Lake Village Stormwater Investigation
Draft Final Report
A Study of Pre- and Post-CIP and BMP Implementation

Reporting Period
October 2003 – March 2008

SNPLMA Round 6
Grant No. 06-DG-11051900-028

Prepared for:
US Forest Service
Lake Tahoe Basin Management Unit
South Lake Tahoe, CA

Prepared by:
Nevada Tahoe Conservation District
Stateline, NV

25 September 2009

Table of Contents

1.0 INTRODUCTION 1
1.1 Project Development and Funding 2
1.2 Study Objectives 4
2.0 ENVIRONMENTAL IMPROVEMENT PROJECTS 4
2.1 Public BMP Project 4
2.2 Residential BMP Program 6
3.0 SITE DESCRIPTIONS 7
4.0 METHODS 16
4.1 Sample Collection and Analysis 16
4.2 Precipitation 17
4.3 Flow 18
4.3.1 Catchment A 18
4.3.2 Catchments B and C 18
4.4 Pre-BMP and Post-BMP Dates 18
4.4.1 Catchment A 19
4.4.2 Catchment B 19
4.4.3 Catchment C 19
4.4.4 Drip Lines 19
5.0 RESULTS AND DISCUSSION 20
5.1 Catchment A Concentrations 21
5.2 Catchment A Flow and Load 26
5.3 Catchment B 29
5.4 Catchment C 35
5.5 Drip Lines 37
6.0 CONCLUSIONS 39
7.0 LESSONS LEARNED 40
BIBLIOGRAPHY 1
APPENDIX A 1
APPENDIX B 1
APPENDIX C 1
APPENDIX D 1
APPENDIX E 1
APPENDIX F 1

List of Tables

Table 1. Grant numbers and funding amounts for this study. 4
Table 2. Quantities of improvements installed for EIP 679 and the quantity in Catchment A and B.. 5
Table 3. The number of condominium buildings to complete their BMPs in each year. . 6
Table 4. Drip line topographic information (collected July 2005). 16
Table 5. Water quality constituents and in-situ parameters collected for water samples at the catchments. 17
Table 6. Number of samples “pre-“ and “post-“ BMP for each study site. 20
Table 7. TRPA surface water discharge limits of average concentrations (TRPA Code of Ordinances, Chapter 81). 20
Table-8. P-values for the Mann Whitney test for Pre- vs Post-CIP concentrations of the combined Catchment A and B3 data set. 26
Table-9. P-values for the Krushkal Wallis test by event type for a combined Catchment A and B3 data set. 26
Table-10. P-values for Catchment A loads using the Mann Whitney U test for pre- vs post-CIP loads. 28
Table 11. The number of samples collected and analyzed from Catchment B “pre-“ improvement and “post-“ improvement. All collection was completed by January 2008. 30
Table-12. P-values for the Krushkal Wallis test by event type for the Catchment C data set. 36
Table 13. Average TSS concentrations (in mg/l) for the drip line sites. 37
Table 14. Average particle size (in µm) for the drip line sites. 38

List of Figures

Figure 1. Lake Village HOA within Burke Creek Watershed, NV 1
Figure 2. Capital improvement project BMPs in Lake Village consisting of revegetation, rock slope toe protection, and curb and gutter. 5
Figure 3. Timeline of EIP construction and the stormwater monitoring for Lake Village Catchment A. 6
Figure 4. Timeline of EIP construction and the stormwater monitoring for Lake Village Catchment B. 7
Figure 5. Roads within Lake Village and approximate locations of the three study catchments. 8
Figure 6. The ISCO Auto Sampler at Site A. 9
Figure 7. The passive sampler was buried in the ground to collect storm runoff. 10
Figure 8. Lake Village CIP project plan, study catchments, and water quality sample locations. 11
Figure 9. Campbell level transducer and passive sampler at Site B3 (post EIP construction) 12

Figure 10. Sample site configuration for Catchment C. 13
Figure 11. A Google Earth view of the Lake Village community and the Kingsbury Middle School..... 14
Figure 12. Sample locations and site names for the seven roof drip lines. The light grey boxes are the building numbers. 15
Figure 13. Conceptual drawing of a roof drip line sample configuration. 15
Figure 14. Monthly precipitation at the Marlette Lake SNOTEL site for the period of this report relative to monthly mean precipitation for the period of record. The percent of annual historical average is provided for each WY in the legend. 18
Figure 15. Overall pre- and post-CIP average concentrations for water quality constituents for Catchment A events..... 22
Figure 16. Overall Catchment A pre- and post-CIP average for TSS concentrations and particle size distributions. The percentages indicate the volume of sediment that exceeded a given particle size. 22
Figure 17. Average nutrient concentration for runoff at Catchment A according to each event type for A) pre-CIP events and B) post-CIP events. The number of events sampled are shown next to the event type in the legend. 23
Figure 18. Average concentration of organic nitrogen-dominated nutrients for runoff at Catchment A according to each event type for A) pre-CIP events and B) post-CIP events. 23
Figure 19. Average TSS concentration and particle size for runoff at Catchment A according to each event type for A) pre-CIP events and B) post-CIP events. 24
Figure 20. Peak discharge leading peak turbidity for the rain events on 29 October 2007 for Catchment A. 24
Figure 21. Peak discharge trailing peak turbidity for the thunderstorm event on 29 October 2007 at Catchment A. 25
Figure 22. Coincident peak turbidity and discharge for the snowmelt event on 10 February 2008 for Catchment A. 25
Figure 23. Average runoff volume for all pre- and post-CIP events. 26
Figure 24. Average precipitation for all Catchment A runoff events. 27
Figure 25. Average peak runoff for all pre- and post-CIP events for Catchment A. 27
Figure 26. Average load of TSS and particle size distribution for each flow-weighted average particle size (the vertical inset values) for Catchment A 28
Figure 27. Average load of water quality constituents all pre- and post-CIP events at Catchment A. Bio-available nitrogen is the sum of NH_3 and $NO_{2/3}$. 29
Figure 28. Average mass of organic-dominated nitrogen species for all pre- and post-CIP events at Catchment A. 29
Figure 29. Average water quality concentrations for the three sites in Catchment B for events sampled prior to installation of residential or public improvements. 31
Figure 30. Average TSS concentration and particle size distribution for the three sites in Catchment B for events sampled prior to installation of residential or public improvements..... 31
Figure 31. Average constituent concentrations for pre- and post-BMP water quality at B2..... 32

Figure 32. TSS concentration and particle size distribution for pre- and post-BMP water quality samples at B2. 32
Figure 33. Constituent concentrations for pre- and post-BMP water quality samples at B3. 33
Figure 34. TSS concentration and particle size distribution for pre- and post-BMP water quality samples at B3. 33
Figure 35. Constituent concentrations for pre-BMP water quality samples at B3 by event type. 34
Figure 36. Concentrations of organic nitrogen-dominated constituents for pre-BMP water quality samples at B3 by event type. 34
Figure 37. TSS concentrations and particle size data for pre-BMP water quality samples at B3 by event type. 34
Figure 38. Concentrations of water quality constituents for events in Catchment C. 35
Figure 39. TSS concentration and particle size distribution for events in Catchment C. 36
Figure 40. Average TSS concentration for pre- and post-BMP water samples for drip line sites. 37
Figure 41. Average particle size for drip line sites pre- and post-BMP installation. 38
Figure 42. Particle size distribution curves for average pre- and post-BMP events for drip line samples. 39
Figure 43. Hydrographs from a rain event as measured at A) Catchment A and B) Site B3. 41

1.0 INTRODUCTION

Lake Village is a planned development community managed by the Lake Village Home Owners Association (HOA) and consists of 326 town homes located on 52 densely treed acres on steep rocky slopes near Stateline, NV (Figure 1). The area drains into Burke Creek about 0.8 miles from Lake Tahoe. The creation of impervious coverage for the community and the proximity to the lake raised concerns about the load of sediment and nutrients that could easily reach the lake.

Pollutant contributions to Lake Tahoe are of great concern because the Lake's renowned water clarity has declined an average of one foot annually over the past few decades. The primary pollutants reducing lake clarity are fine sediment and bio-available nutrients (Goldman 1988, Reuter and Miller 2000). Research funded by the Nevada Department of Environmental Protection and the Lahontan Regional Water Resources Control Board concludes the primary loss of clarity is strongly linked to urban stormwater runoff (Roberts and Reuter 2007).

Figure 1. Lake Village HOA within Burke Creek Watershed, NV

In 1997, growing concerns for Lake Tahoe's clarity loss inspired a Federal Interagency Partnership Agreement between local, state, regional, and federal agencies. The result was Phase 1 of the Environmental Improvement Plan (EIP)—a 10 year, $900M program to enhance environmental, economic, and cultural values of Lake Tahoe. The Lake Village community was identified as EIP 679—one of many capital improvement project areas for water quality enhancement around Lake Tahoe. The purpose of EIP 679 was

to control sediment sources and convey and treat stormwater runoff from the common areas of Lake Village.

A simultaneous EIP effort was created to focus on reducing the volume and improving the quality of stormwater from private land. Known as EIP 16, this on-going effort requires property owners throughout the basin to install erosion control best management practices (BMPs) that include covering bare soil, armoring drip lines under roofs, and preventing runoff from driveways for the 20 yr 1 hr storm.

The overall goal of the Lake Village Stormwater Investigation study was to compare stormwater quality before and after implementation of EIP 679 and EIP 16 in two catchments in Lake Village.

1.1 Project Development and Funding

This project has a long history beginning in 2003 when it was jointly developed by the Nevada Tahoe Conservation District (NTCD) and Swanson Hydrology and Geomorphology (later, 2NDNature, Inc). The study began as a $94,260 US Forest Service (USFS) Lake Tahoe Basin Management Unit (LTBMU) Comprehensive Urban Runoff Treatment Effectiveness Monitoring (CURTEM) grant called "Evaluating Residential BMPs in a Paired-Watershed Study" (number: 03-DG-11051900-013). The grant was effective between 19 June 2003 and 1 Oct 2004 with the goal to:

> "monitor the water quality effects of residential BMPs installed in one of the two larger Lake Village sub-watersheds, using the untreated sub-watershed as a control. The area provides an ideal location for implementing a paired-watershed study. Using a nearly identical sub-watershed as a control, potential sources of spatial variability or variability over time will be effectively eliminated."

The term "paired-watershed" implies the monitored areas would have similar soil, land use, topography, connectivity, area, and hydrologic response to a given precipitation event. This project had the additional aim to find three "nearly identical" catchments—two would be monitored for water quality changes resulting from implementation of BMPs and the third would be a control. This grant funded the purchase and installation of water quality monitoring equipment to collect baseline water quality data for one year. Additional funds would be sought for two additional years to determine the change in water quality after an NDSL-funded public erosion control project, EIP 679, was completed in the summer of 2004.

Three catchments were established: Catchments A and B were within the HOA and Catchment C was a control outside the HOA on Echo Drive. All three catchments were equipped with continuous stage and turbidity measurement devices. Catchment A used a flow integrated auto sampler, but the other catchments used passive, first flush samplers. A Sampling and Analysis Plan (Appendix F) was developed by Swanson Hydrology and Geomorphology and executed by NTCD. In general, Swanson

Hydrology supplied the majority of technical expertise and NTCD implemented the sample design. Sample data were passed to Swanson Hydrology who generated periodic reports as required by the grant.

Funding for the project continued with USFS grant 04-FG-11051900-012 developed jointly with Swanson Hydrology. This $67,111 grant was in effect between April 2004 and June 2006 and was amended in June 2004 to add $75,600 to the Lake Village monitoring to bring the total monitoring budget to $142,711 for the 04-12 grant. Although the proposal used the phrase "matched catchments" (i.e., paired catchments) it stated the water quality in Catchment A would reflect "large scale" improvements, i.e., water quality changes resulting from the publicly funded erosion control project. Whereas Catchment B would reflect "small scale" improvements, or privately funded residential BMPs, and Catchment C would be a control to "separate the yearly climatic variations in surface water conditions observed at the two sites." As the project progressed, the NDSL-funded public erosion control project slipped from 2004 to 2005 and finally to 2006. Also during this grant period Nicole Beck, the primary scientist on the project, left Swanson Hydrology to start her own consulting firm called 2NDNature, Inc.

In a September 2005 progress report to the grant manager at LTBMU, NTCD and 2NDNature articulated problems with designating Catchment B as primarily reflecting residential BMPs because a significant portion of the watershed contained roads that would receive improvements when the public erosion control project was implemented. In order to more directly measure water quality improvements, the monitoring team proposed adding two additional monitoring configurations. First, was to determine the change in "micro-topography" resulting from roof drip line erosion. Second, was to measure the change in water quality draining roof drip lines using first flush passive samplers. As a result, several drip lines were surveyed and seven first flush samplers were installed in the flow path of the drip lines. These samplers were operated in addition to the Catchment B stormwater samplers.

The final grant, 06-DG-11051900-028, was effective September 2006 to September 2011 and allocated $47,799 for Lake Village monitoring with an additional $15,651 added in July 2008. With this grant, NTCD assumed full responsibility for data management and interpretation from 2NDNature, who was no longer associated with the study. The NTCD proposal no longer referred to "match catchments" but to three individual catchments collecting water quality data inside and outside the project area.

Overall, water quality samples were first analyzed in November 2003 and sampling was terminated in February 2008. The entire study cost $300K (Table 1) and was managed by three different program managers at NTCD and four different grant managers at the USFS LTBMU. This, plus the decision drop the technical and science support provided by 2NDNature contributed to a lack of continuity. The study evolved during the four years as a result of a better collective understanding of the hydrology and science that underpinned the effort and the experiences and qualifications of the individuals

involved. As a result, an extensive data set has been amassed and many lessons have been learned.

Table 1. Grant numbers and funding amounts for this study.

USFS Grant	Total Lake Village Monitoring Budget
03-13	$94,260
04-12	$67,111
04-12 amendment	$75,680
06-28	$47,799
06-28 amendment	$15,651
TOTAL	**$300,501**

1.2 Study Objectives

The original intention of this monitoring effort was to analyze changes in water quality of paired watersheds before and after installation of BMPs, with a similar catchment as a control. But as noted above, and explained in detail in the following sections, the catchments were not similar enough to perform a matched catchment study. As a result, the following are realistic study objectives for this report.

1. Summarize stormwater water quality and quantity from three catchments in and near the Lake Village HOA according to the:
    a. type of precipitation
    b. completion of public and private BMPs
    c. land use and topography
2. Quantify the change in water quality from roof drip line runoff before and after installation of private BMPs.

2.0 ENVIRONMENTAL IMPROVEMENT PROJECTS

Two EIP projects were installed in Lake Village during this study. The first was a capital improvement project (CIP) in the common areas of Lake Village and was publically funded. The second project is an on-going residential BMP retrofit program for private residences. The objectives of the CIP and residential BMPs were to control the source of sediment in runoff and reduce the volume of stormwater runoff.

2.1 Public BMP Project

Engineering and construction of the public BMPs within the common areas of Lake Village were funded as part of EIP 679 by the Nevada Division of State Lands (NDSL) and the HOA. Design began on the stormwater CIP in 2003, but problems with the engineering consultant forced delays in the final design and construction. Nichols Consulting Engineers took over the project in 2005, redesigned it and oversaw the installation by Fergusson Excavating in the summer of 2006. Some additional

construction was accomplished by HOA personnel in the spring of 2007, but these improvements were outside the study areas.

The CIP installed various water quality and erosion control assets throughout the HOA with some of the improvements implemented in the study catchments (Table 2 and Figure 2). Of the two catchments, Catchment A had significantly more CIP improvements than Catchment B, whereas Catchment B had more impervious roof area—roof area whose drip lines were subject to residential BMPs. A detailed description of the catchments is provided in the next section.

Table 2. Quantities of improvements installed for EIP 679 and the quantity in Catchment A and B. The impervious roof and road areas in Catchment A and B were estimated from the EIP 679 as-built drawings. Catchment C area quantities were estimated using Google Earth.

Description	Total EIP 679 Quantity	Catchment A	Catchment B	Catchment C	Units
Rock Slope Stabilization	26,011				Square Feet
Revegetation	7,225	1,800			Square Feet
Curb & Gutter (surface conveyance)	6,584	1,555	480		Linear Feet
Dry Detention Basin	3,000				Cubic Feet
Wood Chip mulch	2,900	1,450			Square Feet
Rock Lined Channel	535		140		Linear Feet
Conveyance Piping	132				Linear Feet
Slotted Drain	32				Linear Feet
Catch Basin	8				Total Units
Vortechnics WQ Treatment Vault	1				Total Units
Sediment Trap	1				Total Units
Roof Area		**14,500**	**21,000**	**33,000**	**Square Feet**
Paved Road/Parking Area		**45,600**	**58,750**	**65,900**	**Square Feet**

Figure 2. Capital improvement project BMPs in Lake Village consisting of revegetation, rock slope toe protection, and curb and gutter.

2.2 Residential BMP Program

Implementation of residential BMPs (aka, EIP 16 or BMP retrofit) throughout the Lake Tahoe basin has been slow, but the HOA management at Lake Village was successful in strongly encouraging their property owners to complete their BMPs as soon as possible. Still, the homeowner was required to take the initiative and pay for the BMPs and the result was a spatially and temporally random completion of residential BMPs. Special emphasis was placed on residents within the study catchments resulting in all residential BMPs being completed before the end of the study. Table 3 lists the number of buildings that completed their BMPs for each year and the timelines presented in Figures 3 and 4 illustrate the relative timing of study sampling and the installation of the public and private erosion control improvements.

Table 3. The number of condominium buildings to complete their BMPs in each year.

Year	Catchment A	Catchment B
2004	11	
2005	1	0.25
2006	14	12
2007	16	8.75
2008		1
Total	42	22

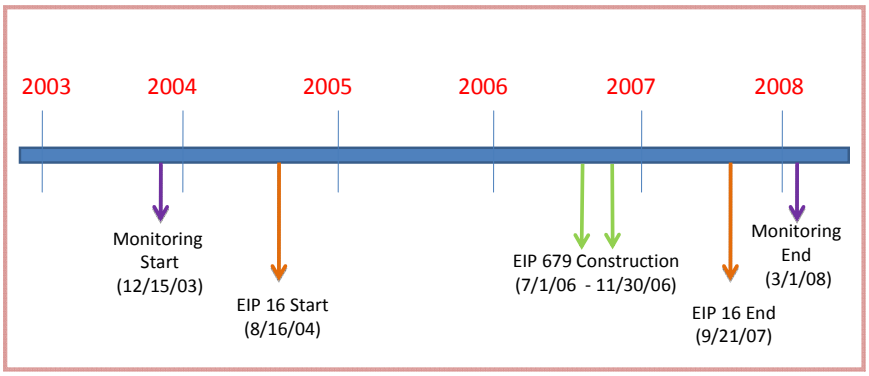


Figure 3. Timeline of EIP construction and the stormwater monitoring for Lake Village Catchment A.

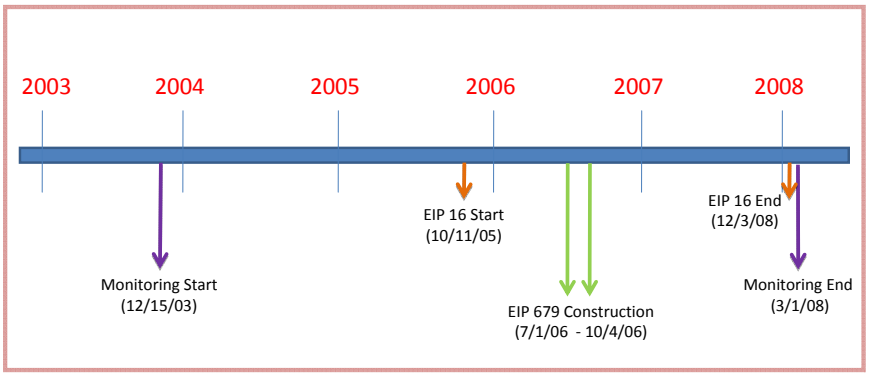


Figure 4. Timeline of EIP construction and the stormwater monitoring for Lake Village Catchment B.

Typical residential BMP measures included armoring drip lines below roofs, armoring drip areas beneath decks, and mulching or armoring areas without ground cover. The BMPs generally include treating runoff from driveways, but because there are effectively no driveways in Lake Village, no treatment was required.

3.0 SITE DESCRIPTIONS

Hydrologic and stormwater quality conditions were investigated for three catchments. Catchments A and B were in the Lake Village condominium complex, and Catchment C was outside the HOA (Figure 5).

3.1 Catchment A

The area of Catchment A was approximately 5.4 acres and the catchment was selected to evaluate the change in water quality resulting from implementation of the EIP 679 CIP. The catchment was topologically separated into two elevations dominated by Club House Circle on the lower level and Holly Lane on the upper. The impervious road and parking areas of the two levels were separated by a steep rocky slope, but connected by a 12-inch corrugated metal pipe (CMPs). Monitoring equipment was installed in a drop inlet on Club House Circle at the outfall of the CMPs and consisted of an FTS DTS-12 turbidimeter and an ISCO 6712 autosampler with twenty-four 1000 ml sample bottles and an ISCO 750 area-velocity meter (Figure 6).

Lake Village HOA used clean washed sand as winter traction control material. No salt was added.

Initially the autosampler used the area-velocity meter to determine the volume of flow and collected samples based on a set volume passing the sample site. Five events were collected using this method. All sample bottles were initially analyzed and the numerical results averaged for an event mean concentration (EMC), or equal aliquots of each sample bottle were composited and a single bottle analyzed with the result representing the EMC. But during the summer of 2005, the sensor partially failed and

could no longer detect the water velocity. As a result, a time paced sample regime was used to sample 200 ml every 10 min when the water level exceeded 0.065 ft. Following a runoff event, a single representative sample was composited from the bottles filled by the autosampler and analyzed. However, because the auto sampler was programmed to collect five 200 ml samples in a single one-liter sample bottle, an EMC could not be analyzed. That is, there was no post-event compositing scheme that could scale each 200 ml sample according to the volume of water that had flowed through the sample site when the sample was taken. Samples were equally composited for analysis and the resulting concentrations were designated as "equal volume averages." That is, *true EMCs* could not be produced for 17 of the 22 events monitored at Catchment A. All samples were analyzed for nutrients, total suspended sediment (TSS), and particle size distribution.

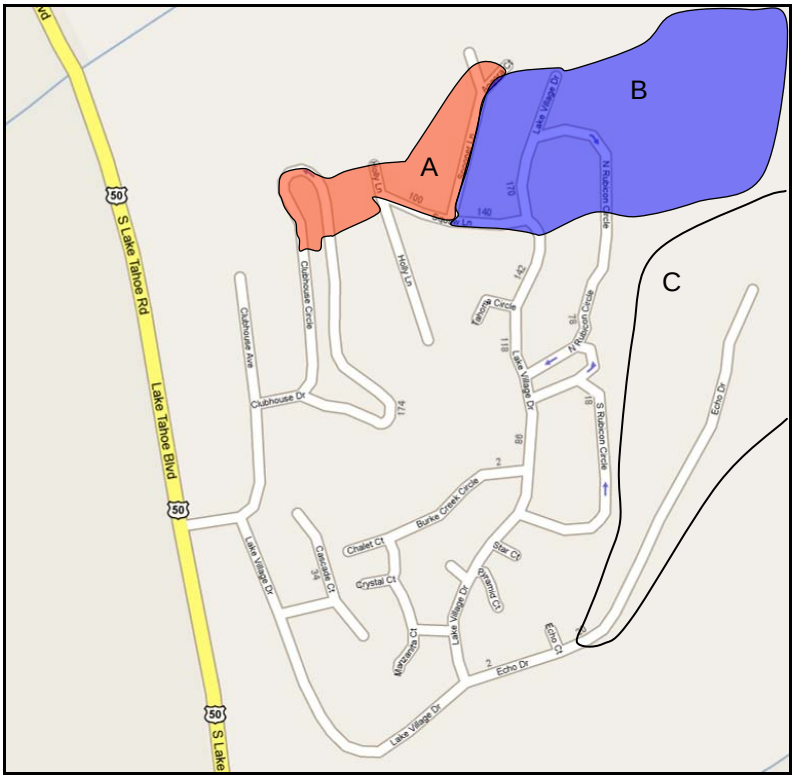


Figure 5. Roads within Lake Village and approximate locations of the three study catchments.

If a basic assumption can be made that peak pollutant concentrations are not constant, then equal volume composites would under represent peak concentrations for a given event. Event pollutant loads were also calculated for Catchment A using the equal volume averages, but likely under represent pollutant *loads* for a typical runoff event.

A mitigating factor is that by sampling up to 120 samples for a single event, the sample frequency was often so dense that unless the runoff flow was very dynamic, all portions of the hydrograph were sampled. Still, because sampling was equally as frequent

during low flow portions of the hydrograph as the high flow portions, loads during high flow would be under represented.

Figure 6. The ISCO Auto Sampler at Site A.

3.2 Catchment B

Catchment B is estimated to have a drainage area of seven acres and was selected because the stormwater improvements would be dominated by residential BMPs. Stormwater conveyance in this catchment was via surface swales, and three passive samplers were installed along the primary swale. The passive samplers were made of 2.3 L plastic containers housed in a PVC sleeve below the ground surface (Figure 7). As stormwater flowed over the top of the container, it filled and was sealed by a floating ping pong ball. Bottles were typically replaced before a runoff event was anticipated so the bottles were free of wind blown sediment, spiders, and mice. Passive sampler B1 was installed upstream of most residential runoff to collect background runoff from the forested, unimproved portion of the catchment. B2 was installed 300 ft downstream of B1 and below most of the residential areas, but before the majority of the road runoff. B3 was installed 150 ft below B2 and captured runoff from Lake Village Drive and Squaw Lane (Figure 8).

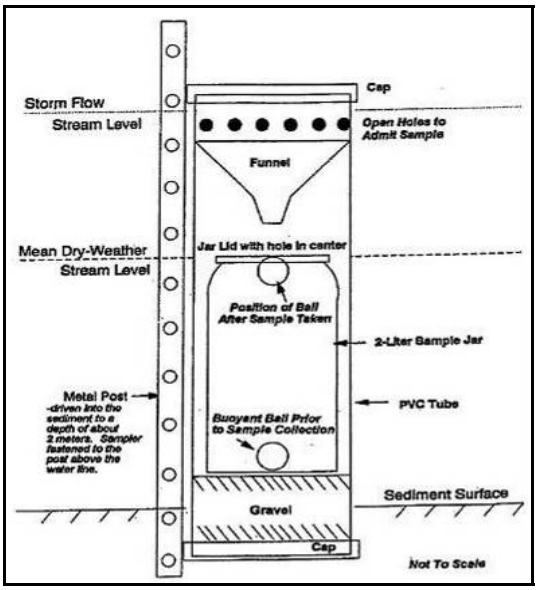


Figure 7. The passive sampler was buried in the ground to collect storm runoff.

The B3 sampler was collocated with a 2-inch 60-degree trapezoidal flume and a Campbell Scientific level transducer connected to a stilling well to monitor stage (Figure 9). Continuous turbidity was monitored using a D & A Instrument Company OBS-3 sensor, and data was recorded with a Campbell Scientific CR510 datalogger. All samples were analyzed for nutrients, TSS, and particle size distribution.

3.3 Catchment C

Catchment C was approximately 21 acres south of Lake Village HOA and was monitored as an untreated reference site. The catchment was drained by two drop inlets at the bottom of Echo Drive, a steep 1,100 ft-long road with AC dikes on both sides. The drop inlets were connected to 300 ft of CMP that discharged to the forest. At the outfall of the CMP, stage and turbidity were measured by the same configuration of equipment as found at Catchment B (Figure 10). Water quality samples were collected by a single passive sampler also at the outfall and analyzed for nutrients, TSS, and particle size distribution.

Echo Drive supported the Kingsbury Middle School that closed in June 2008. The school building (surface area of ~33,000 ft^2) was surrounded by impervious areas in the form of basketball courts (~15,000 ft^2), parking lots (~5,000 ft^2), and support roads (~18,500 ft^2). A turf field (~73,000 ft^2) was maintained behind the school. All these areas drained to Echo Drive (Figure 11). Private BMPs at the school were never accomplished and the impervious areas are generally connected by surface conveyance with no water quality treatment.

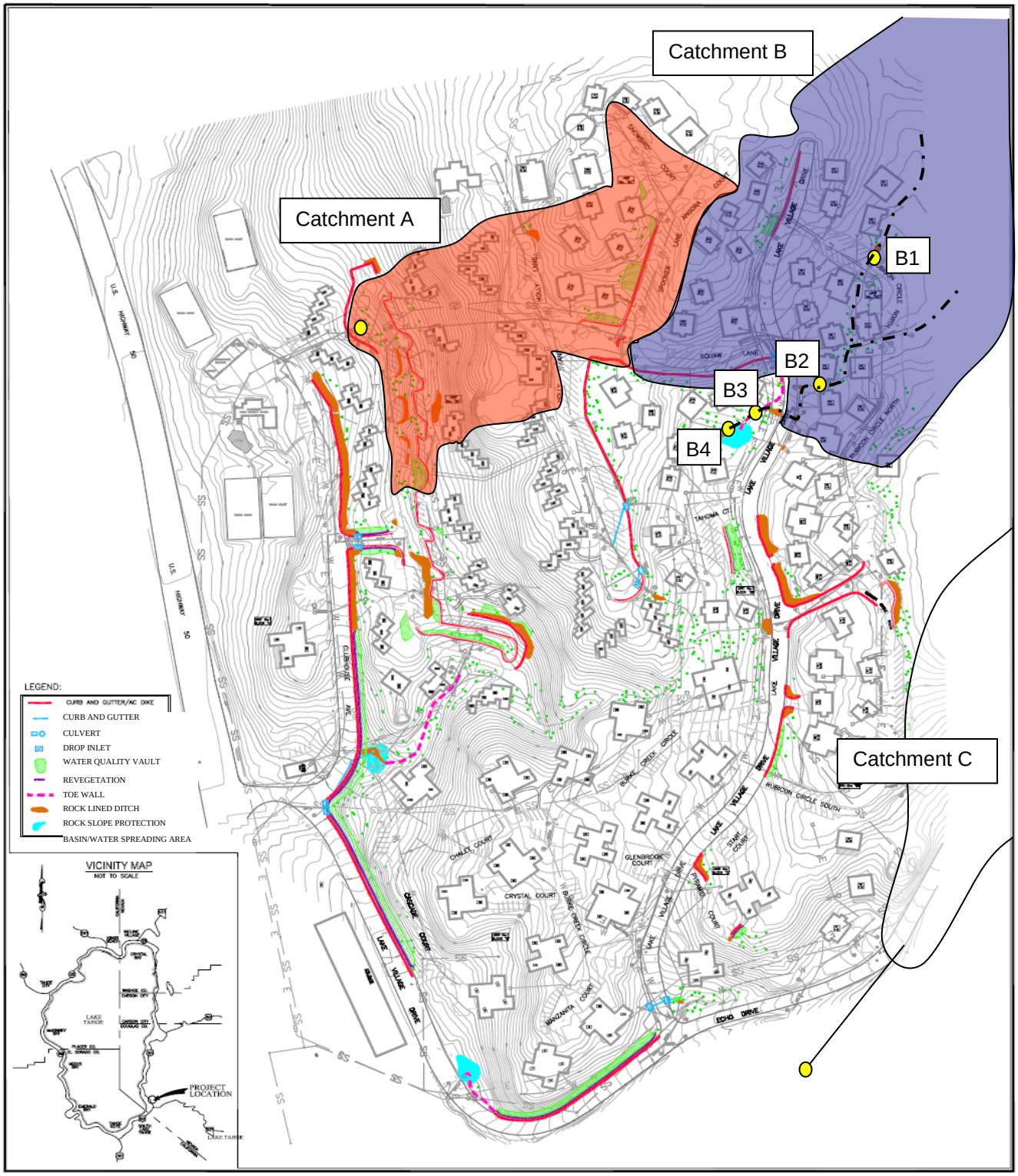


Figure 8. Lake Village CIP project plan, study catchments, and water quality sample locations.

