12	0.19	0.13	0.21
Hourly Measurable Average	0.08	0.16	0.08	0.16	0.18	0.16	0.12	0.18
Hourly Measurable Median	0.05	0.09	0.04	0.06	0.05	0.07	0.06	0.10
Hourly Measurable 25th Percentile	0.01	0.03	0.01	0.02	0.01	0.03	0.02	0.02
Hourly Measurable Minimum	0.01	0.00	0.00	0.01	0.00	0.00	0.00	0.00
WDM DSN ID	**1710**	**1910**	**2110**	**2310**	**2510**	**2710**	**2910**	**3110**
Location	**SWCD179**	**SWCD598**	**NWS143**	**SWCD591**	**SWCD912**	**SWCD566**	**MN215073**	**SWCD185**
Acres	18,896.7	38,005.5	63,921.6	63,019.3	34,989.2	34,812.4	11,124.2	14,576.4
Monthly Total Precipitation (in)	10.45	9.816	8.28	13.203	13.238	9.924	5.93	9.8
Percent of Days with Measureable Precipitation	37%	40%	27%	47%	33%	40%	23%	57%
Daily Measurable Max	5.88	2.87	2.69	4.90	5.56	3.95	2.16	4.20
Daily Measurable 75th Percentile	0.85	1.76	1.53	1.62	0.88	1.07	1.28	0.48
Daily Measurable Average	0.95	0.82	1.04	0.94	1.32	0.83	0.85	0.58
Daily Measurable Median	0.41	0.19	0.90	0.13	0.56	0.39	0.75	0.18
Daily Measurable 25th Percentile	0.17	0.03	0.27	0.02	0.09	0.07	0.22	0.01
Daily Measurable Minimum	0.02	0.02	0.14	0.01	0.00	0.00	0.03	0.01

WDM DSN ID	**1710**	**1910**	**2110**	**2310**	**2510**	**2710**	**2910**	**3110**
Location	**SWCD179**	**SWCD598**	**NWS143**	**SWCD591**	**SWCD912**	**SWCD566**	**MN215073**	**SWCD185**
Percent of Hours with Measurable Precipitation	9%	9%	7%	11%	7%	11%	6%	12%
Hourly Measurable Max	2.41	1.55	1.28	1.50	3.90	1.69	0.93	1.93
Hourly Measurable 75th Percentile	0.16	0.15	0.14	0.18	0.20	0.12	0.15	0.10
Hourly Measurable Average	0.16	0.14	0.16	0.16	0.26	0.13	0.13	0.12
Hourly Measurable Median	0.07	0.06	0.07	0.07	0.08	0.06	0.07	0.04
Hourly Measurable 25th Percentile	0.04	0.01	0.03	0.01	0.03	0.02	0.02	0.01
Hourly Measurable Minimum	0.01	0.00	0.00	0.00	0.00	0.00	0.01	0.00
WDM DSN ID	**3310**	**3510**	**3710**	**3910**	**4110**	**4510**	**4710**	
Location	**MN210981**	**SWCD922**	**NWS910**	**SWCD397**	**SWCD137**	**MN219046**	**MN212698**	
Acres	92,531.4	19,837.8	4,999.2	36,233.9	26,041.7	58,717.5	55,350.1	
Monthly Total Precipitation (in)	8.28	11.302	13.85	10.411	13.402	11.018	8.67	
Percent of Days with Measureable Precipitation	27%	37%	33%	33%	40%	33%	37%	
Daily Measurable Max	2.69	5.48	7.94	3.82	3.33	5.40	3.49	
Daily Measurable 75th Percentile	1.53	0.57	0.73	1.52	1.68	0.78	0.82	
Daily Measurable Average	1.04	1.03	1.39	1.04	1.12	1.10	0.79	
Daily Measurable Median	0.90	0.43	0.47	0.72	0.63	0.48	0.57	
Daily Measurable 25th Percentile	0.27	0.10	0.30	0.06	0.18	0.19	0.10	
Daily Measurable Minimum	0.14	0.03	0.11	0.00	0.00	0.05	0.01	
Percent of Hours with Measurable Precipitation	7%	8%	8%	8%	11%	9%	9%	
Hourly Measurable Max	1.28	2.60	3.24	1.61	1.09	2.15	1.60	
Hourly Measurable 75th Percentile	0.14	0.19	0.24	0.20	0.21	0.18	0.14	
Hourly Measurable Average	0.16	0.20	0.25	0.19	0.17	0.16	0.13	
Hourly Measurable Median	0.07	0.07	0.10	0.09	0.07	0.06	0.07	
Hourly Measurable 25th Percentile	0.03	0.04	0.04	0.02	0.03	0.02	0.02	
Hourly Measurable Minimum	0.00	0.01	0.00	0.00	0.00	0.00	0.01	

Table 38. April 2001 Precipitation Analysis for Blue Earth

WDM DSN ID	110	310	510	710	910	1110	1310	1510
Location	**IA138270**	**SWCD151**	**IA138026**	**SWCD172**	**SWCD604**	**MN210852**	**SWCD571**	**MN218808**
Acres	52,919.3	94,209.3	48,033.1	55,870.3	25,291.0	43,495.1	58,557.5	44,748.5
Monthly Total Precipitation (in)	6.314	7.25	6.4	5.62	7.384	3.964	7.1	5.052
Percent of Days with Measureable Precipitation	33%	33%	43%	37%	43%	37%	37%	43%
Daily Measurable Max	1.69	3.20	2.51	2.40	2.47	0.95	2.25	1.29
Daily Measurable 75th Percentile	0.84	0.87	0.44	0.36	0.71	0.36	0.92	0.57
Daily Measurable Average	0.63	0.73	0.49	0.51	0.57	0.36	0.65	0.39
Daily Measurable Median	0.30	0.32	0.24	0.21	0.35	0.28	0.25	0.30
Daily Measurable 25th Percentile	0.25	0.15	0.20	0.13	0.18	0.21	0.14	0.11
Daily Measurable Minimum	0.10	0.03	0.09	0.05	0.00	0.05	0.13	0.01
Percent of Hours with Measurable Precipitation	5%	5%	5%	7%	7%	4%	7%	8%
Hourly Measurable Max	0.80	0.99	0.77	0.68	0.48	0.41	0.51	0.49
Hourly Measurable 75th Percentile	0.20	0.28	0.20	0.12	0.21	0.18	0.24	0.11
Hourly Measurable Average	0.17	0.22	0.17	0.11	0.14	0.13	0.15	0.09
Hourly Measurable Median	0.10	0.14	0.13	0.07	0.10	0.09	0.13	0.09
Hourly Measurable 25th Percentile	0.09	0.08	0.09	0.02	0.06	0.07	0.05	0.03
Hourly Measurable Minimum	0.01	0.02	0.05	0.00	0.00	0.01	0.01	0.01
WDM DSN ID	**1710**	**1910**	**2110**	**2310**	**2510**	**2710**	**2910**	**3110**
Location	**SWCD179**	**SWCD598**	**NWS143**	**SWCD591**	**SWCD912**	**SWCD566**	**MN215073**	**SWCD185**
Acres	18,896.7	38,005.5	63,921.6	63,019.3	34,989.2	34,812.4	11,124.2	14,576.4
Monthly Total Precipitation (in)	4.39	6.835	5.611	6.77	7.131	6.35	5.98	6.921
Percent of Days with Measureable Precipitation	40%	33%	50%	47%	33%	33%	47%	57%
Daily Measurable Max	0.89	2.14	1.27	2.22	1.57	1.84	1.70	1.92
Daily Measurable 75th Percentile	0.52	1.00	0.54	0.59	1.06	0.81	0.41	0.64
Daily Measurable Average	0.37	0.68	0.37	0.48	0.71	0.64	0.43	0.41
Daily Measurable Median	0.30	0.51	0.22	0.26	0.74	0.36	0.27	0.16
Daily Measurable 25th Percentile	0.20	0.17	0.05	0.11	0.14	0.21	0.16	0.02
Daily Measurable Minimum	0.02	0.05	0.00	0.01	0.05	0.10	0.06	0.00

WDM DSN ID	**1710**	**1910**	**2110**	**2310**	**2510**	**2710**	**2910**	**3110**
Location	**SWCD179**	**SWCD598**	**NWS143**	**SWCD591**	**SWCD912**	**SWCD566**	**MN215073**	**SWCD185**
Percent of Hours with Measurable Precipitation	4%	6%	8%	7%	9%	7%	9%	10%
Hourly Measurable Max	0.43	0.85	0.52	0.61	0.50	0.44	0.32	0.56
Hourly Measurable 75th Percentile	0.25	0.21	0.13	0.16	0.17	0.19	0.12	0.15
Hourly Measurable Average	0.15	0.16	0.10	0.13	0.12	0.13	0.09	0.10
Hourly Measurable Median	0.13	0.10	0.07	0.10	0.05	0.11	0.09	0.04
Hourly Measurable 25th Percentile	0.08	0.04	0.01	0.04	0.02	0.08	0.03	0.01
Hourly Measurable Minimum	0.01	0.01	0.00	0.01	0.01	0.01	0.01	0.00
WDM DSN ID	**3310**	**3510**	**3710**	**3910**	**4110**	**4510**	**4710**	
Location	**MN210981**	**SWCD922**	**NWS910**	**SWCD397**	**SWCD137**	**MN219046**	**MN212698**	
Acres	92,531.4	19,837.8	4,999.2	36,233.9	26,041.7	58,717.5	55,350.1	
Monthly Total Precipitation (in)	5.184	6.061	7.151	6.465	5.04	6.287	5.91	
Percent of Days with Measureable Precipitation	50%	43%	37%	30%	37%	40%	37%	
Daily Measurable Max	1.76	1.79	1.79	2.10	1.71	1.87	1.79	
Daily Measurable 75th Percentile	0.34	0.44	0.88	1.00	0.57	0.68	0.80	
Daily Measurable Average	0.35	0.47	0.65	0.72	0.46	0.52	0.54	
Daily Measurable Median	0.26	0.31	0.66	0.42	0.29	0.16	0.25	
Daily Measurable 25th Percentile	0.05	0.22	0.32	0.20	0.20	0.11	0.19	
Daily Measurable Minimum	0.01	0.03	0.10	0.10	0.06	0.09	0.10	
Percent of Hours with Measurable Precipitation	7%	10%	11%	6%	6%	8%	8%	
Hourly Measurable Max	0.76	0.32	0.43	0.77	0.51	0.34	0.43	
Hourly Measurable 75th Percentile	0.11	0.11	0.12	0.20	0.15	0.17	0.11	
Hourly Measurable Average	0.10	0.09	0.09	0.15	0.13	0.11	0.11	
Hourly Measurable Median	0.09	0.08	0.07	0.11	0.09	0.10	0.10	
Hourly Measurable 25th Percentile	0.02	0.02	0.02	0.04	0.06	0.04	0.03	
Hourly Measurable Minimum	0.01	0.01	0.00	0.01	0.01	0.01	0.01	

3.8 Middle Minnesota (07020007)

Middle Minnesota has five high sediment loading months. Figure 17 shows that 40% of the high sediment loading months occur in a 13-month period between March 2010 and April 2011. Figure 18 identifies the overall highest sediment loading months as April through June with those three months contributing 64% of the sediment load during the simulation. Table 39 shows that the individual highest sediment loading month is April 2001 and Table 40 shows the individual monthly loads and the unit area export for the upstream drainage area. The five highest sediment loading months account for approximately 24% of the sediment load delivered in an 18-year period but account for only about 13% of the volume of water delivered in the same 18-year period. Surface outflow shows high variability but when monthly precipitation is greater than about 5 inches then surface outflow is greater than 8% of the volume of water running off the land. Area-weighted monthly precipitation values range from about 1.5 inches to about 8.5 inches and the area-weighted monthly largest 24-hour storms range from approximately 0.6 inches to 3.0 inches. The high sediment loading months associated with March and April have snowmelt released to the land.

Table 41 shows that with the exception of September 2010 all high sediment loading months have upland source attribution less than 26% and sediment sources are dominated by bluff and stream.

Table 42 shows that monthly total precipitation for April 2001 ranges from 5.32 inches/month to 8.16 inches/month and Table 43 shows that June 2004 ranges from 2.76 inches/month to 8.65 inches/month. Both months show moderate to high frequency of daily measurable rainfall (ranging from 27% to 57%) indicating likely moderate to high soil moisture content and reduced infiltration capacity. Both months also show large daily maximum for each station (21% to 76% of monthly total) and daily averages much greater than the daily median and occasionally above the daily 75th percentile. Additionally, hourly statistics show very intense hourly precipitation maximum (5% to 38% of monthly total) with hourly averages much greater than the hourly median. These results indicate that the rain came in infrequent (less than 2-3 times per month), short duration, but intense storms.

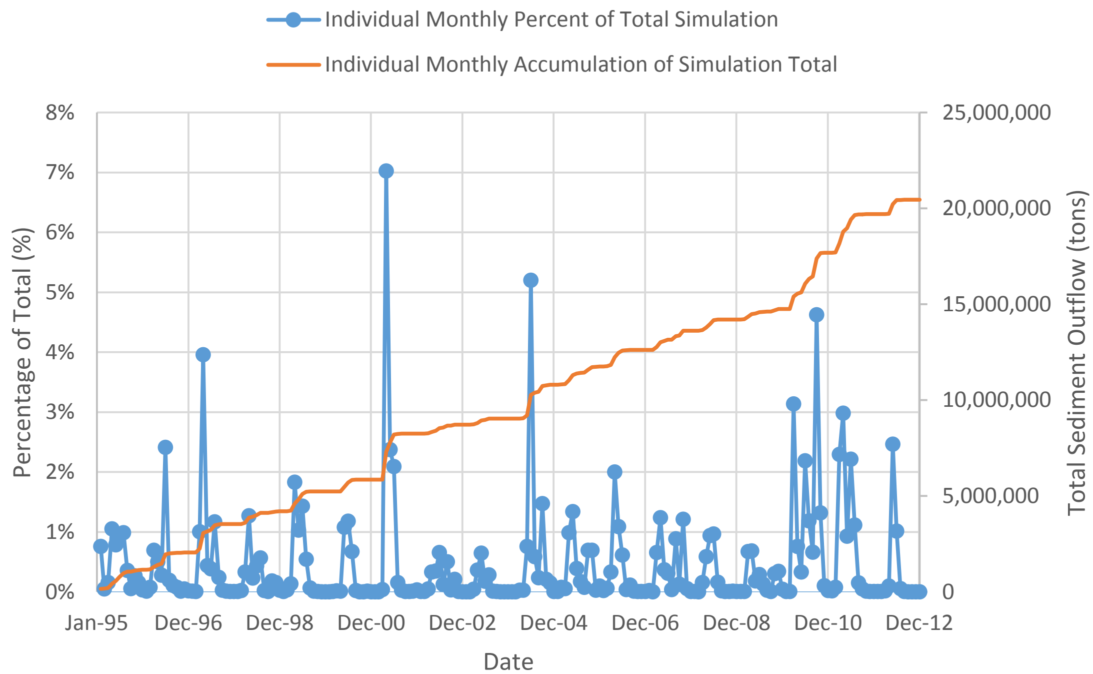

Figure 17. Monthly Sediment Export Percent of Total Simulation and Accumulation for Middle Minnesota at HUC8 Outlet

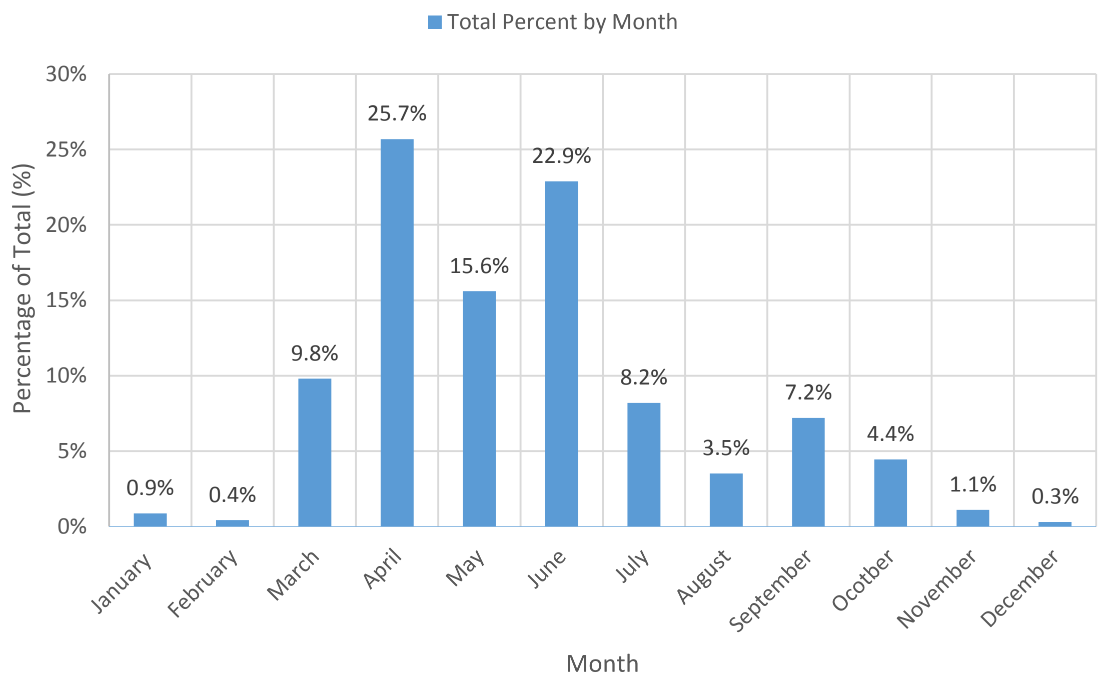

Figure 18. Total Percent by Month for Middle Minnesota at HUC8 Outlet

Table 39. High Sediment Loading Months Statistical Summary for Middle Minnesota at HUC8 Outlet

High Sediment Load Month and Year	Sediment Export Percent of simulation total (%)	Volume Export Percent of simulation total (%)	Surface Percent of monthly outflow (%)	Interflow Percent of monthly outflow (%)	Baseflow Percent of monthly outflow (%)	Snowpack water yield compared to total land outflow (%)	Area-weighted monthly precipitation (in)	Area-weighted daily maximum precipitation (in)
April 1997	4.0%	3.3%	2.2%	24.8%	73.0%	44.2%	1.45	0.58
April 2001	7.0%	4.1%	8.3%	33.3%	58.4%	77.5%	6.78	2.00
June 2004	5.2%	1.9%	16.3%	53.2%	30.5%	0.0%	5.09	2.61
March 2010	3.1%	2.3%	2.7%	26.7%	70.5%	164.4%	1.44	0.65
September 2010	4.6%	1.6%	19.4%	39.3%	41.3%	0.0%	8.42	3.06
Average	4.8%	2.6%	9.8%	35.5%	54.7%	57.2%	4.64	1.78

Table 40. High Sediment Loading Months Load Summary for Middle Minnesota at HUC8 Outlet

High Sediment Load Month and Year	Sediment Load (ton/month)	Sediment Yield (ton/acre/month)
April 1997	809,570	0.115
April 2001	1,437,100	0.205
June 2004	1,063,500	0.152
March 2010	641,530	0.091
September 2010	946,060	0.135
Average	979,552	0.140

Table 41. High Sediment Loading Months Source Attribution for Middle Minnesota at HUC8 Outlet

High Sediment Load Month and Year	Upland	Tile Drain	Ravine	Bluff	Stream
April 1997	2.3%	0.5%	0.1%	51.7%	45.4%
April 2001	25.9%	1.0%	1.1%	47.4%	24.7%
June 2004	23.1%	0.8%	12.0%	27.8%	36.4%
March 2010	2.1%	1.1%	0.0%	59.1%	37.7%
September 2010	47.3%	1.2%	22.1%	25.3%	4.2%
Average	20.1%	0.9%	7.1%	42.3%	29.7%

Table 42. April 2001 Precipitation Analysis for Middle Minnesota

WDM DSN ID	110	310	510	710	910	1310	1510	1910	2110	2310
Location	**MN216835**	**MN216152**	**SWCD1265**	**SWCD1190**	**SWCD1062**	**SWCD966**	**SWCD82**	**SWCD938**	**SWCD967**	**SWCD1184**
Acres	39,469.5	35,789.8	4,019.6	91,593.1	34,861.7	2,962.8	47,689.5	17,596.5	16,086.0	28,502.4
Monthly Total Precipitation (in)	7.55	6.349	7.98	6.782	6.274	7	8.16	6.31	6.23	6.752
Percent of Days with Measureable Precipitation	43%	30%	37%	47%	47%	37%	37%	57%	50%	47%
Daily Measurable Max	3.25	3.06	2.72	1.91	1.73	1.44	3.00	1.76	1.63	2.50
Daily Measurable 75th Percentile	0.31	0.45	0.85	0.76	0.67	1.00	0.71	0.42	0.48	0.59
Daily Measurable Average	0.58	0.71	0.73	0.48	0.45	0.64	0.74	0.37	0.42	0.48
Daily Measurable Median	0.17	0.41	0.42	0.17	0.16	0.60	0.39	0.12	0.27	0.16
Daily Measurable 25th Percentile	0.10	0.11	0.25	0.04	0.05	0.30	0.20	0.06	0.10	0.06
Daily Measurable Minimum	0.01	0.03	0.15	0.00	0.00	0.10	0.10	0.02	0.01	0.00
Percent of Hours with Measurable Precipitation	7%	9%	8%	6%	6%	7%	7%	11%	10%	7%
Hourly Measurable Max	0.83	0.53	0.83	0.57	0.76	0.93	0.93	0.78	0.35	0.48
Hourly Measurable 75th Percentile	0.22	0.11	0.22	0.22	0.14	0.18	0.21	0.08	0.11	0.19
Hourly Measurable Average	0.15	0.10	0.15	0.16	0.14	0.15	0.16	0.08	0.09	0.14
Hourly Measurable Median	0.10	0.05	0.10	0.14	0.10	0.09	0.11	0.03	0.06	0.11
Hourly Measurable 25th Percentile	0.05	0.02	0.04	0.07	0.04	0.04	0.07	0.01	0.03	0.08
Hourly Measurable Minimum	0.01	0.01	0.01	0.00	0.00	0.01	0.02	0.00	0.01	0.00
WDM DSN ID	**2510**	**2910**	**3310**	**3710**	**4310**	**4510**	**4710**	**4910**	**5110**	**5310**
Location	**SWCD1182**	**MN215073**	**MN215887**	**NWS1177**	**SWCD958**	**SWCD1166**	**SWCD1167**	**SWCD973**	**SWCD964**	**BYRG695**
Acres	15,878.5	19,418.4	22,284.8	26,873.6	34,562.2	32,321.6	24,137.0	26,329.8	59,820.2	16,805.3
Monthly Total Precipitation (in)	7.58	5.98	7.24	7.246	5.8	6.78	6.92	7.18	6.894	6.96
Percent of Days with Measureable Precipitation	40%	47%	43%	50%	47%	37%	47%	53%	47%	47%
Daily Measurable Max	2.23	1.70	1.63	1.63	1.52	1.61	1.57	1.76	1.66	2.06
Daily Measurable 75th Percentile	0.71	0.41	0.84	0.80	0.59	1.00	0.86	0.68	0.71	0.72
Daily Measurable Average	0.63	0.43	0.56	0.48	0.41	0.62	0.49	0.45	0.49	0.50
Daily Measurable Median	0.39	0.27	0.41	0.32	0.28	0.39	0.16	0.23	0.30	0.26
Daily Measurable 25th Percentile	0.24	0.16	0.24	0.15	0.13	0.16	0.11	0.13	0.11	0.08

WDM DSN ID	**2510**	**2910**	**3310**	**3710**	**4310**	**4510**	**4710**	**4910**	**5110**	**5310**
Location	**SWCD1182**	**MN215073**	**MN215887**	**NWS1177**	**SWCD958**	**SWCD1166**	**SWCD1167**	**SWCD973**	**SWCD964**	**BYRG695**
Daily Measurable Minimum	0.08	0.06	0.02	0.00	0.01	0.06	0.02	0.05	0.00	0.01
Percent of Hours with Measurable Precipitation	7%	9%	7%	7%	10%	7%	7%	10%	9%	6%
Hourly Measurable Max	0.56	0.32	0.53	0.53	0.37	0.68	0.59	0.38	0.40	0.64
Hourly Measurable 75th Percentile	0.21	0.12	0.21	0.20	0.11	0.17	0.15	0.14	0.12	0.22
Hourly Measurable Average	0.16	0.09	0.15	0.14	0.08	0.14	0.13	0.10	0.11	0.15
Hourly Measurable Median	0.11	0.09	0.11	0.11	0.07	0.10	0.09	0.08	0.09	0.12
Hourly Measurable 25th Percentile	0.09	0.03	0.10	0.10	0.03	0.09	0.05	0.04	0.03	0.06
Hourly Measurable Minimum	0.01	0.01	0.01	0.00	0.01	0.01	0.01	0.01	0.00	0.00
WDM DSN ID	**5510**	**5710**	**5910**	**6110**	**6310**	**6510**	**6910**	**7310**	**7510**	
Location	**BYRG689**	**NWS848**	**SWCD1064**	**BYRG708**	**SWCD437**	**MN217405**	**SWCD435**	**SWCD440**	**BYRG701**	
Acres	34,234.8	36,572.2	34,361.8	33,943.2	13,600.5	40,940.4	23,917.2	8,375.6	21,092.8	
Monthly Total Precipitation (in)	5.33	7.558	7.48	7.35	5.322	6.18	5.69	5.379	6.77	
Percent of Days with Measureable Precipitation	37%	57%	43%	47%	50%	47%	43%	37%	40%	
Daily Measurable Max	1.53	3.25	2.14	2.13	1.46	1.76	1.53	1.73	1.60	
Daily Measurable 75th Percentile	0.63	0.30	0.64	0.80	0.47	0.64	0.50	0.59	0.84	
Daily Measurable Average	0.48	0.44	0.58	0.53	0.35	0.44	0.44	0.49	0.56	
Daily Measurable Median	0.25	0.14	0.38	0.23	0.21	0.21	0.28	0.21	0.30	
Daily Measurable 25th Percentile	0.12	0.01	0.14	0.14	0.12	0.11	0.14	0.08	0.21	
Daily Measurable Minimum	0.02	0.00	0.02	0.01	0.00	0.01	0.02	0.01	0.02	
Percent of Hours with Measurable Precipitation	7%	8%	6%	8%	9%	10%	9%	8%	7%	
Hourly Measurable Max	0.35	0.83	0.83	0.51	0.72	0.37	0.37	0.64	0.51	
Hourly Measurable 75th Percentile	0.15	0.21	0.21	0.19	0.10	0.11	0.11	0.14	0.18	
Hourly Measurable Average	0.11	0.14	0.19	0.13	0.08	0.09	0.09	0.09	0.13	
Hourly Measurable Median	0.10	0.10	0.10	0.11	0.06	0.07	0.06	0.07	0.10	
Hourly Measurable 25th Percentile	0.04	0.02	0.08	0.03	0.01	0.02	0.02	0.03	0.05	
Hourly Measurable Minimum	0.00	0.00	0.02	0.01	0.00	0.00	0.01	0.01	0.01	

Table 43. June 2004 Precipitation Analysis for Middle Minnesota

WDM DSN ID	110	310	510	710	910	1310	1510	1910	2110	2310
Location	**MN216835**	**MN216152**	**SWCD1265**	**SWCD1190**	**SWCD1062**	**SWCD966**	**SWCD82**	**SWCD938**	**SWCD967**	**SWCD1184**
Acres	39,469.5	35,789.8	4,019.6	91,593.1	34,861.7	2,962.8	47,689.5	17,596.5	16,086.0	28,502.4
Monthly Total Precipitation (in)	4.233	3.832	3.93	4.22	4.805	7.094	3.15	5.29	8.229	5.876
Percent of Days with Measureable Precipitation	47%	43%	27%	30%	47%	47%	40%	33%	37%	37%
Daily Measurable Max	2.13	1.20	1.69	1.92	2.59	4.34	0.95	3.56	5.68	2.51
Daily Measurable 75th Percentile	0.09	0.37	0.58	0.25	0.13	0.23	0.38	0.35	0.37	0.66
Daily Measurable Average	0.30	0.29	0.49	0.47	0.34	0.51	0.26	0.53	0.75	0.53
Daily Measurable Median	0.06	0.12	0.27	0.10	0.06	0.08	0.13	0.17	0.22	0.10
Daily Measurable 25th Percentile	0.04	0.10	0.12	0.05	0.04	0.04	0.05	0.07	0.07	0.02
Daily Measurable Minimum	0.01	0.01	0.07	0.03	0.01	0.02	0.04	0.05	0.01	0.00
Percent of Hours with Measurable Precipitation	4%	4%	3%	4%	3%	6%	6%	5%	5%	3%
Hourly Measurable Max	1.25	1.20	0.95	0.98	1.84	1.12	0.31	0.88	1.72	1.50
Hourly Measurable 75th Percentile	0.09	0.12	0.20	0.14	0.20	0.14	0.12	0.11	0.22	0.22
Hourly Measurable Average	0.14	0.14	0.18	0.16	0.20	0.16	0.08	0.14	0.23	0.24
Hourly Measurable Median	0.03	0.08	0.11	0.06	0.06	0.04	0.05	0.04	0.09	0.11
Hourly Measurable 25th Percentile	0.01	0.02	0.07	0.02	0.02	0.01	0.02	0.01	0.04	0.03
Hourly Measurable Minimum	0.00	0.01	0.01	0.00	0.01	0.00	0.01	0.01	0.01	0.00
WDM DSN ID	**2510**	**2910**	**3310**	**3710**	**4310**	**4510**	**4710**	**4910**	**5110**	**5310**
Location	**SWCD1182**	**MN215073**	**MN215887**	**NWS1177**	**SWCD958**	**SWCD1166**	**SWCD1167**	**SWCD973**	**SWCD964**	**BYRG695**
Acres	15,878.5	19,418.4	22,284.8	26,873.6	34,562.2	32,321.6	24,137.0	26,329.8	59,820.2	16,805.3
Monthly Total Precipitation (in)	4.65	8.334	3.45	3.458	6.65	2.758	4.004	6.158	8.653	4.106
Percent of Days with Measureable Precipitation	33%	43%	40%	47%	33%	33%	40%	40%	43%	53%
Daily Measurable Max	2.89	6.36	1.38	1.38	4.18	1.29	2.11	4.36	6.12	1.92
Daily Measurable 75th Percentile	0.33	0.25	0.39	0.23	0.38	0.33	0.18	0.26	0.40	0.20
Daily Measurable Average	0.47	0.64	0.29	0.25	0.67	0.28	0.33	0.51	0.67	0.26
Daily Measurable Median	0.08	0.10	0.06	0.05	0.20	0.14	0.07	0.18	0.10	0.03
Daily Measurable 25th Percentile	0.03	0.06	0.02	0.01	0.11	0.06	0.04	0.09	0.05	0.00
Daily Measurable Minimum	0.01	0.01	0.00	0.00	0.03	0.01	0.01	0.02	0.02	0.00

WDM DSN ID	2510	2910	3310	3710	4310	4510	4710	4910	5110	5310
Location	**SWCD1182**	**MN215073**	**MN215887**	**NWS1177**	**SWCD958**	**SWCD1166**	**SWCD1167**	**SWCD973**	**SWCD964**	**BYRG695**
Percent of Hours with Measurable Precipitation	4%	4%	4%	5%	5%	3%	4%	4%	7%	5%
Hourly Measurable Max	0.89	1.99	0.77	0.77	1.39	0.37	1.01	1.45	1.07	1.08
Hourly Measurable 75th Percentile	0.29	0.24	0.09	0.09	0.19	0.19	0.11	0.17	0.12	0.12
Hourly Measurable Average	0.18	0.29	0.12	0.10	0.19	0.15	0.13	0.21	0.17	0.11
Hourly Measurable Median	0.09	0.10	0.06	0.02	0.07	0.10	0.06	0.09	0.04	0.02
Hourly Measurable 25th Percentile	0.02	0.06	0.01	0.01	0.02	0.06	0.03	0.02	0.01	0.01
Hourly Measurable Minimum	0.00	0.01	0.00	0.00	0.01	0.01	0.01	0.00	0.00	0.00
WDM DSN ID	**5310**	**5510**	**5710**	**5910**	**6110**	**6310**	**6510**	**6910**	**7310**	**7510**
Location	**BYRG695**	**BYRG689**	**NWS848**	**SWCD1064**	**BYRG708**	**SWCD437**	**MN217405**	**SWCD435**	**SWCD440**	**BYRG701**
Acres	16,805.3	34,234.8	36,572.2	34,361.8	33,943.2	13,600.5	40,940.4	23,917.2	8,375.6	21,092.8
Monthly Total Precipitation (in)	4.106	4.325	3.63	4.81	5.135	7.482	4.3	6.355	4.521	4.18
Percent of Days with Measureable Precipitation	53%	47%	30%	30%	33%	37%	37%	40%	37%	47%
Daily Measurable Max	1.92	1.59	1.45	2.25	2.04	5.40	1.60	4.45	2.97	1.52
Daily Measurable 75th Percentile	0.20	0.22	0.70	0.20	0.73	0.28	0.53	0.26	0.31	0.37
Daily Measurable Average	0.26	0.31	0.40	0.53	0.51	0.68	0.39	0.53	0.41	0.30
Daily Measurable Median	0.03	0.13	0.10	0.17	0.09	0.21	0.23	0.14	0.09	0.06
Daily Measurable 25th Percentile	0.00	0.08	0.07	0.12	0.07	0.05	0.07	0.04	0.02	0.03
Daily Measurable Minimum	0.00	0.00	0.02	0.07	0.00	0.00	0.01	0.00	0.01	0.00
Percent of Hours with Measurable Precipitation	5%	4%	4%	3%	3%	5%	3%	5%	5%	5%
Hourly Measurable Max	1.08	0.91	1.04	1.32	1.17	1.69	0.90	1.39	0.76	0.86
Hourly Measurable 75th Percentile	0.12	0.20	0.12	0.27	0.25	0.14	0.24	0.15	0.14	0.19
Hourly Measurable Average	0.11	0.15	0.13	0.27	0.21	0.22	0.20	0.18	0.14	0.13
Hourly Measurable Median	0.02	0.10	0.04	0.17	0.08	0.07	0.20	0.05	0.08	0.07
Hourly Measurable 25th Percentile	0.01	0.05	0.01	0.06	0.05	0.04	0.09	0.03	0.03	0.02
Hourly Measurable Minimum	0.00	0.00	0.01	0.02	0.00	0.00	0.01	0.00	0.00	0.00

3.9 LOWER MINNESOTA (07020012)

The analysis for Lower Minnesota was performed at two locations. Minnesota River at Jordan and Minnesota River at Fort Snelling. The results are both locations are similar and are discussed together.

Lower Minnesota has six high sediment loading months. Figure 19 and Figure 20 show that 50% of the high sediment loading months occur in a 13-month period between March 2010 and April 2011. Figure 21 and Figure 22 identify the overall highest sediment loading months as April through June with those three months contributing over 63% of the sediment load during the simulation. Table 45 and Table 48 show that the individual highest sediment loading month is April 2001 and Table 2 and Table 5 show the individual monthly loads and the unit area export for the upstream drainage area. The six highest sediment loading months account for approximately 28% of the sediment load delivered in an 18-year period but account for only about 15% of the volume of water delivered in the same 18-year period. Surface outflow shows high variability but when monthly precipitation is greater than about 5 inches then surface outflow is greater than 7% of the volume of water running off the land. Area-weighted monthly precipitation values range from about 1 inch to about 7 inches and the area-weighted monthly largest 24-hour storms range from approximately 0.2 inches to 2.8 inches. The high sediment loading months associated with March and April have snowmelt released to the land.

Table 46 and Table 49 show, with the exception of September 2010, that all high sediment loading months have upland source attribution less than 23% and sediment sources are dominated by bluff and stream.

Table 50 shows that monthly total precipitation for April 2001 ranges from 5.32 inches/month to 8.16 inches/month and Table 51 shows that June 2004 ranges from 2.9 inches/month to 7.9 inches/month. Both months show moderate to high frequency of daily measurable rainfall (ranging from 13% to 60%) indicating likely moderate to high soil moisture content and reduced infiltration capacity. Both months also show large daily maximum for each station (22% to 70% of monthly total) and daily averages much greater than the daily median and occasionally above the daily 75th percentile. Additionally, hourly statistics show very intense hourly precipitation maximum (5% to 38% of monthly total) with hourly averages much greater than the hourly median. These results indicate that the rain came in infrequent (less than 2-3 times per month), short duration, but intense storms.

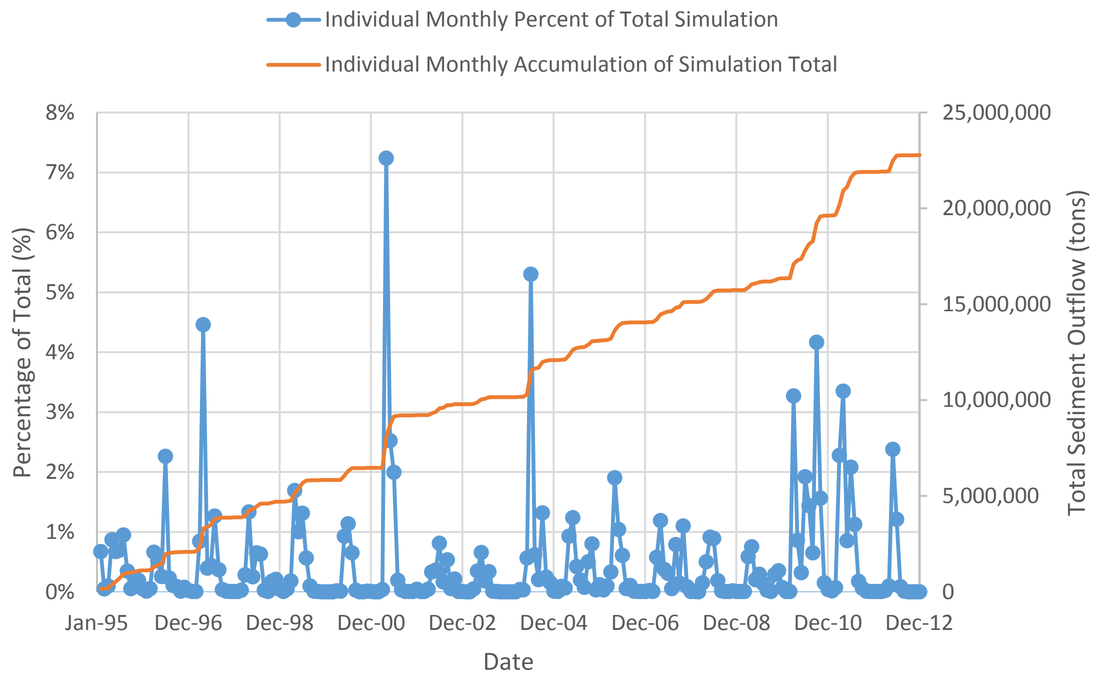

Figure 19. Monthly Sediment Export Percent of Total Simulation and Accumulation for Lower Minnesota River at Jordan

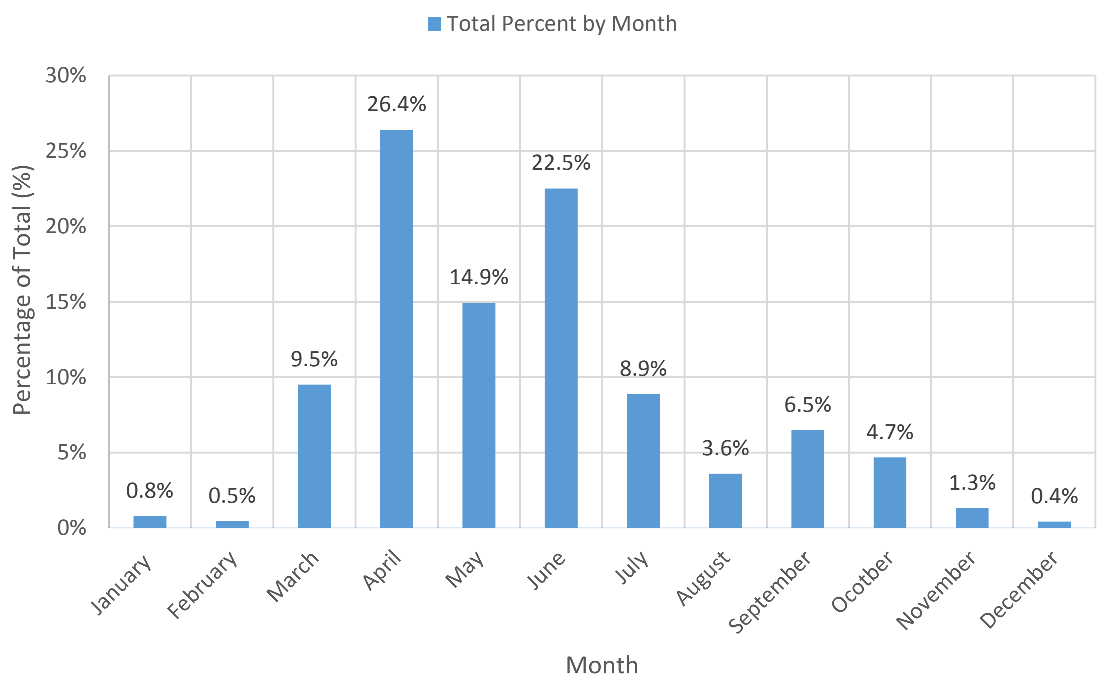

Figure 20. Total Percent by Month for Lower Minnesota River at Jordan

Table 44. High Sediment Loading Months Statistical Summary for Lower Minnesota River at Jordan