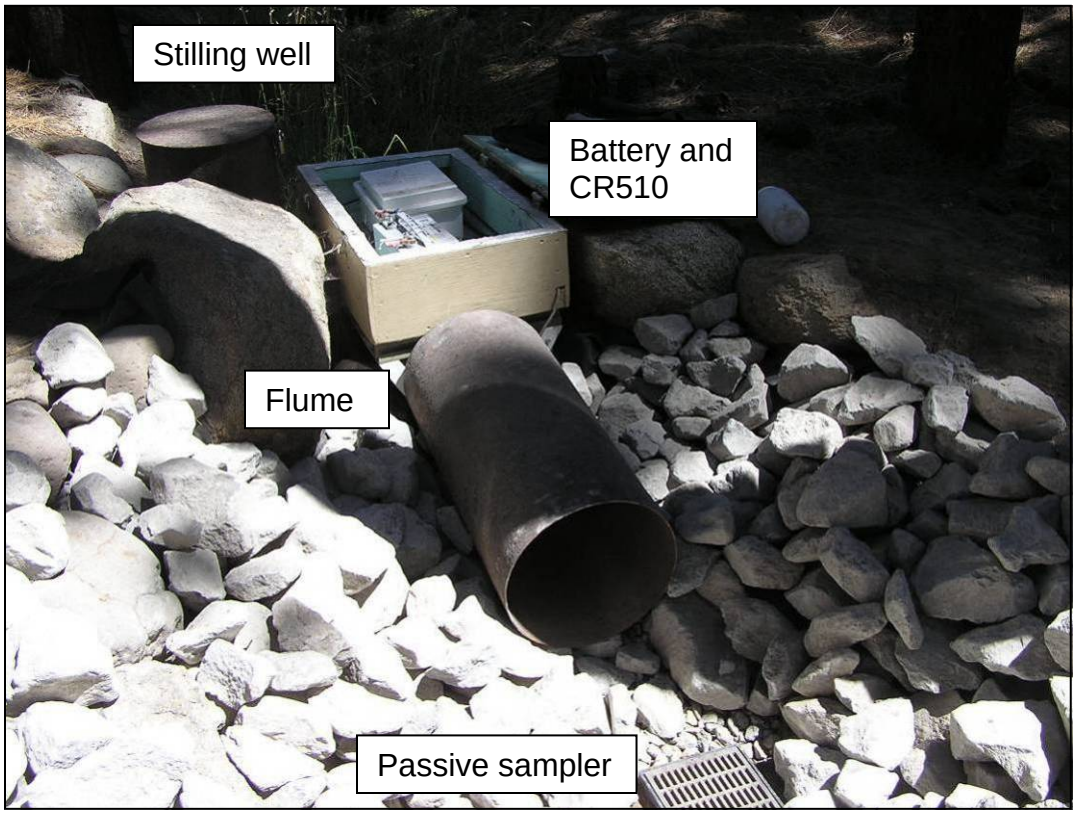


Figure 9. Campbell level transducer and passive sampler at Site B3 (post EIP construction).

The connectedness of the impervious areas, lack of water quality treatment, steep slope, and use of red cinders as traction control material were features of Catchment C that were unlike the other catchments. For example, the volume and velocity of water down Echo Drive moved a significant amount of pine needles, ice, and traction control material that frequently clogged the drop inlets resulting in stormwater bypassing the drop inlets and the monitoring system. Sediment and traction control material frequently inundated the area around the sampler requiring excavation.

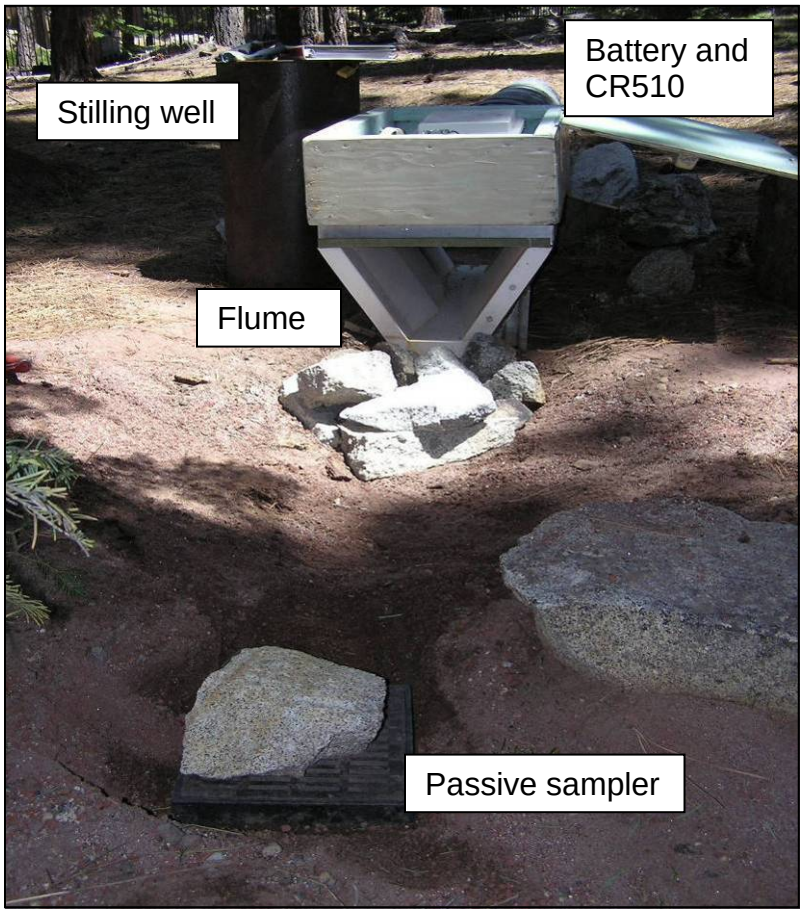


Figure 10. Sample site configuration for Catchment C.

Figure 11. A Google Earth view of the Lake Village community and the Kingsbury Middle School.

3.4 Drip Lines

In 2005, a set of seven passive samplers were installed in the flow path of roof drip lines and decks in Lake Village (Figure 12). The drip line samplers collected the initial 2.3 L of runoff (Figure 13). The drip line BMPs installed by the residents generally consisted of 0.75 to 1.5 inch washed drain rock 3 inches deep and a minimum of 18 inches wide. Water samples were evaluated for TSS and particle size distribution.

Table 4 shows the location of drip line sites (XS) sampled. The drip line sampler at XS-3 was the only control site, meaning no BMPs were installed at this site, thus allowing a comparison between the effect drip line runoff has on an area treated with BMPs and an untreated area.

One of the objectives of the drip line study was to measure the change in “micro-topography” in the drip zone area in order to calculate the mass of material eroded before the BMPs were installed and after installation. An initial detailed survey of the ground surface was conducted at the start of the study, but for some unknown reason follow up surveys were not completed.

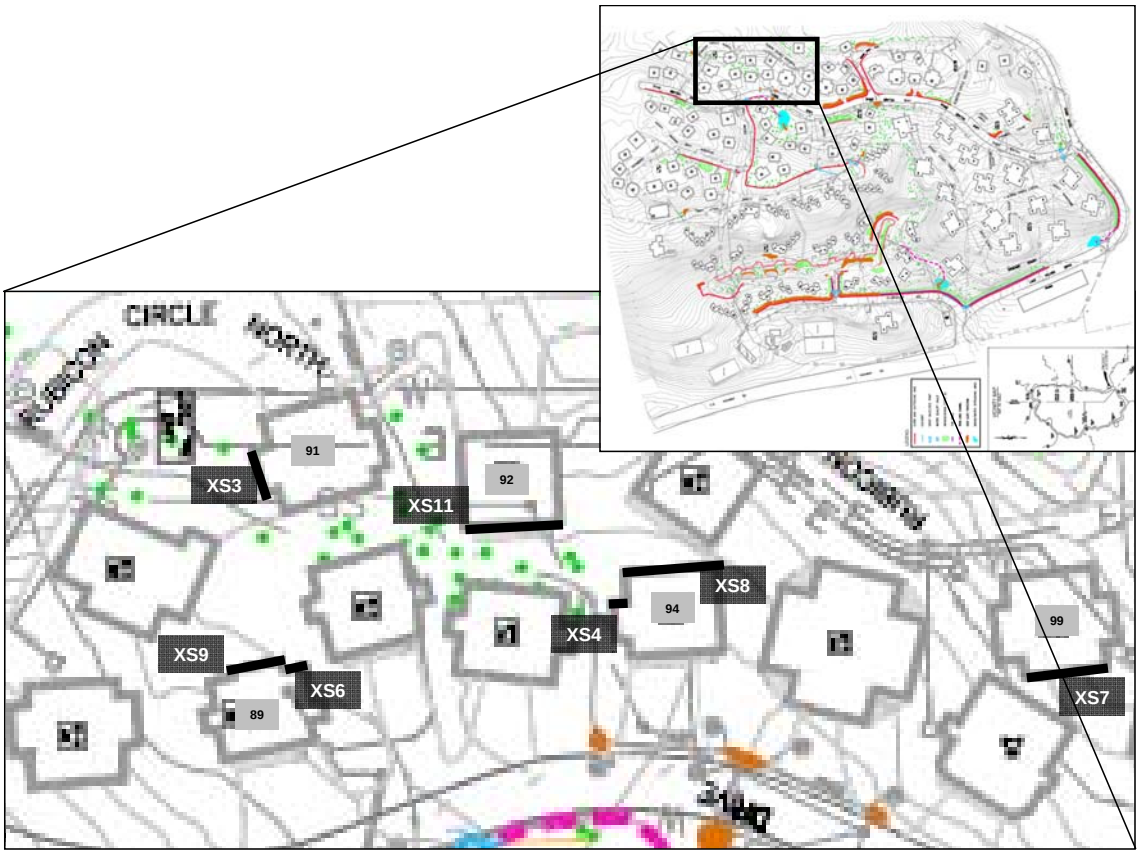


Figure 12. Sample locations and site names for the seven roof drip lines. The light grey boxes are the building numbers.

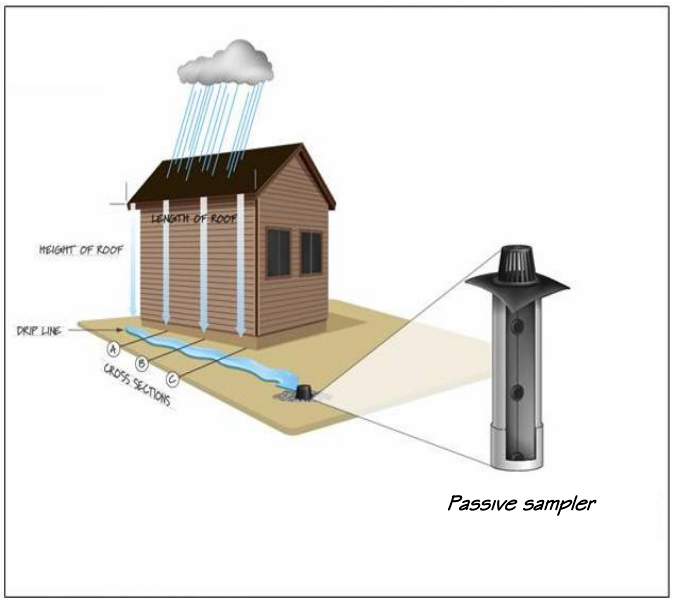


Figure 13. Conceptual drawing of a roof drip line sample configuration.

Table 4. Drip line topographic information (collected July 2005).

Site	Drip Line Type	Length of Roof Line (ft)	Height of Roof (ft)	Width of Drip Line (ft)	Drip Line Area (ft^2)	Slope of XS surface	BMP Installation Date
XS-3	Control	17	25	0.25	4	1.1%	Mar 2007*
XS-4	Short Drip	5	17.9	0.25	1	0.9%	Nov 2006
XS-6	Short Drip	9.7	33	0.25	2	3.9%	Aug 2007
XS-7	Long Drip	40.5	22.6	0.25	10	1.6%	Jul 2007
XS-8	Long Drip	24.8	21.8	0.25	6	1.9%	Nov 2006
XS-9	Long Drip	25	30	0.25	6	6.5%	Aug 2007
XS-11	Deck	22.5	22	5	113	1.4%	Oct 2006

*Arbitary pre vs. post BMP installation date

4.0 METHODS

4.1 Sample Collection and Analysis

Water quality samples were collected from all sites and classified according to the event that generated the runoff: rain (including rain/snow combinations), rain on snow, thunderstorm, or snowmelt. The first two precipitation types are generally characterized by wide spread precipitation from a frontal system. Thunderstorms are generally summer convective events and highly localized. Areas of snowmelt runoff were spotty depending on ambient temperature, aspect of the topography, and solar intensity.

Only single samples were collected at all passive sample sites and the entire sample was given to the lab for analysis. Catchment A samples were generally multiple bottles of equal volume time-paced composite samples collected by the autosampler. All bottles were sent to the lab where aliquots were taken from each bottle to generate equal volume composites for analysis. At the start of the project while the autosampler program was being optimized, some single grab samples and manually activated samples collected by the autosampler samples were analyzed.

Water quality samples were generally recovered from the site within 24 hours of collection. The initial preservation technique was to freeze samples, but starting in October 2007, samples were refrigerated at 3^oC and generally analyzed within 48 hours.

Runoff samples were analyzed by High Sierra Water Labs for the constituents listed in Table 5. Particle size distribution was primarily analyzed at the Tahoe Environmental Research Center using a Beckman-Coulter system. Samples between 28 July and 12 November 2004 were analyzed by the Desert Research Center using a Saturn Digisizer system. Technicians that operate these systems say the machines use the same methods and should produce equivalent results. In-situ turbidity, temperature, and stage were also collected at each site.

Table 5. Water quality constituents and in-situ parameters collected for water samples at the catchments. Also provided are the laboratory methods and constituent abbreviations.

Water Quality Constituent	Abbreviation	Method of Analysis	Nature of Constituent
Ammonia	NH_3-N	Lab (EPA 350.1)	Soluble, bio-available
Nitrate + Nitrite	$NO_{2/3}$-N	Lab (EPA 353.1)	Soluble, bio-available
Organic Nitrogen (TKN – NH_4)	Org N		Insoluble compounds
Total Kjeldahl Nitrogen	TKN	Lab (EPA 351.2)	Mostly insoluble
Total Nitrogen (TKN + $NO_{3/2}$)	TN		Mostly insoluble
Soluble Reactive Phosphorus	SRP	Lab (SM 4500-PE)	Soluble, bio-available
Dissolved Phosphorous	DP	Lab (EPA 365.3)	Soluble
Total Phosphorous	TP	Lab (EPA 365.3)	Partially insoluble (inorganic sorbed to particulates or organic compounds)
Total Suspended Sediment	TSS	Lab (EPA 160.2)	
Particle Size Distribution	PSD	LASER diffraction	
Turbidity	Turbidity	Continuous, in-situ	
Temperature	Temp	Continuous, in-situ	
Stage		Continuous, in-situ	

4.2 Precipitation

To document the amount of precipitation that fell in the study area, NTCD originally established two precipitation monitoring stations at residences in Lake Village. However, reporting by these volunteers was inconsistent and unreliable, and ultimately abandoned. As a result, there is no complete precipitation data set available from within the project area. Instead, precipitation data has been assembled from real-time precipitation gages in Round Hill, Edgewood Golf Course, and Marlette Lake SNOTEL in Nevada, and the South Lake Tahoe Airport gage in California (Figure 1). The first two sites are about a mile from the project area, but have spotty and incomplete data. The Marlette Lake SNOTEL site has a thirty year record, but is 13 miles north and 1,500 ft higher than Lake Village. The South Lake Tahoe Airport about 7 miles southwest of Lake Village, at the same elevation, and has a complete data set, but precipitation patterns at the airport can be significantly different than those on the east side of the lake. If no real-time precipitation data was available, then data recorded from the rain gage at the NTCD office building on Kingsbury Grade (approximately 0.7 miles from Lake Village) provided a total precipitation depth for the event.

To get an overview of monthly precipitation for the general area, Figure 14 shows the average monthly precipitation for the period of record at the Marlette Lake SNOTEL site compared to the monthly total for the water years (WYs) during which the monitoring project was active. Figure 14 also shows the percentage of the total annual precipitation for each WY. WY05 and WY06 had above average annual precipitation whereas the other WYs had significantly less than average precipitation.

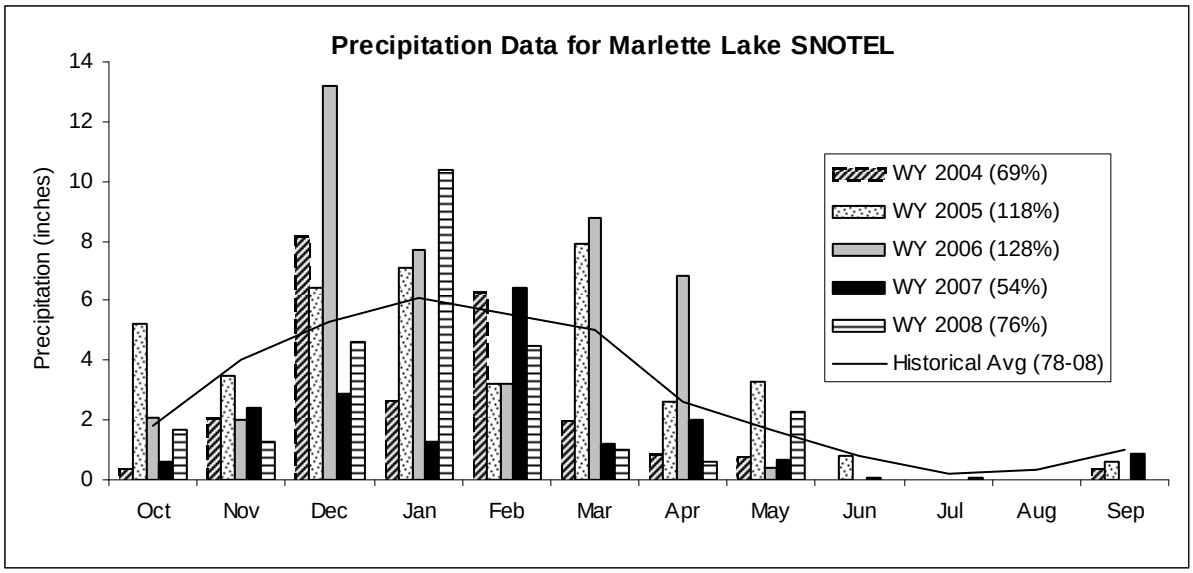


Figure 14. Monthly precipitation at the Marlette Lake SNOTEL site for the period of this report relative to monthly mean precipitation for the period of record. The percent of annual historical average is provided for each WY in the legend.

4.3 Flow

4.3.1 Catchment A

Because of the failure of the area-velocity (AV) meter at Catchment A, the flow was calculated using Manning's equation. The AV meter was placed in the CMP outfall pipe attached to a smooth metal insert. Caulking and a foam liner ensured flow between the insert and the CMP was not possible. The relationship between stage recorded by the ISCO and the actual depth of water at the AV meter was developed. As a result, the volume of water passing the sampling site could be accurately calculated. However, as noted in section 3.1, despite the use of an auto sampler for collecting water quality, a composite sample representing an "event mean" could not be assembled or calculated.

4.3.2 Catchments B and C

Discharge could be calculated for Catchments B and C using the stage measurements and the stage discharge relationship of the flume. However, no event mean composite concentration could be established because only the first 2.3 liters of the runoff was sampled. As a result, the load of the various pollutants could not be calculated. Therefore apart from possibly analyzing the differences in hydrologic response of the three catchments to a precipitation event, there was no reason to calculate the volume of water for runoff events at Catchments B and C.

4.4 Pre-BMP and Post-BMP Dates

A total of 214 events were analyzed for the three catchments and seven drip lines (Table 6). Each event was classified according to the runoff event and whether the

event was before or after implementation of the BMPs. Unfortunately, the BMPs were not installed in a single day, but over a series of years in the case of the residential BMPs. As a result, some assumptions had to be made about the demarcation date between the “pre-BMP” events and “post-BMP” runoff events for each sample site.

4.4.1 Catchment A

For Catchment A, it was assumed the completion of the CIP project in late October 2006 was the demark between pre- and post- BMP sampling. It is recognized that residential BMPs were completed for forty-two buildings within Catchment A over a four year period. However, it is believed the water quality and quantity were dominated by the runoff from the road and parking areas…common areas that received source control and conveyance improvements with the CIP.

4.4.2 Catchment B

Each of the three sample sites at Catchment B have different demark dates. The completion of the CIP project will serve as the demarcation for B3 because the EIP project installed 140 feet of 4 inch coble armor in the swale leading to B3. This rock had the potential to improve water quality, but very likely decreased runoff volume reaching B3 due to storage within the cobles. No public improvements were made above B2, however, the drip lines for two buildings were coincident with the swale leading to B2. Armoring the drip lines in effect armored the swale for 40 feet of the 300 feet between B1 and B2. Still, first flush runoff that reaches B2 would be from the adjacent roofs and therefore, changes in water quality at B2 would primarily be influenced by the completion of residential BMPs for the eight condominiums that drain to B2 (completed between 31 August 2006 and 21 September 2007). Unfortunately the late BMP completion date resulted in only two post-BMP events sampled at B2. Water quality at B1 captured water from four buildings with BMPs that likely influenced the water quality at that site. However it is felt the dominant water quality signature at B1 was from the forested upland. This conclusion is supported by the fact that surface runoff at B1 only occurred during high precipitation years. No pre-/post- demark date was established for B1.

4.4.3 Catchment C

No improvements that would affect stormwater quality were made within Catchment C during the study.

4.4.4 Drip Lines

Each condo unit installed residential BMPs individually, therefore, the demarcation date for pre- and post- water quality analysis is unique to each drip line site. For example, at XS-7 the BMP date is July 2007, but for XS-11 it was October 2006 (see Table 6). The lack of coordination for installing the residential BMPs complicates comparison of the data between drip line sites.

Because XS-3 was a control site with no BMPs installed, March 2007 was chosen as the demark date because this is the average of the other installation dates and because no drip line runoff events were sampled between February 2007 and November 2007.

Table 6. Number of samples pre- and post-BMP for each study site.

	Pre-BMP	Post-BMP	Total
Catchment A	10	12	22
Site B1	6	--	6
Site B2	12	2	14
Site B3	34	4	38
Catchment C	59	--	59
Drip Lines	51	24	75
Total	**172**	**42**	**214**

5.0 RESULTS AND DISCUSSION

To help assess the relative merit of a constituent concentration, comparisons will be made to the TRPA surface water discharge limits (Table 7).

Table 7. TRPA surface water discharge limits of average concentrations (TRPA Code of Ordinances, Chapter 81).

Constituent	Maximum Concentration
Dissolved Inorganic Nitrogen as N	500 µg/l
Dissolved Phosphorus as P	100 µg/l
Dissolved Iron as Fe	500 µg/l
Grease and Oil	2 mg/l
Suspended Sediment	250 mg/l

The statistical analyses were accomplished independently by a professor at Lake Tahoe Community College under a separate contract with the USFS. This analysis concluded there were insufficient data points to assume normality, a precondition for using typical statistical tools like the student t-test. In addition, no analysis was conducted for sample sets with less than six data points each. But with sample sets greater than six, the non-parametric Mann Whitney U test was used to determine statistical significance between two data sets. This test determines if there is a tendency for one of the data set to take on higher values than the other based on median values. To examine a statistical difference between distributions of more than one data set a non-parametric analog of an ANOVA, called the Krushkal Wallis test, was used. Typically this test is a first step in a multi-step process to determine if there is statistical difference between a multi value parameter. For example, Krushkal Wallis was applied to a data set to determine if the constituent values could be stratified by event type. If p-values indicate a constituent is stratified, Mann Whitney would typically be applied to a pair of event types to determine

which event type is significantly different from another event type. In the case of these data sets, there was insufficient data to test between event types. Finally, an alpha value for significance is not specified for this report, instead only p-values are presented.

5.1 Catchment A Concentrations

Ten events were sampled in Catchment A before October 2006 (i.e., before the CIP effort) and twelve events after the CIP (see Appendix B for water quality data for each event and Appendix C for graphs of the events). Pollutant concentrations in stormwater at Catchment A were, like all sites in this study, extremely variable with coefficient of variations above 100% for most constituents. Average and median concentrations were generally different by an order of magnitude. The variability in the data made it difficult to identify trends in either event type or in the pre-/post-BMP analysis. Overall, after the public BMPs were installed, the concentrations of most constituents decreased.

Average pre- and post- ammonia concentrations were nearly identical at 82 and 83 µg/l, respectively (Figure 15). Ammonia combined with $NO_{2/3}$ concentrations yielded pre- and post- dissolved inorganic nitrogen (DIN) concentrations of 360 and 310 µg/l, respectively. These values are below the TRPA surface water discharge limit, although the standard deviations (611 and 388 µg/l, respectively) indicate individual events exceeded the TRPA limit.

Overall, average organic nitrogen made up ninety-four percent of the total nitrogen concentrations which, from NTCD experience, is typical for stormwater runoff in Tahoe.

Dissolved phosphorus (DP) concentrations routinely exceeded the TRPA surface water discharge limit of 100 µg/l with average pre- and post- concentrations of 270 and 240 µg/l, respectively. Of the 22 events sampled at Catchment A, 13 had average DP concentrations above 100 µg/l.

Soluble reactive phosphorus (SRP) is generally considered the bio-available form of phosphorus and average SRP concentrations were 157 and 210 µg/l, pre- and post-CIP, respectively. If the Redfield N:P Ratio is assumed (Redfield 1958), then SRP concentrations should be seven times less than bio-available nitrogen (aka, DIN). However, SRP and DIN concentrations in this catchment were approximately the same magnitude suggesting the system is relatively rich in bio-available phosphorus.

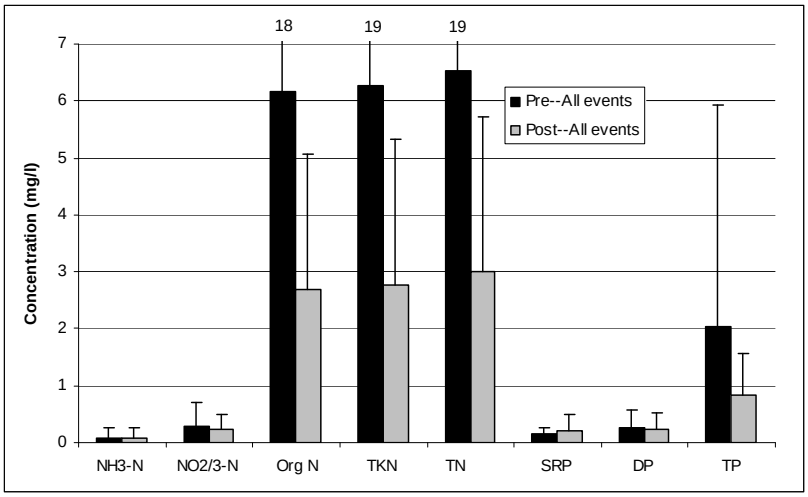


Figure 15. Overall pre- and post-CIP average concentrations for water quality constituents for Catchment A events.

Total suspended sediment (TSS) concentrations generally exceeded TRPA discharge limits of 250 mg/l. Average TSS concentrations dropped by 76% following the CIP installation, but the coefficient of variation was 259% pre-CIP and 117% post-CIP (Figure16).

Particle size distribution shows a slight shift to smaller particle sizes after the CIP. This may have occurred because curb and gutter systems segregated stormwater from decomposed granite soils, or because average peak runoff for events post-CIP were slightly less.

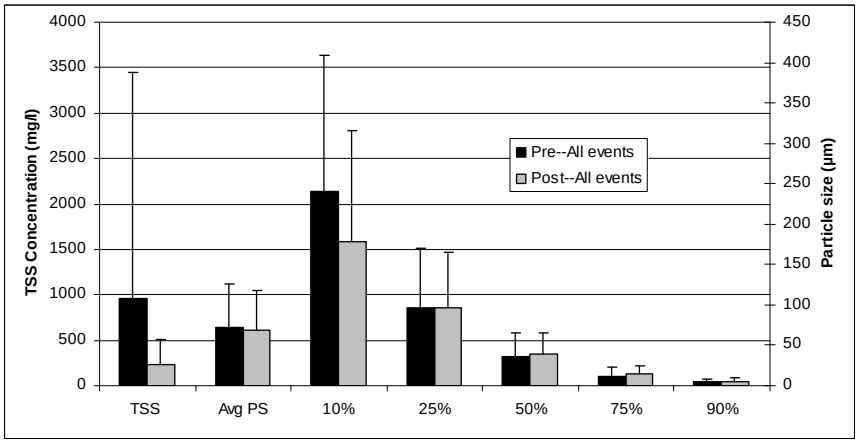


Figure 16. Overall Catchment A pre- and post-CIP average for TSS concentrations and particle size distributions. The percentages indicate the volume of sediment that exceeded a given particle size.

Constituent concentrations by event type generally showed a decline in concentration post-CIP (Figures 17, 18, and 19, and Appendix A for additional summary tables and graphs). Average concentration for rain events however defied this trend and exhibited

an increase in most nutrient concentrations (with a decrease in TSS concentration and average particle size). Clearly the single pre-CIP thunderstorm was an exceptional event in terms of the concentrations of constituents (Figures 17 and 18), but the average particle size was small (Figure 19). The amount of precipitation and peak flow for the thunderstorm was not exceptional (Appendix B Table 12) suggesting this event on 28 June was a seasonal first flush event. Post-CIP thunderstorm events had the highest average $NO_{2/3}$ concentrations and the biggest average particle size, but the other constituents were in general consistent with the average response of other events. Finally for post-CIP analysis, snowmelt events had the highest average concentrations of TP and TSS likely due to runoff of fine traction control particles.