High Sediment Load Month and Year	Sediment Export Percent of simulation total (%)	Volume Export Percent of simulation total (%)	Surface Percent of monthly outflow (%)	Interflow Percent of monthly outflow (%)	Baseflow Percent of monthly outflow (%)	Snowpack water yield compared to total land outflow (%)	Area-weighted monthly precipitation (in)	Area-weighted daily maximum precipitation (in)
April 1997	4.5%	3.3%	0.5%	24.8%	74.6%	15.1%	1.18	0.47
April 2001	7.2%	3.9%	7.6%	39.7%	52.7%	63.4%	6.64	2.19
June 2004	5.3%	2.0%	12.4%	52.1%	35.5%	0.5%	4.85	2.18
March 2010	3.3%	2.3%	2.6%	31.4%	66.0%	187.9%	1.32	0.64
September 2010	4.2%	1.4%	14.3%	40.9%	44.8%	0.0%	7.04	2.76
April 2011	3.3%	2.9%	1.5%	25.1%	73.4%	66.2%	2.84	0.85
Average	4.6%	2.6%	6.5%	35.7%	57.8%	55.5%	3.98	1.52

Table 45. High Sediment Loading Months Load Summary for Lower Minnesota River at Jordan

High Sediment Load Month and Year	Sediment Load (ton/month)	Sediment Yield (ton/acre/month)
April 1997	1,015,500	0.132
April 2001	1,649,800	0.214
June 2004	1,207,500	0.156
March 2010	744,660	0.097
September 2010	949,650	0.123
April 2011	763,050	0.099
Average	1,055,027	0.137

Table 46. High Sediment Loading Months Source Attribution for Lower Minnesota River at Jordan

High Sediment Load Month and Year	Upland	Tile Drain	Ravine	Bluff	Stream
April 1997	1.9%	0.4%	0.1%	55.7%	41.9%
April 2001	23.3%	0.9%	1.0%	51.3%	23.4%
June 2004	22.7%	0.8%	10.8%	29.2%	36.5%
March 2010	2.0%	1.1%	0.0%	60.9%	36.0%
September 2010	47.2%	1.2%	22.0%	27.9%	1.7%
April 2011	2.7%	0.7%	0.1%	52.6%	43.8%
Average	16.6%	0.9%	5.7%	46.3%	30.6%

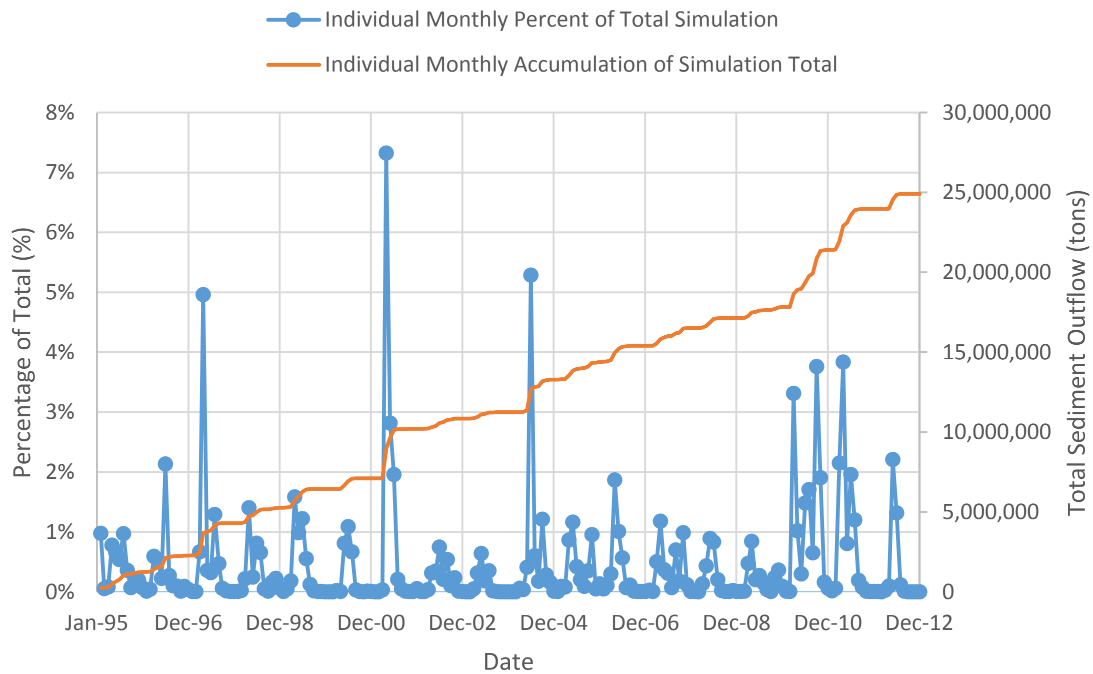

Figure 21. Monthly Sediment Export Percent of Total Simulation and Accumulation for Lower Minnesota River at Fort Snelling

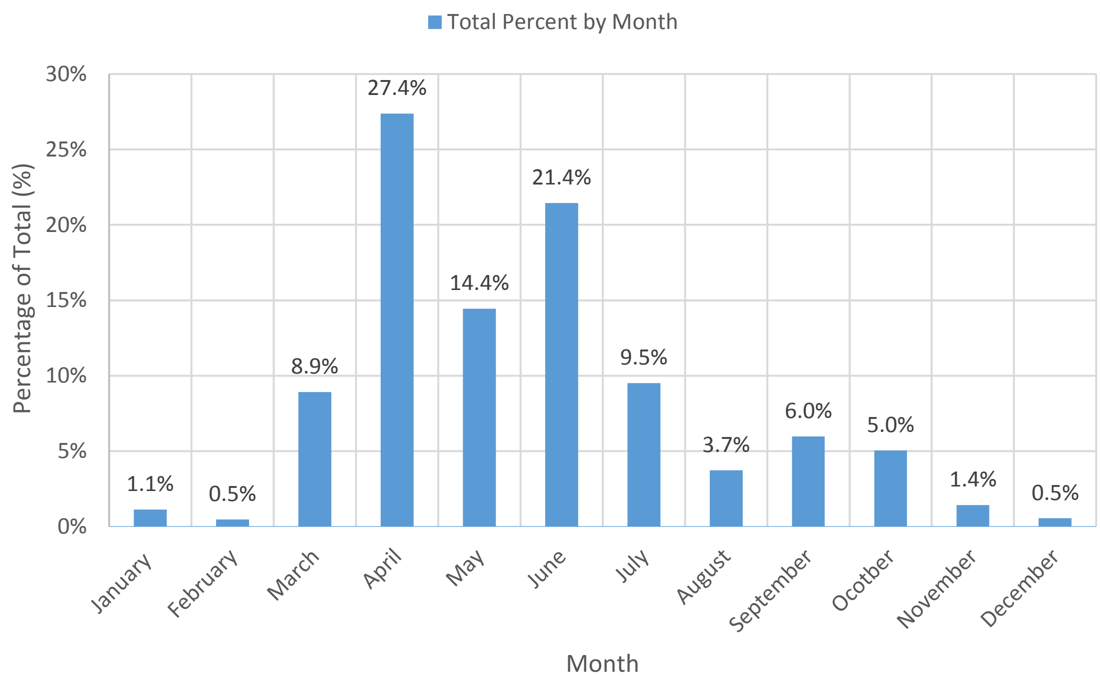

Figure 22. Total Percent by Month for Lower Minnesota River at Fort Snelling

Table 47. High Sediment Loading Months Statistical Summary for Lower Minnesota River at Fort Snelling

High Sediment Load Month and Year	Sediment Export Percent of simulation total (%)	Volume Export Percent of simulation total (%)	Surface Percent of monthly outflow (%)	Interflow Percent of monthly outflow (%)	Baseflow Percent of monthly outflow (%)	Snowpack water yield compared to total land outflow (%)	Area-weighted monthly precipitation (in)	Area-weighted daily maximum precipitation (in)
April 1997	5.0%	3.2%	4.7%	22.9%	72.3%	9.4%	1.25	0.54
April 2001	7.3%	3.7%	28.1%	35.7%	36.2%	78.8%	6.53	2.30
June 2004	5.3%	2.1%	23.0%	44.5%	32.4%	0.0%	4.08	1.67
March 2010	3.3%	2.1%	18.8%	31.4%	49.8%	258.3%	0.99	0.42
September 2010	3.8%	1.2%	44.9%	35.4%	19.7%	0.0%	7.01	2.41
April 2011	3.8%	2.9%	15.7%	31.1%	53.1%	107.0%	2.85	1.14
Average	4.7%	2.5%	22.6%	33.5%	43.9%	75.6%	3.78	1.41

Table 48. High Sediment Loading Months Load Summary for Lower Minnesota River at Fort Snelling

High Sediment Load Month and Year	Sediment Load (ton/month)	Sediment Yield (ton/acre/month)
April 1997	1,235,400	0.151
April 2001	1,824,600	0.223
June 2004	1,317,400	0.161
March 2010	825,290	0.101
September 2010	937,010	0.115
April 2011	954,870	0.117
Average	1,182,428	0.145

Table 49. High Sediment Loading Months Source Attribution for Lower Minnesota River at Fort Snelling

High Sediment Load Month and Year	Upland	Tile Drain	Ravine	Bluff	Stream
April 1997	1.5%	0.4%	0.1%	59.0%	39.0%
April 2001	21.6%	0.9%	0.9%	55.3%	21.3%
June 2004	21.4%	0.7%	9.9%	32.2%	35.8%
March 2010	1.9%	1.0%	0.0%	64.4%	32.6%
September 2010	48.3%	1.2%	22.4%	30.1%	-2.0%
April 2011	2.3%	0.6%	0.1%	56.0%	41.0%
Average	16.2%	0.8%	5.6%	49.5%	28.0%

Table 50. April 2001 Precipitation Analysis for Lower Minnesota

WDM DSN ID	110	310	510	710	910	1110	1310	1510	1710	1910
Location	MN214721	BYRG262	MOSQ1018	MOSQ295	SWCD467	SWCD1061	NWS1082	SWCD1046	SWCD526	SWCD1081
Acres	38,585.3	25,626.6	34,976.0	20,051.6	50,118.2	35,772.2	47,523.1	22,906.4	46,439.1	22,744.1
Monthly Total Precipitation (in)	6.5	6.76	6.72	6.95	6.042	6.92	7.447	6.076	6.772	6.96
Percent of Days with Measureable Precipitation	40%	37%	37%	30%	50%	30%	30%	53%	50%	40%
Daily Measurable Max	1.90	2.34	2.76	2.39	1.64	2.33	2.55	1.85	2.04	1.97
Daily Measurable 75th Percentile	0.80	0.97	0.84	1.40	0.46	0.97	0.81	0.42	0.65	0.84
Daily Measurable Average	0.54	0.61	0.61	0.77	0.40	0.77	0.83	0.38	0.45	0.58
Daily Measurable Median	0.25	0.18	0.21	0.51	0.22	0.40	0.70	0.15	0.17	0.33
Daily Measurable 25th Percentile	0.18	0.07	0.10	0.18	0.10	0.24	0.35	0.04	0.07	0.16
Daily Measurable Minimum	0.10	0.02	0.03	0.04	0.00	0.10	0.20	0.00	0.00	0.08
Percent of Hours with Measurable Precipitation	6%	6%	8%	7%	10%	7%	7%	9%	8%	9%
Hourly Measurable Max	0.40	0.61	0.68	0.38	0.34	0.68	0.58	0.68	0.64	0.46
Hourly Measurable 75th Percentile	0.20	0.24	0.14	0.20	0.11	0.21	0.20	0.10	0.14	0.15
Hourly Measurable Average	0.15	0.16	0.12	0.14	0.09	0.15	0.14	0.09	0.12	0.11
Hourly Measurable Median	0.10	0.10	0.06	0.11	0.07	0.12	0.10	0.06	0.08	0.09
Hourly Measurable 25th Percentile	0.10	0.04	0.01	0.08	0.03	0.07	0.06	0.02	0.03	0.04
Hourly Measurable Minimum	0.10	0.01	0.01	0.01	0.00	0.01	0.01	0.00	0.00	0.01
WDM DSN ID	**2110**	**2310**	**2510**	**2710**	**2910**	**3110**	**3310**	**3510**	**3710**	**3910**
Location	**SWCD1040**	**BYRG317**	**BYRG693**	**SWCD1008**	**NWS1034**	**SWCD1056**	**SWCD1110**	**SWCD1107**	**SWCD1075**	**SWCD1100**
Acres	26,549.5	15,569.4	38,906.7	53,447.0	19,162.0	35,148.2	22,405.9	25,733.3	21,503.2	42,314.9
Monthly Total Precipitation (in)	6.594	7.93	6.035	6.351	6.032	6.72	6.84	7.268	6.63	7.01
Percent of Days with Measureable Precipitation	43%	40%	37%	57%	47%	23%	27%	53%	30%	40%
Daily Measurable Max	2.50	2.60	1.87	2.73	1.86	1.90	2.41	2.20	2.17	2.09
Daily Measurable 75th Percentile	0.89	0.84	0.76	0.27	0.57	1.43	1.09	0.58	0.99	0.90
Daily Measurable Average	0.51	0.66	0.55	0.37	0.43	0.96	0.86	0.45	0.74	0.58
Daily Measurable Median	0.11	0.35	0.23	0.08	0.24	0.93	0.65	0.26	0.44	0.25
Daily Measurable 25th Percentile	0.03	0.16	0.14	0.01	0.11	0.41	0.28	0.06	0.07	0.09
Daily Measurable Minimum	0.00	0.05	0.01	0.00	0.00	0.21	0.03	0.01	0.05	0.01

WDM DSN ID	**2110**	**2310**	**2510**	**2710**	**2910**	**3110**	**3310**	**3510**	**3710**	**3910**
Location	**SWCD1040**	**BYRG317**	**BYRG693**	**SWCD1008**	**NWS1034**	**SWCD1056**	**SWCD1110**	**SWCD1107**	**SWCD1075**	**SWCD1100**
Percent of Hours with Measurable Precipitation	8%	8%	7%	9%	10%	5%	7%	9%	8%	9%
Hourly Measurable Max	0.69	1.20	0.57	0.86	0.72	0.56	0.38	0.43	0.68	0.72
Hourly Measurable 75th Percentile	0.16	0.13	0.16	0.15	0.08	0.27	0.18	0.13	0.15	0.15
Hourly Measurable Average	0.11	0.13	0.12	0.10	0.08	0.19	0.14	0.11	0.12	0.11
Hourly Measurable Median	0.10	0.09	0.10	0.05	0.04	0.16	0.11	0.09	0.09	0.07
Hourly Measurable 25th Percentile	0.02	0.03	0.06	0.01	0.01	0.09	0.07	0.03	0.03	0.03
Hourly Measurable Minimum	0.00	0.01	0.01	0.00	0.00	0.01	0.01	0.00	0.01	0.01
WDM DSN ID	**4110**	**4310**	**4510**	**4710**	**4910**	**5110**	**5310**	**5510**	**5710**	**5910**
Location	**SWCD998**	**MOSQ9**	**SWCD3**	**SWCD2**	**MN214176**	**SWCD462**	**BYRG695**	**SWCD460**	**SWCD1002**	**SWCD21**
Acres	53,340.8	23,385.7	36,039.6	21,693.5	38,192.7	58,090.2	19,788.0	23,623.9	31,765.0	13,689.7
Monthly Total Precipitation (in)	6.54	7.883	7.142	6.79	5.43	6.17	6.96	5.532	6.634	7.682
Percent of Days with Measureable Precipitation	60%	50%	43%	33%	37%	40%	47%	47%	57%	50%
Daily Measurable Max	2.30	2.84	2.68	2.44	1.19	1.71	2.06	1.30	2.36	2.30
Daily Measurable 75th Percentile	0.58	0.57	0.82	0.84	1.02	0.57	0.72	0.40	0.56	0.58
Daily Measurable Average	0.36	0.53	0.55	0.68	0.49	0.51	0.50	0.40	0.39	0.51
Daily Measurable Median	0.12	0.29	0.19	0.29	0.24	0.29	0.26	0.34	0.17	0.30
Daily Measurable 25th Percentile	0.05	0.09	0.10	0.19	0.13	0.17	0.08	0.08	0.03	0.07
Daily Measurable Minimum	0.02	0.00	0.00	0.01	0.00	0.04	0.01	0.00	0.00	0.00
Percent of Hours with Measurable Precipitation	11%	9%	9%	8%	7%	8%	6%	9%	8%	8%
Hourly Measurable Max	1.24	0.77	0.76	0.76	0.59	0.47	0.64	0.67	0.60	0.40
Hourly Measurable 75th Percentile	0.11	0.10	0.18	0.19	0.12	0.12	0.22	0.11	0.15	0.20
Hourly Measurable Average	0.08	0.12	0.11	0.12	0.10	0.10	0.15	0.09	0.12	0.13
Hourly Measurable Median	0.03	0.04	0.09	0.08	0.09	0.09	0.12	0.03	0.08	0.10
Hourly Measurable 25th Percentile	0.01	0.01	0.03	0.03	0.02	0.04	0.06	0.01	0.04	0.04
Hourly Measurable Minimum	0.00	0.00	0.00	0.01	0.00	0.01	0.00	0.00	0.00	0.00
WDM DSN ID	**6110**	**6310**	**6510**	**6710**	**6910**	**7110**	**7310**	**7510**	**7710**	
Location	**MN211448**	**MOSQ1021**	**BYRG12**	**SWCD1111**	**SWCD435**	**BYRG688**	**SWCD440**	**MN215435**	**BYRG106**	
Acres	11,687.1	28,159.8	8,109.6	42,352.6	8,834.9	27,387.0	28,929.3	14,621.5	18,367.2	
Monthly Total Precipitation (in)	7.1	6.28	7.52	7.04	5.69	5.76	5.379	7	5.78	

WDM DSN ID	6110	6310	6510	6710	6910	7110	7310	7510	7710
Location	**MN211448**	**MOSQ1021**	**BYRG12**	**SWCD1111**	**SWCD435**	**BYRG688**	**SWCD440**	**MN215435**	**BYRG106**
Percent of Days with Measureable Precipitation	47%	27%	43%	33%	43%	33%	37%	43%	40%
Daily Measurable Max	2.50	3.25	2.55	3.11	1.53	1.77	1.33	2.28	1.71
Daily Measurable 75th Percentile	0.54	0.93	0.71	0.87	0.50	0.82	0.60	0.66	0.68
Daily Measurable Average	0.51	0.79	0.58	0.70	0.44	0.58	0.49	0.54	0.48
Daily Measurable Median	0.20	0.43	0.25	0.39	0.28	0.25	0.42	0.28	0.23
Daily Measurable 25th Percentile	0.08	0.07	0.08	0.06	0.14	0.06	0.17	0.11	0.12
Daily Measurable Minimum	0.01	0.03	0.04	0.03	0.02	0.05	0.01	0.01	0.01
Percent of Hours with Measurable Precipitation	11%	7%	11%	6%	9%	8%	7%	9%	8%
Hourly Measurable Max	0.63	0.80	0.64	0.54	0.37	0.74	0.38	0.57	0.36
Hourly Measurable 75th Percentile	0.11	0.14	0.12	0.23	0.11	0.12	0.14	0.14	0.17
Hourly Measurable Average	0.09	0.13	0.09	0.16	0.09	0.10	0.10	0.11	0.10
Hourly Measurable Median	0.05	0.06	0.06	0.11	0.06	0.06	0.09	0.07	0.09
Hourly Measurable 25th Percentile	0.02	0.01	0.02	0.08	0.02	0.02	0.04	0.03	0.03
Hourly Measurable Minimum	0.01	0.01	0.01	0.01	0.01	0.01	0.00	0.01	0.00