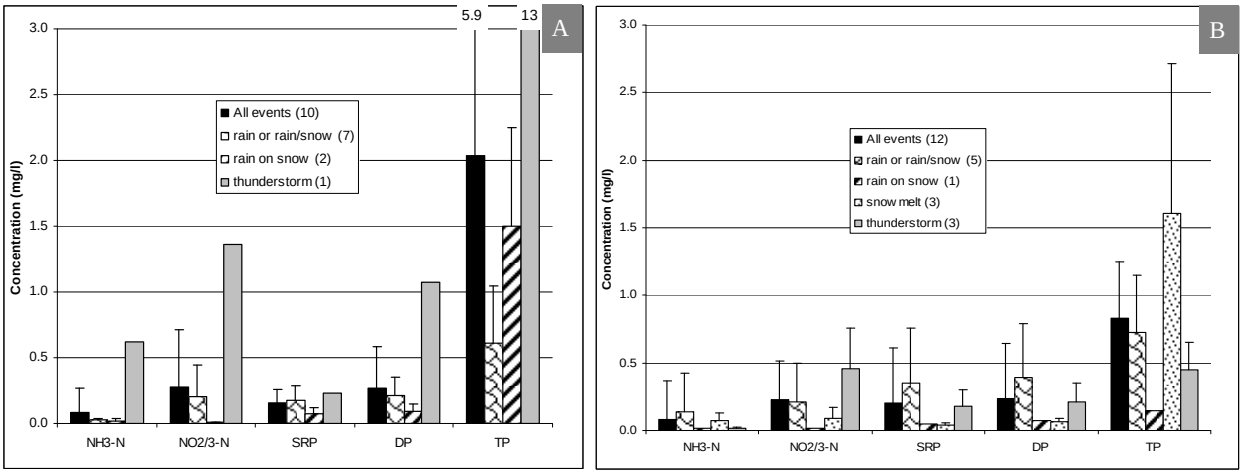


Figure 17. Average nutrient concentration for runoff at Catchment A according to each event type for A) pre-CIP events and B) post-CIP events. The number of events sampled are shown next to the event type in the legend.

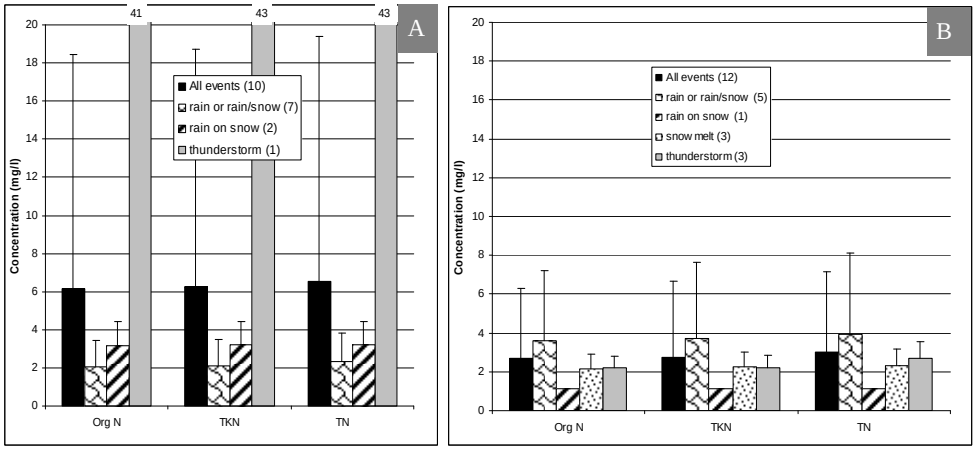


Figure 18. Average concentration of organic nitrogen-dominated nutrients for runoff at Catchment A according to each event type for A) pre-CIP events and B) post-CIP events.

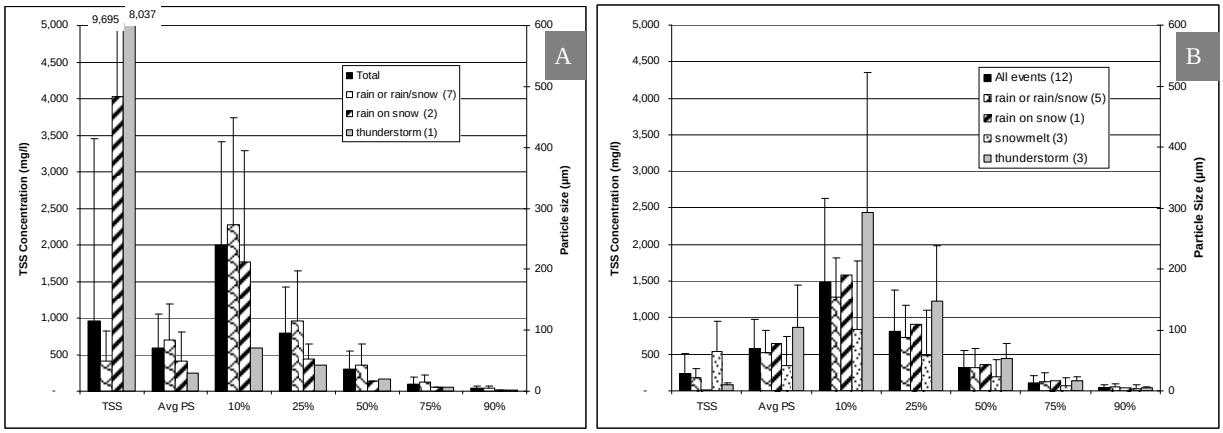


Figure 19. Average TSS concentration and particle size for runoff at Catchment A according to each event type for A) pre-CIP events and B) post-CIP events.

Turbidity for all storms in Catchment A ranged as high 1,870 NTU. Peak turbidity occurred at different points in the hydrograph depending on the individual storm. The following three figures show turbidity peaking before, after, and coincident with the peak discharge (Figure 20, 21, and 22).

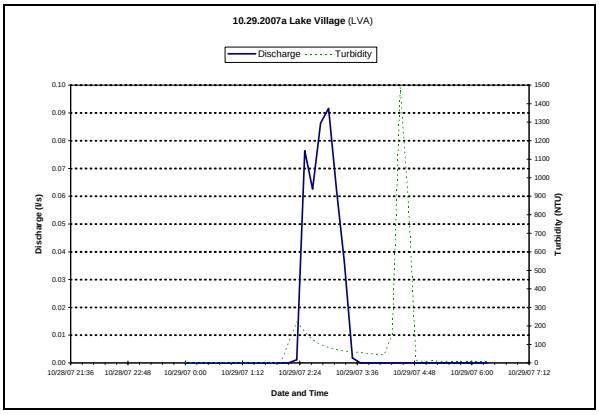


Figure 20. Peak discharge leading peak turbidity for the rain events on 29 October 2007 for Catchment A.

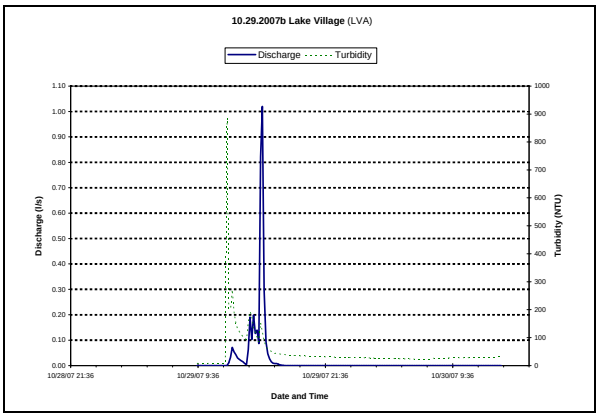


Figure 21. Peak discharge trailing peak turbidity for the thunderstorm event on 29 October 2007 at Catchment A.

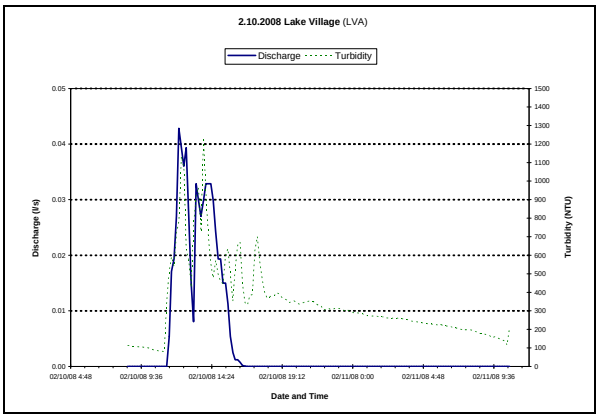


Figure 22. Coincident peak turbidity and discharge for the snowmelt event on 10 February 2008 for Catchment A.

To enhance the confidence of statistical results, pre-CIP data from Catchment A and Site B3 were combined and compared to a combined Catchment A and Site B3 post-CIP sample set. Only the Catchment A and Site B3 data sets were combined because the site treatment was similar (i.e., installation of the capital improvement project) and the magnitude of the concentrations were similar despite the fact that the sample methods were different. The results (Table 8) show a more significant difference in pre- vs post- values for ammonia than any other constituent. In addition, the Krushkal Wallis test (Table 9) on a combined Catchment A/Site B3 data set indicates concentration values were stratified according to event type for all constituents except SRP, DP, and possibly $NO_{2/3}$. These results indicate dissolved constituent concentrations are not influenced by event type.

Table-8. P-values for the Mann Whitney test for pre- vs post-CIP concentrations of the combined Catchment A and B3 data set. The lower the p-value, the greater the tendency for pre- values to be of a higher magnitude than post-CIP values.

	NH3-N	NO2/3-N	Org N	TKN	TN	SRP	DP	TP	TSS	Avg Particle Size
P-value	0.048	0.47	0.45	0.47	0.45	0.49	0.51	0.47	0.42	0.51

Table-9. P-values for the Krushkal Wallis test by event type for a combined Catchment A and B3 data set. The results show the degree of statistical difference in the distribution of concentrations for event types.

	NH3-N	NO2/3-N	Org N	TKN	TN	SRP	DP	TP	TSS	Avg Particle Size
P-value	0.01	0.19	0.04	0.04	0.05	0.89	0.64	0.02	0.01	0.01

5.2 Catchment A Flow and Load

Twenty-two events were sampled with volumes ranging from 23 ft^3 to 1315 ft^3 (see Appendix B for flow data for each event). The average volume for a pre-CIP event was 922 ft^3 versus 136 ft^3 for a post-CIP event (6.7 times greater) (Figure 23). This difference in event volume can be attributed to 5 times more precipitation for pre-CIP events than post-CIP (Figure 24). It was considered that the above average precipitation in WYs 05 and 06 might have skewed these data, but the average precipitation for WY04 events (four events including a 10/19/04 rain event) was also 5 times more than the average event precipitation for WY07 and WY08.

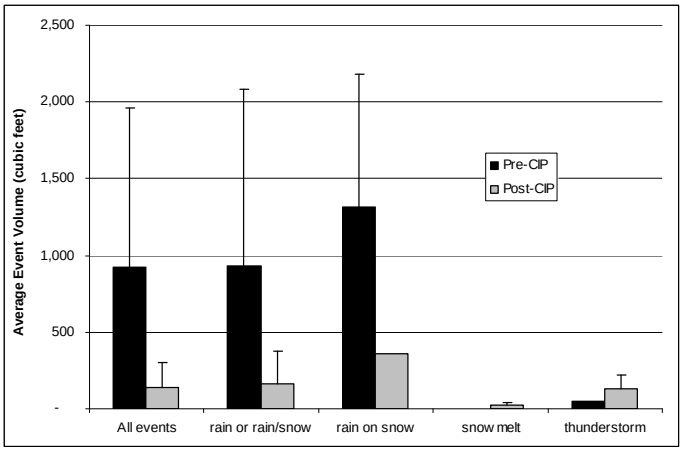


Figure 23. Average runoff volume for all pre- and post-CIP events.

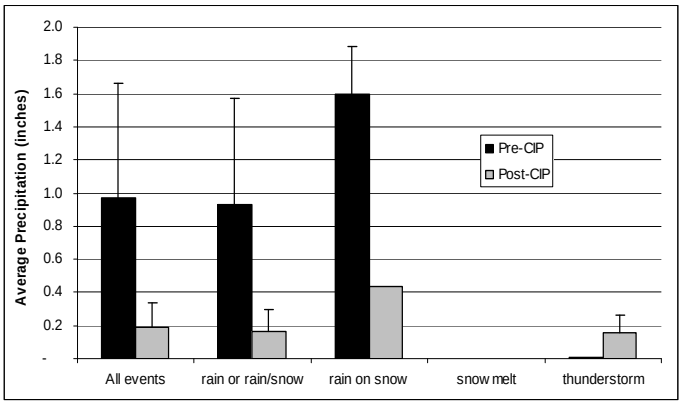


Figure 24. Average precipitation for all Catchment A runoff events.

Peak flows averaged 0.039 and 0.029 cubic feet per second (cfs) for pre- and post-CIP events, respectively (Figure 25). Average peak flow for WY04 was 0.043 cfs, comparable to post-CIP average peak flow.

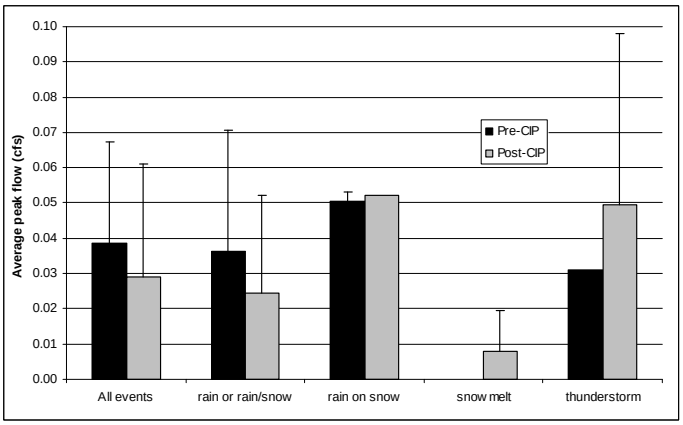


Figure 25. Average peak runoff for all pre- and post-CIP events for Catchment A.

Pollutant loads were generally an order of magnitude greater pre- versus post-CIP. However, this is partially explained by the 6.7-fold difference in event volumes as explained above. It is possible that the implementation of the CIP in Catchment A could explain the remaining reduction in pollutant loads (see Appendix A for additional summary graphs and tables for Catchment A load). Table 11 shows Catchment A has a strong tendency for loads prior to the CIP project to be greater than after, with the possible exception of nitrate/nitrite.

Table-10. P-values for Catchment A loads using the Mann Whitney U test for pre- vs post-CIP loads. The lower the p-value, the greater the tendency for pre- values to be of a higher magnitude than post-CIP values.

	NH3-N	NO2/3-N	Org N	TKN	TN	SRP	DP	TP	TSS	Avg Particle Size
P-value	0.03	0.16	0.02	0.02	0.02	0.04	0.04	0.03	0.03	0.03

Average particle size for each event was weighted by the volume of the event (Equation 1) with the resulting average weighted particle size of 67 µm and 101 µm, pre- and post-CIP, respectively. The weighted particle size distribution (Figure 26) shows post-CIP events had a more narrow distribution compared to the pre-CIP weighted distribution (see the inset particle size values in Figure 26). The reason for this feature is unknown.

Equation 1. Formula for weighted average particle size.

$$\text{weighted average particle size} = \frac{\sum (\text{event particle size})_n * (\text{event volume})_n}{\sum (\text{event volume})_n}$$

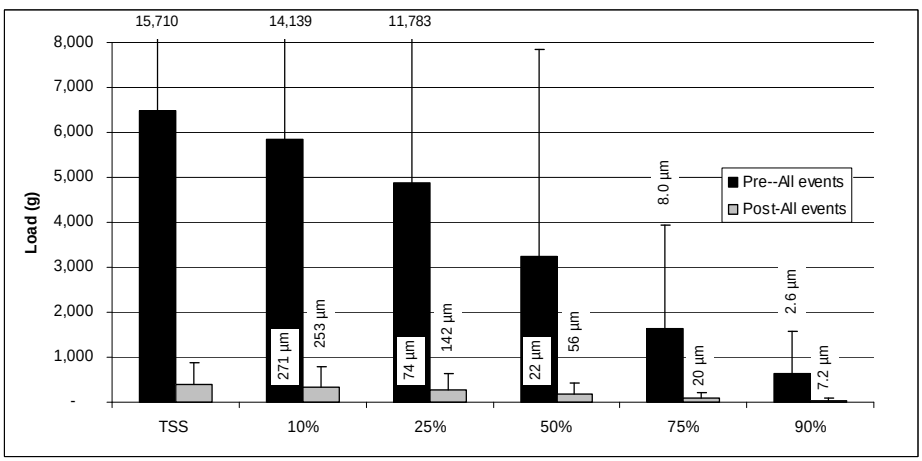


Figure 26. Average load of TSS and particle size distribution for each flow-weighted average particle size (the vertical inset values) for Catchment A. The percentages on the X-axis indicate the percentage of TSS mass that exceeds the associated particle size (vertical inset values).

The average stormwater event moved 6.5 kg (14 lbs) of suspended sediment before the CIP compared to 0.38 kg (0.84 lbs) after (Figure 26). Bio-available nitrogen averaged 4.6 g pre-CIP and 0.53 g post-CIP, and bio-available phosphorus (i.e., SRP) averaged 2.5 g pre-CIP and 0.55 g post-CIP (Figure 27). An average of 65 g of total nitrogen was transported before the CIP compared to 8 g after (Figure 28).

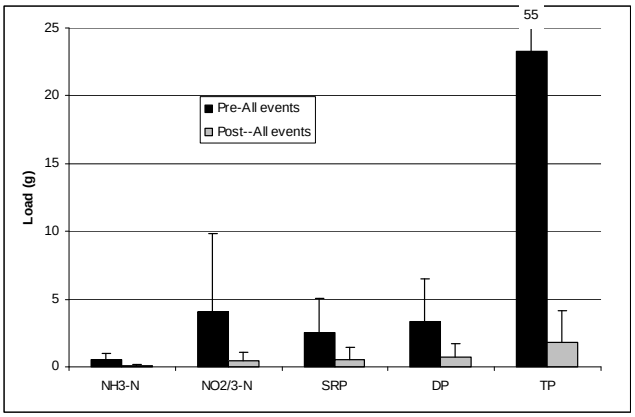


Figure 27. Average load of water quality constituents all pre- and post-CIP events at Catchment A. Bio-available nitrogen is the sum of NH_3 and $NO_{2/3}$.

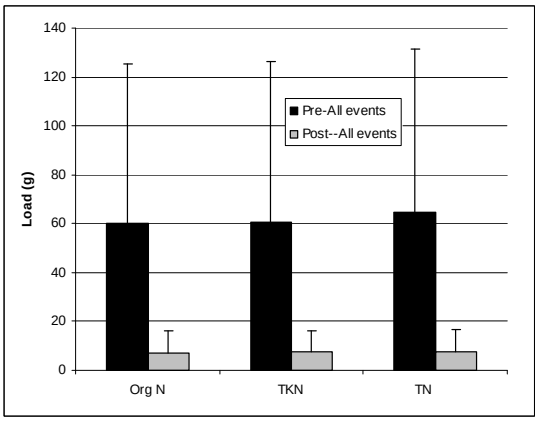


Figure 28. Average mass of organic-dominated nitrogen species for all pre- and post-CIP events at Catchment A.

It was considered that omitting the events from above average water years and comparing the pollutant loads from only the low water years (i.e., WYs 04 (pre-CIP), and 07 and 08 (post-CIP)) might result in more consistent precipitation and runoff volumes. But because the average precipitation associated with the WY04 events was 5 times greater and the resulting WY04 event volumes ten times greater, it is not surprising that the corresponding loads for every constituent were an order of magnitude higher. This analysis was not pursued further.

5.3 Catchment B

The three passive samplers in Catchment B collected 58 first flush samples distributed as shown in Table 8. Each sampler represented water quality from different land use areas. B1 represented background water quality from the forested uplands and two adjacent condominium buildings. B1 had the least number of samples, six over the entire study period. The area between B1 and B2 is dominated by impervious surfaces

from roads, sidewalks, and roofs with the latter being the closest to the sampler and therefore having the greatest influence on the water quality. It is highly unlikely runoff from B1 influenced the water quality at B2 because the runoff from the several condominiums adjacent to B2 was more flashy and filled the 2.3 liter passive sampler before runoff from B1, over 300 ft away, could arrive at B2. The same was true for B3. B3 sampled runoff from large parking lots and roadways and was not likely influenced by B2 runoff 150 ft away.

Table 11. The number of samples collected and analyzed from Catchment B pre- and post-improvement. All collection was completed by January 2008.

Site	Pre-	Post-	Total	Notes
B1	6	-	6	No pre-/post- criteria
B2	12	2	14	Pre-/post- demark is 9/07
B3	34	4	38	Pre-/post- demark is 10/06
Total	52	6	58	

Comparing the Catchment B sites before installation of the various BMPs, B2 and B3 had larger average concentrations of TP and TSS than B1 possibly due to more impervious surfaces and flashy flows of the former (Figure 29). In addition, B3 had the largest average concentration of organic nitrogen-dominated species and the smallest average particle size than B1 and B2. This difference could be attributed to the physical action of vehicle traffic on the adjacent road grinding traction control material, road surface, pine needles, and pine cones into a fine dust that was easily transported by stormwater.

Conversely, B1 had very low TSS concentrations (Figure 30) and correspondingly low TP and organic nitrogen concentrations. This difference can be attributed to the largely overland flow from the forested upland at B1 compared to channelized flow of urban runoff at B2 and B3.

The average ammonia concentration for B1 was an order of magnitude greater than average ammonia concentrations at B2, B3, and Catchment A (and B1 was three times greater than Catchment C). This high concentration was not a chronic condition, but due to two of the six events having very elevated concentrations. The source of the ammonia does not appear to be from lawn fertilizer because there were no lawns in the area. The elevated ammonia could be from the area being used as a pet latrine.

The average $NO_{2/3}$ concentrations, pre- and post-BMP, at B2 were double the concentrations at B1, B3, Catchment A, and Catchment C. The coefficient of variation was 79% indicating a relatively consistent condition of high $NO_{2/3}$ concentration at B2, but no source was readily apparent.

Comparing the concentrations to the TRPA water quality standards (Table 7), B1 exceeded the dissolved inorganic nitrogen threshold on the strength of the very high ammonia concentrations. All sites exceeded the dissolved phosphorus threshold, and

only B1 met the TSS threshold, although average TSS concentration at B2 was in compliance after the installation of the residential BMPs.

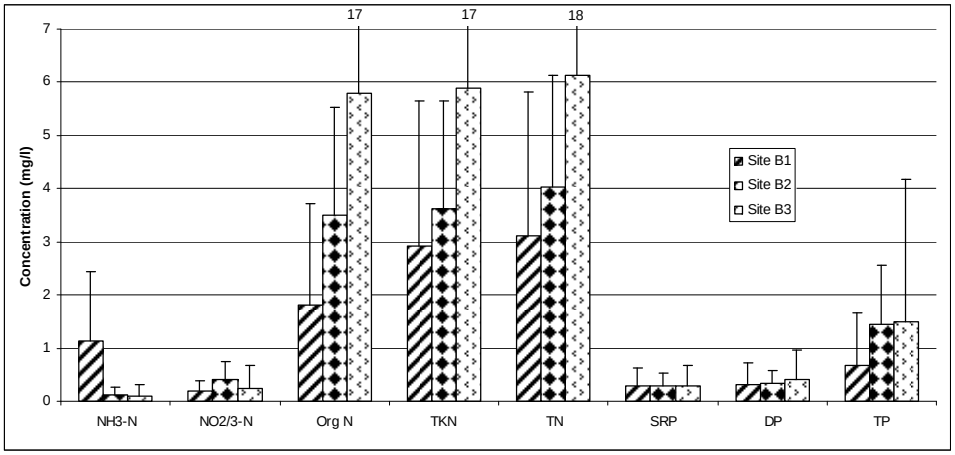


Figure 29. Average water quality concentrations for the three sites in Catchment B for events sampled prior to installation of residential or public improvements.

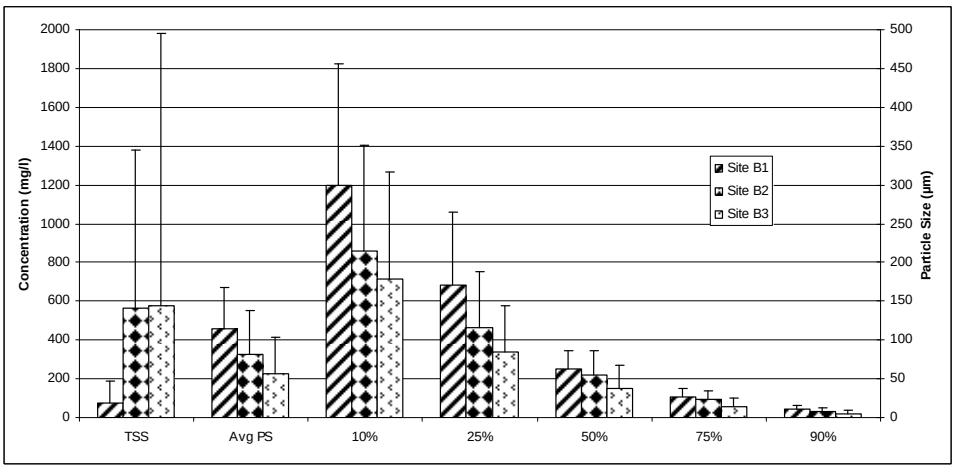


Figure 30. Average TSS concentration and particle size distribution for the three sites in Catchment B for events sampled prior to installation of residential or public improvements. The percentages indicate the portion of sediment volume above the given particle size.

The change in water quality at B2 following the completion of the residential BMPs was mixed. Constituents associated with particulate matter showed a slight decrease, but dissolved constituents increased (Figure 31). No statistical conclusions could be made with these data in part because the residential BMPs were phased in over essentially a two year period (Table 3) and there were only two post-BMP events (Table 8). Having said that, TSS was dramatically less following the BMP installation (Figure 32) and particle size increased.

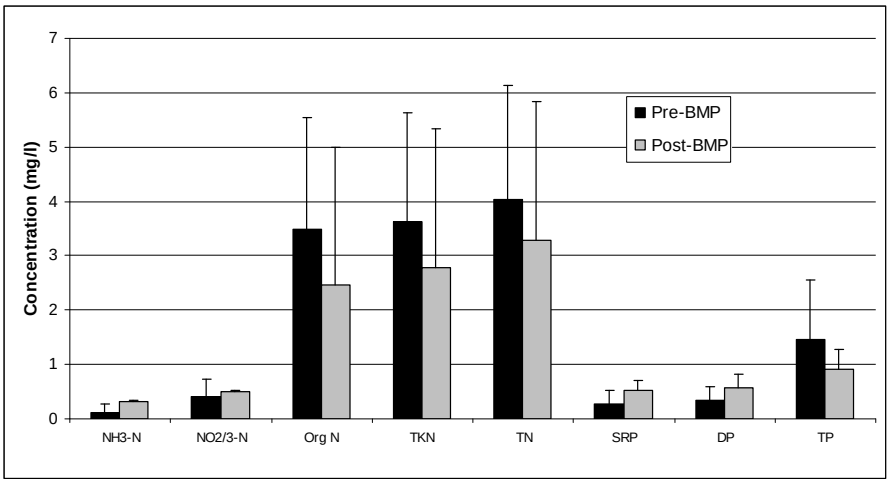


Figure 31. Average constituent concentrations for pre- and post-BMP water quality at B2.

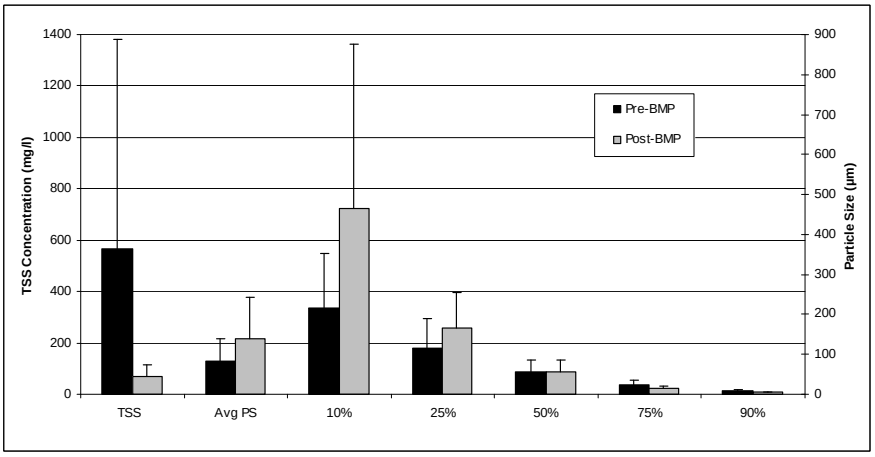


Figure 32. TSS concentration and particle size distribution for pre- and post-BMP water quality samples at B2.

Average constituent concentrations at B3 were similar to the concentrations at Catchment A, and there was a trend to lower concentrations for organic nitrogen species following implementation of the CIP (Figure 33). Average nitrite/nitrate concentrations deceased, but SRP increased at B3. Although there was a decrease in TSS (Figure 34) and organic nitrogen, indicating a decrease in particulate matter, total phosphorus remained largely unchanged. Particle size trended slightly smaller. The statistical analysis for a combined Catchment A and Site B3 data set is provided in Tables 8 and 9.

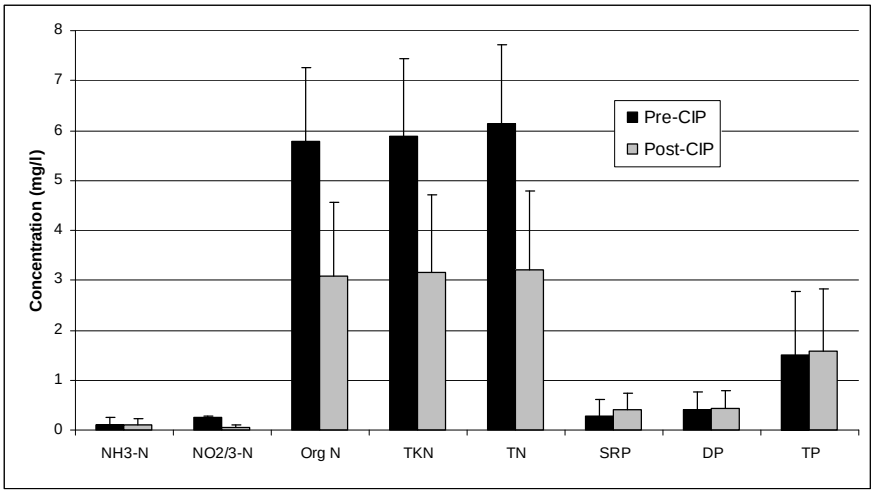


Figure 33. Constituent concentrations for pre- and post-BMP water quality samples at B3.

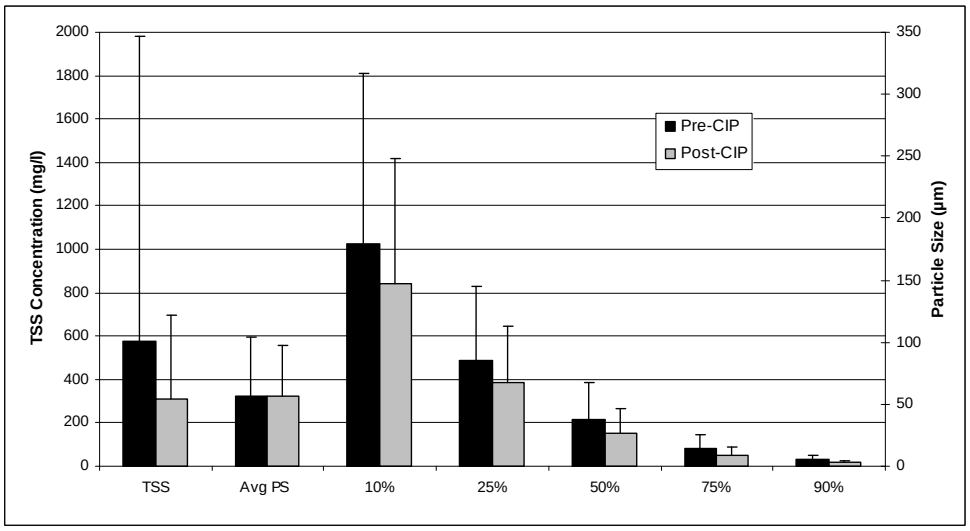


Figure 34. TSS concentration and particle size distribution for pre- and post-BMP water quality samples at B3.

Looking at the pre-BMP B3 concentrations by event type, thunderstorms stand out as delivering the highest concentrations of particulate pollutants in comparison to other event types (Figures 35, 36, and 37). But thunderstorms also had the highest concentration for other constituents as well, plus the biggest average particle size. Rain on snow events had the lowest concentration for all constituents for all event types, but only slightly.

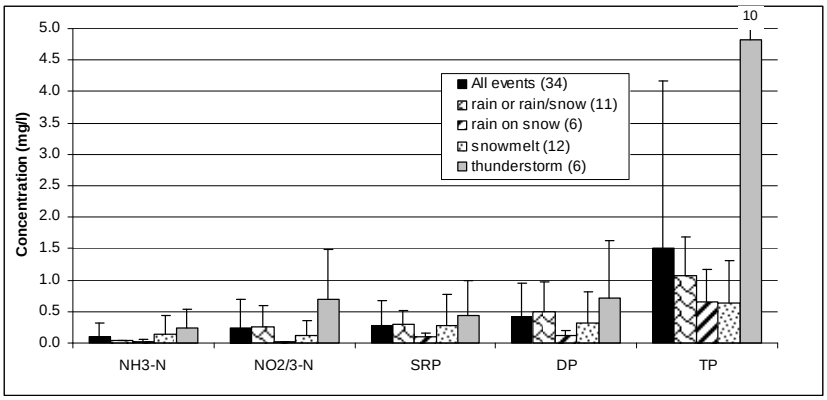


Figure 35. Constituent concentrations for pre-BMP water quality samples at B3 by event type.

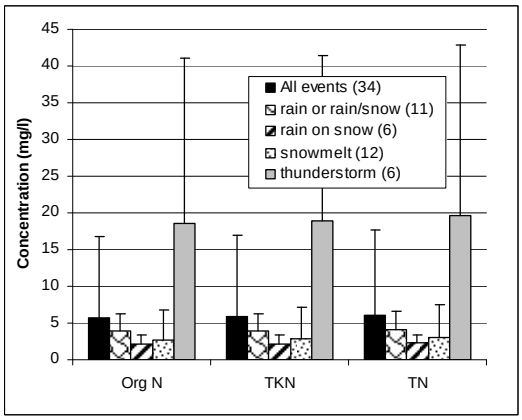


Figure 36. Concentrations of organic nitrogen-dominated constituents for pre-BMP water quality samples at B3 by event type.

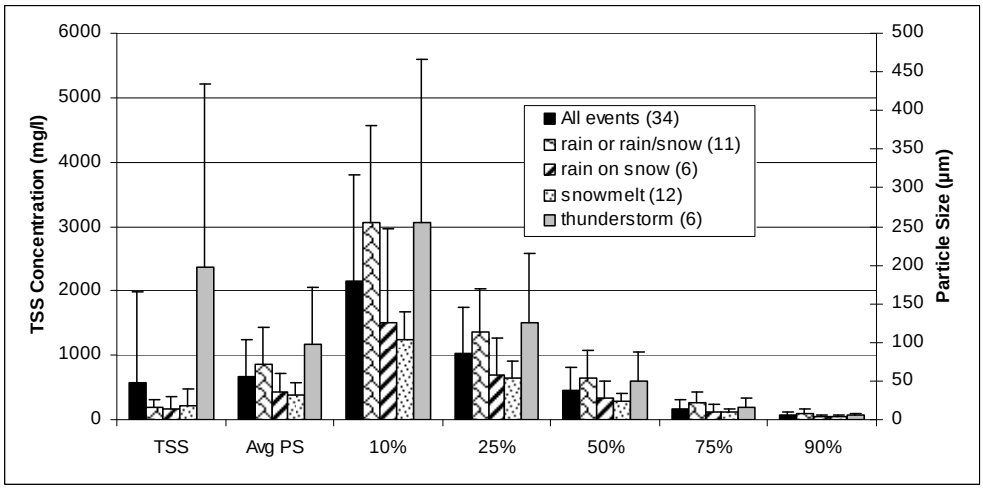


Figure 37. TSS concentrations and particle size data for pre-BMP water quality samples at B3 by event type.

5.4 Catchment C

Fifty-nine samples were analyzed from Catchment C between November 2003 and January 2008—25 events were rain or rain/snow, 10 rain on snow, 13 snowmelt, and 11 thunderstorms. There were no BMP improvements in this catchment, so no pre- versus post- analysis was needed.

Overall the Catchment C concentrations (Figure 38) were consistent with Catchment A pre-CIP except ammonia that was about 5 times greater than Catchment A ammonia concentration and twice that of Catchment C nitrate. The elevated ammonia concentration was due to three samples two orders of magnitude greater than the median value. The source of the high ammonia concentration is unknown, but probably not due to fertilizer from the turf field at the middle school because the passive sampler would be filled before the field runoff would get to the sampler. It may be possible the high ammonia is a first flush from the drop inlets on Echo Drive or the long CMP conveyance to the sample site.

The average bio-available nitrogen concentration (0.68 mg/l) was above the TRPA threshold for DIN, but the median value at 0.08 mg/l was well below the threshold. Using the average values of DIN and SRP (0.14 mg/l), the N:P ratio of 5 indicates this system is slightly rich in bio-available phosphorus.

Organic nitrogen is the dominant nitrogen species at an order of magnitude greater than ammonia. Average TSS concentrations were 838 mg/l (greater than the TRPA threshold) and average particle was 83 µm (Figure 39).

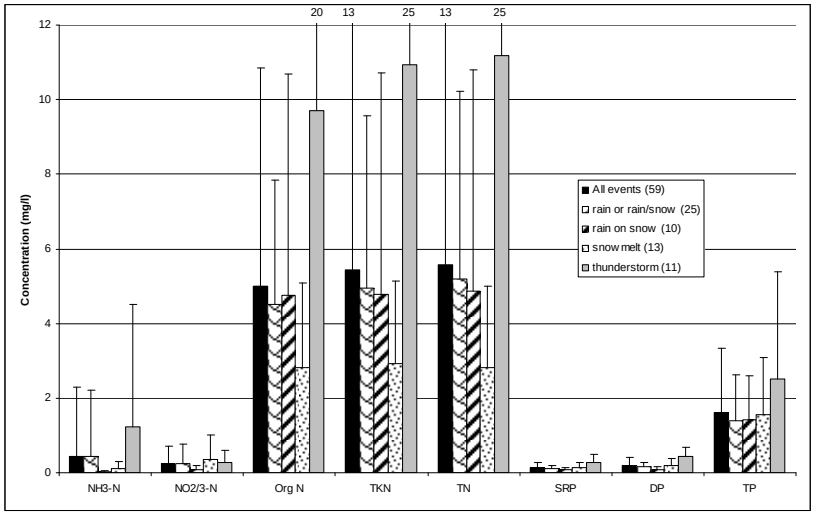


Figure 38. Concentrations of water quality constituents for events in Catchment C.

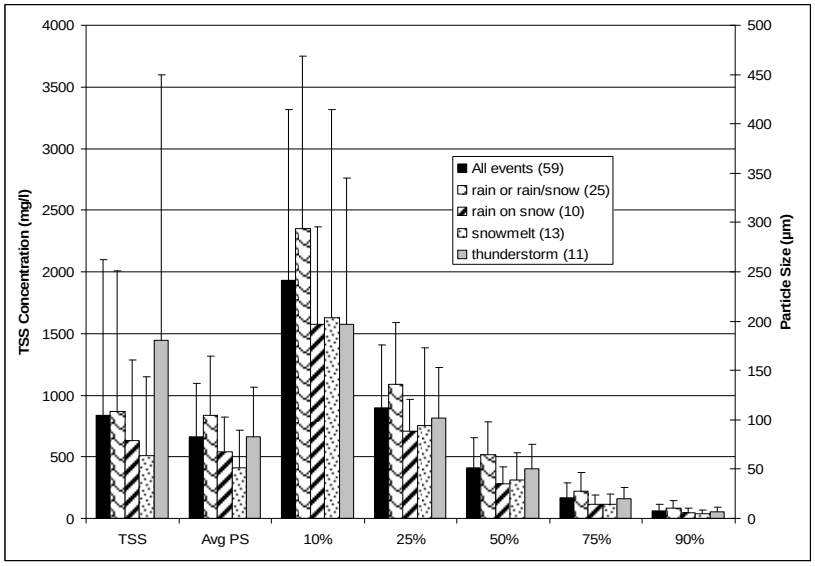


Figure 39. TSS concentration and particle size distribution for events in Catchment C.

Thunderstorms had the highest peak flows and the largest average concentrations for all constituents except nitrate. Rain on snow events or snowmelt events generally had the lowest concentrations. The results of the Krushkal Wallis test for Catchment C constituent concentrations for event type defy easy explanation because p-values are low for both dissolved and sorbed constituents and high for both dissolved and sorbed constituents.

Table-12. P-values for the Krushkal Wallis test by event type for the Catchment C data set. The results show the degree of statistical difference in the distribution of concentrations for event types.

	NH3-N	NO2/3-N	Org N	TKN	TN	SRP	DP	TP	TSS	Avg Particle Size
P-value	0.31	0.58	0.01	0.01	0.01	0.07	0.00	0.29	0.43	0.03

Correlation values between constituents resulted in no surprises—particulate-bound constituents had good correlation with other particulate associated constituents, whereas dissolved constituents did not. The one exception was ammonia and TKN/Total N. The very high concentrations of ammonia influenced the concentration of TKN (organic N and ammonia) and Total N (TKN and nitrate) with R values of 0.85 and 0.87, respectively.

It was expected that flow from this catchment would be significantly greater than the other catchments due to the larger impervious areas, but average event volume was only one-third larger than Catchment A. However, it was observed during many runoff events that the two small drop inlets on Echo Drive clogged with pine needles or snow causing stormwater to bypass the drop inlets and subsequently the flow measurement system. This could have resulted in an erroneously low runoff volume measurement.

5.5 Drip Lines

Each drip line water sample was analyzed for TSS and particle size distribution. Because the BMPs were finished late in the study and because of the below normal precipitation in WY07 and WY08, the number of pre-BMP samples were greater than the number of post-BMP events for all sites (Table 9).

Table 13. Average TSS concentrations (in mg/l) for the drip line sites.

	PRE BMP installation			POST BMP installation		
	# Events Sampled	Mean TSS	STDEV	# Events Sampled	Mean TSS	STDEV
XS-3 (control)	9	703	939	3	20	9
XS-4 (short)	6	872	593	5	81	100
XS-6 (short)	7	1836	1650	3	9	4
XS-7 (long)	7	1902	1852	3	39	16
XS-8 (long)	6	2396	1842	4	65	101
XS-9 (long)	9	513	653	3	35	44
XS-11 (deck)	7	4018	4113	3	355	255

Average TSS concentrations for the drip lines ranged from 4,018 to 513 mg/l before the residential BMPs were installed compared to 355 to 9 mg/l after the BMP installation for an overall decrease in TSS concentrations of approximately 95% (Figure 40). There were insufficient data points to conduct statistical analysis but the difference in TSS concentrations after the BMPs were installed appear significant.

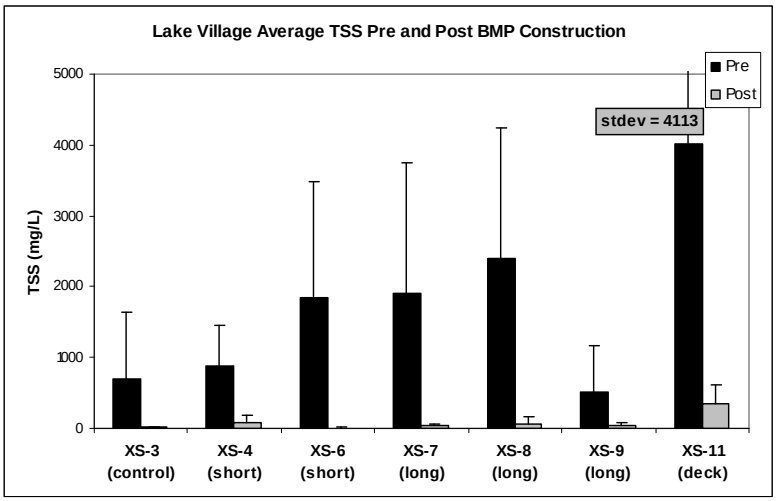


Figure 40. Average TSS concentration for pre- and post-BMP water samples for drip line sites.

The average TSS concentration at XS-11, which received drip line runoff from a deck, was larger than the other XS sites for both pre- and post-BMP samples. This was likely due to a difference in areas captured by the sampler. The deck area of XS-11 was 113 square feet, whereas XS-7 had the next largest drip line area of approximately 10 square feet (assuming the width of a drip line was 3 inches).

Average TSS concentration for the control site, XS-3, dropped two orders of magnitude from the pre-BMP to post-BMP events, 703 mg/L versus 20 mg/L, respectively. This difference in concentration occurred even though no residential BMPs were installed. It is likely that when the sites were installed in 2005, they were raked clear of all rocks, pine needles, vegetation, etc. But over the succeeding years, pine needles recovered the drip area and decreased drip erosion. An increase in ground cover at XS-3 could account for the decrease in average TSS concentrations. This explanation may also apply to the relatively low pre-BMP TSS concentration at XS-9.

The average particle size for pre- and post-BMP events was 127 µm to 137 µm (Table 10), respectively, and these values were relatively constant regardless of the drip line type. The particle size distribution shifted slightly to larger sizes for post-BMP events (Figures 41 and 42).

Table 14. Average particle size (in µm) for the drip line sites.

	PRE BMP installation			POST BMP installation		
	# Events Sampled	Mean PS	STDEV	# Events Sampled	Mean PS	STDEV
XS-3 (control)	9	130	40	3	120	62
XS-4 (short)	6	121	34	5	128	20
XS-6 (short)	7	108	54	3	141	23
XS-7 (long)	7	140	59	3	144	41
XS-8 (long)	6	155	55	4	144	44
XS-9 (long)	9	133	60	3	143	68
XS-11 (deck)	7	104	39	3	144	31

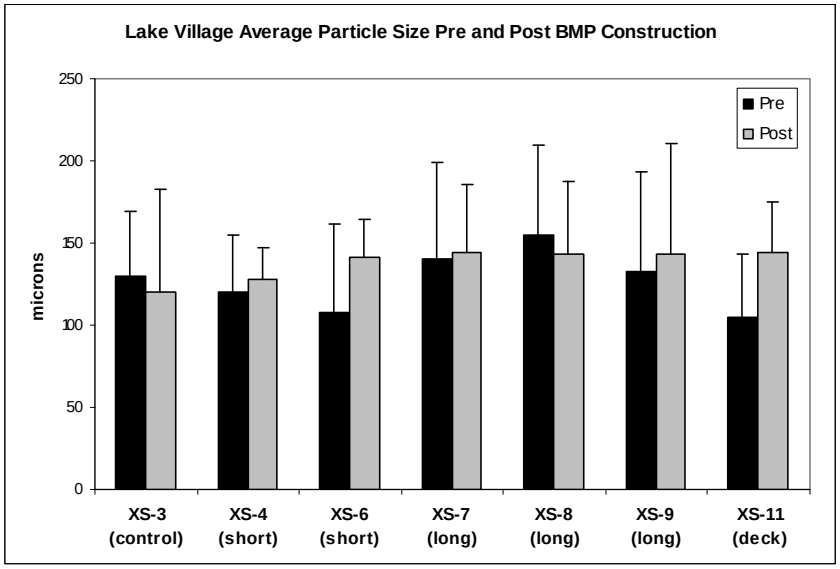


Figure 41. Average particle size for drip line sites pre- and post-BMP installation.

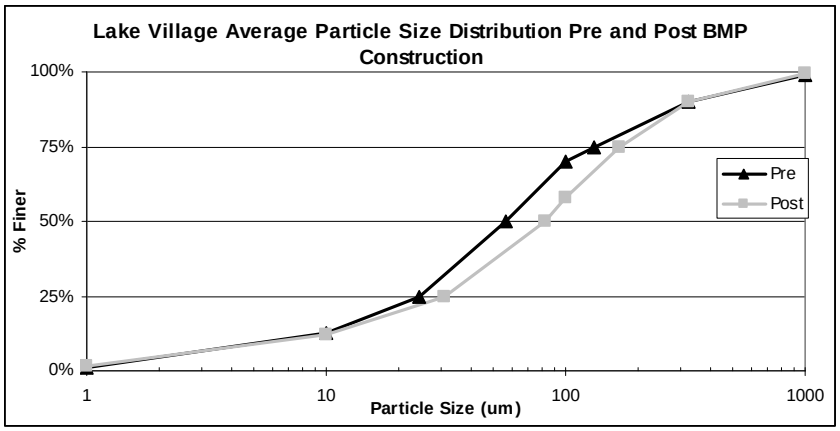


Figure 42. Particle size distribution curves for average pre- and post-BMP events for drip line samples.

Although the drip line sites captured runoff from short, long, and deck areas and from roof heights varying from 18 to 33 ft, there were no statistical trends that could link drip height or length/area to pre-BMP TSS concentrations. This was also true after the BMPs were installed, but then it is clearly apparent that the TSS concentrations were very similar regardless of the drip line type.

6.0 CONCLUSIONS

Water quality of the stormwater was highly variable making the determination of statistically significant results challenging. The statistical results for a combined Catchment A and Site B3 indicates only ammonia had significant different concentration whereas nearly all Catchment A loads were statistically different.

The average particle size was relatively unchanged for pre- vs post- events. The overall average particle size for TSS at Catchment A and Site B3, the sample sites dominated by road runoff in the HOA, was 61 µm. But the overall average particle size for the drip line sites was 130 µm. In addition, 25% of TSS from road runoff was smaller than 14 µm compared to 27 µm for the drip lines. These data support the Lake Tahoe TMDL findings that fine sediment primarily originates from road runoff (Roberts and Reuter 2007).

There were occasional spikes in ammonia concentrations (above 1 mg/l) at B1, B3, and Catchment C. Fertilizer does not appear to be the source of these spikes, but perhaps pet waste and/or first flush might be partial explanations.

Compared to bio-available nitrogen the runoff in this study was rich in bio-available phosphorus. The overall average for DIN for all samples was 0.55 mg/l compared to 0.21 mg/l for SRP. The resulting N:P ratio of 39% is substantially higher than the Redfield ratio of 14% would suggest is typical.

The traction control material used on Echo Drive, sampled by Catchment C, was red cinders. These cinders have in the past been accused of being a more significant source of phosphorus compared to other traction control material (e.g., sand). However, Catchment C phosphorus concentrations (i.e., SRP, DP, and TP) are consistent with the concentrations at the other sites. Therefore, red cinders do not appear to be a greater source for phosphorus compared to local soils.

Thunderstorm events were generally brief with a relatively small volume, but they generally produced the highest concentration of particulate pollutants for each catchment. Statistical analysis of event types was not possible beyond noting that some stratification of concentrations was evident for Catchment A and Site B3 for sorbed constituents. However, similar analysis for Catchment C did not produce similar results regarding event types. Further analysis was not possible due to insufficient data points.

The drip line data clearly indicates armoring of drip line areas significantly reduces TSS concentration. However, the decrease in TSS concentration at XS-3 (the control site) suggests this armoring could be in the form of pine needles. As much as the average TSS concentrations changed, the average particle size remained relatively unchanged over the course of the study suggesting that neither the length of the drip line, drip fall height, drip line slope, nor armoring affect the size of particles transported during runoff events. The particle distribution is likely controlled by the soil type.

TRPA threshold limits were routinely exceeded for TSS and DP. DIN was also in exceedance on some occasions. These results are not likely unique to Lake Village, because anthropogenic impervious surfaces that support vehicle traffic may be ideal sources for fine sediment pollution.

7.0 LESSONS LEARNED

The original goal of establishing “matched catchments” to determine the improvement in water quality resulting, in part, from incremental installation of residential BMPs over a four year period was ambitious. Ideally, matched catchments for this study would be similarly sized, with similar conveyance connectivity, impervious surface area, land use, and topography. In addition, the degree of hydrologic similarity would be verified by monitoring flow and comparing hydrographs from more than one precipitation event before embarking on a multi-year water quality study. Figure 43 shows a similar response to a rain event for Catchment A and B suggesting the catchments may be relatively matched, at least for this one example. But the ability to compare water quality data between catchments was made impossible due to the catchments being instrumented so differently…one with an auto sampler capable of collecting 120 samples throughout the hydrograph and the other with a single first flush passive sampler.

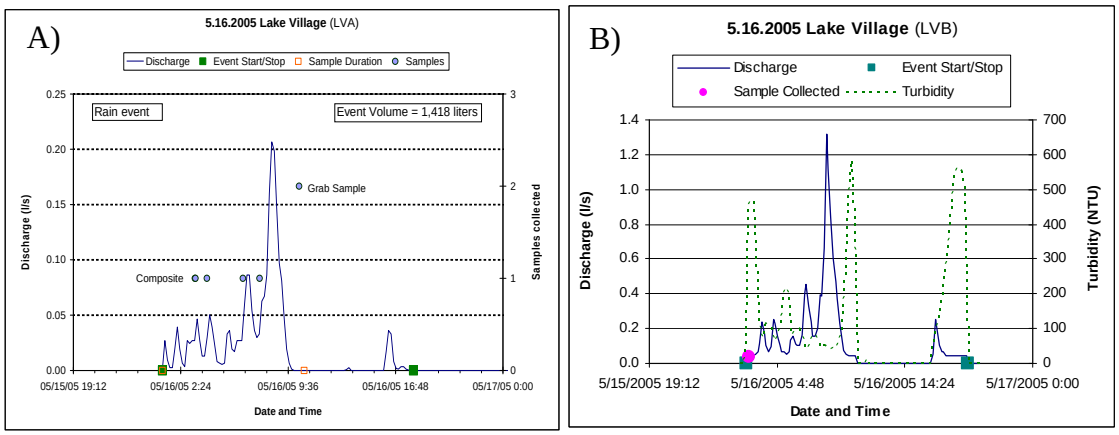


Figure 43. Hydrographs from a rain event as measured at A) Catchment A and B) Site B3.

The "control" site at Catchment C had topographic, land use, and road maintenance differences (i.e., copious application of traction control material) that compromised its usefulness as a control (Table 2). The propensity of the drop inlets to clog on Echo Drive and stormwater to bypass the sample location introduced error in hydrographs. The data collected were interesting stand alone, but did not contribute much to understanding the water quality changes in the other catchments.

Residential BMPs appear to substantially decrease TSS on the BMP scale (i.e., the drip line data), but these results could not be corroborated on the catchment scale, in part, because the residential BMPs were completed over a multi-year period. If the BMPs would have been completed in one month or over a single summer, then the process of statistical analysis would have been more straight forward and perhaps the results more definitive.

The programming of the auto-sampler to collect multiple time-paced, equal volume samples in a single bottle was unfortunate and prevented the determination of "event mean concentrations." As a result, the concentrations and loads found at Catchment A cannot be compared to values found from other studies.

The project's monitoring effort could have benefitted from a more involved data management process. It is clear this project was complicated by the delay of installing the CIP and residential BMPs making a two year project a five year project. Had an interim report been generated at the mid-point of the study and/or periodic technical exchange meetings held, these issues may have been revealed and given the management team a chance to correct them.

BIBLIOGRAPHY

Goldman, C.R., 1988. Primary productivity, nutrients, and transparency during the early onset of eutrophication in ultra-oligotrophic Lake Tahoe, California-Nevada. *Limnology and Oceanography*, Vol. 33, No. 6, pp. 1321-1333

Redfield, A.C., 1958. The biological control of chemical factors in the environment. *American Scientist*. Vol. 46, pp. 205-221

Reuter, J.E. and W.W. Miller. 2000. Aquatic resources, water quality and limnology of Lake Tahoe and its upland watershed, pp. 215-399. *In*: The Lake Tahoe Watershed Assessment (ed.) D. Murphy and C. Knopp. Vol. 1. United States Department of Agriculture – Forest Service.

Roberts, D.M. and J.E. Reuter, 2007. Lake Tahoe Total Maximum Daily Load Technical Report–California and Nevada. California–Lahontan Regional Water Control Board and Nevada Division of Environmental Protection.

APPENDIX A

Appendix A provides tables and graphs that summarize the water quality data discussed in the main body of the report. Raw data for each sample event can be found in Appendix B and the hydrographs of each event in subsequent appendices by catchment.

Table 1. Constituent concentrations for pre-CIP runoff event types for Catchment A. All values are in (mg/l).

Event type		NH_3-N	$NO_{2/3}$-N	Org N	TKN	TN	SRP	DP	TP
All events (10)	Average	0.08	0.28	6.18	6.26	6.54	0.16	0.27	2.03
rain or rain/snow (7)		0.024	0.201	2.08	2.10	2.30	0.17	0.21	0.61
rain on snow (2)		0.019	0.008	3.18	3.20	3.21	0.07	0.09	1.50
thunderstorm (1)		0.62	1.4	41	41	43	0.23	1.08	13
All events	StDev	0.19	0.44	12	12	13	0.11	0.31	3.91
rain or rain/snow		0.012	0.25	1.37	1.38	1.53	0.11	0.14	0.43
rain on snow		0.021	0.001	1.26	1.24	1.24	0.05	0.06	0.75
thunderstorm									
All events	CV%	229%	158%	258%	199%	196%	68%	113%	192%
rain or rain/snow		49%	124%	66%	65%	66%	67%	65%	70%
rain on snow		112%	9%	40%	39%	39%	73%	63%	50%
thunderstorm									

Table 2. TSS concentration and particle size distribution for pre-CIP runoff event types at Catchment A.

Event type		TSS (mg/l)	Avg Particle Size (µm)	Particle Size Exceedance Percentage (µm >)				
				10%	25%	50%	75%	90%
All events (10)	Average	962	71	241	96	35	12	4.1
rain or rain/snow (7)		83	84	273	116	43	15	4.9
rain on snow (2)		499	49	213	53	16	6.1	2.1
thunderstorm (1)		8037	29	71	43	20	6.5	2.4
All events	StDev	2492	55	168	74	31	11	3.5
rain or rain/snow		50	59	175	82	34	12	4.0
rain on snow		71	47	183	24	0.85	1.2	0.28
thunderstorm								
All events	CV%	259%	77%	70%	78%	87%	90%	85%
rain or rain/snow		60%	70%	64%	71%	80%	85%	81%
rain on snow		14%	96%	86%	46%	5%	19%	13%
thunderstorm								

Table 3. Water quality constituent concentrations for post-CIP event at Catchment A. All units are (mg/l).

Event type		NH_3-N	$NO_{2/3}$-N	Org N	TKN	TN	SRP	DP	TP
All events (12)	Average	0.083	0.23	2.7	2.8	3.0	0.21	0.24	0.83
rain or rain/snow (5)		0.14	0.21	3.6	3.7	3.9	0.350	0.390	0.729
rain on snow (1)		0.013	0.016	1.1	1.1	1.2	0.049	0.073	0.149
snowmelt (3)		0.077	0.087	2.2	2.2	2.3	0.041	0.066	1.606
thunderstorm (3)		0.018	0.46	2.2	2.2	2.7	0.181	0.216	0.445
All events	StDev	0.18	0.27	2.4	2.6	2.7	0.286	0.289	0.738
rain or rain/snow		0.28	0.29	3.6	3.9	4.2	0.405	0.404	0.419
rain on snow									
snowmelt		0.053	0.086	0.73	0.77	0.86	0.017	0.025	1.10
thunderstorm		0.008	0.304	0.60	0.61	0.89	0.12	0.13	0.21
All events	CV%	218%	119%	219%	93%	91%	139%	121%	89%
rain or rain/snow		203%	135%	101%	105%	105%	116%	104%	57%
rain on snow									
snowmelt		69%	98%	34%	34%	37%	42%	38%	69%
thunderstorm		46%	67%	27%	27%	33%	67%	61%	47%

Table 4. TSS concentration and particle size distribution for post-CIP event types at Catchment A.

Event type		TSS (mg/l)	Avg Particle Size (µm)	Particle Size Exceedance Percentage (µm >) 10%	25%	50%	75%	90%
All events (12)	Average	233	69	178	97	39	14	5.1
rain or rain/snow (5)		182	63	154	88	39	15	6.0
rain on snow (1)		16	78	190	108	43	16	5.1
snowmelt (3)		542	41	100	58	22	9	3.8
thunderstorm (3)		82	104	293	146	53	17	5.1
All events	StDev	272	48	137	68	27	11	4.6
rain or rain/snow		126	35	64	53	30	15	6.3
rain on snow								
snowmelt		406	49	114	74	30	12	5.5
thunderstorm		33	70	229	91	25	5.8	1.9
All events	CV%	117%	70%	77%	71%	70%	80%	90%
rain or rain/snow		69%	55%	41%	61%	78%	98%	104%
rain on snow								
snowmelt		75%	118%	114%	128%	132%	141%	146%
thunderstorm		41%	68%	78%	62%	46%	35%	37%

Table 5. Constituent loads for pre-CIP runoff event types for Catchment A. All values are in (g).

Event Type		NH_3-N	$NO_{2/3}$-N	Org N	TKN	TN	SRP	DP	TP	TSS
All events (10)	Average	0.53	4.0	60	61	65	2.5	3.3	23	6495
rain or rain/snow (7)		0.493	5.4	39	40	45	2.6	3.4	12	1996
rain on snow (2)		0.448	0.3	134	134	135	3.2	4.0	65	19460
thunderstorm (1)		0.924	2.0	61	62	64	0.3	1.6	20	12056
All events	StDev	0.484	5.8	65	65	67	2.6	3.2	32	9215
rain or rain/snow		0.551	6.6	38	39	44	2.6	3.4	12	2404
rain on snow		0.325	0.21	125	125	125	3.6	4.3	65	14862
thunderstorm										
All events	CV%	92%	143%	108%	108%	103%	103%	97%	139%	142%
rain or rain/snow		112%	121%	97%	97%	99%	101%	102%	100%	120%
rain on snow		72%	73%	93%	93%	93%	112%	107%	100%	76%
thunderstorm										

Table 6. Weighted particle size values and exceedance mass for pre-CIP runoff events at Catchment A.