Table 51. June 2004 Precipitation Analysis for Lower Minnesota

WDM DSN ID	**110**	**310**	**510**	**710**	**910**	**1110**	**1310**	**1510**	**1710**	**1910**
Location	**MN214721**	**BYRG262**	**MOSQ1018**	**MOSQ295**	**SWCD467**	**SWCD1061**	**NWS1082**	**SWCD1046**	**SWCD526**	**SWCD1081**
Acres	38,585.3	25,626.6	34,976.0	20,051.6	50,118.2	35,772.2	47,523.1	22,906.4	46,439.1	22,744.1
Monthly Total Precipitation (in)	4.5	3.656	5.02	3.517	3.264	3.963	5.7	4.661	6.033	4.535
Percent of Days with Measureable Precipitation	23%	27%	27%	17%	30%	23%	27%	53%	33%	27%
Daily Measurable Max	1.10	1.43	1.74	1.37	1.80	1.80	1.54	2.08	3.61	2.05
Daily Measurable 75th Percentile	0.90	0.53	1.06	0.71	0.39	0.83	1.00	0.28	0.46	0.79
Daily Measurable Average	0.64	0.46	0.63	0.70	0.36	0.57	0.71	0.29	0.60	0.57
Daily Measurable Median	0.60	0.33	0.30	0.63	0.18	0.18	0.76	0.16	0.19	0.18
Daily Measurable 25th Percentile	0.40	0.16	0.06	0.57	0.06	0.13	0.21	0.03	0.07	0.08
Daily Measurable Minimum	0.20	0.08	0.04	0.24	0.01	0.07	0.05	0.00	0.00	0.02
Percent of Hours with Measurable Precipitation	3%	3%	4%	1%	3%	3%	4%	6%	4%	3%
Hourly Measurable Max	0.50	0.37	1.50	0.71	0.51	0.51	1.00	0.59	1.11	1.40
Hourly Measurable 75th Percentile	0.30	0.23	0.18	0.46	0.20	0.27	0.25	0.14	0.25	0.33
Hourly Measurable Average	0.21	0.15	0.16	0.35	0.14	0.17	0.22	0.11	0.21	0.25
Hourly Measurable Median	0.10	0.09	0.08	0.35	0.09	0.13	0.12	0.07	0.05	0.11
Hourly Measurable 25th Percentile	0.10	0.05	0.02	0.14	0.02	0.04	0.05	0.03	0.02	0.07
Hourly Measurable Minimum	0.10	0.01	0.01	0.11	0.00	0.00	0.01	0.00	0.00	0.02
WDM DSN ID	**2110**	**2310**	**2510**	**2710**	**2910**	**3110**	**3310**	**3510**	**3710**	**3910**
Location	**SWCD1040**	**BYRG317**	**BYRG693**	**SWCD1008**	**NWS1034**	**SWCD1056**	**SWCD1110**	**SWCD1107**	**SWCD1075**	**SWCD1100**
Acres	26,549.5	15,569.4	38,906.7	53,447.0	19,162.0	35,148.2	22,405.9	25,733.3	21,503.2	42,314.9
Monthly Total Precipitation (in)	6.364	4.362	3.44	3.131	3.23	3.22	4.27	6.07	6.47	6.1
Percent of Days with Measureable Precipitation	43%	30%	30%	43%	23%	17%	27%	30%	33%	33%
Daily Measurable Max	2.50	1.20	2.20	1.11	1.80	1.85	1.98	2.43	1.61	2.68
Daily Measurable 75th Percentile	0.67	0.85	0.18	0.19	0.55	0.72	0.60	1.17	1.34	0.59
Daily Measurable Average	0.49	0.48	0.38	0.24	0.46	0.64	0.53	0.67	0.65	0.61
Daily Measurable Median	0.08	0.25	0.14	0.05	0.18	0.47	0.09	0.22	0.31	0.13
Daily Measurable 25th Percentile	0.04	0.06	0.04	0.00	0.06	0.13	0.06	0.04	0.12	0.04
Daily Measurable Minimum	0.00	0.03	0.02	0.00	0.03	0.05	0.00	0.01	0.04	0.02

WDM DSN ID	**2110**	**2310**	**2510**	**2710**	**2910**	**3110**	**3310**	**3510**	**3710**	**3910**
Location	**SWCD1040**	**BYRG317**	**BYRG693**	**SWCD1008**	**NWS1034**	**SWCD1056**	**SWCD1110**	**SWCD1107**	**SWCD1075**	**SWCD1100**
Percent of Hours with Measurable Precipitation	6%	7%	3%	5%	4%	3%	3%	4%	5%	5%
Hourly Measurable Max	0.73	0.48	0.63	0.68	0.49	0.53	1.34	0.74	0.86	1.07
Hourly Measurable 75th Percentile	0.19	0.12	0.27	0.08	0.11	0.29	0.18	0.31	0.28	0.20
Hourly Measurable Average	0.16	0.09	0.18	0.08	0.10	0.18	0.20	0.19	0.17	0.18
Hourly Measurable Median	0.10	0.08	0.12	0.03	0.05	0.16	0.03	0.08	0.10	0.12
Hourly Measurable 25th Percentile	0.02	0.04	0.05	0.01	0.01	0.06	0.01	0.03	0.04	0.04
Hourly Measurable Minimum	0.00	0.01	0.02	0.00	0.01	0.00	0.00	0.00	0.00	0.01
WDM DSN ID	**4110**	**4310**	**4510**	**4710**	**4910**	**5110**	**5310**	**5510**	**5710**	**5910**
Location	**SWCD998**	**MOSQ9**	**SWCD3**	**SWCD2**	**MN214176**	**SWCD462**	**BYRG695**	**SWCD460**	**SWCD1002**	**SWCD21**
Acres	53,340.8	23,385.7	36,039.6	21,693.5	38,192.7	58,090.2	19,788.0	23,623.9	31,765.0	13,689.7
Monthly Total Precipitation (in)	4.44	5.73	4.169	4.907	3.89	3.48	4.106	3.751	3.442	6.09
Percent of Days with Measureable Precipitation	30%	40%	13%	30%	30%	33%	53%	27%	40%	37%
Daily Measurable Max	2.69	1.85	1.90	2.25	1.51	1.41	1.92	1.63	1.50	2.91
Daily Measurable 75th Percentile	0.34	0.73	1.80	0.43	0.49	0.51	0.20	0.54	0.27	0.38
Daily Measurable Average	0.49	0.48	1.04	0.55	0.43	0.35	0.26	0.47	0.29	0.55
Daily Measurable Median	0.27	0.22	1.04	0.20	0.17	0.16	0.03	0.29	0.05	0.16
Daily Measurable 25th Percentile	0.09	0.10	0.28	0.05	0.04	0.05	0.00	0.14	0.02	0.05
Daily Measurable Minimum	0.05	0.00	0.19	0.03	0.01	0.01	0.00	0.02	0.00	0.01
Percent of Hours with Measurable Precipitation	5%	8%	3%	5%	5%	4%	5%	4%	5%	6%
Hourly Measurable Max	0.73	0.58	0.70	0.81	0.56	0.79	1.08	1.09	0.60	0.91
Hourly Measurable 75th Percentile	0.12	0.15	0.33	0.14	0.10	0.12	0.12	0.15	0.11	0.13
Hourly Measurable Average	0.12	0.10	0.22	0.14	0.10	0.12	0.11	0.13	0.10	0.15
Hourly Measurable Median	0.04	0.06	0.12	0.07	0.04	0.07	0.02	0.04	0.02	0.08
Hourly Measurable 25th Percentile	0.01	0.01	0.10	0.02	0.02	0.02	0.01	0.01	0.01	0.03
Hourly Measurable Minimum	0.00	0.00	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.01
WDM DSN ID	**6110**	**6310**	**6510**	**6710**	**6910**	**7110**	**7310**	**7510**	**7710**	
Location	**MN211448**	**MOSQ1021**	**BYRG12**	**SWCD1111**	**SWCD435**	**BYRG688**	**SWCD440**	**MN215435**	**BYRG106**	
Acres	11,687.1	28,159.8	8,109.6	42,352.6	8,834.9	27,387.0	28,929.3	14,621.5	18,367.2	
Monthly Total Precipitation (in)	3.89	6.42	4.393	5.032	6.355	3.571	4.521	2.86	3.322	

WDM DSN ID	**6110**	**6310**	**6510**	**6710**	**6910**	**7110**	**7310**	**7510**	**7710**
Location	**MN211448**	**MOSQ1021**	**BYRG12**	**SWCD1111**	**SWCD435**	**BYRG688**	**SWCD440**	**MN215435**	**BYRG106**
Percent of Days with Measureable Precipitation	30%	40%	37%	33%	40%	27%	33%	27%	37%
Daily Measurable Max	1.51	3.40	1.40	2.30	4.45	1.64	2.97	1.09	1.28
Daily Measurable 75th Percentile	0.49	0.41	0.52	0.18	0.26	0.56	0.33	0.41	0.32
Daily Measurable Average	0.43	0.54	0.40	0.50	0.53	0.45	0.45	0.36	0.30
Daily Measurable Median	0.17	0.17	0.12	0.12	0.14	0.18	0.12	0.23	0.17
Daily Measurable 25th Percentile	0.04	0.05	0.07	0.05	0.04	0.15	0.03	0.17	0.05
Daily Measurable Minimum	0.01	0.00	0.02	0.02	0.00	0.10	0.01	0.04	0.01
Percent of Hours with Measurable Precipitation	5%	7%	5%	4%	5%	3%	5%	3%	6%
Hourly Measurable Max	0.56	0.84	0.65	1.93	1.39	0.53	0.76	0.56	0.70
Hourly Measurable 75th Percentile	0.10	0.15	0.11	0.19	0.15	0.25	0.16	0.20	0.08
Hourly Measurable Average	0.10	0.13	0.13	0.19	0.18	0.19	0.13	0.13	0.08
Hourly Measurable Median	0.04	0.06	0.08	0.05	0.05	0.17	0.05	0.10	0.04
Hourly Measurable 25th Percentile	0.02	0.01	0.05	0.02	0.03	0.09	0.02	0.02	0.02
Hourly Measurable Minimum	0.00	0.00	0.01	0.01	0.00	0.02	0.00	0.01	0.00

4 Intense Storms Results

Results and discussion for intense storms analysis are presented in the section. As stated above the intense storms daily sediment load analysis was conducted three different ways. First, the area-weighted largest daily precipitation (LDP) total by season for the upstream area to each analysis location was found. Second, the area-weighted largest hourly precipitation (LHP) total by season for the upstream area to each analysis location was found. Third, the largest observed daily sediment load (LDS) by season based on the percentage each day contributed to the two year total at each analysis location was found. For each analysis location and season this provided that dates that 1) had the most daily rainfall, 2) had the most intense hourly rainfall, and 3) had the highest observed loads.

Provided below are time series plots showing daily precipitation, daily observed sediment load, and daily simulated sediment load for each analysis approach. The time series plots for each location and analysis type are all organized the same way. The schematic below identifies the organization of the figures in this section. The time series plots were prepared for a simple visual confirmation of the information tabulated in the tables.

Daily Total Precipitation % of 2 year Total and Analysis Dates	Observed Sediment Load, Simulated Sediment Load, Daily Total Precipitation, and Analysis Dates
Late Winter (LW) Analysis	Spring (SP) Analysis
Early Summer (ES) Analysis	Late Summer (LS) Analysis
Fall (FA) Analysis	Early Winter (EW) Analysis

The tables present the following information:

- For the dates with the most daily rainfall and most intense hourly rainfall (first table in each section): method used to determine analysis date, season, analysis date, daily total precipitation, daily total precipitation % of two year total, hourly precipitation maximum, percent contribution of the two year total of the sediment load for the analysis dates plus the next seven days for observed data and simulated output.
- For the dates with the highest observed sediment load (second table in each section): method used to determine analysis date, season, analysis date, preceding seven days and analysis day precipitation total, preceding seven day and analysis day total precipitation % of two year total, percent contribution of the two year total of the sediment load for the preceding 5 days plus the analysis date plus the next two days for observed data and simulated output.

4.1 E26057001 CHIPPEWA RIVER NEAR MILAN, MN40

For the 2011 and 2012 analysis period Late Fall, Early Winter, and Late Winter contribute very little sediment therefore the analysis will only focus on Spring, Early Summer, and Late Summer. The following discussion pertains to the results in Table 52 and Table 53. Time series plots, although not discussed are provided in Figure 23, Figure 24, and Figure 25.

For Spring LDP and LDH selected days in April 2012 that were two days apart with windowed observed sediment load approximately 2% of the two year total but LDS selected a day in April 2011 with windowed observed sediment load approximately 8% of the total. LDP and LDH both selected intense precipitation events that didn't produce much sediment but LDS selected high sediment with very little preceding precipitation to for the preceding seven days. For Early Summer LDP and LDH selected days in June 2012 that were ten days apart with windowed observed sediment load for LDP approximately 2.5% of the two year total and LDH approximately 7.7 % of the observed two year total. LDS selected a day in June 2012 one day after LDH. Therefore, high hourly intensity in Early Summer correlated to a high daily Early Summer sediment load. For Late Summer LDP selected a day in July 2011 with windowed observed sediment load approximately 4.9% of the two year total and LDH selected a day in July 2011 12 days after LDP with windowed observed sediment load approximately 3.9 % of the observed two year total. LDS selected a day in July 2011 two days after LDP with windowed observed sediment load approximately 4.2% of the total. Comparing precipitation for LDP and LDS shows that likely a multi-day precipitation pattern caused a high daily Late Summer sediment load.

Table 52. Intense Storms Analysis for Chippewa River near Milan, MN40

Method	Season	Date	Precipitation Daily Total (in)	Precipitation Daily Total % of 2 Year Total	Hourly Maximum (in)	Observed Sediment Load % of 2 Year Total (+7 day window)	Simulated Sediment Load % of 2 Year Total (+7 day window)
Largest Daily Precipitation	Late Winter	2/28/2012	0.71	1.48%	0.22	0.0%	0.0%
	Spring	4/15/2012	1.16	2.42%	0.17	2.2%	0.2%
	Early Summer	6/7/2012	1.57	3.27%	0.67	2.5%	7.9%
	Late Summer	7/14/2011	1.39	2.89%	0.29	4.9%	53.6%
	Fall	10/18/2012	0.78	1.62%	0.07	0.0%	0.0%
	Early Winter	12/9/2012	0.63	1.31%	0.15	0.0%	0.0%
Largest Hourly Precipitation	Late Winter	2/28/2012	0.71	1.48%	0.22	0.0%	0.0%
	Spring	4/13/2012	0.48	0.99%	0.22	1.8%	0.1%
	Early Summer	6/17/2012	1.14	2.38%	0.73	7.7%	1.5%
	Late Summer	7/26/2011	1.05	2.19%	0.86	3.9%	2.9%
	Fall	10/12/2011	0.33	0.69%	0.15	0.6%	0.0%
	Early Winter	11/10/2012	0.39	0.82%	0.16	0.0%	0.0%

Table 53. Highest Sediment Daily Load Analysis for Chippewa River near Milan, MN40

Method	Season	Date	Precipitation Total (-7 day window) (in)	Precipitation % of 2 Year Total (-7 day window)	Observed Sediment Load % of 2 Year Total (-5 +2 day window)	Simulated Sediment Load % of 2 Year Total (-5 +2 day window)
Largest Daily Sediment Load	Late Winter	2/19/2011	0.00	0.0%	0.2%	0.0%
	Spring	4/4/2011	0.18	0.4%	8.1%	2.1%
	Early Summer	6/18/2012	1.69	3.5%	4.8%	1.3%
	Late Summer	7/16/2011	3.62	7.5%	4.2%	49.0%
	Fall	9/1/2011	0.10	0.2%	1.4%	0.4%
	Early Winter	11/1/2011	0.08	0.2%	0.4%	0.0%

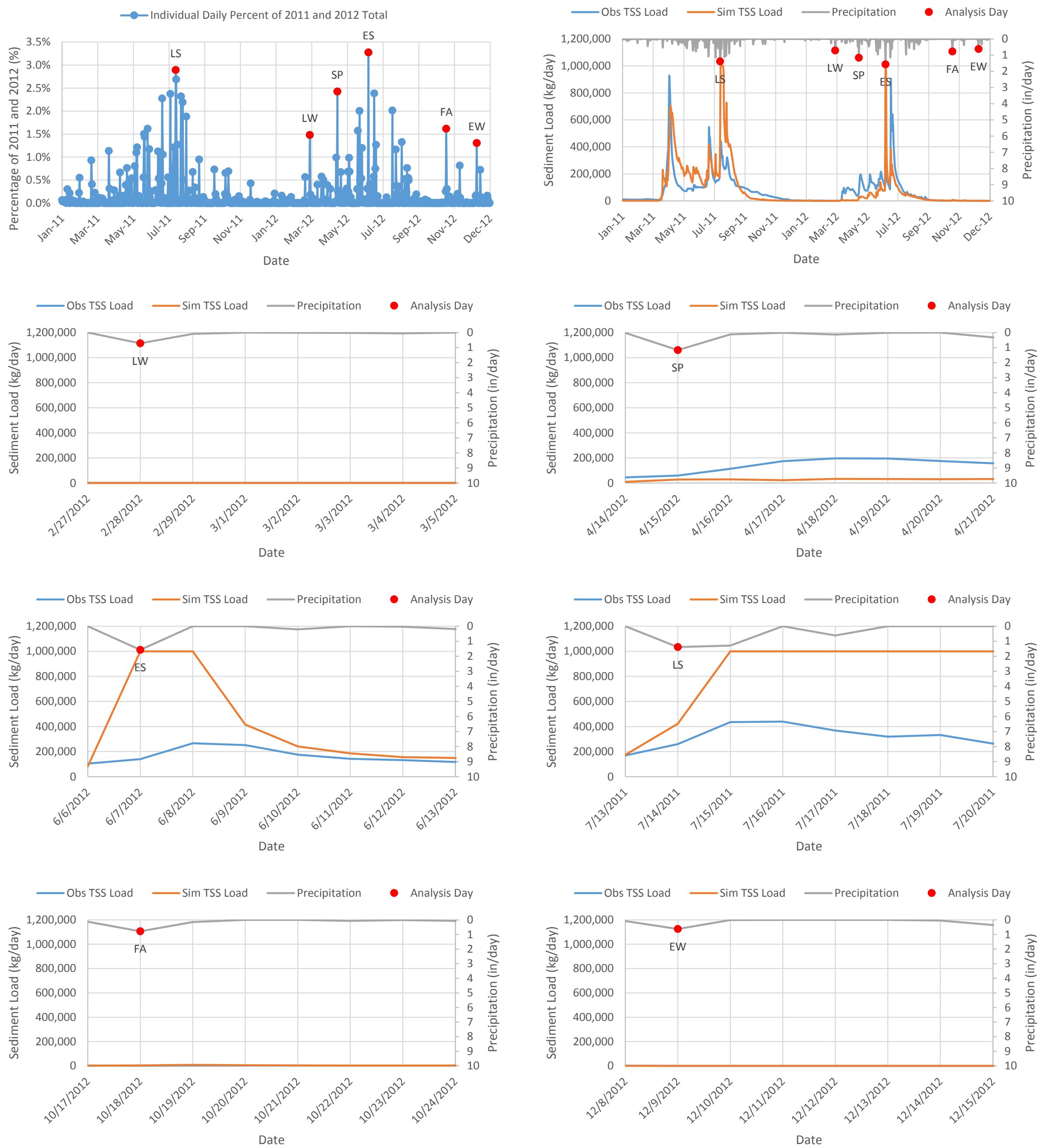

Figure 23. Time Series Plots for Largest Daily Precipitation Days for Chippewa River near Milan, MN40

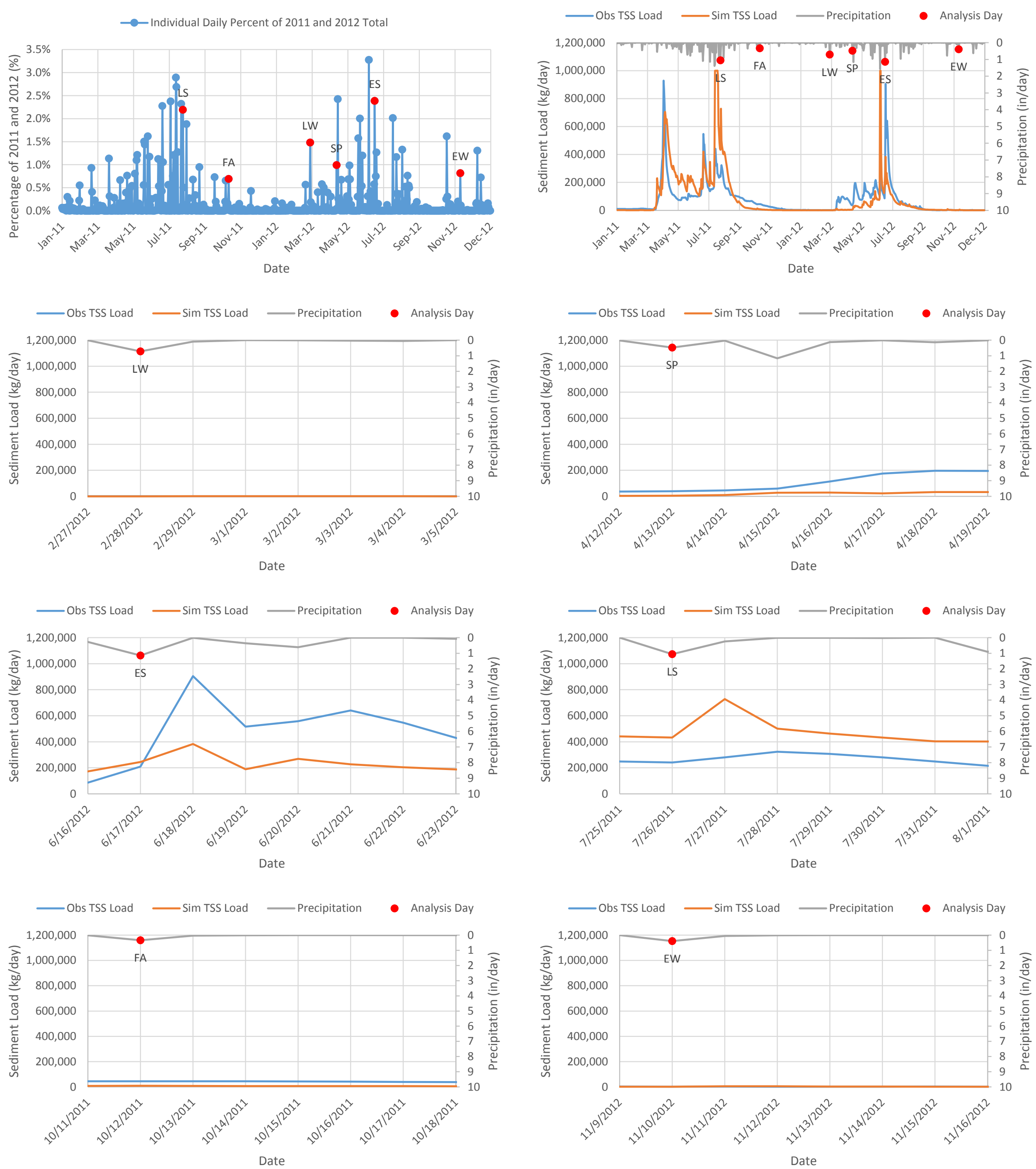

Figure 24. Time Series Plots for Largest Hourly Precipitation Days for Chippewa River near Milan, MN40