Event Type		Weighted Avg PS (µm)	Weighted Particle Size Exceedance (µm)					Mass of Sediment for the Weighted Particle Size Exceedance (g)				
			10%	25%	50%	75%	90%	10%	25%	50%	75%	90%
All events (10)	Average	67	271	74	22	8.0	2.6	5845	4871	3247	1624	649
rain or rain/snow (7)	Average	68	272	79	25	8.9	2.9	1797	1497	998	499	200
rain on snow (2)	Average	65	273	61	16	5.7	2.0	17514	14595	9730	4865	1946
thunderstorm (1)	Average	29	71	43	20	6.5	2.4	10850	9042	6028	3014	1206
All events	StDev							8294	6912	4608	2304	922
rain or rain/snow	StDev							2164	1803	1202	601	240
rain on snow	StDev							13376	11147	7431	3716	1486
thunderstorm	StDev											
All events	CV%							142%	142%	142%	142%	142%
rain or rain/snow	CV%							120%	120%	120%	120%	120%
rain on snow	CV%							76%	76%	76%	76%	76%
thunderstorm	CV%											

For thunderstorm events, only 10% of the mass exceeded this size.

90% of the TSS mass in grams (1085 g, in this case) was less than 71 µm.

Table 7. Constituent load by event type for post-CIP runoff events at Catchment A. All values are in (g).

Event Type		NH_3-N	$NO_{2/3}$-N	Org N	TKN	TN	SRP	DP	TP	TSS
All events (12)	Average	0.09	0.44	7.3	7.3	7.8	0.55	0.70	1.8	381
rain or rain/snow (5)	Average	0.12	0.16	9.5	9.7	9.8	0.68	0.87	2.4	554
rain on snow (1)	Average	0.13	0.16	11.5	11.6	11.7	0.50	0.74	1.5	163
snowmelt (3)	Average	0.03	0.03	1.2	1.2	1.2	0.03	0.05	0.63	202
thunderstorm (3)	Average	0.08	1.42	8.1	8.2	9.6	0.88	1.03	2.0	342
All events	StDev	0.09	0.67	8.78	8.8	9.0	0.90	1.06	2.3	485
rain or rain/snow	StDev	0.13	0.15	12.7	12.8	12.9	1.17	1.39	3.3	719
rain on snow	StDev									
snowmelt	StDev	0.01	0.01	0.70	0.7	0.7	0.03	0.06	0.23	109
thunderstorm	StDev	0.08	0.67	4.54	4.6	4.9	1.06	1.21	2.2	318
All events	CV%	105%	150%	121%	120%	116%	164%	152%	129%	127%
rain or rain/snow	CV%	107%	93%	133%	133%	132%	172%	160%	136%	130%
rain on snow	CV%									
snowmelt	CV%	38%	50%	59%	57%	55%	96%	118%	37%	54%
thunderstorm	CV%	98%	47%	56%	56%	51%	121%	117%	107%	93%

Table 8. Weighted particle size values and exceedance mass for post-CIP runoff events at Catchment A.

Event Type		Weighted Avg PS (µm)	Weighted Particle Size Exceedance (µm)					Mass of Sediment for the Weighted Particle Size Exceedance (g)				
			10%	25%	50%	75%	90%	10%	25%	50%	75%	90%
All events (12)	Average	101	253	142	56	20	7.2	343	285	190	95	38
rain or rain/snow (5)	Average	97	219	139	60	23	8.8	499	416	277	139	55
rain on snow (1)	Average	78	190	108	43	16	5.1	147	122	81	41	16
snowmelt (3)	Average	70	168	102	40	16	7.1	182	151	101	50	20
thunderstorm (3)	Average	134	390	184	63	19	5.9	308	257	171	86	34
All events	StDev							437	364	243	121	49
rain or rain/snow	StDev							647	539	359	180	72
rain on snow	StDev											
snowmelt	StDev							98	81	54	27	11
thunderstorm	StDev							286	238	159	79	32
All events	CV%							127%	127%	127%	127%	127%
rain or rain/snow	CV%							130%	130%	130%	130%	130%
rain on snow	CV%											
snowmelt	CV%							54%	54%	54%	54%	54%
thunderstorm	CV%							93%	93%	93%	93%	93%

For thunderstorm events, only 10% of the mass exceeded this size.

90% of the TSS mass in grams (308 g, in this case) was less than 390 µm

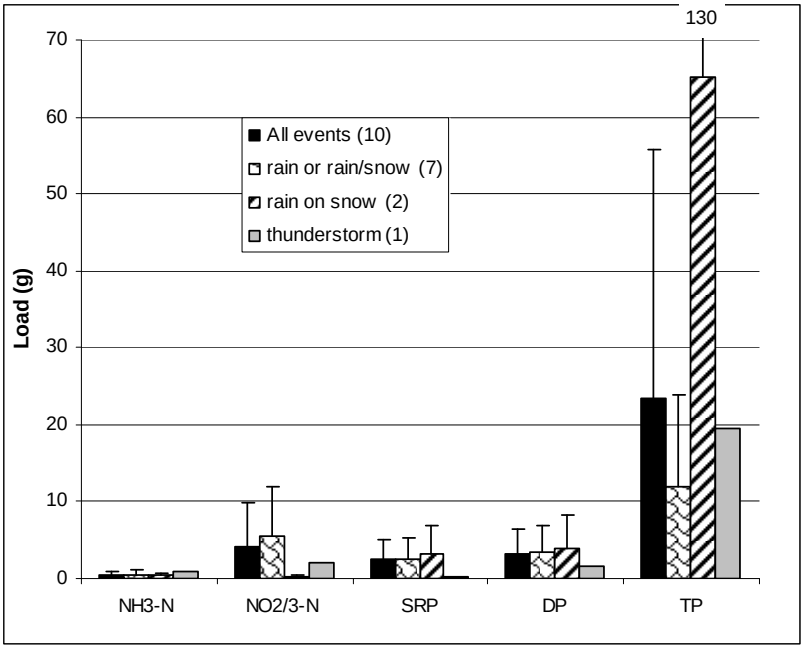


Figure 1. Average load of water quality constituents for pre-CIP events at Catchment A.

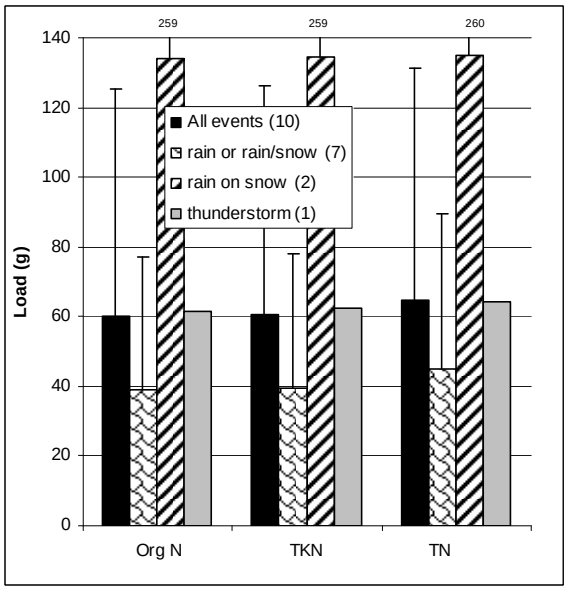


Figure 2. Average load of organic nitrogen -dominated species for pre-CIP events at Catchment A.

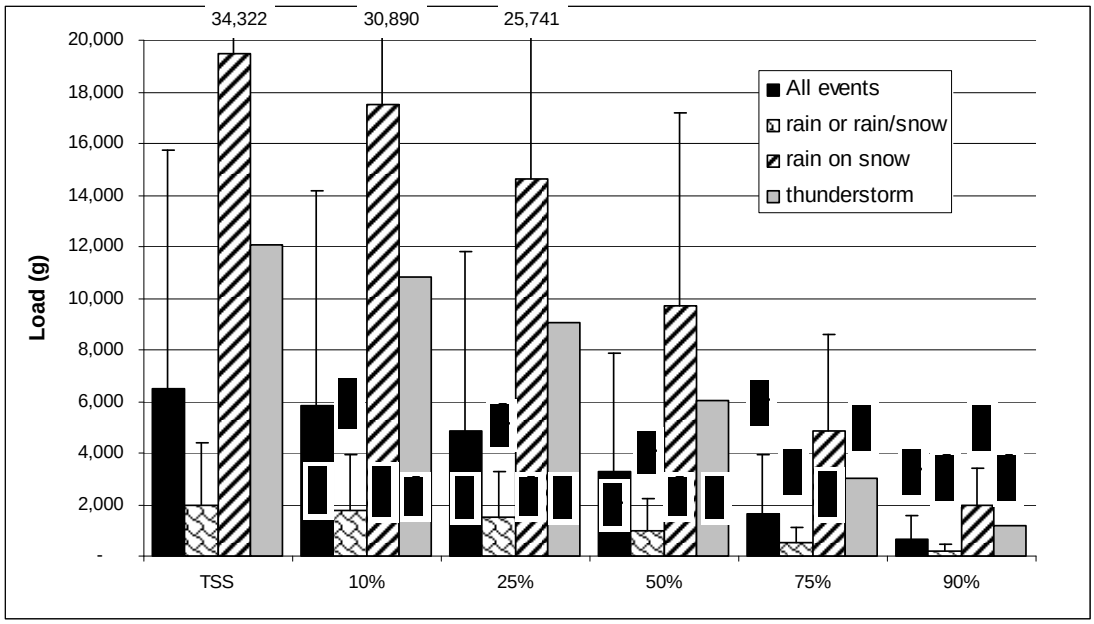


Figure 3. Mass of sediment below the exceedance particle size for pre-CIP events at Catchment A.

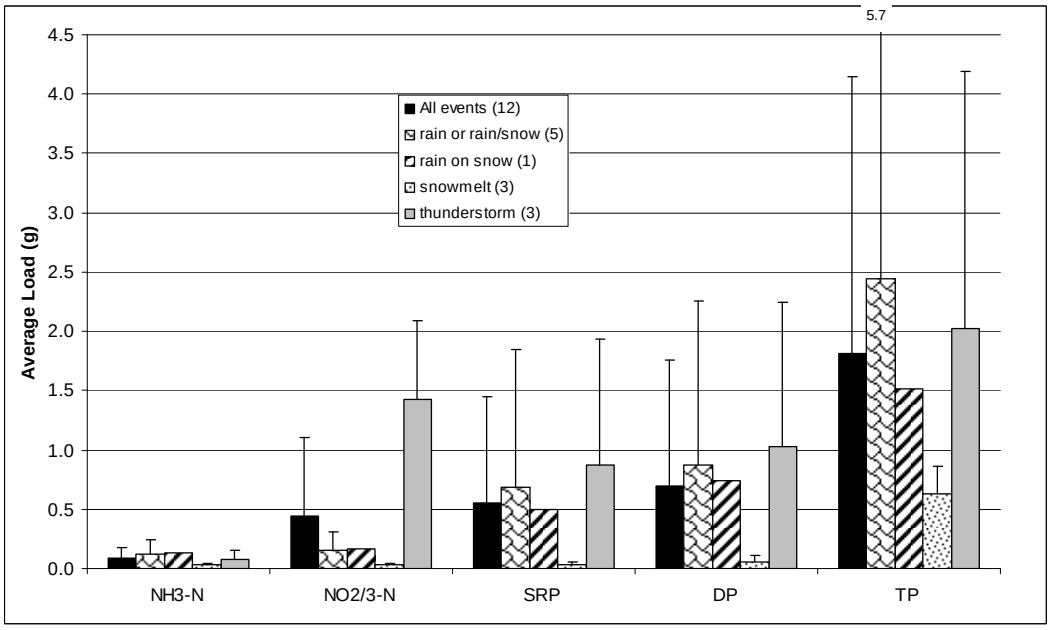


Figure 4. Average load of water quality constituents for post-CIP events at Catchment A**.**

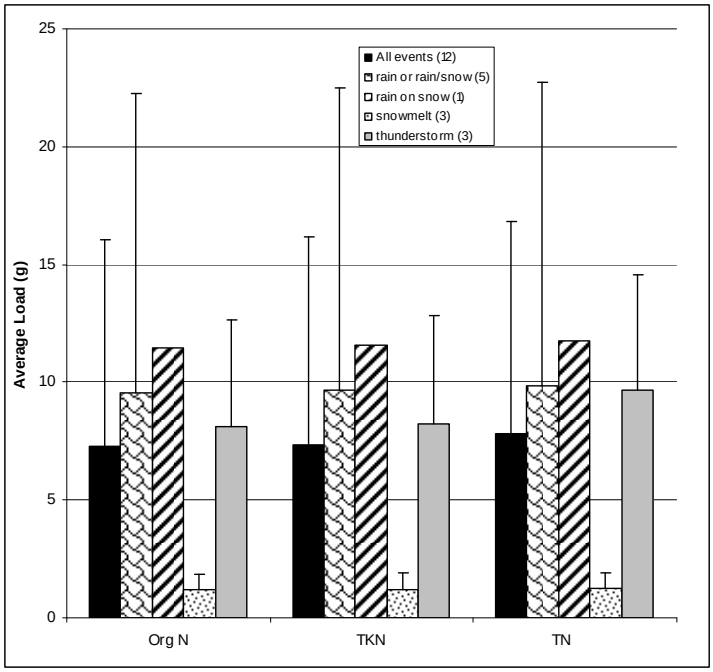


Figure 5. Average mass of organic nitrogen -dominated species for post-CIP events at Catchment A.

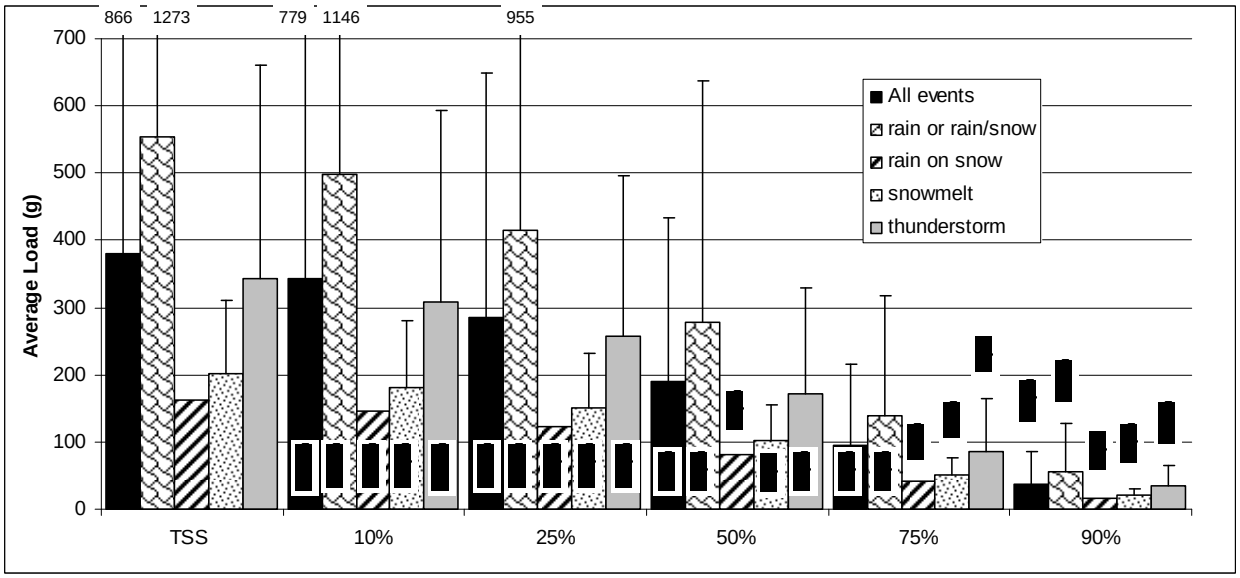


Figure 6. Mass of sediment below the exceedance particle size.

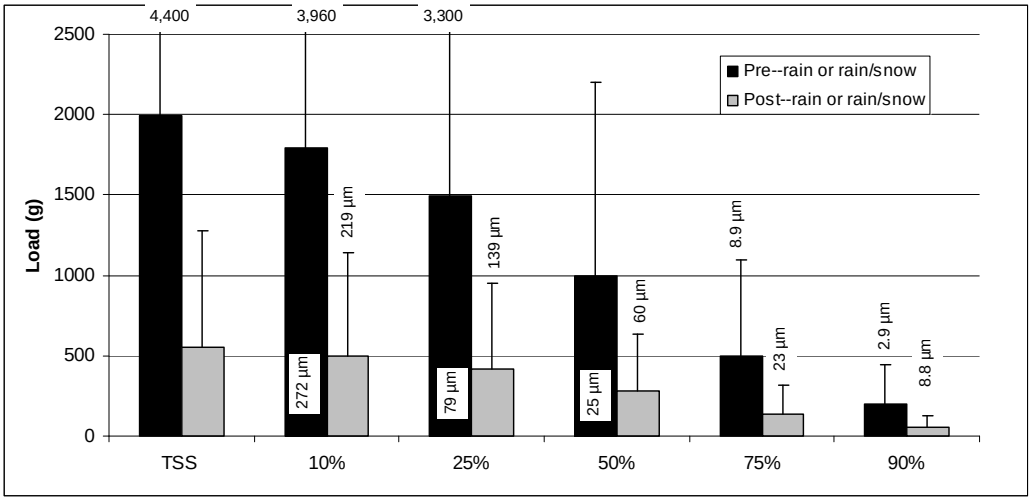


Figure 7. TSS and average weighted particle size distribution for rain events at Catchment A. The percentages indicate the volume of sediment load that exceeds the particle size (inset values).

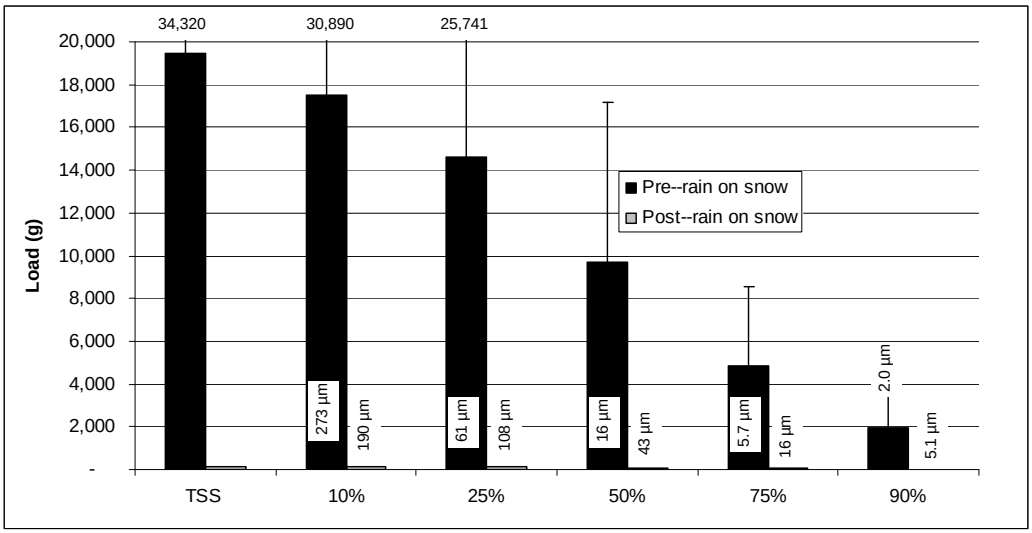


Figure 8. TSS and average weighted particle size distribution for rain on snow events at Catchment A. The percentages indicate the volume of sediment load that exceeds the particle size (inset values).

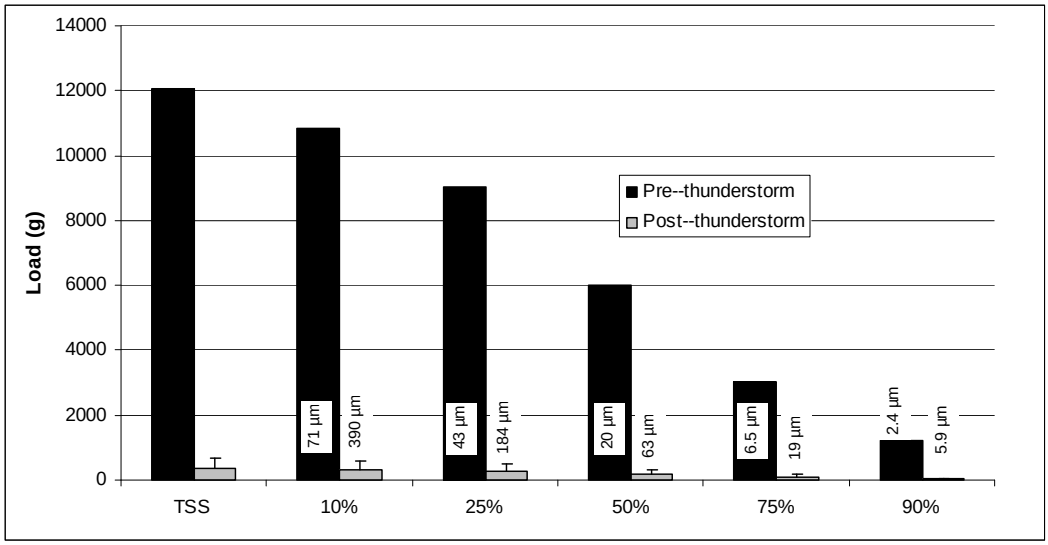


Figure 9. TSS and average weighted particle size distribution for thunderstorm events at Catchment A. The percentages indicate the volume of sediment load that exceeds the particle size (inset values).

Table 9. Constituent concentrations for samples at Site B1. The values in parentheses are number of event types sampled.

		NH_3-N	$NO_{2/3}$-N	Org N	TKN	TN	SRP	DP	TP	TSS	Avg PS (µm)	Particle Size Exceedance Percentage (µm >)				
												10%	25%	50%	75%	90%
All events (6)	Average	1.13	0.18	1.80	2.93	3.11	0.28	0.32	687	77	114	300	171	62	26	10
rain or rain/snow (2)		1.79	0.38	1.12	2.91	3.29	0.14	0.16	268	23	174	482	283	85	35	14
snowmelt (4)		0.80	0.09	2.14	2.94	3.02	0.35	0.40	897	104	84	209	115	51	22	9
All events	StDev	1.30	0.19	1.93	2.73	2.70	0.35	0.40	983	110	53	157	93	23	11	5
rain or rain/snow		1.71	0.25	1.03	0.69	0.44	0.10	0.08	0.0	27	7	46	13	3	3	2
snowmelt		1.18	0.07	2.32	3.50	3.47	0.43	0.49	1198	131	32	86	44	20	11	5
All events	CV%	115%	106%	107%	93%	87%	127%	126%	143%	143%	46%	52%	55%	37%	42%	45%
rain or rain/snow		96%	66%	92%	24%	13%	70%	53%	0%	114%	4%	10%	5%	4%	7%	16%
snowmelt		149%	79%	108%	119%	115%	123%	123%	134%	126%	38%	41%	38%	38%	50%	55%
All events	Min	0.11	0.02	0.39	1.04	1.11	0.07	0.10	197	5	50	121	74	33	12	5
rain or rain/snow		0.58	0.20	0.39	2.43	2.98	0.07	0.10	268	5	169	449	274	83	33	12
snowmelt		0.11	0.02	0.93	1.04	1.11	0.08	0.10	197	20	50	121	74	33	12	5
All events	Max	3.01	0.55	5.62	8.18	8.22	0.99	1.12	2685	296	179	514	292	87	37	15
rain or rain/snow		3.01	0.55	1.85	3.40	3.60	0.21	0.22	268	42	179	514	292	87	37	15
snowmelt		2.57	0.16	5.62	8.18	8.22	0.99	1.12	2685	296	118	305	154	77	36	15
All events	Median	0.47	0.15	1.01	1.93	2.29	0.17	0.18	268	31	111	280	152	66	29	12
rain or rain/snow		1.79	0.38	1.12	2.91	3.29	0.14	0.16	268	23	174	482	283	85	35	14
snowmelt		0.26	0.08	1.01	1.26	1.38	0.17	0.18	352	51	84	205	116	47	20	8

Table 10. Average concentrations for water quality constituents and particle size distribution for Site B2, prior to the installation of residential BMPs. The number of events sampled is included in the parentheses next to the event type.

		NH_3-N	$NO_{2/3}$-N	Org N	TKN	TN	SRP	DP	TP	TSS	Avg PS (µm)	Particle Size Exceedance Percentage (µm >)				
												10%	25%	50%	75%	90%
All events (12)	Average	0.12	0.41	3.50	3.61	4.03	0.28	0.33	1.45	565	82	215	115	55	23	8.2
rain or rain/snow (5)		0.04	0.40	3.26	3.30	3.70	0.31	0.37	1.17	246	106	260	143	67	27	9.5
rain on snow (3)		0.18	0.55	3.19	3.36	3.91	0.23	0.27	1.54	622	55	164	91	42	17	6.2
snowmelt (3)		0.21	0.39	3.41	3.63	4.01	0.33	0.40	1.20	274	66	206	97	46	21	7.6
thunderstorm (1)		0.03	0.16	5.87	5.90	6.06	0.12	0.13	3.36	2861	92	170	105	61	28	9.3
All events	StDev	0.15	0.32	2.03	2.03	2.11	0.24	0.25	1.10	814	57	136	73	31	12	4.3
rain or rain/snow		0.02	0.28	1.77	1.79	2.01	0.36	0.37	0.96	227	64	164	89	35	13	5.0
rain on snow		0.27	0.49	1.99	1.74	1.27	0.11	0.11	1.21	692	55	102	60	27	10	3.4
snowmelt		0.13	0.34	3.07	3.20	3.52	0.13	0.19	1.09	214	59	168	79	36	15	5.4
thunderstorm																
All events	CV%	132%	79%	58%	56%	52%	86%	76%	75%	144%	69%	63%	63%	56%	52%	52%
rain or rain/snow		50%	71%	54%	54%	54%	117%	100%	82%	92%	61%	63%	62%	53%	48%	53%
rain on snow		153%	90%	62%	52%	33%	48%	40%	79%	111%	100%	62%	66%	64%	57%	55%
snowmelt		61%	88%	90%	88%	88%	40%	47%	91%	78%	91%	81%	82%	79%	75%	70%
thunderstorm																
All events	Min	0.02	0.01	0.77	0.86	0.88	0.11	0.13	0.23	49	8.7	35.7	16.0	7.0	3.1	1.4
rain or rain/snow		0.02	0.09	1.47	1.50	1.76	0.11	0.13	0.23	49	8.7	35.7	18.7	10.0	4.3	1.4
rain on snow		0.02	0.01	1.05	1.53	2.52	0.11	0.15	0.30	98	18.4	96.6	48.6	20.9	8.3	2.8
snowmelt		0.09	0.02	0.77	0.86	0.88	0.19	0.20	0.29	82	17.1	47.1	16.0	7.0	3.1	1.4
thunderstorm																
All events	Max	0.49	0.98	6.78	7.13	7.82	0.95	1.01	3.36	2861	169	438	266	104	36	14
rain or rain/snow		0.07	0.70	5.33	5.40	6.09	0.95	1.01	2.57	508	169	438	266	104	36	14
rain on snow		0.49	0.98	4.97	4.99	5.01	0.32	0.35	2.73	1407	118	281	160	73	28	10
snowmelt		0.35	0.69	6.78	7.13	7.82	0.45	0.57	2.41	505	132	381	175	79	32	11
thunderstorm																
All events	Median	0.04	0.37	3.44	3.46	3.82	0.22	0.26	1.37	300	88	187	112	60	28	9.5
rain or rain/snow		0.04	0.29	3.33	3.35	3.44	0.12	0.19	1.22	127	113	243	152	79	30	11.5
rain on snow		0.02	0.65	3.54	3.56	4.21	0.26	0.32	1.59	363	28	113	65	33	15	6.1
snowmelt		0.20	0.45	2.70	2.90	3.35	0.37	0.41	0.90	236	48	191	99	53	26	10.5
thunderstorm																

Table 11. Average concentrations for water quality constituents and particle size distribution for Site B2, after the installation of residential BMPs. Only two rain on snow events were sampled.

		NH_3-N	$NO_{2/3}$-N	Org N	TKN	TN	SRP	DP	TP	TSS	Avg PS (µm)	Particle Size Exceedance Percentage (µm >)				
												10%	25%	50%	75%	90%
rain on snow (2)	Avg	0.32	0.50	2.47	2.79	3.29	0.53	0.57	0.90	68	139	464	165	56	15	4.8
rain on snow	StDev	0.01	0.02	2.52	2.53	2.55	0.19	0.24	0.38	46	103	412	89	29	5.8	2.2
rain on snow	CV%	4%	4%	102%	91%	77%	35%	43%	43%	68%	74%	89%	54%	53%	38%	46%
rain on snow	Min	0.31	0.49	0.69	1.00	1.49	0.40	0.40	0.63	35	67	173	102	35	11	3.2
rain on snow	Max	0.33	0.51	4.25	4.58	5.10	0.66	0.74	1.17	100	212	755	228	76	19	6.3
rain on snow	Median	0.32	0.50	2.47	2.79	3.29	0.53	0.57	0.90	68	139	464	165	56	15	4.8

Table 12. Average concentrations for water quality constituents and particle size distribution for Site B3 prior to the installation of residential BMPs. The number of events sampled is included in the parentheses next to the event type.

		NH_3-N	$NO_{2/3}$-N	Org N	TKN	TN	SRP	DP	TP	TSS	Avg PS (µm)	Particle Size Exceedance Percentage (µm >)				
												10%	25%	50%	75%	90%
All events (34)	Average	0.11	0.25	5.78	5.89	6.13	0.28	0.41	1.51	579	56	179	85	38	15	5
rain or rain/snow (11)		0.03	0.23	3.83	3.86	4.09	0.29	0.48	1.01	207	87	286	133	61	24	8.6
rain on snow (8)		0.04	0.03	1.87	1.91	1.94	0.11	0.13	0.60	184	45	155	64	28	11	3.9
snowmelt (11)		0.15	0.13	2.93	3.08	3.21	0.28	0.31	0.72	207	33	107	56	25	10	3.8
thunderstorm (4)		0.33	1.04	26.8	27.2	28.2	0.60	1.02	6.87	3415	55	129	73	29	11	4.0
All events	StDev	0.22	0.44	11.0	11.1	11.5	0.39	0.55	2.67	1401	48	138	60	29	11	3.9
rain or rain/snow		0.01	0.33	2.22	2.23	2.32	0.20	0.44	0.62	134	66	159	74	39	14	5.0
rain on snow		0.03	0.02	1.19	1.17	1.15	0.12	0.12	0.47	190	40	151	52	23	8.5	3.0
snowmelt		0.30	0.24	4.16	4.45	4.58	0.51	0.52	0.71	254	16	35	21	10	4.4	1.6
thunderstorm		0.34	0.76	23.9	24.0	24.7	0.65	1.01	5.56	3013	17	49	14	3.77	2.65	1.06
All events	CV%	208%	180%	190%	188%	187%	140%	136%	177%	242%	85%	77%	71%	77%	73%	72%
rain or rain/snow		40%	145%	58%	58%	57%	69%	92%	62%	65%	75%	55%	56%	63%	57%	58%
rain on snow		86%	83%	63%	61%	60%	110%	93%	78%	103%	89%	97%	82%	81%	77%	76%
snowmelt		207%	181%	142%	145%	143%	185%	167%	100%	122%	47%	33%	38%	41%	43%	41%
thunderstorm		102%	73%	89%	88%	88%	110%	99%	81%	88%	32%	38%	20%	13%	25%	26%
All events	min	0.01	0.01	0.42	0.50	0.54	0.02	0.04	0.15	21	12	27	19	8	3	0
rain or rain/snow		0.02	0.01	1.18	1.20	1.27	0.05	0.06	0.30	38	26	102	48	10	4	2
rain on snow		0.01	0.01	0.42	0.50	0.54	0.02	0.04	0.15	28	12	27	19	8	3	0
snowmelt		0.02	0.01	0.75	0.81	0.83	0.04	0.05	0.17	21	17	52	25	8	3	2
thunderstorm		0.03	0.25	3.22	3.25	3.50	0.08	0.10	0.83	362	45	97	66	24	7	3
All events	max	1.04	2.08	58.5	59.0	61.1	1.81	2.08	12.97	6466	228	609	289	142	54	19
rain or rain/snow		0.06	0.97	7.74	7.80	8.58	0.59	1.68	2.54	450	228	609	289	142	54	19
rain on snow		0.09	0.06	3.53	3.55	3.56	0.39	0.43	1.51	546	131	424	146	70	26	9
snowmelt		1.04	0.69	15.2	16.2	16.7	1.81	1.85	2.67	810	64	163	86	44	21	8
thunderstorm		0.68	2.08	58.5	59.0	61.1	1.45	2.08	12.97	6466	81	202	95	33	13	5
All events	median	0.03	0.04	2.61	2.62	2.64	0.12	0.21	0.72	151	44	122	66	28	12	4
rain or rain/snow		0.03	0.08	3.11	3.14	3.65	0.24	0.30	0.98	151	50	263	123	56	23	8
rain on snow		0.02	0.02	1.62	1.64	1.66	0.07	0.10	0.51	87	27	85	41	17	8	3
snowmelt		0.04	0.02	1.30	1.34	1.40	0.11	0.14	0.45	151	24	101	52	22	9	4
thunderstorm		0.30	0.91	22.8	23.2	24.1	0.43	0.95	6.85	3417	47	108	66	29	11	4

Table 13. Average concentrations for water quality constituents and particle size distribution for Site B3 following the installation of residential BMPs. The number of events sampled is included in the parentheses next to the event type.

		NH_3-N	$NO_{2/3}$-N	Org N	TKN	TN	SRP	DP	TP	TSS	Avg PS (µm)	Particle Size Exceedance Percentage (µm >)				
												10%	25%	50%	75%	90%
All events (4)	Avg	0.09	0.05	3.08	3.17	3.22	0.41	0.42	1.57	309	56	147	67	26	9.1	2.78
rain on snow (2)		0.16	0.06	2.74	2.90	2.96	0.17	0.16	2.02	496	34	100	41	12	4.3	1.42
thunderstorm (2)		0.03	0.04	3.42	3.45	3.48	0.65	0.69	1.12	121	78	194	93	41	14.0	4.14
All events	StDev	0.14	0.04	1.48	1.55	1.58	0.34	0.36	1.26	386	41	101	45	21	6.8	1.98
rain on snow		0.19	0.07	1.76	1.96	2.02	0.13	0.18	1.96	551	31	99	42	11	3.9	1.08
thunderstorm		0.02	0.02	1.72	1.75	1.77	0.30	0.27	0.32	51	47	111	41	17	5.1	1.80
All events	CV%	149%	86%	48%	49%	49%	82%	85%	80%	125%	73%	69%	67%	78%	74%	71%
rain on snow		123%	105%	64%	68%	68%	78%	115%	97%	111%	91%	99%	101%	91%	91%	76%
thunderstorm		97%	51%	50%	51%	51%	45%	39%	29%	42%	60%	57%	44%	42%	36%	43%
All events	min	0.01	0.02	1.49	1.51	1.53	0.08	0.03	0.63	85	12	30	12	4.1	1.5	0.66
rain on snow		0.02	0.02	1.49	1.51	1.53	0.08	0.03	0.63	107	12	30	12	4.1	1.5	0.66
thunderstorm		0.01	0.02	2.20	2.21	2.23	0.44	0.50	0.89	85	45	116	64	29	10	2.87
All events	max	0.30	0.11	4.64	4.68	4.73	0.86	0.88	3.41	886	111	272	123	53	18	5.41
rain on snow		0.30	0.11	3.99	4.28	4.39	0.26	0.29	3.41	886	57	170	71	19	6.99	2.18
thunderstorm		0.04	0.05	4.64	4.68	4.73	0.86	0.88	1.35	157	111	272	123	53	17.7	5.41
All events	median	0.03	0.04	3.09	3.25	3.31	0.35	0.39	1.12	132	51	143	68	24	8.71	2.53
rain on snow		0.16	0.06	2.74	2.90	2.96	0.17	0.16	2.02	496	34	100	41	12	4.25	1.42
thunderstorm		0.04	0.05	3.09	3.25	3.31	0.35	0.39	1.35	157	51	143	68	24	8.71	2.53

Table 14. Average water quality concentrations (in mg/l) and particle size distribution for samples at Catchment C.

		NH_3-N	$NO_{3/2}$-N	Org N	TKN	TN	SRP	DP	TP	TSS	Avg PS (µm)	Particle Size Exceedance Percentage (µm >)				
												10%	25%	50%	75%	90%
All events (59)	Average	0.44	0.24	5.0	5.4	5.6	0.14	0.20	1.62	838	82	241	112	51	21	7.8
rain or rain/snow (25)		0.43	0.23	4.5	4.9	5.2	0.11	0.16	1.40	863	104	293	136	64	27	10.3
rain on snow (10)		0.02	0.09	4.8	4.8	4.9	0.07	0.09	1.43	629	68	197	88	35	14	5.4
snowmelt (13)		0.11	0.36	2.8	2.9	2.8	0.14	0.18	1.55	510	52	204	94	39	14	5.2
thunderstorm (11)		1.22	0.26	9.7	10.9	11.2	0.28	0.43	2.51	1447	83	197	102	50	20	7.0
All events	StDev	1.85	0.48	5.9	7.4	7.4	0.14	0.20	1.71	1260	54	174	64	31	16	6.4
rain or rain/snow		1.78	0.53	3.3	4.6	5.1	0.07	0.11	1.23	1144	60	176	63	33	19	7.8
rain on snow		0.02	0.09	5.9	5.9	5.9	0.06	0.06	1.16	656	35	99	32	17	9	4.8
snowmelt		0.20	0.65	2.3	2.2	2.2	0.14	0.22	1.55	635	38	211	79	28	10	3.7
thunderstorm		3.29	0.34	10.5	13.7	13.6	0.21	0.25	2.89	2147	51	148	52	25	12	4.3
All events	CV%	417%	200%	117%	135%	133%	98%	99%	106%	150%	66%	72%	57%	60%	77%	82%
rain or rain/snow		414%	229%	74%	93%	97%	64%	70%	88%	133%	58%	60%	46%	52%	71%	76%
rain on snow		76%	101%	125%	124%	121%	82%	70%	81%	104%	52%	50%	37%	48%	67%	89%
snowmelt		187%	183%	81%	76%	78%	103%	122%	100%	124%	73%	103%	85%	72%	73%	71%
thunderstorm		271%	131%	108%	125%	122%	76%	60%	115%	148%	61%	75%	51%	50%	61%	61%
All events	min	0.002	0.003	0.48	0.54	0.00	0.005	0.023	0.138	5.710	7.4	15	10	5.8	2.8	0.8
rain or rain/snow		0.002	0.003	0.61	0.62	0.62	0.020	0.053	0.166	14.440	21.0	90	21	8.5	4.6	2.4
rain on snow		3.66	1.10	5.3	9.0	9.9	0.16	0.28	1.23	1,373	48.8	142	42	27.9	17.8	7.2
snowmelt		0.42	0.63	5.1	5.2	5.2	0.20	0.20	1.49	1,397	71.9	227	85	35.3	15.8	5.9
thunderstorm		0.29	0.11	3.0	3.1	3.2	0.15	0.18	1.50	782	33.1	128	45	21.9	4.3	2.0
All events	max	11.04	2.60	40	51	51	0.73	0.92	10.56	6,982	254.8	837	322	132.7	76.2	32.1
rain or rain/snow		8.93	2.60	14	23	25	0.28	0.54	4.28	4,374	254.8	829	322	132.7	76.2	32.1
rain on snow		8.93	2.60	14	23	25	0.53	0.82	4.28	4,374	163.1	483	170	90.7	52.5	22.2
snowmelt		1.54	2.09	15	15	15	0.73	0.77	4.58	4,109	254.8	829	322	119.9	53.0	18.1
thunderstorm		0.87	0.27	8.4	8.9	8.9	0.45	0.57	5.04	2,352	125.8	429	164	93.6	19.2	8.2
All events	median	0.04	0.05	3.6	3.7	3.6	0.11	0.14	0.96	356	68.5	190	98	46.8	16.7	6.4
rain or rain/snow		0.04	0.03	4.0	4.0	4.0	0.11	0.12	0.81	340	95.6	226	142	55.6	18.8	7.1
rain on snow		0.26	0.16	4.3	4.3	4.5	0.21	0.32	1.80	579	116.6	267	134	64.0	28.2	11.2
snowmelt		0.04	0.05	3.8	3.9	3.3	0.08	0.15	0.77	360	66.1	150	89	48.2	17.4	6.0
thunderstorm		0.04	0.04	2.1	2.1	2.2	0.13	0.18	0.89	220	96.5	213	116	45.4	16.6	6.6

APPENDIX B

Raw data tables for each sample event followed by the hydrographs of each event.

Table 1. Water quality concentration (in mg/l) and particle size distribution for individual pre-CIP events at Catchment A.

Event Type	Event Dates	NH_3-N	$NO_{2/3}$-N	Org N	TKN	TN	SRP	DP	TP	TSS (mg/l)	Avg Particle Size (µm)	Particle Size Exceedance Percentage (µm >)				
												10%	25%	50%	75%	90%
rain or rain/snow	12/6/2003	0.013	0.32	1.66	1.68	2.00	0.088	0.11	0.53	145	48	277	125	60	23.0	6.5
rain on snow	12/24/2003	0.034	0.007	2.29	2.32	2.33	0.034	0.049	0.97	449	16	84	36	17	6.9	2.3
thunderstorm	6/28/2004	0.616	1.36	41	41	43	0.23	1.08	13	8037	29	71	43	20	6.5	2.4
rain or rain/snow	10/19/2004	0.032	0.31	1.87	1.90	2.21	0.11	0.15	0.39	58	11	27	13	6.1	3.0	1.5
rain or rain/snow	5/16/2005	0.021	0.030	1.11	1.14	1.17	0.080	0.099	0.52	157	18	42	21	11	4.0	1.6
rain or rain/snow	10/24/2005	0.039	0.67	4.1	4.1	4.8	0.31	0.41	1.53	40	141	472	198	30	9.5	4.6
rain or rain/snow	10/27/2005	0.036	0.040	1.27	1.31	1.35	0.29	0.32	0.42	30	128	316	173	86	37.3	12.8
rain or rain/snow	11/25/2005	0.018	0.021	3.91	3.93	3.95	0.27	0.32	0.69	82	152	422	208	87	18.1	5.6
rain or rain/snow	12/18/2005	0.009	0.014	0.63	0.64	0.65	0.045	0.057	0.21	69	88	353	72	23	7.4	2.1
rain on snow	2/26/2006	0.004	0.008	4.07	4.08	4.09	0.11	0.13	2.03	549	82	342	71	15	5.2	1.9

Table 2. Water quality concentrations (in mg/l) and particle size distribution for individual post-CIP events at Catchment A.

Event Type	Event Dates	NH_3-N	$NO_{2/3}$-N	Org N	TKN	TN	SRP	DP	TP	TSS (mg/l)	Avg Particle Size (µm)	Particle Size Exceedance Percentage (µm >)				
												10%	25%	50%	75%	90%
rain or rain/snow	11/2/2006	0.019	0.027	2.23	2.25	2.27	0.20	0.24	0.57	62	97	231	140	48	14	4.6
rain or rain/snow	12/12/2006	0.010	0.010	1.50	1.51	1.52	0.01	0.05	0.43	215	105	212	149	87	41	17
snowmelt	3/23/2007	0.016	0.013	1.48	1.50	1.51	0.05	0.09	0.33	77	97	231	144	56	23	10
rain or rain/snow	8/31/2007	0.646	0.653	10.1	10.7	11.4	1.05	1.08	1.43	383	36	94	50	19	6.6	3.1
thunderstorm	9/22/2007	0.025	0.208	1.95	1.98	2.18	0.32	0.37	0.69	107	184	556	246	78	23	7.2
rain or rain/snow	10/5/2007	0.012	0.015	2.33	2.35	2.36	0.33	0.37	0.80	140	47	134	65	26	10	3.6
rain or rain/snow	10/29/2007	0.010	0.362	1.84	1.85	2.21	0.17	0.20	0.42	108	32	101	34	13	4.5	1.7
thunderstorm	10/29/2007	0.009	0.363	1.78	1.79	2.15	0.13	0.15	0.35	95	50	141	66	29	11	3.4
thunderstorm	11/9/2007	0.019	0.794	2.90	2.92	3.71	0.09	0.13	0.30	44	78	181	127	52	16	4.8
rain on snow	11/10/2007	0.013	0.016	1.13	1.14	1.15	0.05	0.07	0.15	16	78	190	108	43	16	5.1
snowmelt	1/2/2008	0.103	0.181	2.94	3.04	3.22	0.02	0.05	2.16	722	8.6	22	10	2.8	0.9	0.4
snowmelt	2/10/2008	0.113	0.068	2.06	2.18	2.24	0.06	0.06	2.32	828	18	48	20	8.0	2.4	0.8

Table 3. Water quality concentrations (in mg/l) and particle size distribution for individual events at Site B1 (there were no "pre-/post-BMP" samples for B1).

Event Type	Event Date	NH_3-N	$NO_{2/3}$-N	Org N	TKN	TN	SRP	DP	TP	TSS	Avg PS (µm)	Particle Size Exceedance Percentage (µm >)				
												10%	25%	50%	75%	90%
snowmelt	10/21/2004	2.57	0.036	5.62	8.18	8.22	0.99	1.12	2.69	296	65	156	81	40	15	4.8
snowmelt	11/6/2004	0.11	0.128	0.94	1.04	1.17	0.08	0.10	0.20	20	50	121	74	33	12	4.7
snowmelt	12/15/2004	0.16	0.021	0.93	1.09	1.11	0.13	0.15	0.24	20	104	305	154	55	25	11
rain or rain/snow	11/29/2005	3.01	0.201	0.39	3.40	3.60	0.07	0.10	0.27	42	179	514	274	83	37	15
rain or rain/snow	12/18/2005	0.58	0.553	1.85	2.43	2.98	0.21	0.22	0.27	4.5	169	449	292	87	33	12
snowmelt	4/12/2006	0.35	0.162	1.08	1.43	1.59	0.20	0.22	0.46	81	118	255	151	77	36	15

Table 4. Water quality concentrations (in mg/l) and particle size distribution for individual pre-CIP events at Site B2.

Event Type	Event Date	NH_3-N	$NO_{2/3}$-N	Org N	TKN	TN	SRP	DP	TP	TSS	Avg PS (µm)	Particle Size Exceedance Percentage (µm >)				
												10%	25%	50%	75%	90%
rain or rain/snow	12/6/2003	0.039	0.69	4.68	4.72	5.42	0.27	0.37	2.57	508	8.7	36	19	10	4.3	1.4
rain on snow	12/24/2003	0.022	0.65	3.54	3.56	4.21	0.26	0.32	1.59	363	18	97	49	21	8.3	2.8
rain on snow	12/29/2003	0.020	0.012	4.97	4.99	5.01	0.32	0.35	2.73	1407	28	113	65	33	15	6.1
snowmelt	5/11/2004	0.200	0.45	2.70	2.90	3.35	0.37	0.41	0.90	236	48	191	99	53	26	11
snowmelt	10/19/2004	0.350	0.69	6.78	7.13	7.82	0.45	0.57	2.41	505	17	47	16	7.0	3.1	1.4
snowmelt	12/13/2004	0.485	0.98	1.05	1.53	2.52	0.11	0.15	0.30	98	118	281	160	73	28	10
snowmelt	3/9/2005	0.043	0.025	1.10	1.15	1.17	0.05	0.07	0.22	29	24	52	33	18	9.0	3.6
rain or rain/snow	4/30/2005	0.021	0.087	3.33	3.35	3.44	0.12	0.19	1.22	478	84	183	119	60	28	12
thunderstorm	10/24/2005	0.069	0.70	5.33	5.40	6.09	0.95	1.01	1.53	127	155	399	161	79	35	14
rain or rain/snow	11/29/2005	0.025	0.29	1.47	1.50	1.79	0.11	0.14	0.32	71	113	243	152	81	36	12
rain or rain/snow	12/18/2005	0.036	0.22	1.50	1.54	1.76	0.11	0.13	0.23	49	169	438	266	104	30	8.1
snowmelt	4/12/2006	0.089	0.020	0.77	0.86	0.88	0.19	0.20	0.29	82	132	381	175	79	32	11
thunderstorm	4/25/2006	0.031	0.16	5.87	5.90	6.06	0.12	0.13	3.36	2861	92	170	105	61	28	9.3

Table 5. Water quality concentration (in mg/l) and particle size distribution for individual post-CIP events at Site B2.

Event Type	Event Date	NH_3-N	$NO_{2/3}$-N	Org N	TKN	TN	SRP	DP	TP	TSS	Avg PS (µm)	Particle Size Exceedance Percentage (µm >)				
												10%	25%	50%	75%	90%
rain or rain/snow	11/11/2007	0.33	0.51	4.25	4.58	5.10	0.66	0.74	1.17	100	67	173	102	35	11	3.2
rain on snow	1/4/2008	0.31	0.49	0.69	1.00	1.49	0.40	0.40	0.63	35	212	755	228	76	19	6.3

Table 6. Water quality concentration (in mg/l) and particle size distribution for individual pre-CIP events at Site B3.

Event Type	Event Date	NH_3-N	$NO_{2/3}$-N	Org N	TKN	TN	SRP	DP	TP	TSS	Avg PS (µm)	Particle Size Exceedance Percentage (µm >) 10%	25%	50%	75%	90%
snowmelt	11/9/2003	0.054	0.020	5.92	5.97	5.99	0.43	0.45	1.28	283	26	159	70	28	11	4.1
rain or rain/snow	12/5/2003	0.024	0.070	1.18	1.20	1.27	0.18	0.22	0.30	38	49	263	133	56	23	7.7
rain or rain/snow	12/6/2003	0.028	0.116	1.64	1.67	1.79	0.27	0.30	0.72	125	50	375	123	52	23	7.8
rain on snow	12/24/2003	0.013	0.010	1.31	1.32	1.33	0.08	0.10	0.72	150	58	356	146	70	26	8.8
rain on snow	12/29/2003	0.022	0.007	1.93	1.95	1.96	0.10	0.10	0.91	546	18	78	35	20	10	4.0
snowmelt	3/5/2004	0.259	0.042	0.75	1.00	1.05	0.10	0.10	0.17	33	22	95	55	26	12	4.4
snowmelt	3/11/2004	0.024	0.019	0.79	0.81	0.83	0.04	0.05	0.45	157	19	87	46	22	10	3.5
snowmelt	3/16/2004	0.028	0.020	1.03	1.06	1.08	0.04	0.05	0.40	170	17	101	42	18	8.0	2.8
snowmelt	3/25/2004	0.027	0.019	3.86	3.89	3.91	0.05	0.05	0.68	204	31	195	74	30	14	5.3
snowmelt	3/26/2004	0.026	0.012	1.76	1.79	1.80	0.09	0.11	0.46	204	12	64	30	14	5.5	1.9
snowmelt	5/11/2004	0.018	0.694	1.63	1.65	2.34	0.14	0.20	0.36	21	38	163	86	44	21	7.6
rain or rain/snow	5/28/2004	0.024	0.347	2.03	2.05	2.40	0.13	0.24	0.58	203	45	413	128	49	17	5.3
thunderstorm	6/28/2004	0.551	2.076	58.5	59.0	61.1	0.77	2.08	13.0	5492	47	97	66	24	7.4	2.7
snowmelt	9/20/2004	1.041	0.515	15.2	16.2	16.7	1.81	1.85	2.67	574	56	141	85	35	9.0	3.2
thunderstorm	10/9/2004	0.683	0.871	15.1	15.8	16.7	1.45	1.69	3.77	1341	46	111	67	28	9.5	3.6
rain or rain/snow	10/17/2004	0.032	0.081	4.94	4.97	5.05	0.54	0.60	1.08	100	40	114	49	10	4.4	2.3
snowmelt	10/19/2004	0.026	0.019	3.49	3.52	3.54	0.45	0.57	0.89	116	33	94	42	12	4.9	2.4
snowmelt	10/20/2004	0.029	0.014	2.20	2.23	2.24	0.23	0.27	0.67	79	12	23	8.8	4.3	2.0	1.0
snowmelt	10/22/2004	0.038	0.070	1.29	1.33	1.40	0.24	0.29	0.38	32	44	108	63	25	7.9	3.2
snowmelt	11/6/2004	0.000	0.000	0.00	0.00	0.00	0.00	0.00	0.00	61	30	103	38	7.1	2.5	1.1
rain on snow	11/10/2004	0.005	0.016	2.40	2.41	2.42	0.02	0.09	0.21	76	32	92	47	13	5.0	2.3
snowmelt	12/13/2004	0.019	0.019	3.47	3.49	3.51	0.06	0.11	1.51	419	21	59	21	7.9	2.8	1.3
snowmelt	3/9/2005	0.038	0.015	1.30	1.34	1.36	0.11	0.17	0.61	151	39	99	46	21	8.7	2.9
rain on snow	3/19/2005	0.083	0.035	0.42	0.50	0.54	0.06	0.07	0.15	28	12	27	19	11	3.5	0.3
rain on snow	3/22/2005	0.048	0.062	0.69	0.73	0.80	0.04	0.04	0.23	80	19	47	27	14	5.9	2.2
rain or rain/snow	4/27/2005	0.014	0.398	4.89	4.90	5.30	0.11	0.13	1.40	694	43	98	56	31	16	6.3
rain or rain/snow	5/16/2005	0.023	0.038	2.08	2.10	2.14	0.05	0.06	0.98	450	40	102	48	26	13	5.0
rain or rain/snow	6/17/2005	0.036	0.970	3.01	3.05	4.02	0.11	0.21	0.59	141	73	151	101	61	34	16
thunderstorm	8/15/2005	0.052	0.948	30.5	30.6	31.5	0.08	0.22	9.93	6466	45	105	66	30	13	5.1
rain or rain/snow	9/21/2005	0.031	0.089	6.83	6.86	6.95	0.59	0.61	1.42	328	175	347	233	142	54	19
thunderstorm	9/26/2005	0.031	0.018	3.11	3.14	3.16	0.58	0.66	1.15	151	138	409	169	71	21	7.2
thunderstorm	10/24/2005	0.058	0.780	7.74	7.80	8.58	0.12	1.68	2.54	378	228	609	289	117	36	11
rain or rain/snow	11/25/2005	0.019	0.010	3.53	3.55	3.56	0.39	0.43	0.77	90	131	424	141	53	20	7.0
rain or rain/snow	11/29/2005	0.016	0.011	3.62	3.64	3.65	0.24	0.27	0.46	75	93	205	118	62	27	10
rain on snow	2/26/2006	0.086	0.063	1.21	1.30	1.36	0.12	0.12	0.30	84	71	158	77	36	15	5.4
snowmelt	4/12/2006	0.072	0.013	3.52	3.59	3.61	0.13	0.14	1.27	810	64	147	83	38	15	5.7
thunderstorm	4/25/2006	0.031	0.251	3.22	3.25	3.50	0.09	0.10	0.83	362	81	202	95	33	13	4.7
thunderstorm	7/21/2006	1.153	0.027	31.6	32.8	32.8	0.41	1.83	13.6	4254	52	125	63	26	10	4.0

Table 7. Water quality concentration (in mg/l) and particle size distribution for individual post-CIP events at Site B3.

Event Type	Event Date	NH_3-N	$NO_{2/3}$-N	Org N	TKN	TN	SRP	DP	TP	TSS	Avg PS (µm)	Particle Size Exceedance Percentage (µm >) 10%	25%	50%	75%	90%
thunderstorm	9/22/2007	0.043	0.049	4.64	4.68	4.73	0.86	0.88	1.35	157	111	272	123	53	18	5.4
thunderstorm	10/29/2007	0.008	0.023	2.20	2.21	2.23	0.44	0.50	0.89	85	45	116	64	29	10	2.9
rain or rain/snow	11/11/2007	0.021	0.016	1.49	1.51	1.53	0.26	0.29	0.63	107	57	170	71	19	7.0	2.2
rain on snow	1/4/2008	0.296	0.109	3.99	4.28	4.39	0.08	0.03	3.41	886	12	30	12	4.1	1.5	0.7

Table 8. Water quality concentration (in mg/l) and particle size distribution for individual events at Catchment C (2003 – 2005).

Event Type	Event Date	NH_3-N	$NO_{3/2}$-N	Org N	TKN	TN	SRP	DP	TP	TSS	Average PS (µm)	Particle Size Exceedance Percentage (>µm)				
												10%	25%	50%	75%	90%
rain or rain/snow	11/9/2003	0.041	0.317	1.511	1.552	1.869	0.045	0.053	0.414	107	48	468	147	49	16	7
rain or rain/snow	12/5/2003	0.042	0.003	8.145	8.187	8.190	0.041	0.081	3.123	1339	21	163	66	21	8	3
rain or rain/snow	12/6/2003	0.037	0.705	7.501	7.538	8.243	0.078	0.104	2.852	1623	69	340	159	78	34	13
rain on snow	12/24/2003	0.023	0.027	0.894	0.917	0.944	0.034	0.045	0.350	126	24	113	58	28	12	4
rain on snow	12/29/2003	0.020	0.018	0.825	0.845	0.863	0.034	0.040	0.454	151	29	173	79	30	13	5
snowmelt	3/5/2004	0.013	0.026	0.810	0.823	0.849	0.026	0.030	0.395	165	12	54	28	14	6	2
snowmelt	3/11/2004	0.022	0.042	4.942	4.964	5.006	0.125	0.140	2.444	962	51	275	127	61	22	8
snowmelt	3/16/2004	0.011	0.028	4.890	4.901	4.929	0.128	0.146	2.982	1071	106	837	318	110	43	15
snowmelt	3/25/2004	0.056	0.097	5.326	5.382	5.479	0.112	0.118	1.427	777	40	207	90	40	19	8
snowmelt	3/26/2004	0.211	0.092	1.214	1.425	1.517	0.032	0.039	0.433	170	10	46	24	11	5	2
snowmelt	5/11/2004	0.035	0.406	2.482	2.517	2.923	0.258	0.327	0.846	186	36	214	98	39	15	5
rain or rain/snow	5/28/2004	0.024	0.339	1.705	1.729	2.068	0.200	0.268	0.545	124	24	182	70	26	10	3
thunderstorm	6/28/2004	11.041	0.092	39.620	50.661	50.753	0.217	0.920	10.555	6982	57	121	81	49	16	5
thunderstorm	8/19/2004	0.079	0.020	5.336	5.415	5.435	0.308	0.451	1.238	185	74	200	94	47	12	4
snowmelt	9/20/2004	0.711	1.273	0.483	1.194	2.467	0.525	0.822	3.246	548	54	135	80	34	11	4
thunderstorm	10/9/2004	0.035	0.659	3.878	3.913	4.572	0.045	0.150	0.585	67	67	162	92	43	10	3
rain or rain/snow	10/17/2004	0.024	0.019	1.477	1.501	1.520	0.076	0.120	0.292	49	27	90	21	8	5	2
rain or rain/snow	10/19/2004	0.038	0.021	3.968	4.006	4.027	0.146	0.184	1.378	985	66	145	97	55	19	5
snowmelt	10/20/2004	0.021	0.018	1.822	1.843	1.861	0.054	0.090	0.138	28	21	70	21	7	3	2
snowmelt	10/22/2004	0.029	2.088	0.509	0.538	2.626	0.096	0.119	0.144	6	7	15	10	6	3	2
snowmelt	11/6/2004									360	68	155	99	51	14	4
rain on snow	11/10/2004	0.009	0.056	16.425	16.434	16.490	0.053	0.088	3.169	1740	57	138	82	38	12	4
snowmelt	12/13/2004	0.117	0.130	1.695	1.812	1.942	0.005	0.025	0.553	107	126	405	160	51	17	6
snowmelt	3/9/2005	0.036	0.064	7.472	7.508	7.572	0.130	0.138	5.041	2352	27	62	36	17	7	3
rain on snow	3/19/2005	0.035	0.107	1.143	1.178	1.285	0.195	0.216	0.748	121	66	190	78	18	6	2
rain on snow	3/22/2005	0.039	0.031	1.007	1.046	1.077	0.068	0.074	0.491	165	123	429	139	47	11	3
rain or rain/snow	4/27/2005	0.027	0.256	8.352	8.379	8.635	0.118	0.132	3.390	3751	96	226	130	51	18	7
rain or rain/snow	4/30/2005	0.022	0.215	6.576	6.598	6.813	0.030	0.066	3.582	1300	69	164	85	37	17	7
rain or rain/snow	5/16/2005	0.020	0.047	2.553	2.573	2.620	0.046	0.060	0.694	360	103	308	116	38	16	7
rain or rain/snow	6/17/2005	0.144	0.745	5.775	5.919	6.664	0.020	0.094	1.503	402	255	829	322	112	46	15
thunderstorm	8/15/2005	0.042	0.029	15.036	15.078	15.107	0.062	0.263	4.578	4109	63	129	87	56	25	10
rain or rain/snow	9/21/2005	8.925	2.604	13.851	22.776	25.380	0.246	0.538	2.365	845	163	483	170	80	34	13
thunderstorm	9/26/2005	0.028	0.024	3.845	3.873	3.897	0.426	0.518	1.469	990	227	624	249	120	53	18
thunderstorm	10/24/2005	1.544	1.095	10.148	11.692	12.787	0.725	0.766	1.855	774	51	101	76	45	21	9
rain or rain/snow	10/27/2005	0.032	0.012	2.614	2.646	2.658	0.113	0.124	0.706	610	155	353	157	87	46	17
rain or rain/snow	10/27/2005	0.094	0.020	10.161	10.255	10.275	0.135	0.140	4.280	4374	117	205	142	91	52	22
rain or rain/snow	11/25/2005	0.933	0.187	5.759	6.692	6.879	0.283	0.336	1.018	326	204	485	209	131	76	32
rain or rain/snow	11/29/2005	0.025	0.031	4.576	4.601	4.632	0.047	0.064	0.612	257	134	405	158	70	21	7
rain or rain/snow	12/18/2005	0.071	0.010	2.225	2.296	2.306	0.038	0.054	0.613	340	117	254	142	70	27	10

Table 9. Water quality concentration (in mg/l) and particle size distribution for individual events at Catchment C (2006 – 2008).