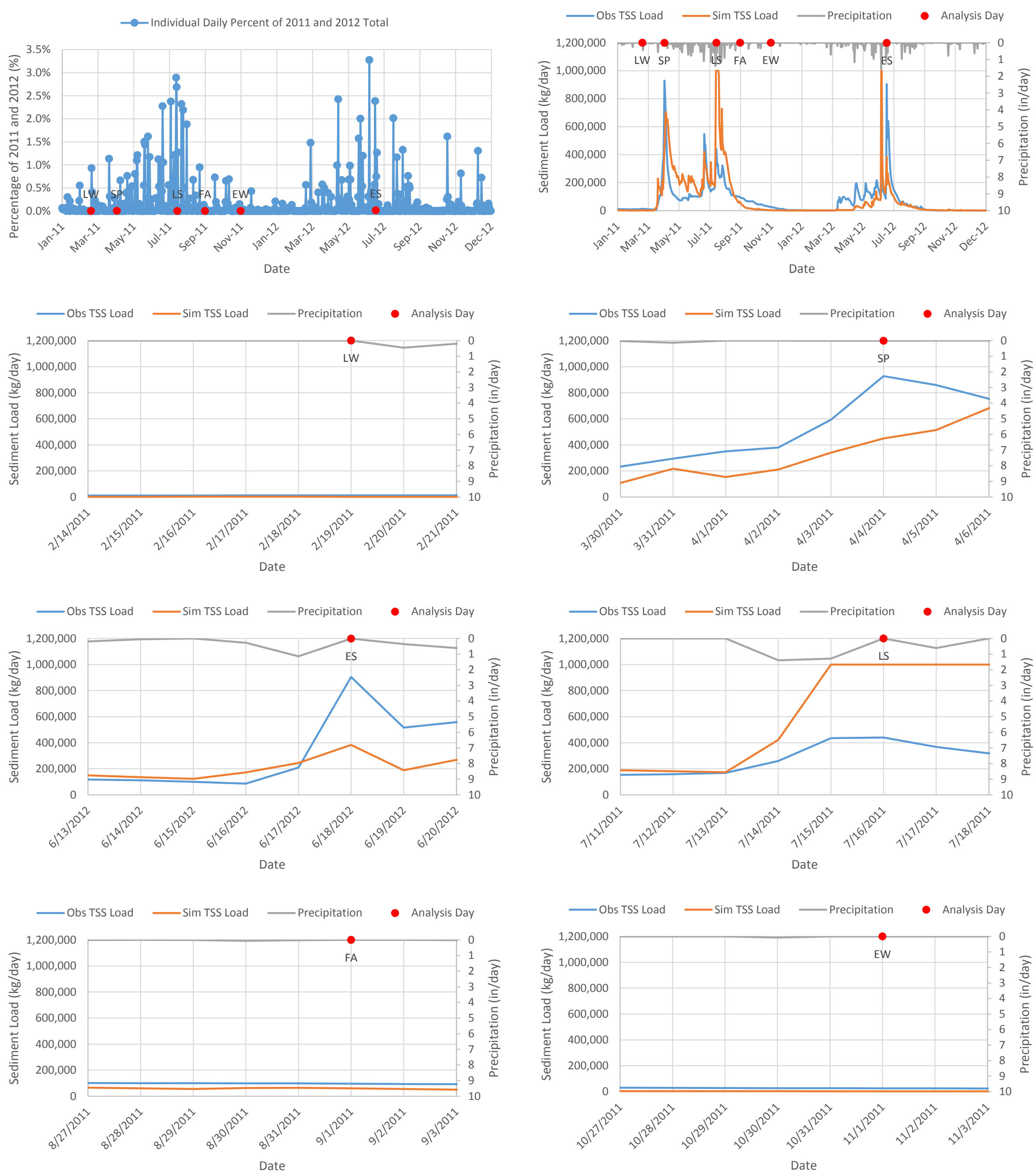

Figure 25. Time Series Plots for Largest Sediment Loading Days for Chippewa River near Milan, MN40

4.2 E27035001 Redwood River near Redwood Falls, MN

For the 2011 and 2012 analysis period Late Fall, Early Winter, and Late Winter contribute very little sediment therefore the analysis will only focus on Spring, Early Summer, and Late Summer. The following discussion pertains to the results in Table 54 and Table 55. Time series plots, although not discussed are provided in Figure 26, Figure 27, and Figure 28.

For Spring LDP selected a day in March 2011 with windowed observed sediment load approximately 11.6% of the two year total and LDH selected a day in April 2011 with windowed observed sediment load approximately 2.9 % of the observed two year total. LDS selected a day in March 2011 one day after LDP. Since LDP and LDS selected essentially the same day, high daily precipitation caused a high daily Spring sediment load. For Early Summer LDP and LDH selected the same day in June 2011 with windowed observed sediment load approximately 9.4% of the two year total. LDS selected a day in May 2012 which had a lot of rain for the preceding seven days. The day selected by LDP and LDH was followed by a large sediment load but it did not contain the individual daily highest sediment load which was selected by LDS. For Late Summer LDP and LDH selected the same day in July 2011 with windowed observed sediment load approximately 3.9% of the two year total. LDS selected a day in July 2011 six days after LDP with windowed observed sediment load approximately 4.2% of the total. LDP, LDH, and LDS selected the essentially selected the same storm. For Late Summer, daily total and peak intensity both contributed to high sediment.

Table 54. Intense Storms Analysis for Redwood River near Redwood Falls, MN

Method	Season	Date	Precipitation Daily Total (in)	Precipitation Daily Total % of 2 Year Total	Hourly Maximum (in)	Observed Sediment Load % of 2 Year Total (+7 day window)	Simulated Sediment Load % of 2 Year Total (+7 day window)
Largest Daily Precipitation	Late Winter	2/28/2012	0.73	1.48%	0.25	0.0%	0.0%
	Spring	3/22/2011	1.40	2.85%	0.23	11.6%	14.1%
	Early Summer	6/21/2011	1.89	3.85%	0.71	9.4%	5.2%
	Late Summer	7/10/2011	1.15	2.35%	0.56	3.9%	1.1%
	Fall	10/18/2012	0.65	1.33%	0.07	0.1%	0.0%
	Early Winter	12/9/2012	0.66	1.36%	0.10	0.0%	0.0%
Largest Hourly Precipitation	Late Winter	2/28/2012	0.73	1.48%	0.25	0.0%	0.0%
	Spring	4/9/2011	0.67	1.37%	0.40	2.9%	9.5%
	Early Summer	6/21/2011	1.89	3.85%	0.71	9.4%	5.2%
	Late Summer	7/10/2011	1.15	2.35%	0.56	3.9%	1.1%
	Fall	9/17/2012	0.43	0.88%	0.19	0.0%	0.0%
	Early Winter	11/10/2012	0.27	0.55%	0.16	0.0%	0.0%

Table 55. Highest Sediment Daily Load Analysis for Redwood River near Redwood Falls, MN

Method	Season	Date	Precipitation Total (-7 day window) (in)	Precipitation % of 2 Year Total (-7 day window)	Observed Sediment Load % of 2 Year Total (-5 +2 day window)	Simulated Sediment Load % of 2 Year Total (-5 +2 day window)
Largest Daily Sediment Load	Late Winter	2/20/2011	0.62	1.3%	0.2%	0.3%
	Spring	3/23/2011	1.80	3.7%	9.7%	8.3%
	Early Summer	5/7/2012	4.63	9.4%	8.8%	20.4%
	Late Summer	7/16/2011	2.63	5.4%	4.2%	1.2%
	Fall	9/8/2011	0.04	0.1%	0.1%	0.0%
	Early Winter	11/1/2012	0.14	0.3%	0.0%	0.0%

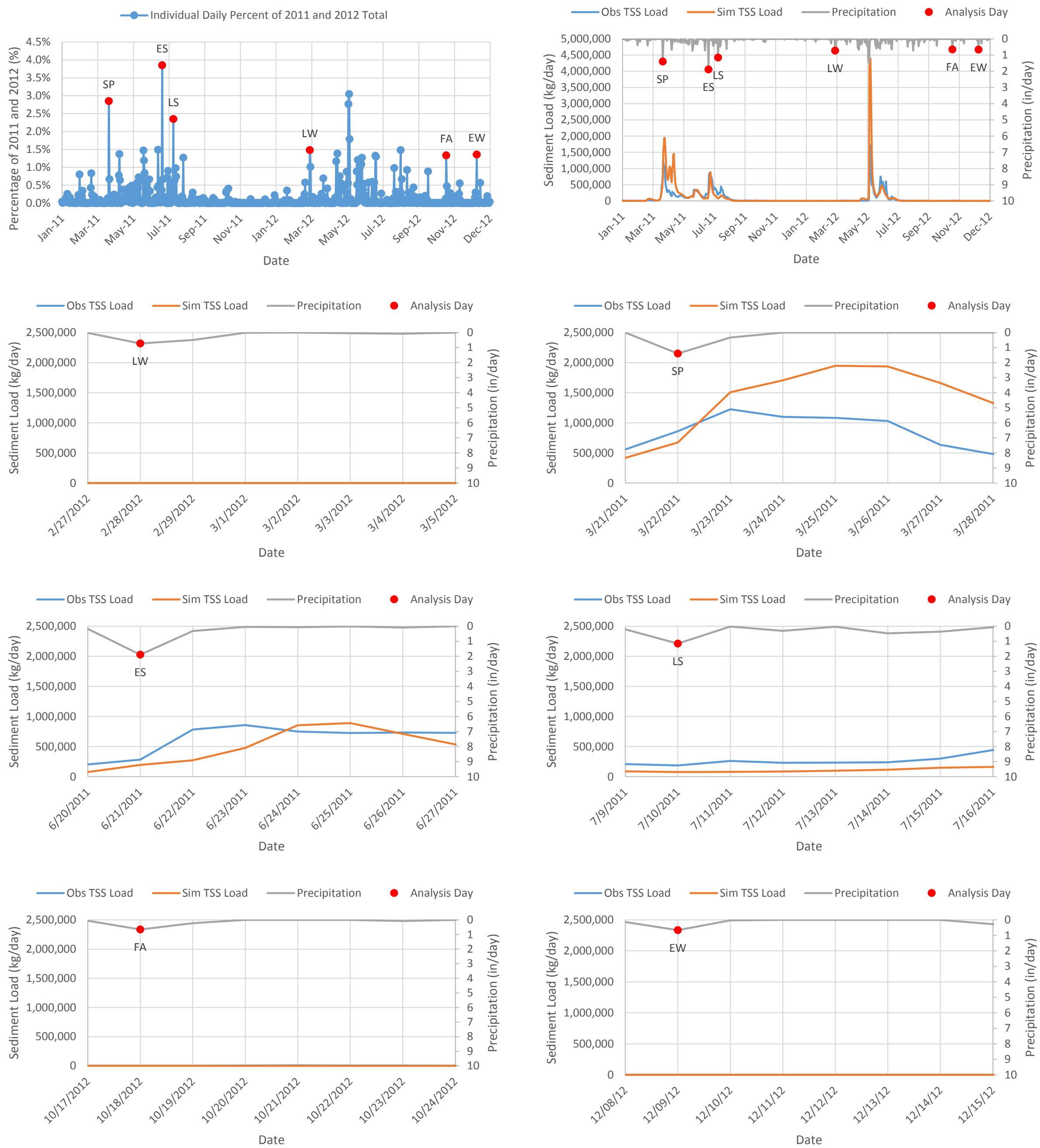

Figure 26. Time Series Plots for Largest Daily Precipitation Days for Redwood River near Redwood Falls, MN

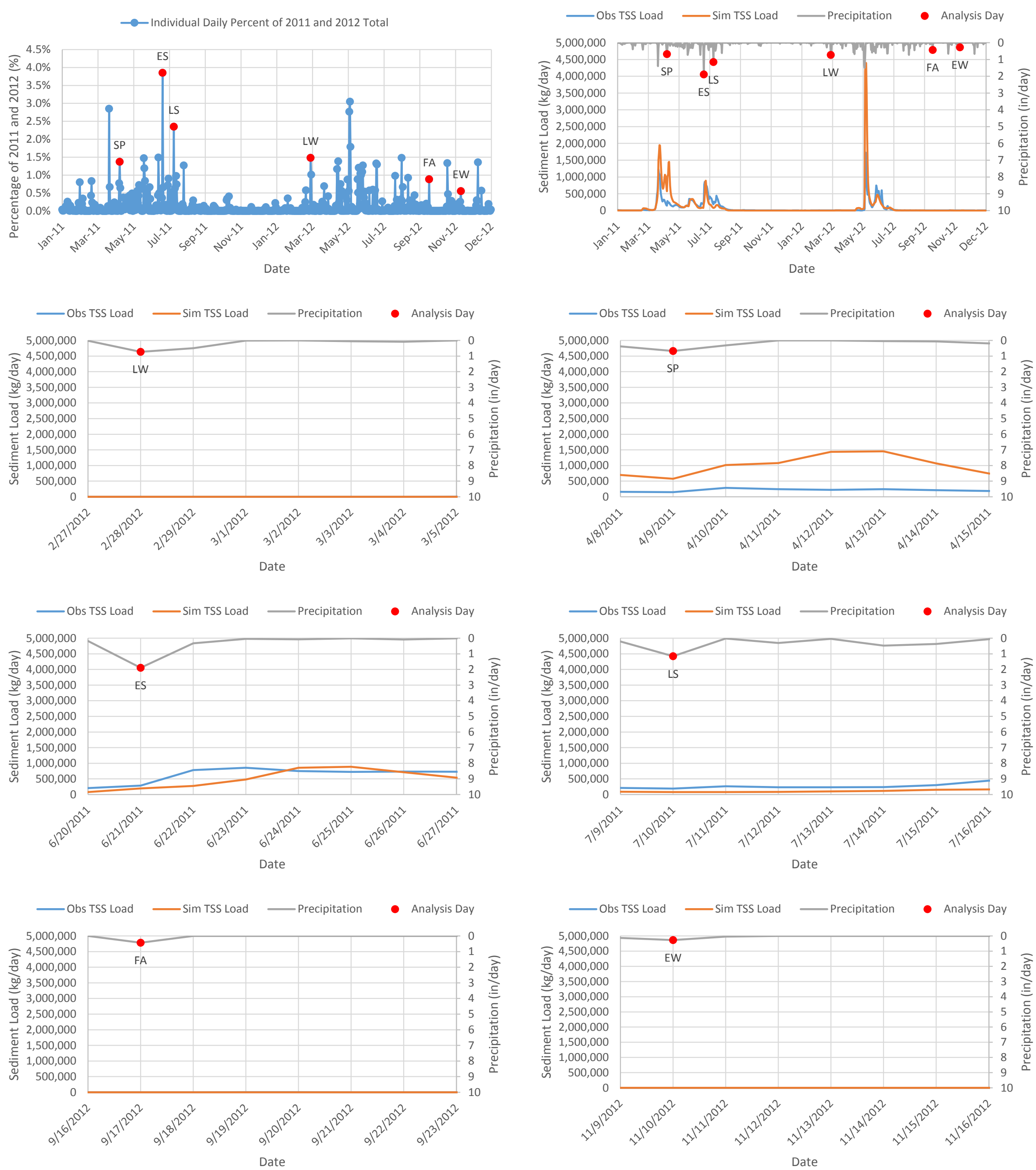

Figure 27. Time Series Plots for Largest Hourly Precipitation Days for Redwood River near Redwood Falls, MN

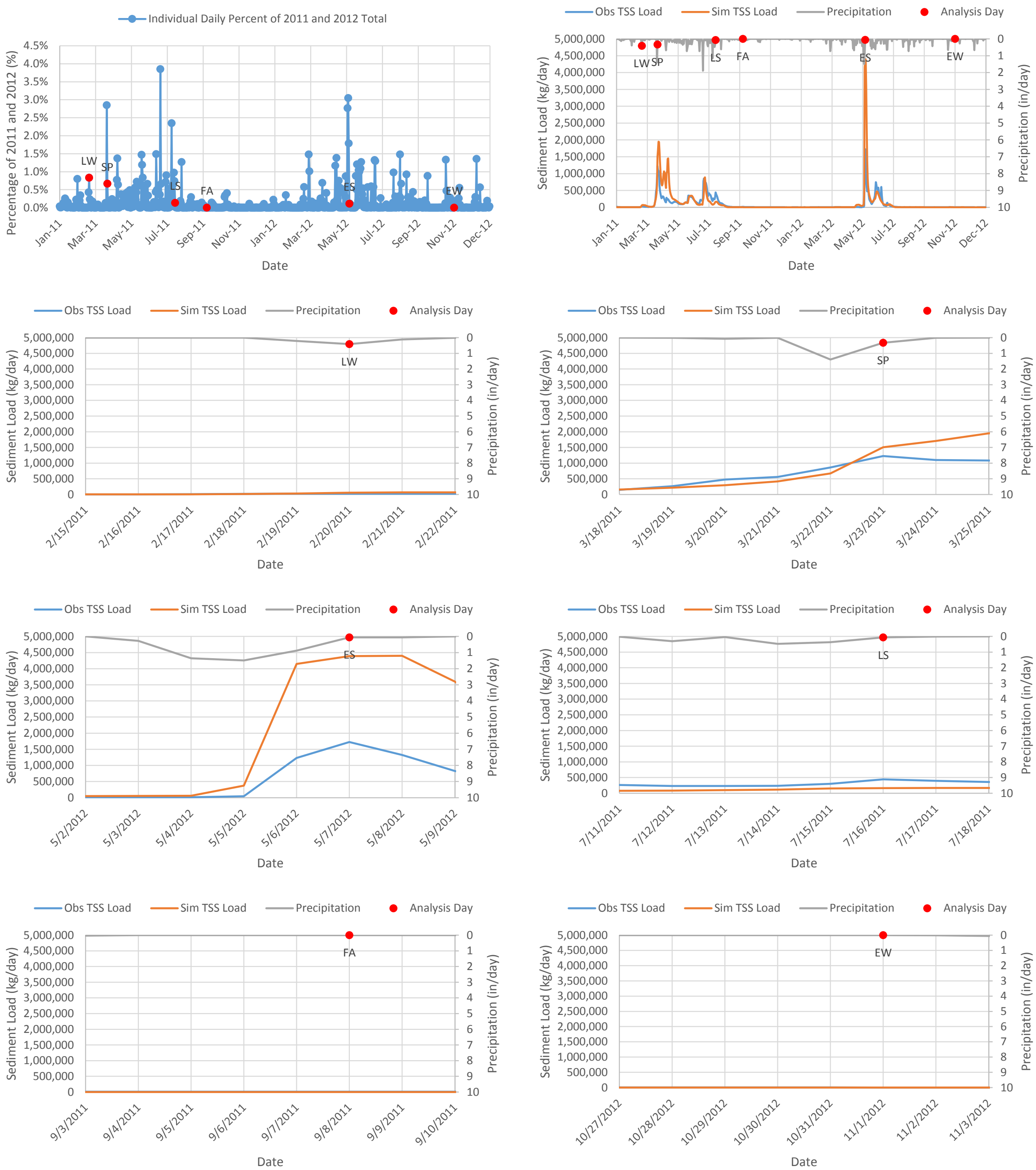

Figure 28. Time Series Plots for Largest Sediment Loading Days for Redwood River near Redwood Falls, MN

4.3 E25075001 YELLOW MEDICINE RIVER NEAR GRANITE FALLS, MN

For the 2011 and 2012 analysis period Late Fall, Early Winter, and Late Winter contribute very little sediment therefore the analysis will only focus on Spring, Early Summer, and Late Summer. The following discussion pertains to the results in Table 56 and Table 57. Time series plots, although not discussed are provided in Figure 29, Figure 30, and Figure 31.

For Spring LDP selected a day in April 2012 with windowed observed sediment load approximately 0.1% of the two year total and LDH selected a day in March 2011 with windowed observed sediment load approximately 28.4% of the observed two year total. LDS selected a day in March 2011 one day after LDH. LDH and LDS essentially selected the same day and since they are in March the high sediment load is likely due to a rain on snow event. For Early Summer LDP selected a day in June 2011 with windowed observed sediment load approximately 6.4% of the two year total and LDH selected a day in May 2012 with windowed observed sediment load approximately 7.9 % of the observed two year total. LDS selected a day in May 2012 two days after LDH. Therefore, high hourly intensity in Early Summer correlated to a high daily Early Summer sediment load. For Late Summer LDP and LDH selected the same day in July 2011 with windowed observed sediment load approximately 3.2% of the two year total. LDS selected a day in July 2011 six days after LDP and LDH with windowed observed sediment load approximately 4.2% of the total. Comparing precipitation for LDP/LDH and LDS shows that a multi-day precipitation pattern likely caused a high daily Late Summer sediment load.

Table 56. Intense Storms Analysis for Yellow Medicine River near Granite Falls, MN

Method	Season	Date	Precipitation Daily Total (in)	Precipitation Daily Total % of 2 Year Total	Hourly Maximum (in)	Observed Sediment Load % of 2 Year Total (+7 day window)	Simulated Sediment Load % of 2 Year Total (+7 day window)
Largest Daily Precipitation	Late Winter	2/28/2012	0.79	1.63%	0.19	0.0%	0.0%
	Spring	4/15/2012	1.17	2.42%	0.24	0.1%	0.1%
	Early Summer	6/21/2011	1.97	4.06%	0.43	6.4%	10.2%
	Late Summer	7/10/2011	1.29	2.66%	0.63	3.2%	2.1%
	Fall	10/18/2012	0.89	1.84%	0.09	0.0%	0.0%
	Early Winter	12/9/2012	0.60	1.23%	0.11	0.0%	0.0%
Largest Hourly Precipitation	Late Winter	2/28/2012	0.79	1.63%	0.19	0.0%	0.0%
	Spring	3/22/2011	0.95	1.96%	0.27	28.4%	6.8%
	Early Summer	5/6/2012	1.21	2.49%	0.77	7.9%	39.6%
	Late Summer	7/10/2011	1.29	2.66%	0.63	3.2%	2.1%
	Fall	9/18/2011	0.22	0.45%	0.15	0.0%	0.0%
	Early Winter	12/8/2012	0.58	1.20%	0.15	0.0%	0.0%

Table 57. Highest Sediment Daily Load Analysis for Yellow Medicine River near Granite Falls, MN

Method	Season	Date	Precipitation Total (-7 day window) (in)	Precipitation % of 2 Year Total (-7 day window)	Observed Sediment Load % of 2 Year Total (-5 +2 day window)	Simulated Sediment Load % of 2 Year Total (-5 +2 day window)
Largest Daily Sediment Load	Late Winter	2/22/2011	0.81	1.7%	0.3%	0.2%
	Spring	3/23/2011	1.55	3.2%	20.6%	4.6%
	Early Summer	5/8/2012	3.58	7.4%	6.7%	41.0%
	Late Summer	7/16/2011	2.74	5.6%	3.4%	2.2%
	Fall	9/1/2011	0.19	0.4%	0.0%	0.0%
	Early Winter	11/4/2011	0.00	0.0%	0.0%	0.0%

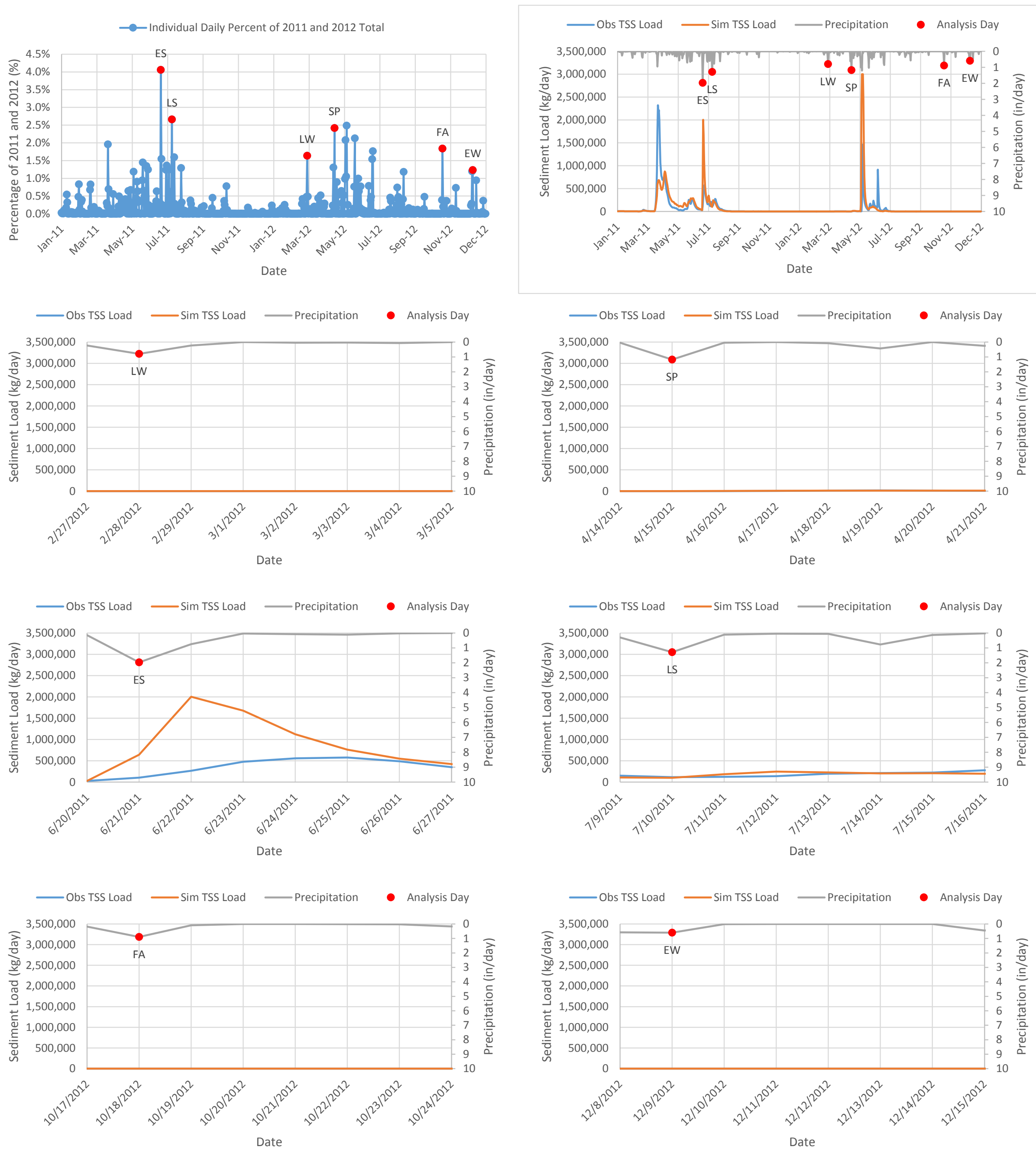

Figure 29. Time Series Plots for Largest Daily Precipitation Days for Yellow Medicine River near Granite Falls, MN

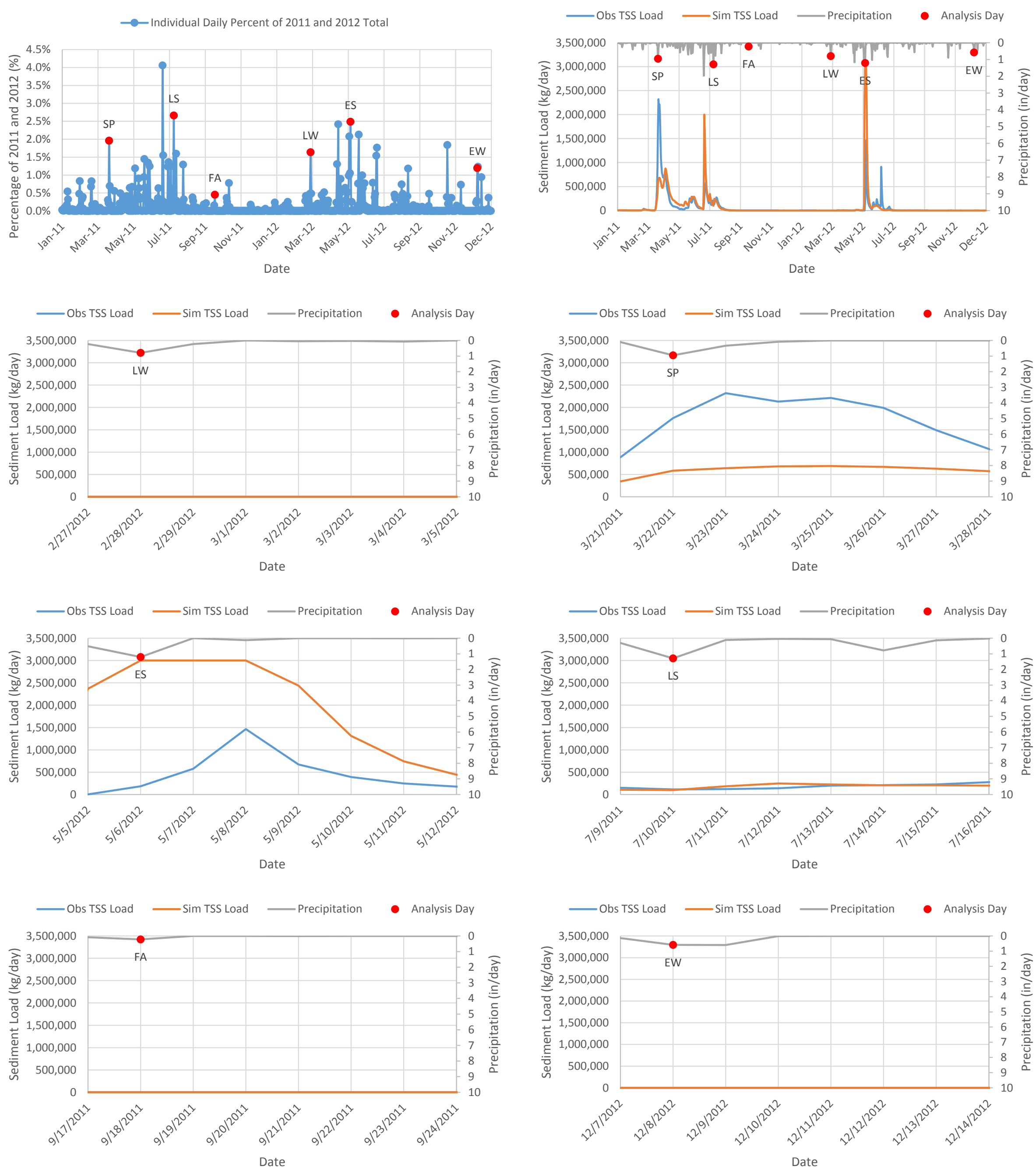

Figure 30. Time Series Plots for Largest Hourly Precipitation Days for Yellow Medicine River near Granite Falls, MN

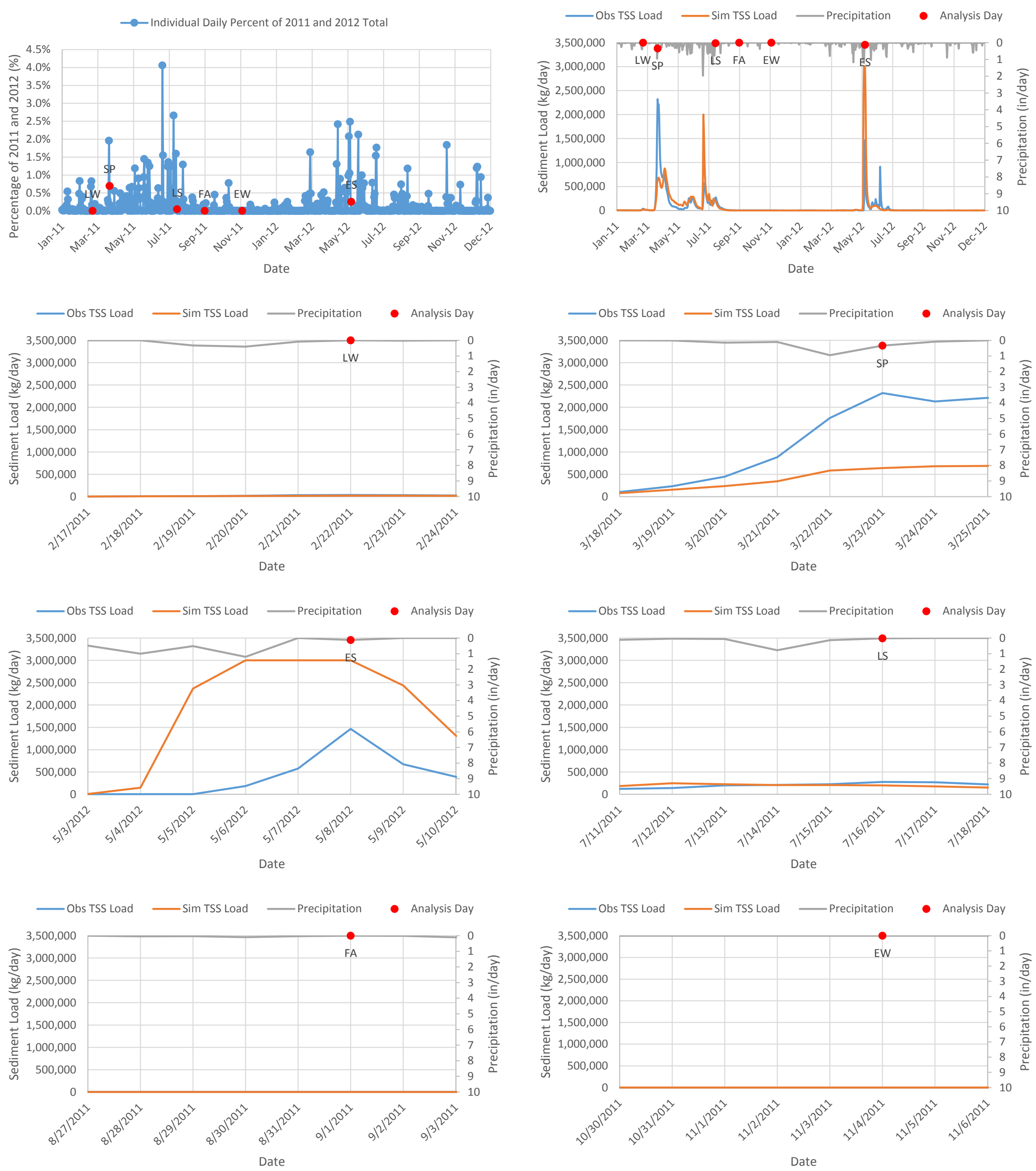

Figure 31. Time Series Plots for Largest Sediment Loading Days for Yellow Medicine River near Granite Falls, MN

4.4 E29001001 Cottonwood River near New Ulm, MN68

For the 2011 and 2012 analysis period Late Fall, Early Winter, and Late Winter contribute very little sediment therefore the analysis will only focus on Spring, Early Summer, and Late Summer. The following discussion pertains to the results in Table 58 and Table 59. Time series plots, although not discussed are provided in Figure 32, Figure 33, and Figure 34.

For Spring LDP selected a day in March 2011 with windowed observed sediment load approximately 24.8% of the two year total and LDH selected a day in April 2012 with windowed observed sediment load approximately 0.0% of the observed two year total. LDS selected a day in March 2011 one day after LDP. LDP and LDS essentially selected the same day and since they are in March the high sediment load is likely due to a rain on snow event. For Early Summer LDP selected a day in June 2011 with windowed observed sediment load approximately 14% of the two year total and LDH selected a day in May 2012 with windowed observed sediment load approximately 5.9 % of the observed two year total. LDS selected a day in June 2011 three days after LDH. Therefore, high daily total precipitation in Early Summer correlated to a high daily Early Summer sediment load. For Late Summer LDP selected a day in July 2011 with windowed observed sediment load approximately 2.1% of the two year total and LDH selected a day in August 2012 with windowed observed sediment load approximately 0.0 % of the observed two year total. LDS selected a day in July 2011 seven days after LDP with windowed observed sediment load approximately 2.7% of the total. Comparing precipitation for LDP and LDS shows that a multi-day precipitation pattern caused a high daily Late Summer sediment load.

Table 58. Intense Storms Analysis for Cottonwood River near New Ulm, MN68

Method	Season	Date	Precipitation Daily Total (in)	Precipitation Daily Total % of 2 Year Total	Hourly Maximum (in)	Observed Sediment Load % of 2 Year Total (+7 day window)	Simulated Sediment Load % of 2 Year Total (+7 day window)
Largest Daily Precipitation	Late Winter	2/20/2011	0.89	1.72%	0.25	0.2%	0.9%
	Spring	3/22/2011	1.36	2.64%	0.23	24.8%	17.3%
	Early Summer	6/14/2011	2.28	4.43%	0.71	14.0%	11.3%
	Late Summer	7/10/2011	0.94	1.82%	0.43	2.1%	0.7%
	Fall	9/17/2012	0.48	0.94%	0.22	0.0%	0.0%
	Early Winter	12/9/2012	0.48	0.94%	0.11	0.0%	0.0%
Largest Hourly Precipitation	Late Winter	2/20/2011	0.89	1.72%	0.25	0.2%	0.9%
	Spring	4/15/2012	0.83	1.61%	0.27	0.0%	0.0%
	Early Summer	5/1/2012	1.35	2.62%	1.02	5.9%	7.2%
	Late Summer	8/1/2012	0.79	1.53%	0.44	0.0%	0.0%
	Fall	9/17/2012	0.48	0.94%	0.22	0.0%	0.0%
	Early Winter	11/10/2012	0.33	0.63%	0.13	0.0%	0.0%

Table 59. Highest Sediment Daily Load Analysis for Cottonwood River near New Ulm, MN68

Method	Season	Date	Precipitation Total (-7 day window) (in)	Precipitation % of 2 Year Total (-7 day window)	Observed Sediment Load % of 2 Year Total (-5 +2 day window)	Simulated Sediment Load % of 2 Year Total (-5 +2 day window)
Largest Daily Sediment Load	Late Winter	2/23/2011	1.20	2.3%	0.2%	0.8%
	Spring	3/23/2011	1.71	3.3%	24.7%	12.2%
	Early Summer	6/17/2011	3.43	6.6%	12.4%	9.6%
	Late Summer	7/17/2011	2.52	4.9%	2.7%	0.9%
	Fall	9/1/2011	0.10	0.2%	0.0%	0.0%
	Early Winter	12/30/2011	0.19	0.4%	0.0%	0.0%