Event Type	Event Date	NH_3-N	$NO_{3/2}$-N	Org N	TKN	TN	SRP	DP	TP	TSS	Average PS (µm)	Particle Size Exceedance Percentage (>µm) 10%	25%	50%	75%	90%
rain on snow	2/27/2006	0.006	0.070	5.508	5.514	5.584	0.029	0.031	3.192	1398	66	165	56	20	8	3
snowmelt	4/12/2006	0.015	0.011	2.066	2.081	2.092	0.133	0.149	0.892	46	100	222	122	51	19	7
thunderstorm	4/25/2006	0.007	0.308	2.914	2.921	3.229	0.028	0.157	0.952	422	87	213	100	37	14	5
thunderstorm	8/4/2006	0.037	0.018	7.288	7.325	7.343	0.451	0.573	1.622	553	97	220	110	44	19	8
rain or rain/snow	10/5/2006	0.038	0.037	3.395	3.433	3.470	0.142	0.221	0.441	38	96	203	164	94	13	6
rain or rain/snow	10/10/2006	0.046	0.015	5.126	5.172	5.187	0.170	0.232	1.401	2517	71	160	106	56	27	12
rain or rain/snow	11/3/2006	0.035	0.010	0.806	0.841	0.851	0.070	0.078	0.166	14	117	298	161	71	18	5
rain or rain/snow	11/13/2006	0.006	0.006	0.612	0.618	0.624	0.099	0.117	0.193	27	163	281	195	133	75	29
rain or rain/snow	12/12/2006	0.011	0.035	1.624	1.635	1.670	0.026	0.088	0.807	266	78	168	110	54	25	11
rain on snow	12/21/2006	0.010	0.092	2.027	2.037	2.129	0.065	0.066	0.973	356	49	120	64	34	18	7
rain on snow	2/9/2007	0.069	0.156	3.188	3.257	3.413	0.173	0.185	1.181	472	116	330	127	48	22	10
rain on snow	3/26/2007	0.026	0.045	1.705	1.731	1.776	0.101	0.124	0.773	323.5	114	229	142	75	37	18
rain or rain/snow	6/5/2007	0.040	0.163	2.118	2.158	2.321	0.157	0.181	0.874	275.0	90	206	97	42	19	7
thunderstorm	7/11/2007	0.532	0.029	8.367	8.899	8.928	0.401	0.442	2.607	852.0	57	108	65	32	16	7
thunderstorm	9/22/2007	0.031	0.334	5.339	5.370	5.704	0.275	0.314	0.835	207.6	84	175	108	53	20	6
rain or rain/snow	10/5/2007	0.056	0.010	7.241	7.297	7.307	0.210	0.257	2.698	1210.8	45	113	58	25	10	3
rain or rain/snow	10/10/2007	0.002	0.012	3.984	3.986	3.998	0.136	0.154	0.512	294.4	70	177	89	33	11	3
thunderstorm	10/29/2007	0.006	0.270	5.084	5.090	5.360	0.134	0.158	1.301	772.0	44	112	55	25	9	3
rain or rain/snow	11/11/2007	0.015	0.019	1.329	1.344	1.363	0.155	0.186	0.537	148.0	207	630	229	97	35	11
rain or rain/snow	1/4/2008	0.021	0.338	3.231	3.252	3.590	0.005	0.023	1.208	322.6	43	142	60	15	3	1

Table 10. Constituent loads for pre-CIP runoff events for Catchment A. All values are in (g).

Event Type	Event Dates	NH_3-N	$NO_{2/3}$-N	Org N	TKN	TN	SRP	DP	TP	TSS
rain or rain/snow	12/6/2003	0.369	9.0	47	48	57	2.5	3.2	15	4114
rain on snow	12/24/2003	0.678	0.1	46	46	46	0.68	0.98	19	8950
thunderstorm	6/28/2004	0.924	2.0	61	62	64	0.34	1.62	20	12056
rain or rain/snow	10/19/2004	1.460	14.1	85	87	101	5.2	6.8	18	2646
rain or rain/snow	5/16/2005	0.030	0.043	1.6	1.61	1.65	0.11	0.14	0.73	223
rain or rain/snow	10/24/2005	0.782	13.5	82	83	96	6.2	8.2	31	802
rain or rain/snow	10/27/2005	0.002	0.003	0.09	0.09	0.09	0.02	0.02	0.03	2.0
rain or rain/snow	11/25/2005	0.006	0.007	1.3	1.26	1.27	0.09	0.10	0.22	26
rain or rain/snow	12/18/2005	0.804	1.25	56	57	58	4.0	5.1	18	6161
rain on snow	2/26/2006	0.218	0.44	222	223	223	5.8	7.0	111	29969
	Average	0.527	4.05	60	60.78	64.83	2.49	3.32	23	6495
	Stdev	0.484	5.8	65	65.4	66.7	2.6	3.2	32.4	9215
	CV	92%	143%	108%	108%	103%	103%	97%	139%	142%
	Median	0.52	0.84	52	52	57	1.6	2.4	18	3380
	Min	0.002	0.003	0.085	0.088	0.090	0.019	0.021	0.028	2
	Max	1.5	14	222	223	223	6.2	8.2	111	29969

Table 11. Constituent loads for post-CIP runoff events for Catchment A. All values are in (g).

Event Type	Event Dates	NH_3-N	$NO_{2/3}$-N	Org N	TKN	TN	SRP	DP	TP	TSS
rain or rain/snow	11/2/2006	0.263	0.374	30.9	31.1	31.5	2.76	3.34	7.90	859
rain or rain/snow	12/12/2006	0.078	0.078	11.7	11.8	11.9	0.078	0.408	3.378	1685
snowmelt	3/23/2007	0.021	0.017	1.98	2.00	2.02	0.060	0.125	0.445	103
rain or rain/snow	8/31/2007	0.240	0.242	3.73	3.97	4.21	0.388	0.402	0.529	142
thunderstorm	9/22/2007	0.165	1.372	12.9	13.0	14.4	2.104	2.428	4.526	706
rain or rain/snow	10/5/2007	0.005	0.006	0.971	0.976	0.982	0.136	0.154	0.333	58
rain or rain/snow	10/29/2007	0.003	0.091	0.462	0.465	0.556	0.042	0.051	0.105	27
thunderstorm	10/29/2007	0.019	0.779	3.812	3.831	4.610	0.281	0.324	0.742	204
thunderstorm	11/9/2007	0.051	2.12	7.74	7.79	9.91	0.246	0.342	0.806	118
rain on snow	11/10/2007	0.132	0.163	11.5	11.6	11.7	0.499	0.743	1.517	163
snowmelt	1/2/2008	0.026	0.046	0.751	0.778	0.824	0.006	0.012	0.553	185
snowmelt	2/10/2008	0.043	0.026	0.792	0.835	0.861	0.022	0.022	0.892	318
	Average	**0.087**	**0.44**	**7.26**	**7.35**	**7.79**	**0.55**	**0.70**	**1.81**	**381**
	StDev	0.092	0.67	8.78	8.85	9.01	0.90	1.06	2.34	485
	CV%	105%	150%	121%	120%	116%	164%	152%	129%	127%
	Median	0.05	0.13	3.77	3.90	4.41	0.19	0.33	0.77	174
	Min	0.00	0.01	0.46	0.46	0.56	0.01	0.01	0.10	27
	Max	0	2	31	31	31	2.76	3.34	7.90	1685

Table 12. Hydrologic data for pre-CIP events.

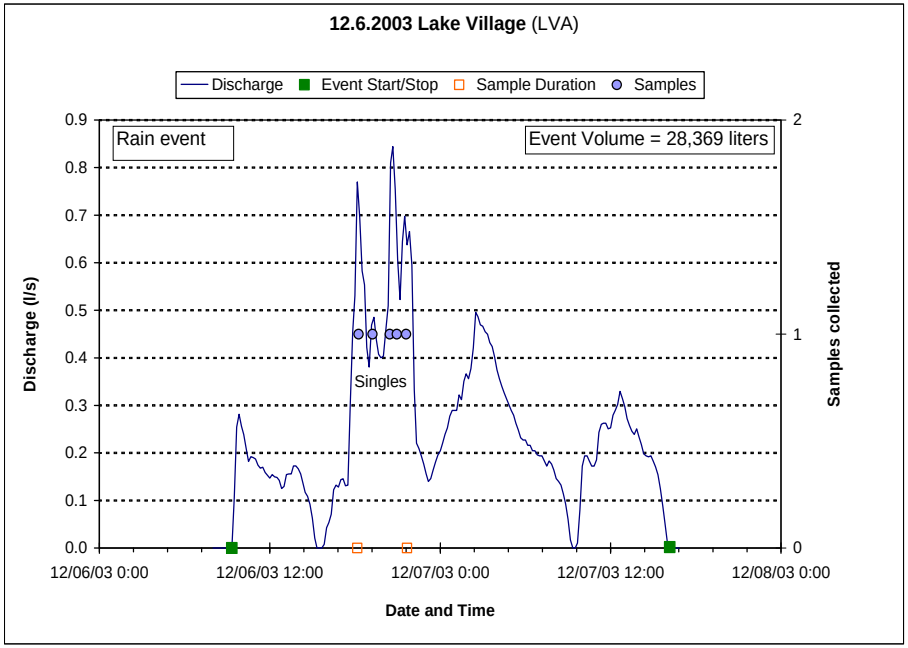
Event Type	Event Dates	Sample Duration (h:m)	Event Duration (h:m)	Total Precipitation (inches)	Precipitation Data Source	Sampled Volume (liters)	Event Volume (liters)	Peak Discharge (l/s)	Percent of event sampled
rain	12/6/2003	3:30	6:40	1.11	RHGID	7,496	28,369	0.845	26%
rain on snow	12/24/2003	5:50	15:20	1.80	RHGID	14,326	19,932	1.379	72%
thunderstorm	6/28/2004	0:40	4:10	0.01	RHGID	948	1,500	0.874	63%
rain/snow	10/19/2004	18:40	45:40	1.75	RHGID	24,916	45,622	1.847	55%
rain	5/16/2005	8:50	16:50	0.55	RHGID	1,228	1,418	0.207	87%
rain	10/24/2005	38:00	47:05	0.97	RHGID	16,909	20,040	2.457	84%
rain/snow	10/27/2005	1:00	3:40	0.08	RHGID	60	67	0.024	90%
rain/snow	11/25/2005	1:50	3:50	0.34	RHGID	319	321	0.120	99%
rain/snow	12/18/2005	16:20	45:20	1.69	SLT AP	38,483	89,288	1.671	43%
rain on snow	2/26/2006	20:00	52:40	1.39	NTCD	25,633	54,604	1.481	47%

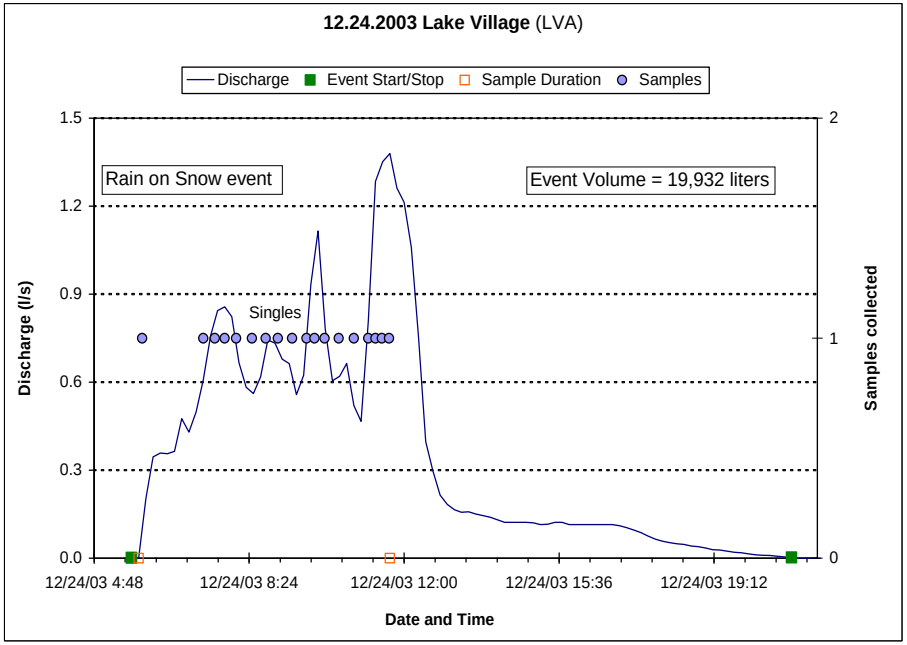
Table 13. Hydrologic data for post-CIP events.

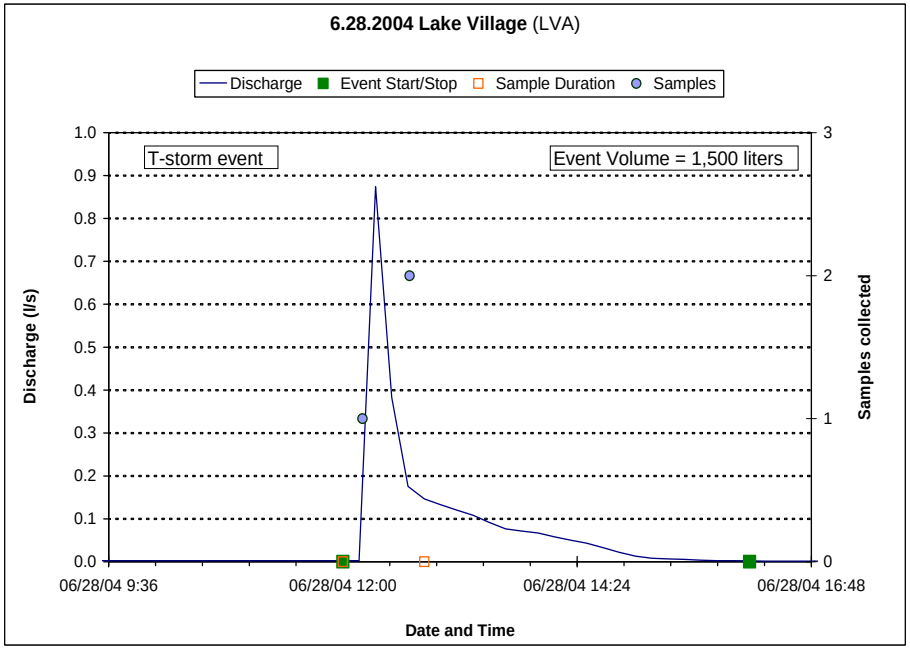
Event Type	Pre-Construction Events	Sample Duration (h:m)	Event Duration (h:m)	Total Precipitation (inches)	Precipitation Data Source	Sampled Volume (liters)	Event Volume (liters)	Peak Discharge (l/s)	Percent of event sampled	Avgerage Turbidity (NTU)	Maximum Turbidity (NTU)
rain	11/2/2006	7:20	10:00	0.245	NTCD	13,679	13,854	2.00	99%	62	141
rain/snow	12/12/2006	29:20	34:40	0.36	NTCD	7,253	7,837	0.839	93%	278	1479
snowmelt	3/23/2007	3:20	6:50		na	1,298	1,333	0.602	97%	134	1592
rain	8/31/2007	2:10	2:10	0.12	Edgewood GC	371	371	0.339	100%	272	1529
thunderstorm	9/22/2007	2:50	3:10	0.2	Edgewood GC	6,597	6,597	2.92	100%	140	1411
rain/snow	10/5/2007	2:40	4:30	0.04	Edgewood GC	409	416	0.191	98%	126	289
rain	10/29/2007	1:20	1:20	0.04	NTCD	251	251	0.092	100%	112	1491
thunderstorm	10/29/2007	4:20	5:40	0.24	Edgewood GC	2,130	2,145	1.02	99%	128	887
thunderstorm	11/9/2007	6:30	7:00	0.04	Edgewood GC	2,668	2,669	0.268	100%	63	1864
rain on snow	11/10/2007	36:10	38:00	0.44	Edgewood GC	10,162	10,180	1.48	100%	47	951
snowmelt	1/2/2008	3:30	5:10		na	241	256	0.024	94%	1287	1876
snowmelt	2/10/2008	4:10	5:30		na	377	384	0.043	98%	646	1236

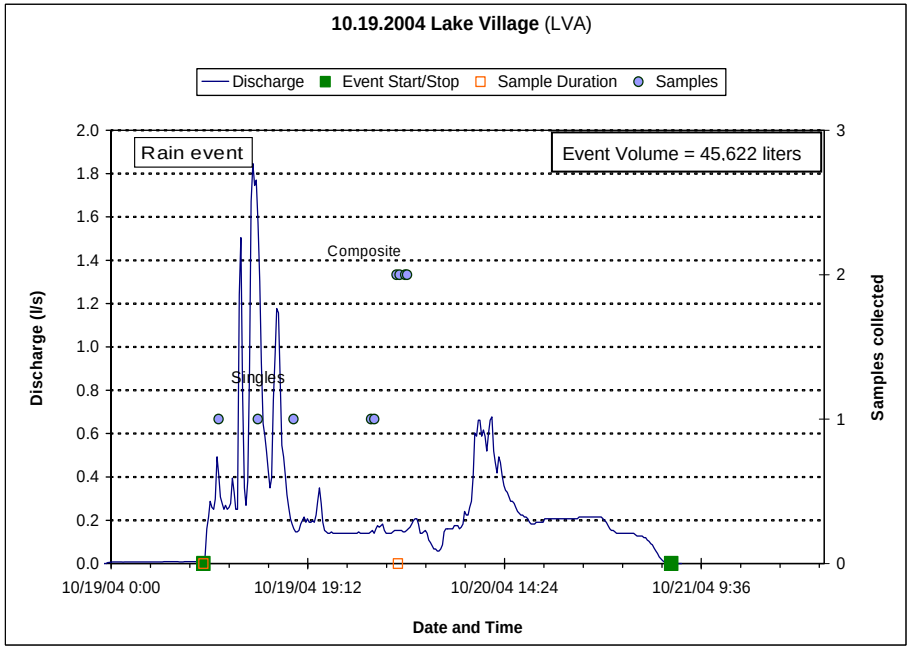
APPENDIX C

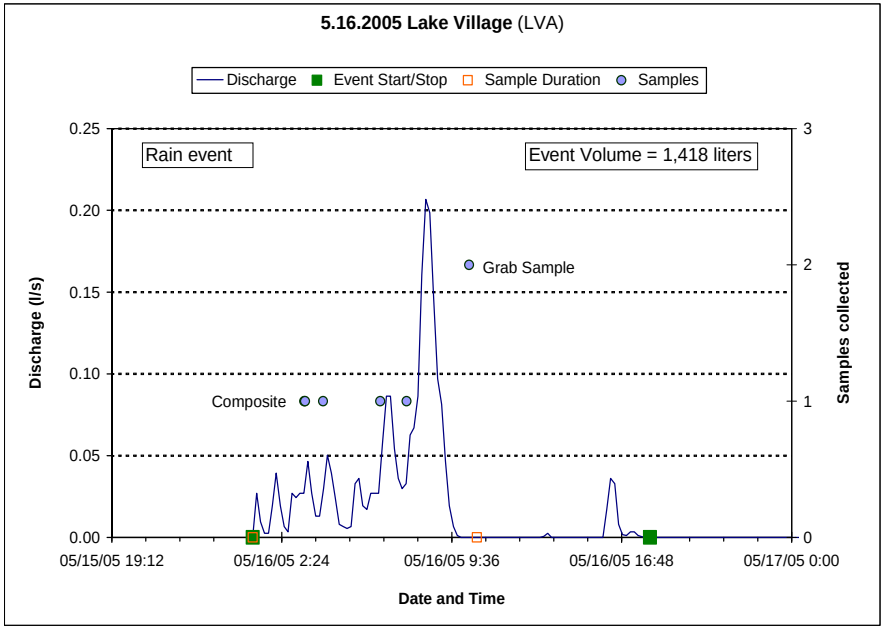
Hydrographs of Catchment A Events

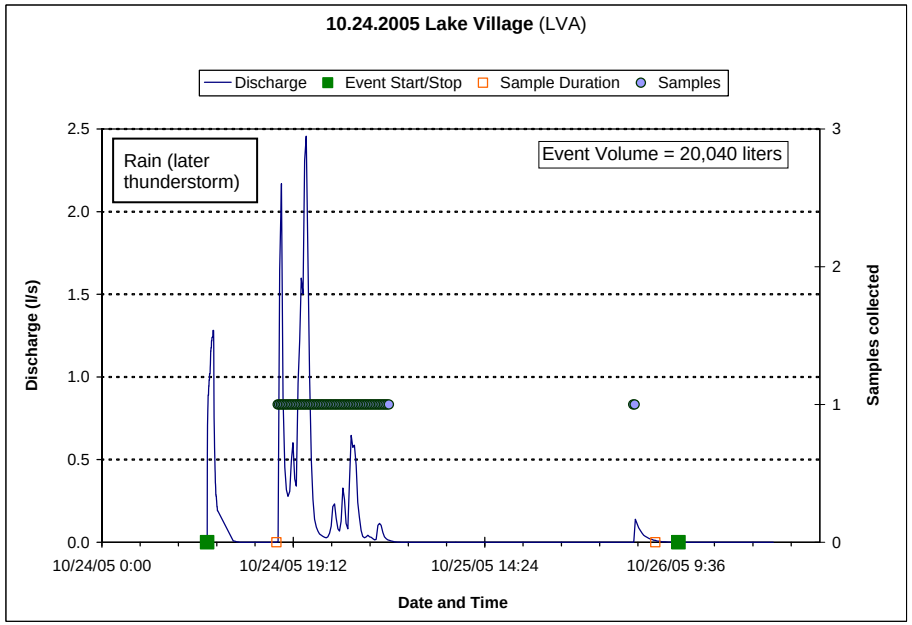

12.6.2003 Lake Village (LVA)
Discharge
Event Start/Stop
Sample Duration
Samples
Rain event
Event Volume = 28,369 liters
Singles
Discharge (l/s)
Samples collected
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
2
1
0
12/06/03 0:00
12/06/03 12:00
12/07/03 0:00
12/07/03 12:00
12/08/03 0:00
Date and Time

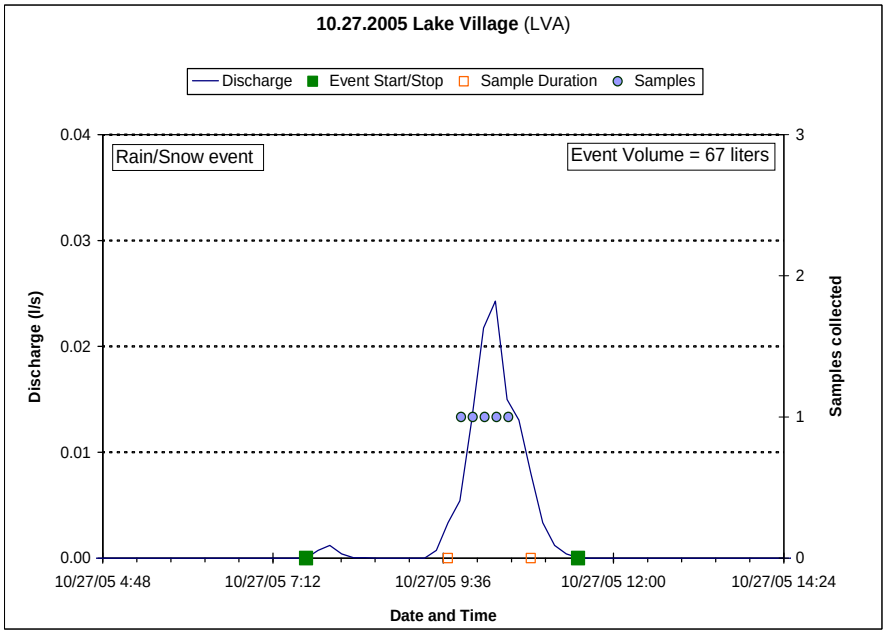

12.24.2003 Lake Village (LVA)
Discharge
Event Start/Stop
Sample Duration
Samples
Rain on Snow event
Event Volume = 19,932 liters
Singles
Discharge (l/s)
Samples collected
1.5
1.2
0.9
0.6
0.3
0.0
2
1
0
12/24/03 4:48
12/24/03 8:24
12/24/03 12:00
12/24/03 15:36
12/24/03 19:12
Date and Time

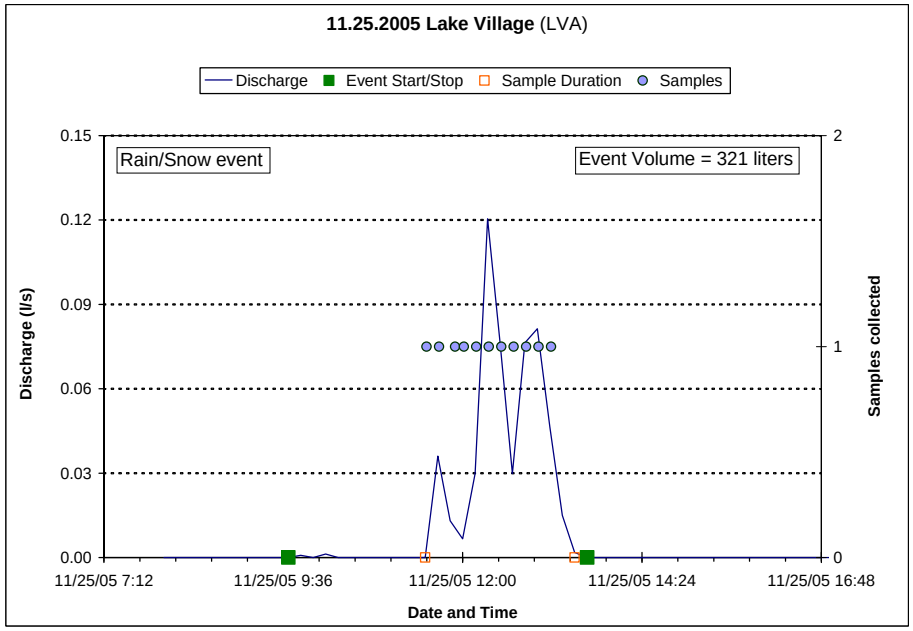

6.28.2004 Lake Village (LVA)
Discharge
Event Start/Stop
Sample Duration
Samples
T-storm event
Event Volume = 1,500 liters
Discharge (l/s)
Samples collected
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
3
2
1
0
06/28/04 9:36
06/28/04 12:00
06/28/04 14:24
06/28/04 16:48
Date and Time

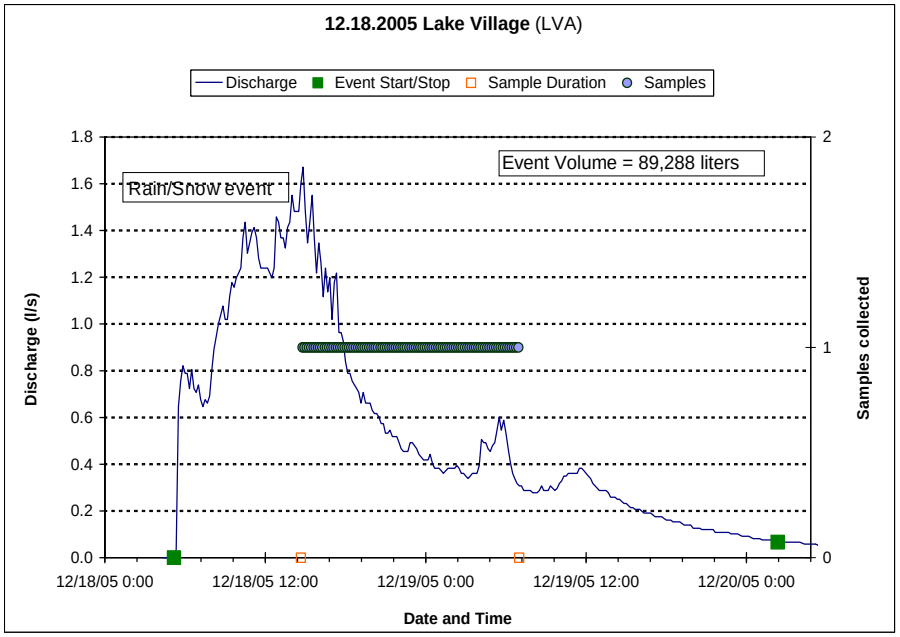

10.19.2004 Lake Village (LVA)
Discharge
Event Start/Stop
Sample Duration
Samples
Rain event
Event Volume = 45,622 liters
Composite
Singles
Discharge (l/s)
Samples collected
2.0
1.8
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
3
2
1
0
10/19/04 0:00
10/19/04 19:12
10/20/04 14:24
10/21/04 9:36
Date and Time

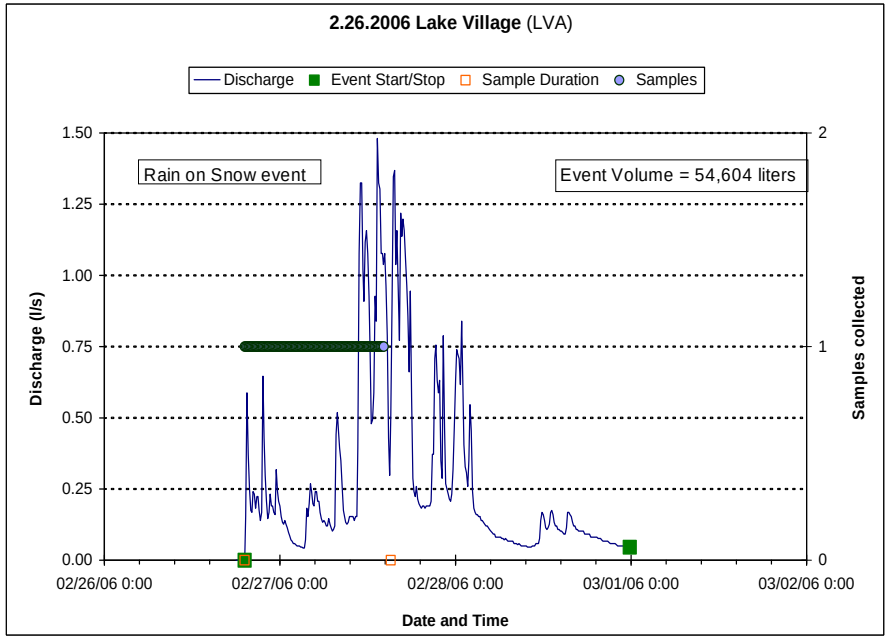

5.16.2005 Lake Village (LVA)
Discharge
Event Start/Stop
Sample Duration
Samples
Rain event
Event Volume = 1,418 liters
Grab Sample
Composite
Discharge (l/s)
Samples collected
0.25
0.20
0.15
0.10
0.05
0.00
3
2
1
0
05/15/05 19:12
05/16/05 2:24
05/16/05 9:36
05/16/05 16:48
05/17/05 0:00
Date and Time