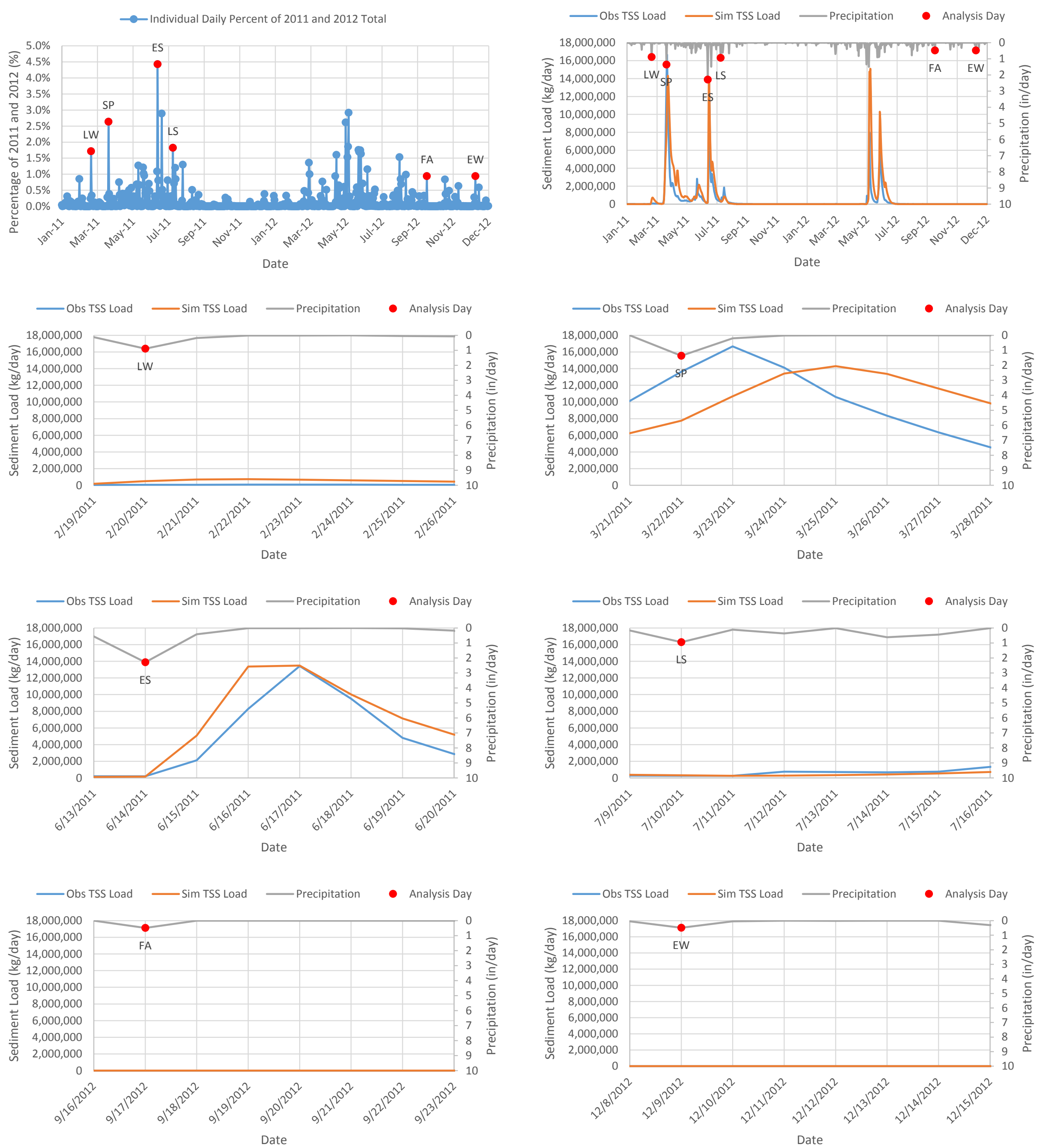

Figure 32. Time Series Plots for Largest Daily Precipitation Days for Cottonwood River near New Ulm, MN68

Figure 33. Time Series Plots for Largest Hourly Precipitation Days for Cottonwood River near New Ulm, MN68

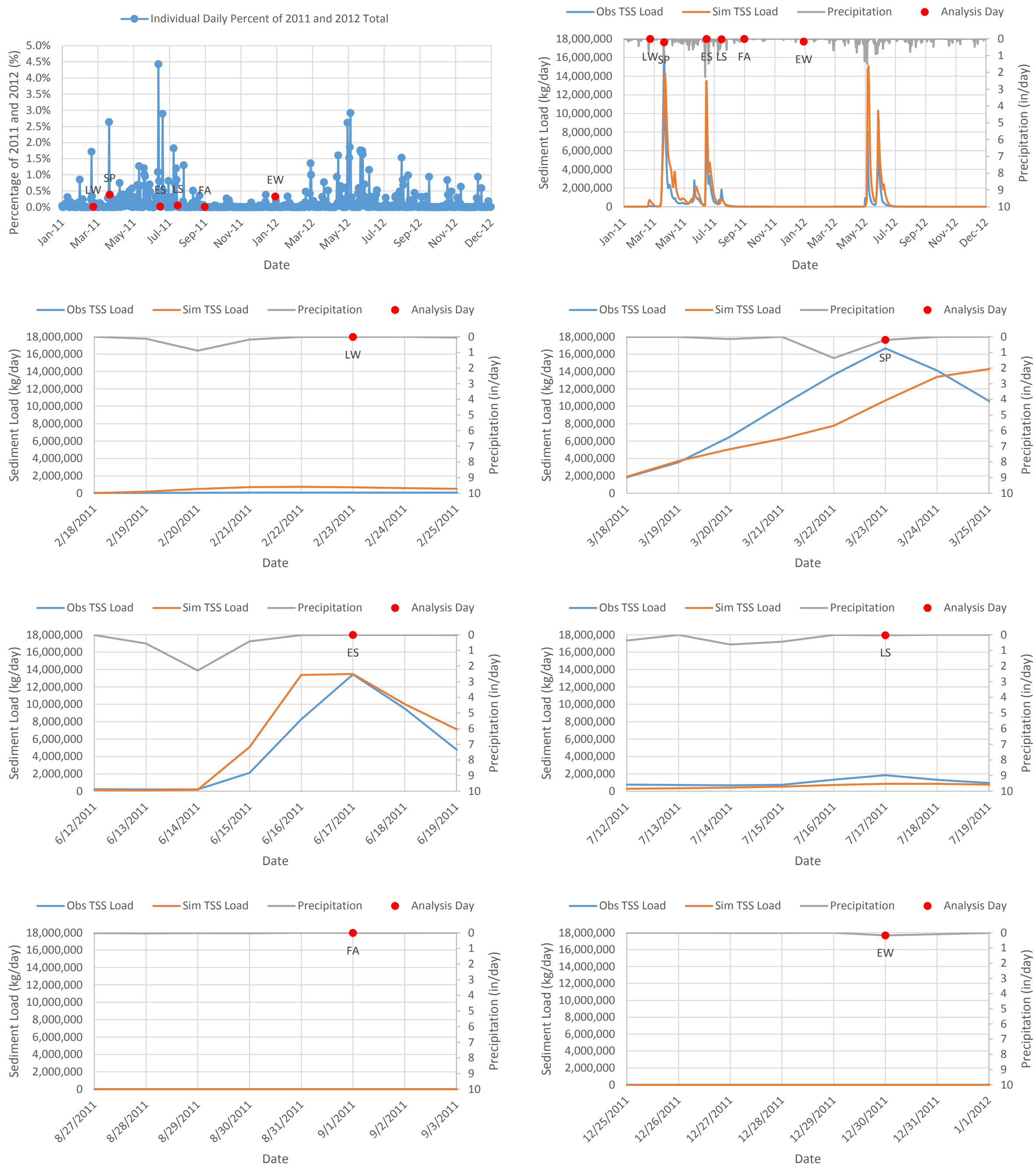

Figure 34. Time Series Plots for Largest Sediment Loading Days for Cottonwood River near New Ulm, MN68

4.5 E31051001 Watonwan River near Garden City, CSAH13

For the 2011 and 2012 analysis period Late Fall, Early Winter, and Late Winter contribute very little sediment therefore the analysis will only focus on Spring, Early Summer, and Late Summer. The following discussion pertains to the results in Table 60 and Table 61. Time series plots, although not discussed are provided in Figure 35, Figure 36, and Figure 37.

For Spring LDP and LDH selected the same day in March 2011 with windowed observed sediment load approximately 18.9% of the two year total. LDS selected the same day in March 2011. LDP, LDH, and LDS all selected the same day and since they are in March the high sediment load is likely due to a rain on snow event. For Early Summer LDP and LDH selected the same day in May 2012 with windowed observed sediment load approximately 14.2% of the two year total. LDS selected a day in May 2012 18 days before LDP and LDH with windowed observed sediment load approximately 7.1% of the two year total. LDP and LDH selected the same day but that event did not contain the highest sediment loading day although their windowed observed sediment load was much greater than the window around LDS. Approximately 2 weeks prior to the LDP and LDH day there was a significant multi day event which caused the high sediment loading day. For Late Summer LDP and LDH selected the same day in July 2011 with windowed observed sediment load approximately 1.8% of the two year total. LDS selected a day in July 2011 7 days after LDP and LDH. LDP, LDH, and LDS essentially selected the same storm event so the high sediment load was driven by both daily total and hourly intensity.

Table 60. Intense Storms Analysis for Watonwan River near Garden City, CSAH13

Method	Season	Date	Precipitation Daily Total (in)	Precipitation Daily Total % of 2 Year Total	Hourly Maximum (in)	Observed Sediment Load % of 2 Year Total (+7 day window)	Simulated Sediment Load % of 2 Year Total (+7 day window)
Largest Daily Precipitation	Late Winter	2/28/2012	0.87	1.77%	0.23	0.4%	0.0%
	Spring	3/22/2011	0.91	1.85%	0.23	18.9%	14.5%
	Early Summer	5/24/2012	1.77	3.61%	0.59	14.2%	14.4%
	Late Summer	7/10/2011	1.12	2.28%	0.56	1.8%	2.3%
	Fall	10/25/2012	0.57	1.17%	0.24	0.0%	0.0%
	Early Winter	11/10/2012	0.33	0.67%	0.11	0.0%	0.0%
Largest Hourly Precipitation	Late Winter	2/28/2012	0.87	1.77%	0.23	0.4%	0.0%
	Spring	3/22/2011	0.91	1.85%	0.23	18.9%	14.5%
	Early Summer	5/24/2012	1.77	3.61%	0.59	14.2%	14.4%
	Late Summer	7/10/2011	1.12	2.28%	0.56	1.8%	2.3%
	Fall	10/25/2012	0.57	1.17%	0.24	0.0%	0.0%
	Early Winter	11/10/2012	0.33	0.67%	0.11	0.0%	0.0%

Table 61. Highest Sediment Daily Load Analysis for Watonwan River near Garden City, CSAH13

Method	Season	Date	Precipitation Total (-7 day window) (in)	Precipitation % of 2 Year Total (-7 day window)	Observed Sediment Load % of 2 Year Total (-5 +2 day window)	Simulated Sediment Load % of 2 Year Total (-5 +2 day window)
Largest Daily Sediment Load	Late Winter	2/29/2012	1.60	3.3%	0.3%	0.0%
	Spring	3/22/2011	1.11	2.3%	20.8%	8.5%
	Early Summer	5/6/2012	4.05	8.3%	7.1%	6.9%
	Late Summer	7/17/2011	3.54	7.2%	2.4%	2.9%
	Fall	9/3/2011	0.39	0.8%	0.0%	0.0%
	Early Winter	11/2/2011	0.00	0.0%	0.0%	0.0%

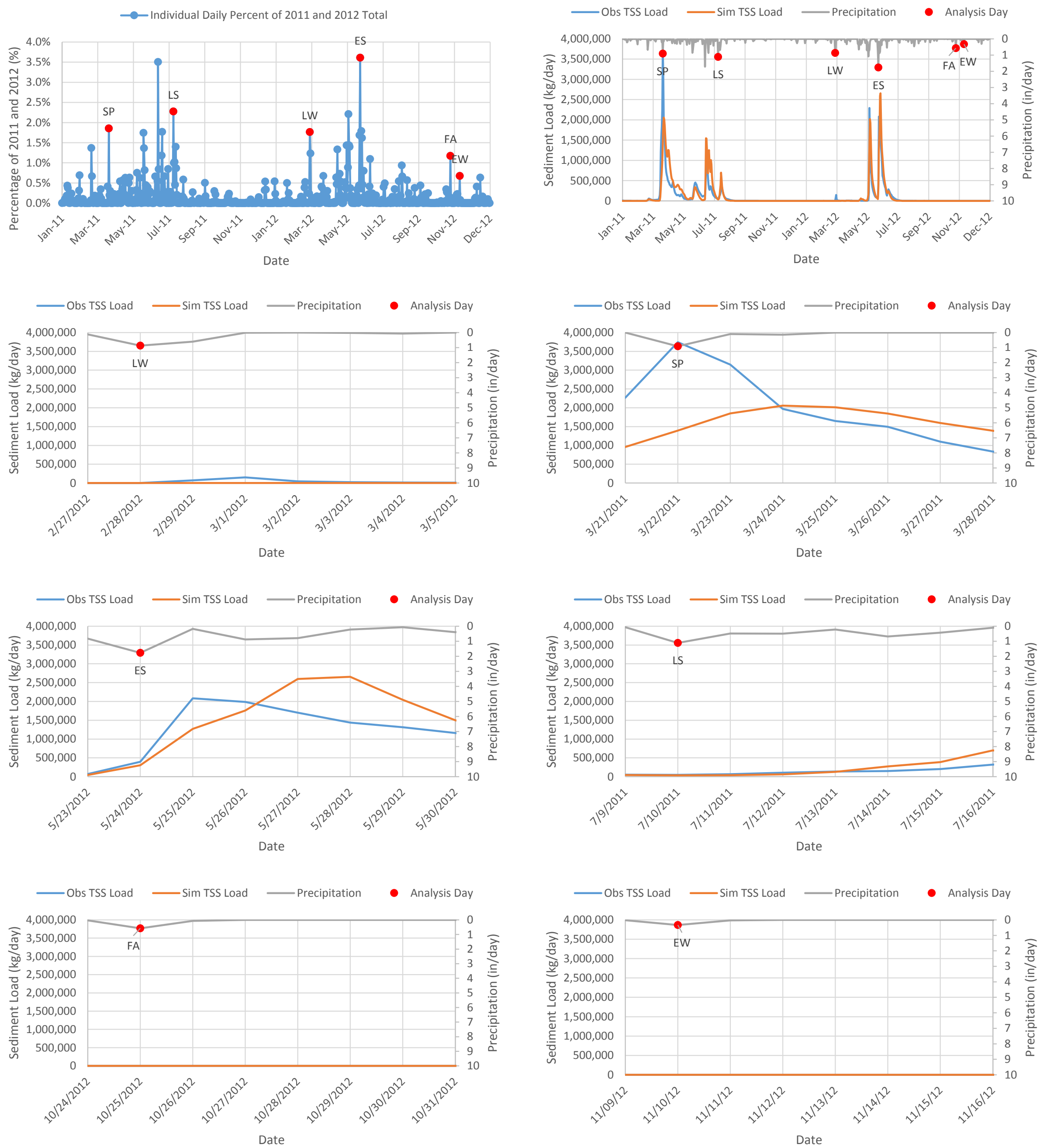

Figure 35. Time Series Plots for Largest Daily Precipitation Days for Watonwan River near Garden City, CSAH13

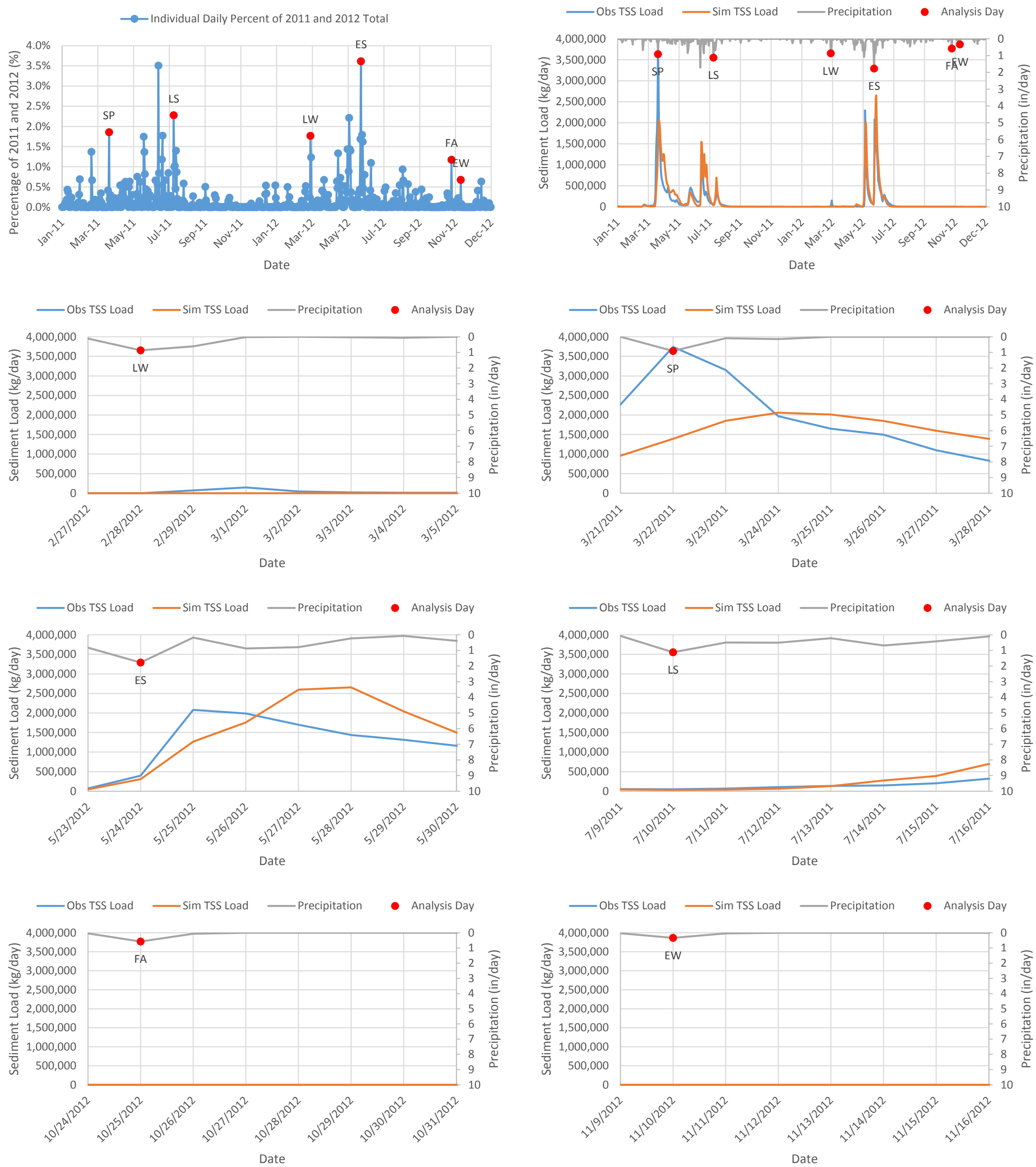

Figure 36. Time Series Plots for Largest Hourly Precipitation Days for Watonwan River near Garden City, CSAH13

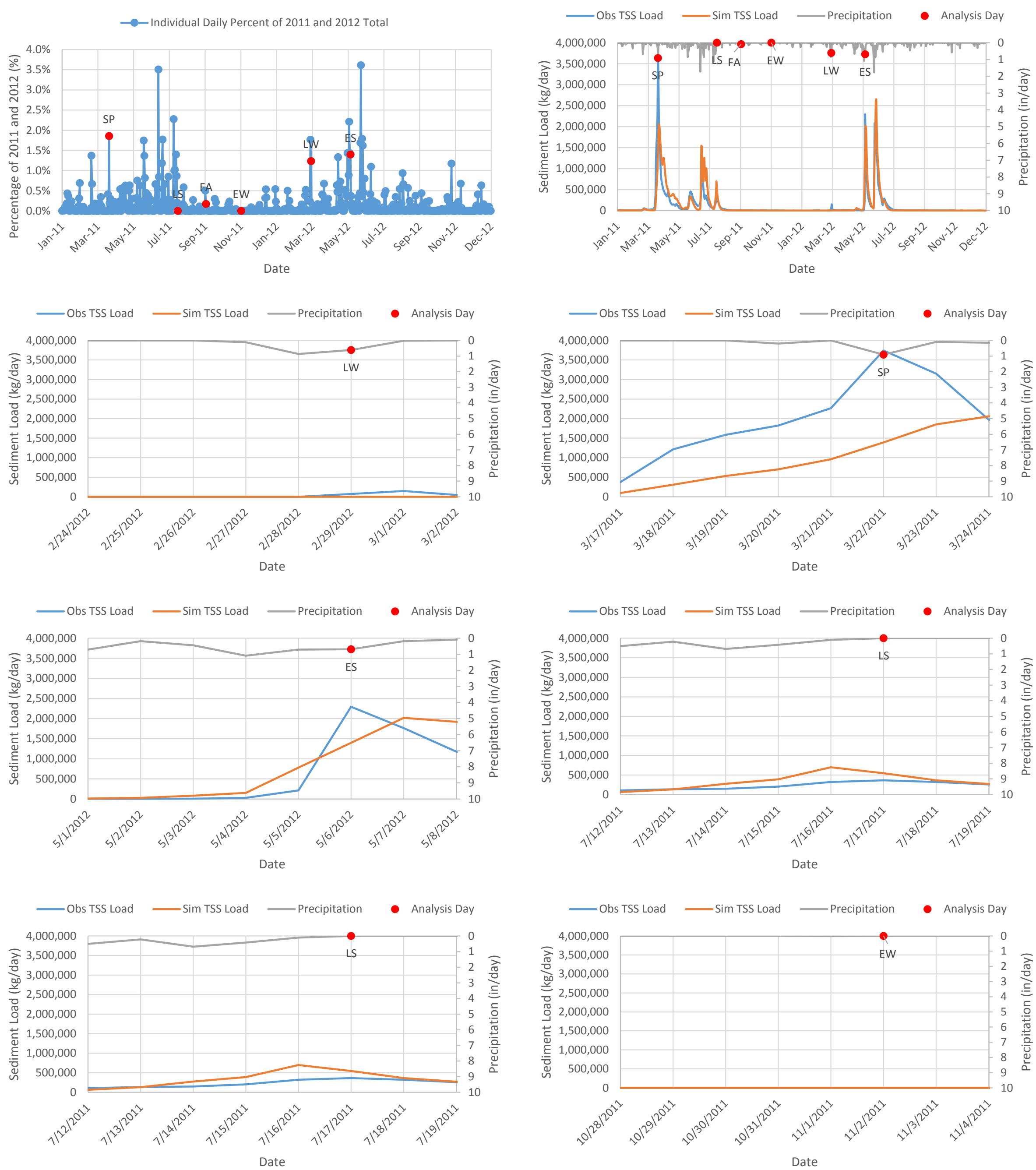

Figure 37. Time Series Plots for Largest Sediment Loading Days for Watonwan River near Garden City, CSAH13

4.6 E32077001 Le Sueur River near Rapidan, MN66

For the 2011 and 2012 analysis period Late Fall, Early Winter, and Late Winter contribute very little sediment therefore the analysis will only focus on Spring, Early Summer, and Late Summer. The following discussion pertains to the results in Table 62 and Table 63. Time series plots, although not discussed are provided in Figure 38, Figure 39, and Figure 40.

Spring LDP selected a day in March 2011 with windowed observed sediment load approximately 19.9% of the two year total and LDH selected a day in April 2012 with windowed observed sediment load approximately 0.0% of the observed two year total. LDS selected a day in March 2011 two days before LDP. LDP and LDS essentially selected the same day and since they are in March the high sediment load is likely due to a rain on snow event. For Early Summer LDP and LDH selected the same day in May with windowed observed sediment load approximately 6.6% of the two year total. LDS selected a day in June 2012 with windowed observed sediment load approximately 13.2% of the two year total. LDP and LDH both selected intense precipitation events that didn't produce as much sediment but LDS selected high sediment with a lot of precipitation to for the preceding seven days. For Early Summer LDP and LDH selected the same day in July 2011 with windowed observed sediment load approximately 9.2% of the two year total. LDS selected a day in July 2011 one day after LDP and LDH. LDP, LDH, and LDS essentially selected the same storm event so the high sediment load was driven by both daily total and hourly intensity.

Table 62. Intense Storms Analysis for Le Sueur River near Rapidan, MN66

Method	Season	Date	Precipitation Daily Total (in)	Precipitation Daily Total % of 2 Year Total	Hourly Maximum (in)	Observed Sediment Load % of 2 Year Total (+7 day window)	Simulated Sediment Load % of 2 Year Total (+7 day window)
Largest Daily Precipitation	Late Winter	2/28/2012	0.88	1.71%	0.16	0.6%	0.0%
	Spring	3/22/2011	0.92	1.77%	0.20	19.9%	15.8%
	Early Summer	5/4/2012	1.47	2.85%	0.72	6.6%	11.8%
	Late Summer	7/15/2011	1.62	3.13%	1.02	9.2%	6.3%
	Fall	10/25/2012	0.66	1.28%	0.22	0.0%	0.0%
	Early Winter	12/15/2012	0.58	1.13%	0.13	0.0%	0.0%
Largest Hourly Precipitation	Late Winter	2/28/2012	0.88	1.71%	0.16	0.6%	0.0%
	Spring	4/13/2012	0.42	0.82%	0.26	0.0%	0.7%
	Early Summer	5/4/2012	1.47	2.85%	0.72	6.6%	11.8%
	Late Summer	7/15/2011	1.62	3.13%	1.02	9.2%	6.3%
	Fall	10/25/2012	0.66	1.28%	0.22	0.0%	0.0%
	Early Winter	12/15/2012	0.58	1.13%	0.13	0.0%	0.0%

Table 63. Highest Sediment Daily Load Analysis for Le Sueur River near Rapidan, MN66

Method	Season	Date	Precipitation Total (-7 day window) (in)	Precipitation % of 2 Year Total (-7 day window)	Observed Sediment Load % of 2 Year Total (-5 +2 day window)	Simulated Sediment Load % of 2 Year Total (-5 +2 day window)
Largest Daily Sediment Load	Late Winter	2/29/2012	1.48	2.9%	0.5%	0.0%
	Spring	3/20/2011	0.30	0.6%	29.8%	6.0%
	Early Summer	6/20/2011	3.32	6.4%	13.2%	11.1%
	Late Summer	7/16/2011	3.75	7.3%	7.9%	2.6%
	Fall	9/2/2011	0.42	0.8%	0.0%	0.0%
	Early Winter	11/2/2011	0.01	0.0%	0.0%	0.0%

Figure 38. Time Series Plots for Largest Daily Precipitation Days for Le Sueur River near Rapidan, MN66

Figure 39. Time Series Plots for Largest Hourly Precipitation Days for Le Sueur River near Rapidan, MN66

Figure 40. Time Series Plots for Largest Sediment Loading Days for Le Sueur River near Rapidan, MN66

4.7 E30092001 Blue Earth River near Rapidan, MN

For the 2011 and 2012 analysis period Late Fall, Early Winter, and Late Winter contribute very little sediment therefore the analysis will only focus on Spring, Early Summer, and Late Summer. The following discussion pertains to the results in Table 64 and Table 65. Time series plots, although not discussed are provided in Figure 41, Figure 42, and Figure 43.

LDP selected a day in April 2012 with windowed observed sediment load approximately 0.1% of the two year total and LDH selected a day in March 2011 with windowed observed sediment load approximately 25.7% of the observed two year total. LDS selected a day in March 2011 one day one LDP. LDP and LDS essentially selected the same day and since they are in March the high sediment load is likely due to a rain on snow event. For Early Summer LDP selected a day in June 2011 with windowed observed sediment load approximately 4.5% of the two year total and LDH selected a day in May 2012 with windowed observed sediment load approximately 7.3 % of the observed two year total. LDS selected a day in May 2012 four days after LDH. Therefore, high daily total precipitation in Early Summer correlated to a high daily Early Summer sediment load. For Early Summer LDP and LDH selected the same day in July 2011 with windowed observed sediment load approximately 1.5% of the two year total. LDS selected a day in July 2011 seven days after LDP and LDH. LDP, LDH, and LDS essentially selected the same storm event so the high sediment load was driven by both daily total and hourly intensity.

Table 64. Intense Storms Analysis for Blue Earth River near Rapidan, MN

Method	Season	Date	Precipitation Daily Total (in)	Precipitation Daily Total % of 2 Year Total	Hourly Maximum (in)	Observed Sediment Load % of 2 Year Total (+7 day window)	Simulated Sediment Load % of 2 Year Total (+7 day window)
Largest Daily Precipitation	Late Winter	2/28/2012	0.86	1.72%	0.15	0.1%	0.0%
	Spring	4/19/2012	0.86	1.70%	0.17	0.1%	0.3%
	Early Summer	6/14/2011	1.69	3.37%	0.36	4.5%	7.5%
	Late Summer	7/11/2011	1.10	2.20%	0.59	1.5%	2.7%
	Fall	10/25/2012	0.77	1.54%	0.26	0.0%	0.0%
	Early Winter	12/15/2012	0.51	1.01%	0.13	0.0%	0.0%
Largest Hourly Precipitation	Late Winter	2/20/2011	0.84	1.67%	0.17	1.1%	0.7%
	Spring	3/22/2011	0.68	1.35%	0.23	25.7%	13.2%
	Early Summer	5/4/2012	1.31	2.60%	1.07	7.3%	8.7%
	Late Summer	7/11/2011	1.10	2.20%	0.59	1.5%	2.7%
	Fall	9/4/2012	0.29	0.57%	0.29	0.0%	0.0%
	Early Winter	12/15/2012	0.51	1.01%	0.13	0.0%	0.0%

Table 65. Highest Sediment Daily Load Analysis for Blue Earth River near Rapidan, MN

Method	Season	Date	Precipitation Total (-7 day window) (in)	Precipitation % of 2 Year Total (-7 day window)	Observed Sediment Load % of 2 Year Total (-5 +2 day window)	Simulated Sediment Load % of 2 Year Total (-5 +2 day window)
Largest Daily Sediment Load	Late Winter	2/24/2011	1.09	2.2%	1.1%	0.6%
	Spring	3/21/2011	0.21	0.4%	28.5%	6.3%
	Early Summer	5/8/2012	3.34	6.7%	6.8%	7.8%
	Late Summer	7/17/2011	3.26	6.5%	1.7%	3.1%
	Fall	9/30/2011	0.02	0.0%	0.0%	0.0%
	Early Winter	11/8/2011	0.01	0.0%	0.0%	0.0%

Figure 41. Time Series Plots for Largest Daily Precipitation Days for Blue Earth River near Rapidan, MN

Figure 42. Time Series Plots for Largest Hourly Precipitation Days for Blue Earth River near Rapidan, MN

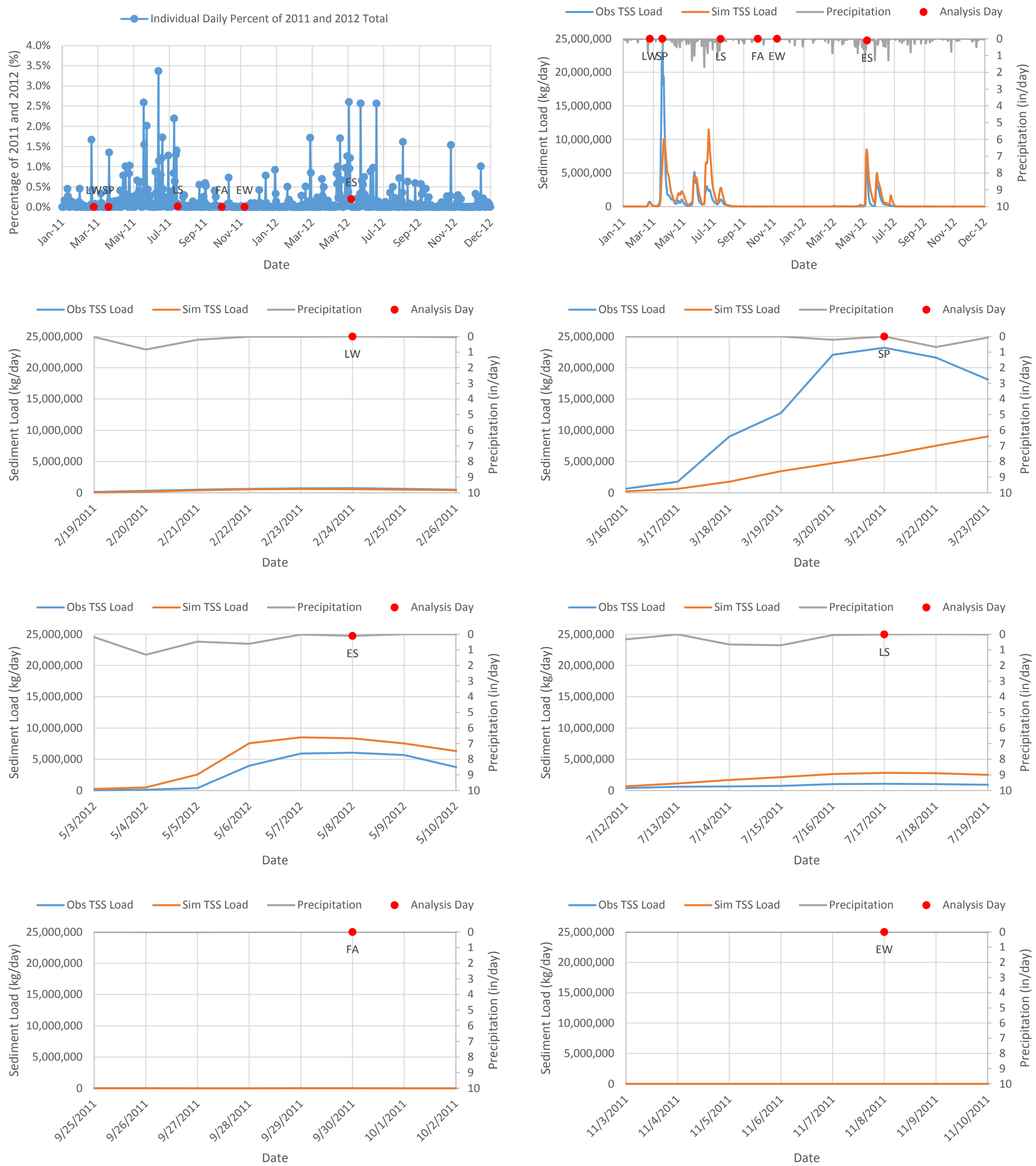

Figure 43. Time Series Plots for Largest Sediment Loading Days for Blue Earth River near Rapidan, MN

5 Conclusions

Analysis of simulated sediment loads by month indicated that a majority of the sediment delivered to the mouth of each HUC8 and the Minnesota River at Jordan was delivered in the months of March, April, May, and June. Table 66 shows that with the exception of an anomalous September 2010 precipitation event (9 of 66 high sediment loading months), almost all high sediment loading months were within the March to June window (51 of 66 high sediment loading months). Table 66 also provides a summary of high sediment loading month source attributions across all analysis locations by month. (Note that in the HSPF models, the pseudo random process of bluff collapse is simulated as an increase in the bed sediment that is available for transport in stream segments. In the sediment source attribution calculation, sediment from streambed scour for reaches containing bluff area is attributed as bluff load. In the sediment source attribution sediment load from stream bed scour for reaches not containing bluff area is designated as stream sources [includes channel and/or bank erosion]). The source attribution summary shows that sediment sources in March and April were primarily from instream sources (bluff and stream); upland sources were slightly higher in May and June but instream sources still dominated. (Note that the models are set up so that spring soil disturbance from plowing and planting occurs on May 1 and May 10; however, in most cases the model simulation of upland sediment load is more strongly controlled by overland flow capacity than by detached sediment storage on the land surface.) Occasionally, there were high sediment loading months where upland sources dominated; those events usually occurred in midsummer or early fall. Those months with a high sediment load outside the March to June time period resulting from upland erosion were typically due to long duration or very intense precipitation events that produced large amounts of overland flow.

Table 66. All Analysis Locations High Sediment Loading Month Summary by Month

Month	Count	Upland	Tile	Ravine	Bluff	Stream
January	0	0%	0%	0%	0%	0%
February	0	0%	0%	0%	0%	0%
March	10	4%	2%	0%	54%	40%
April	24	17%	1%	1%	45%	36%
May	4	48%	2%	5%	33%	11%
June	13	34%	1%	14%	34%	18%
July	4	92%	0%	1%	4%	4%
August	2	44%	0%	34%	17%	5%
September	9	47%	1%	19%	27%	6%
October	0	0%	0%	0%	0%	0%
November	0	0%	0%	0%	0%	0%
December	0	0%	0%	0%	0%	0%

The intense storms analysis was only conducted on a two-year period but that analysis also indicated the majority of sediment loading occurred during the spring and early summer. In the two-year analysis period almost no sediment was delivered during the fall and winter. The intense storm results at individual stations were more difficult to interpret. Sometimes high daily and/or hourly precipitation events caused very little sediment delivery in the following seven day window and sometimes high daily sediment had very little precipitation in the preceding seven day window. Generally, however, a high daily sediment load was matched to either a large daily precipitation total or intense hourly precipitation event at some point during the preceding week.

Determining the most critical practices for sediment load reductions should focus on the conditions that are causing the majority of the sediment to move in the March to June time period. Snowmelt coupled with spring convective storms, little vegetative cover, recent mechanical disturbance of the soil, and the effects of tile drains are likely the major contributing factors for sediment movement in the spring.

Monthly sediment source attribution coupled with snow melt water yield shows that snow melt is generally associated with instream sources of sediment. Table 67 presents a snowmelt source index summary by month and source. The index was calculated by taking snowpack water yield compared to total land outflow (%) and multiplying it by source attribution percentage for each high sediment loading month. These values were then summarized across all loading months for all analysis locations (similar to Table 66). Higher index values show a correlation between snowmelt and source whereas values near zero show low correlation between snowmelt and source. The month of March shows a high index for bluff and stream sources and a low index (little correlation) for upland sources. During March, rivers rebound from winter low-flow conditions, mobilizing sediment from banks and bluff that has been stored in the channel. April shows an index for bluff and stream that is lower than March but the bluff and stream indexes are still greater than the upland index. One theory for the March versus April indexes is that April high sediment loads are driven by a combination of snow melt, rain on snow event, and strong spring convective storms whereas March high sediment loads are driven primarily by snow melt alone. Snowmelt causes higher flows that scour instream sediment (bed, bank, and bluff) and subsequently the scoured sediment gets transported downstream. Practices such as streambank and bluff stabilization and those that reduce stream power (e.g., vegetative filter strips, water and sediment control basins) can be used to reduce the instream sources of sediment by limiting the amount of work that a stream can perform on its bed and banks.

Table 67. All Analysis Locations Snow Melt Index by Month and Source

Month	Upland	Tile	Ravine	Bluff	Stream
January	0.0000	0.0000	0.0000	0.0000	0.0000
February	0.0000	0.0000	0.0000	0.0000	0.0000
March	0.0675	0.0330	0.0018	1.0421	0.7669
April	0.1317	0.0038	0.0055	0.2294	0.2252
May	0.0005	0.0000	0.0001	0.0000	-0.0002
June	0.0001	0.0000	0.0000	0.0001	0.0001
July	0.0000	0.0000	0.0000	0.0000	0.0000
August	0.0000	0.0000	0.0000	0.0000	0.0000
September	0.0000	0.0000	0.0000	0.0000	0.0000
October	0.0000	0.0000	0.0000	0.0000	0.0000
November	0.0000	0.0000	0.0000	0.0000	0.0000
December	0.0000	0.0000	0.0000	0.0000	0.0000

Monthly sediment source attribution coupled with monthly precipitation shows that convective storms detaching sediment from uplands and scouring instream sources of sediment contribute to the late spring and early summer transport of sediment. Table 68 presents a rainfall source index summary by month and source. The index was calculated by taking area-weighted monthly precipitation (in) and multiplying it by source attribution percentage for each high sediment loading month. These values were then summarized across all loading months for all analysis locations (similar to table 66). Higher index values show a greater correlation between rainfall and source whereas values near zero show no correlation between rainfall and source. The months of May through September show a high index for upland with high indexes for bluff and stream in April, May, and June. Therefore, late spring convective storms produce sediment from both upland and instream sources whereas late summer and early fall events produce sediment primarily from land-based sources. Land with recent mechanical disturbance and/or bare soil is more susceptible to raindrop impact and particle detachment and is therefore more likely to contribute to the sediment load exported from each HUC8. Practices such as cover crops and no-till or low-till farming should be considered to reduce the land susceptibility to erosion. However, the simulations indicate that large loads of sediment often occur prior to spring tillage (34 high sediment loading months in March and April [Table 66]), so the benefits to be obtained from tillage management are likely more strongly associated with maintenance of residue cover. Practices identified above (streambank and bluff stabilization, vegetative filter strips, and water and sediment control basins) should also be considered to reduce sediment from convective storms in the Spring, Summer, and Fall.

Table 68. All Analysis Locations Rainfall Index by Month and Source

Month	Upland	Tile	Ravine	Bluff	Stream
January	0.0000	0.0000	0.0000	0.0000	0.0000
February	0.0000	0.0000	0.0000	0.0000	0.0000
March	0.0628	0.0263	0.0020	0.7876	0.5922
April	1.0905	0.0447	0.0526	1.9585	1.2791
May	4.1972	0.1978	0.4404	3.0963	1.2139
June	2.0379	0.0721	0.7039	1.8443	0.8048
July	6.9583	0.0000	0.0415	0.2830	0.2597
August	3.1798	0.0098	3.3188	1.4591	0.4090
September	4.4154	0.1359	1.8363	2.5418	0.6337
October	0.0000	0.0000	0.0000	0.0000	0.0000
November	0.0000	0.0000	0.0000	0.0000	0.0000
December	0.0000	0.0000	0.0000	0.0000	0.0000

Tile drains with surface inlets can be direct sources of sediment load. Sediment transport through tile drains is represented in the models, but is not well-constrained by observations or explicit information on the density of surface inlets. Tile drains also likely exacerbate sediment erosion from stream banks due to both snowmelt and convective storms. Tile drains provide a pathway for water to efficiently be removed from the landscape. Without tile drains snowmelt and/or convective storm water would be held in root zone storage for a longer period of time (weeks to months) as compared to when tile drains are present. Tile drains are implicitly represented in the HSPF simulation via the interflow state variable so it is difficult to assess the exact impact that tile drains are having on the simulation. The sediment source attribution did tabulate the load of sediment contributed by the implicit tile drain simulation; however, this is the direct impact of sediment transported through tile drains and not the indirect impact tile drains have on increased streamflow and sediment scour.

The multiple sources of sediment and relationships to precipitation intensity are variable enough that no one management practice alone is likely to mitigate high sediment loads; instead, a suite of management practices that address the different sources and pathways will likely be needed.