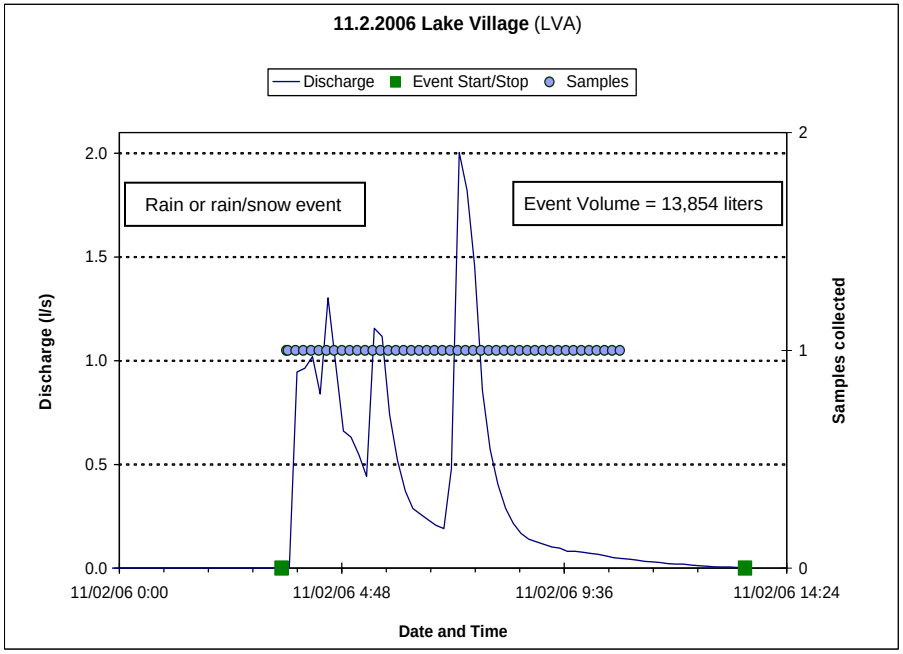

10.24.2005 Lake Village (LVA)
Discharge
Event Start/Stop
Sample Duration
Samples
Rain (later thunderstorm)
Event Volume = 20,040 liters
Discharge (l/s)
Samples collected
2.5
2.0
1.5
1.0
0.5
0.0
3
2
1
0
10/24/05 0:00
10/24/05 19:12
10/25/05 14:24
10/26/05 9:36
Date and Time

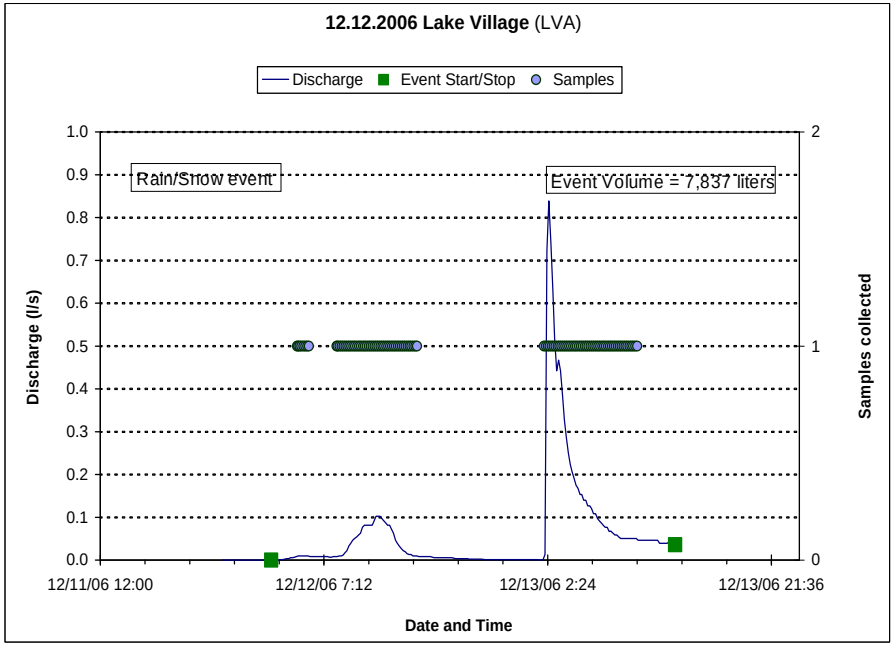

10.27.2005 Lake Village (LVA)
Discharge
Event Start/Stop
Sample Duration
Samples
Rain/Snow event
Event Volume = 67 liters
Discharge (l/s)
Samples collected
0.04
0.03
0.02
0.01
0.00
3
2
1
0
10/27/05 4:48
10/27/05 7:12
10/27/05 9:36
10/27/05 12:00
10/27/05 14:24
Date and Time

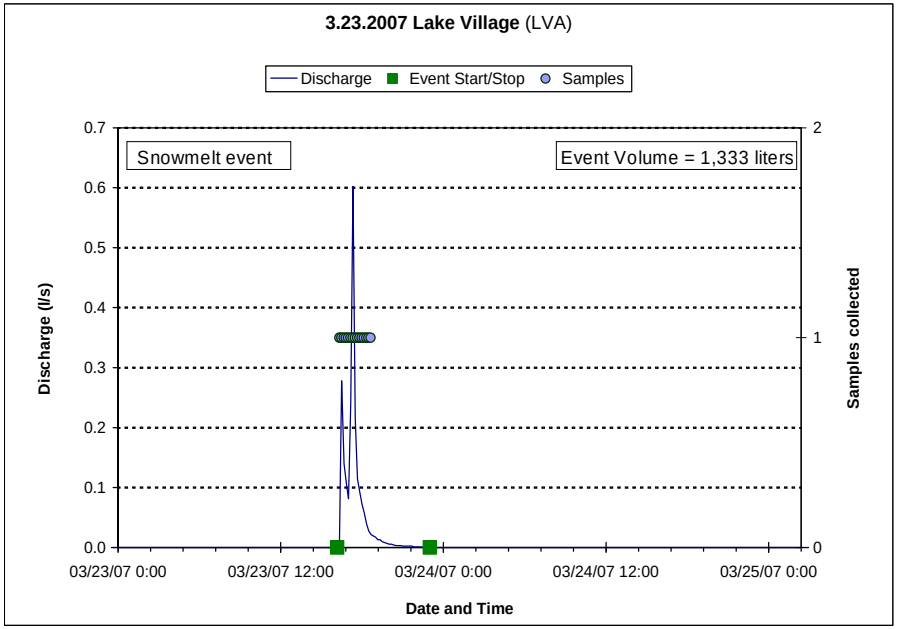

11.25.2005 Lake Village (LVA)
Discharge
Event Start/Stop
Sample Duration
Samples
Rain/Snow event
Event Volume = 321 liters
Discharge (l/s)
Samples collected
0.15
0.12
0.09
0.06
0.03
0.00
2
1
0
11/25/05 7:12
11/25/05 9:36
11/25/05 12:00
11/25/05 14:24
11/25/05 16:48
Date and Time

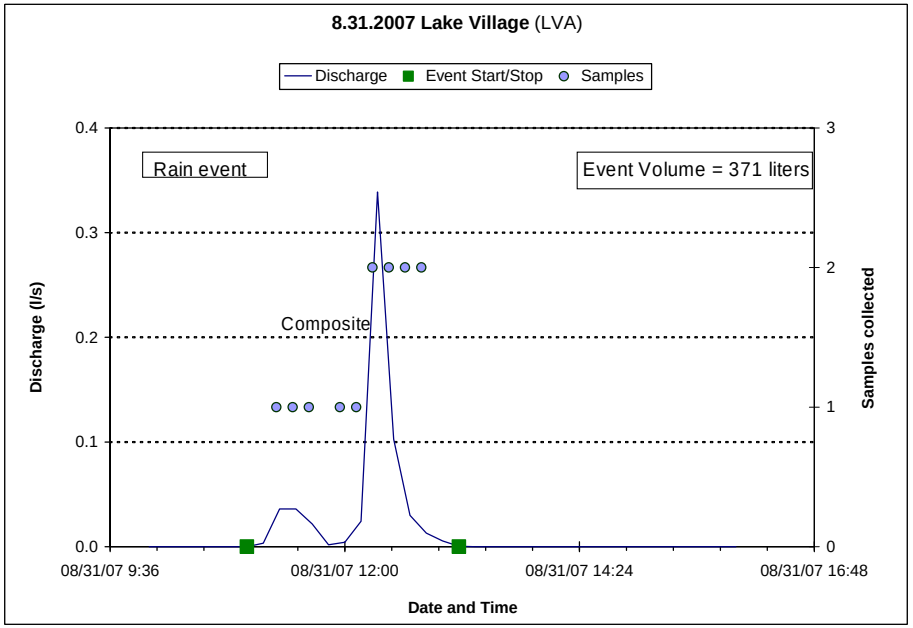

12.18.2005 Lake Village (LVA)
Discharge
Event Start/Stop
Sample Duration
Samples
Rain/Snow event
Event Volume = 89,288 liters
Discharge (l/s)
Samples collected
Date and Time
12/18/05 0:00
12/18/05 12:00
12/19/05 0:00
12/19/05 12:00
12/20/05 0:00

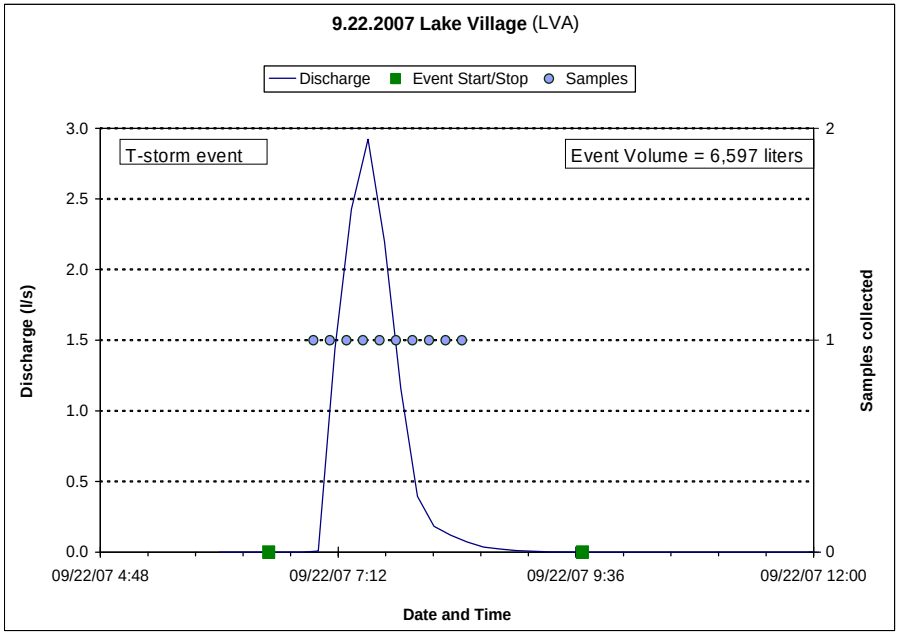

2.26.2006 Lake Village (LVA)
Discharge
Event Start/Stop
Sample Duration
Samples
Rain on Snow event
Event Volume = 54,604 liters
Discharge (l/s)
Samples collected
Date and Time
02/26/06 0:00
02/27/06 0:00
02/28/06 0:00
03/01/06 0:00
03/02/06 0:00

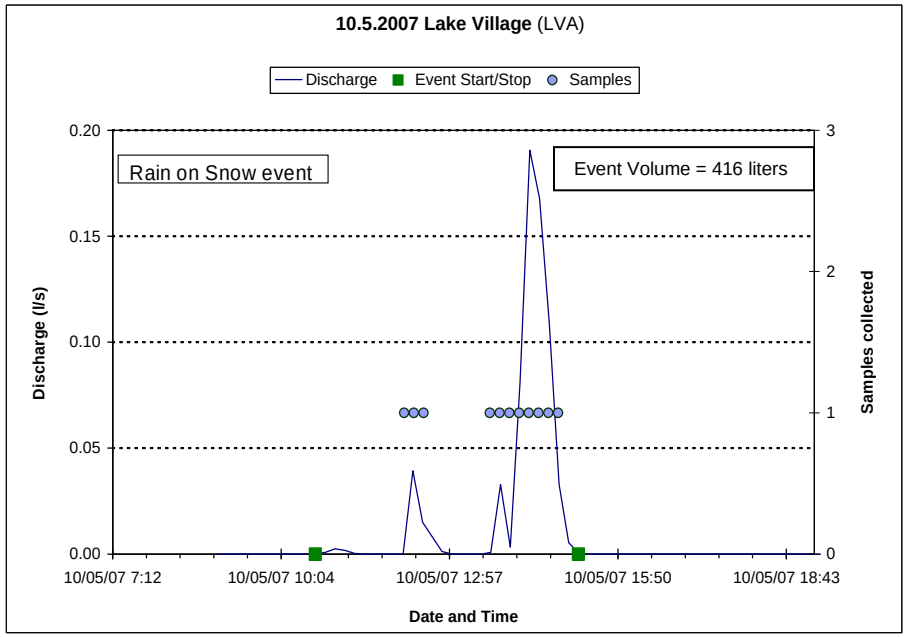

11.2.2006 Lake Village (LVA)
Discharge
Event Start/Stop
Samples
Rain or rain/snow event
Event Volume = 13,854 liters
Discharge (l/s)
Samples collected
Date and Time
11/02/06 0:00
11/02/06 4:48
11/02/06 9:36
11/02/06 14:24

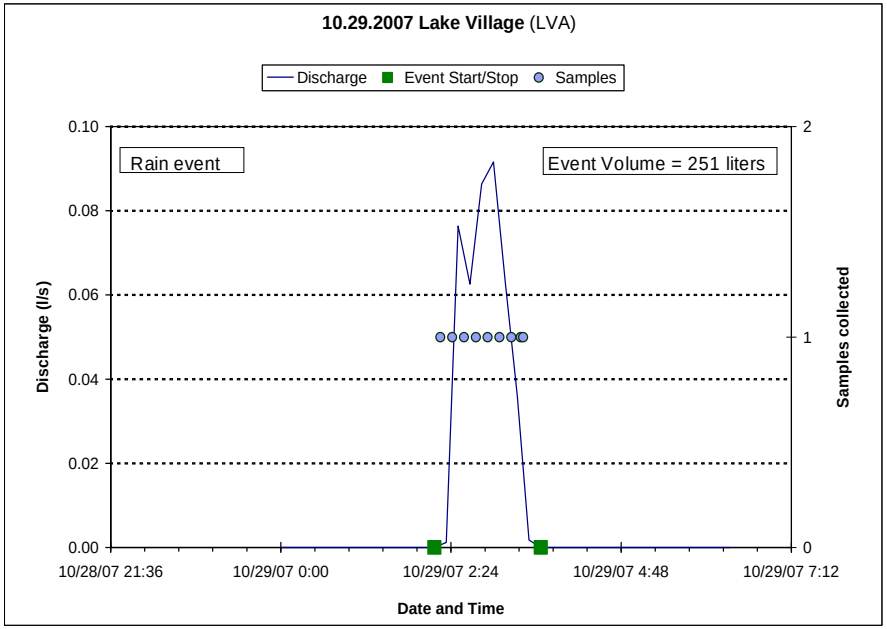

12.12.2006 Lake Village (LVA)
Discharge
Event Start/Stop
Samples
Rain/Snow event
Event Volume = 7,837 liters
Discharge (l/s)
Samples collected
Date and Time
12/11/06 12:00
12/12/06 7:12
12/13/06 2:24
12/13/06 21:36

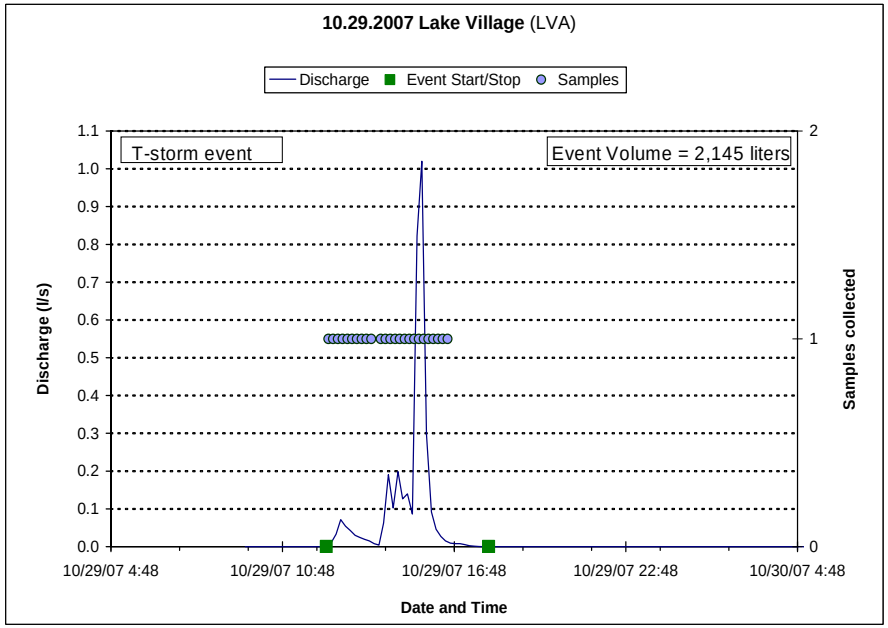

3.23.2007 Lake Village (LVA)
Discharge
Event Start/Stop
Samples
Snowmelt event
Event Volume = 1,333 liters
Discharge (l/s)
Samples collected
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
2
1
0
03/23/07 0:00
03/23/07 12:00
03/24/07 0:00
03/24/07 12:00
03/25/07 0:00
Date and Time

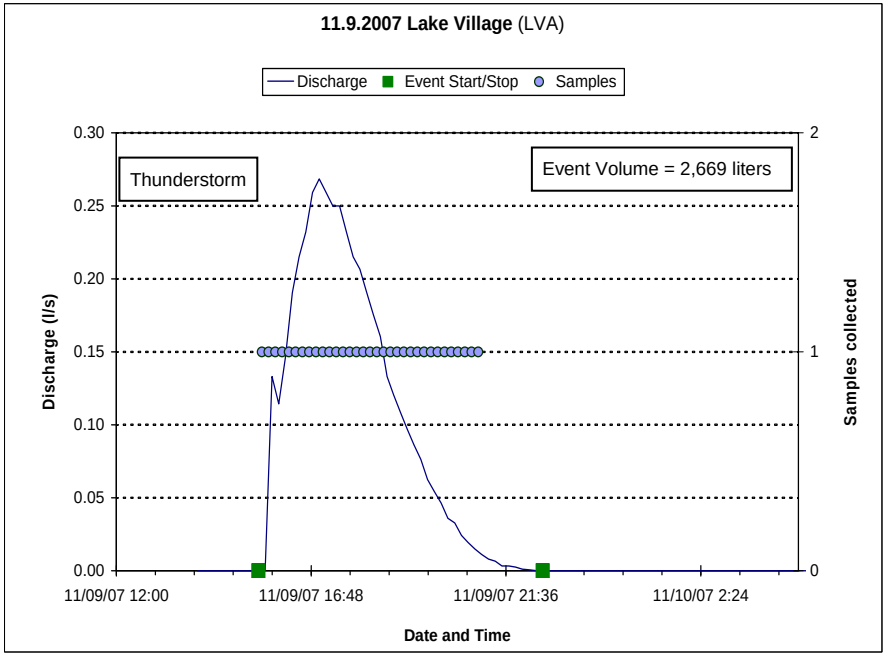

8.31.2007 Lake Village (LVA)
Discharge
Event Start/Stop
Samples
Rain event
Event Volume = 371 liters
Composite
Discharge (l/s)
Samples collected
0.4
0.3
0.2
0.1
0.0
3
2
1
0
08/31/07 9:36
08/31/07 12:00
08/31/07 14:24
08/31/07 16:48
Date and Time

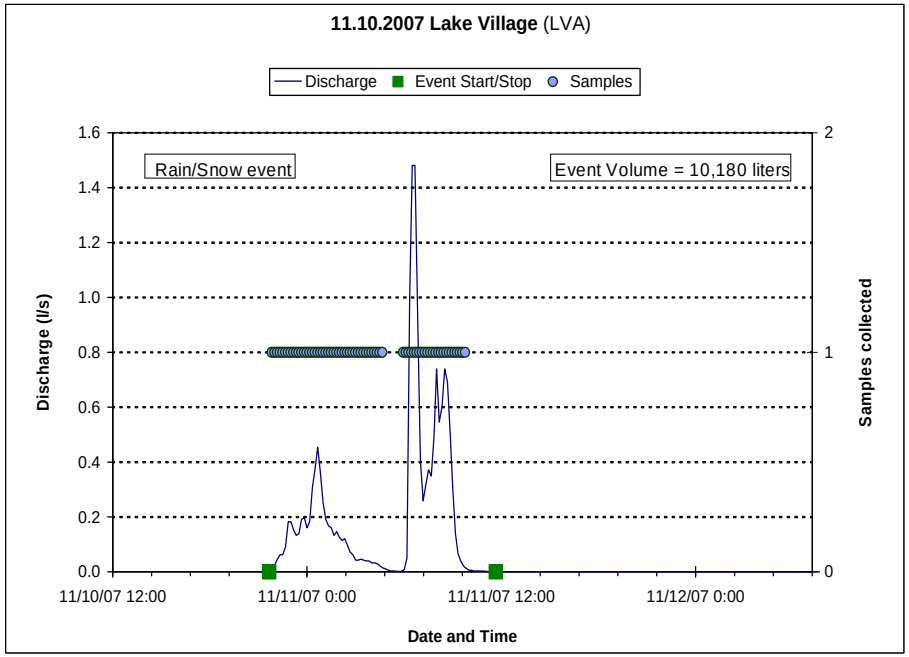

9.22.2007 Lake Village (LVA)
Discharge
Event Start/Stop
Samples
T-storm event
Event Volume = 6,597 liters
Discharge (l/s)
Samples collected
3.0
2.5
2.0
1.5
1.0
0.5
0.0
2
1
0
09/22/07 4:48
09/22/07 7:12
09/22/07 9:36
09/22/07 12:00
Date and Time

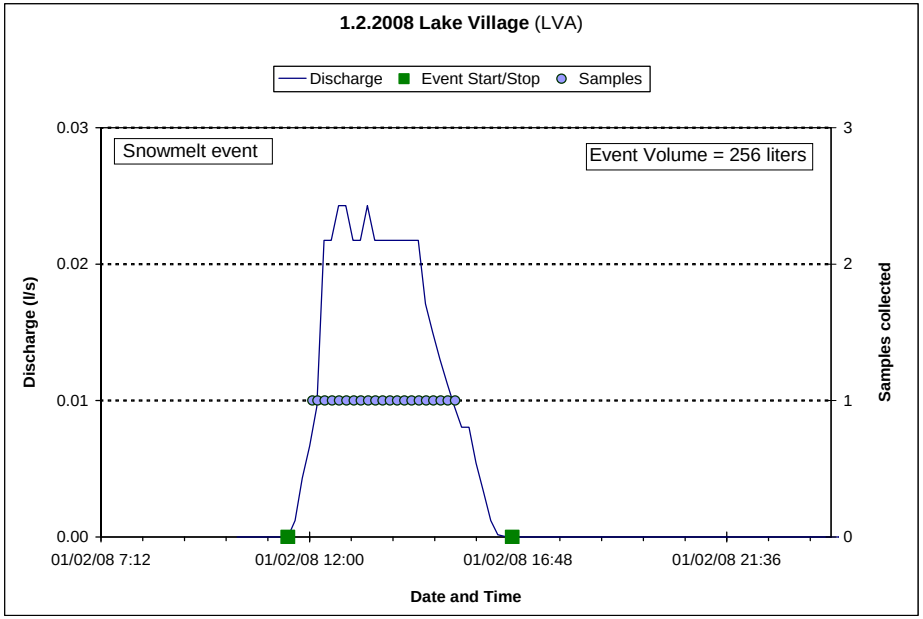

10.5.2007 Lake Village (LVA)
Discharge
Event Start/Stop
Samples
Rain on Snow event
Event Volume = 416 liters
Discharge (l/s)
Samples collected
0.20
0.15
0.10
0.05
0.00
3
2
1
0
10/05/07 7:12
10/05/07 10:04
10/05/07 12:57
10/05/07 15:50
10/05/07 18:43
Date and Time

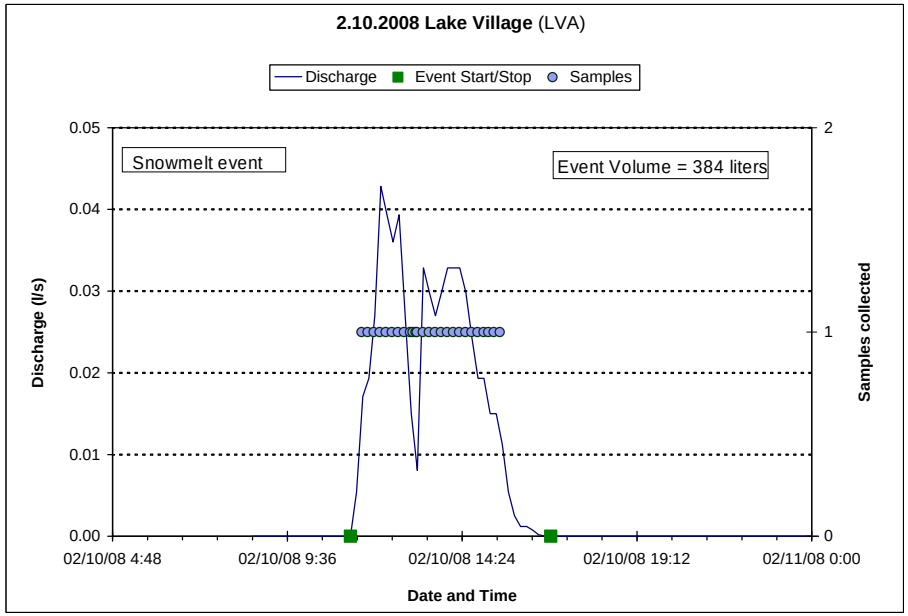

10.29.2007 Lake Village (LVA)
Discharge
Event Start/Stop
Samples
Rain event
Event Volume = 251 liters
Discharge (l/s)
Samples collected
0.10
0.08
0.06
0.04
0.02
0.00
2
1
0
10/28/07 21:36
10/29/07 0:00
10/29/07 2:24
10/29/07 4:48
10/29/07 7:12
Date and Time


10.29.2007 Lake Village (LVA)
Discharge
Event Start/Stop
Samples
T-storm event
Event Volume = 2,145 liters
Discharge (l/s)
Samples collected
1.1
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
2
1
0
10/29/07 4:48
10/29/07 10:48
10/29/07 16:48
10/29/07 22:48
10/30/07 4:48
Date and Time


11.9.2007 Lake Village (LVA)
Discharge
Event Start/Stop
Samples
Thunderstorm
Event Volume = 2,669 liters
Discharge (l/s)
Samples collected
0.30
0.25
0.20
0.15
0.10
0.05
0.00
2
1
0
11/09/07 12:00
11/09/07 16:48
11/09/07 21:36
11/10/07 2:24
Date and Time


11.10.2007 Lake Village (LVA)
Discharge
Event Start/Stop
Samples
Rain/Snow event
Event Volume = 10,180 liters
Discharge (l/s)
Samples collected
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
2
1
0
11/10/07 12:00
11/11/07 0:00
11/11/07 12:00
11/12/07 0:00
Date and Time


1.2.2008 Lake Village (LVA)
Discharge
Event Start/Stop
Samples
Snowmelt event
Event Volume = 256 liters
Discharge (l/s)
Samples collected
0.03
0.02
0.01
0.00
3
2
1
0
01/02/08 7:12
01/02/08 12:00
01/02/08 16:48
01/02/08 21:36
Date and Time


2.10.2008 Lake Village (LVA)
Discharge
Event Start/Stop
Samples
Snowmelt event
Event Volume = 384 liters
Discharge (l/s)
Samples collected
0.05
0.04
0.03
0.02
0.01
0.00
2
1
0
02/10/08 4:48
02/10/08 9:36
02/10/08 14:24
02/10/08 19:12
02/11/08 0:00
Date and Time

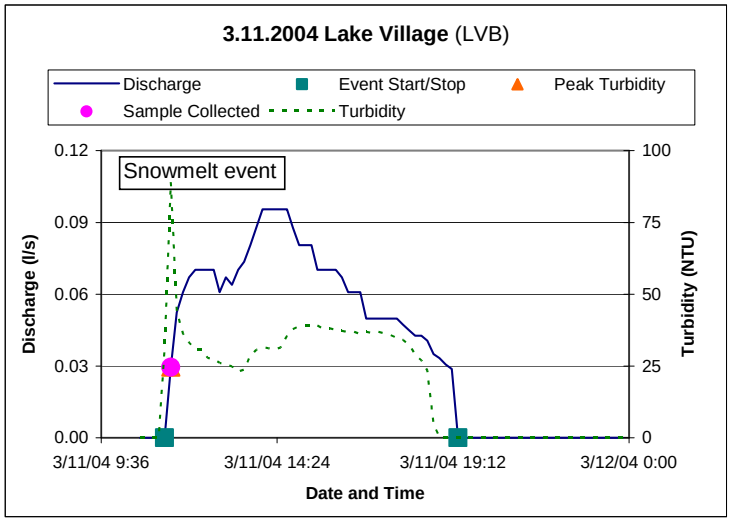
APPENDIX D

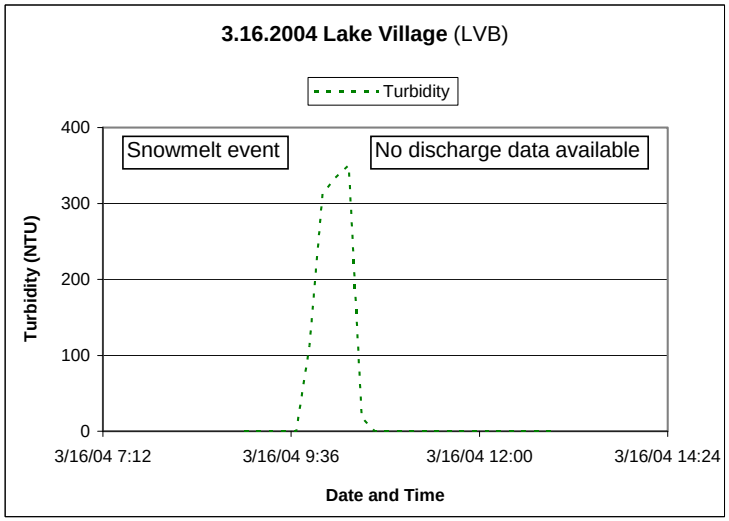
Hydrographs of Catchment B Events

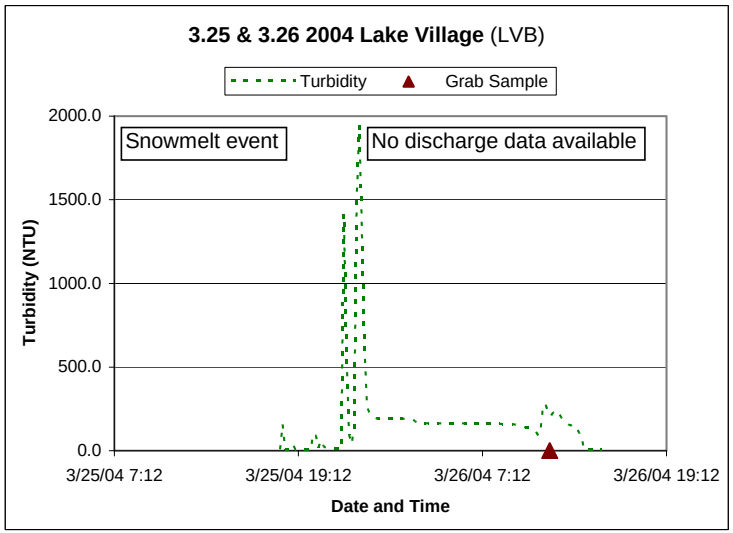
Lake Village Site B3 events with no discharge data available

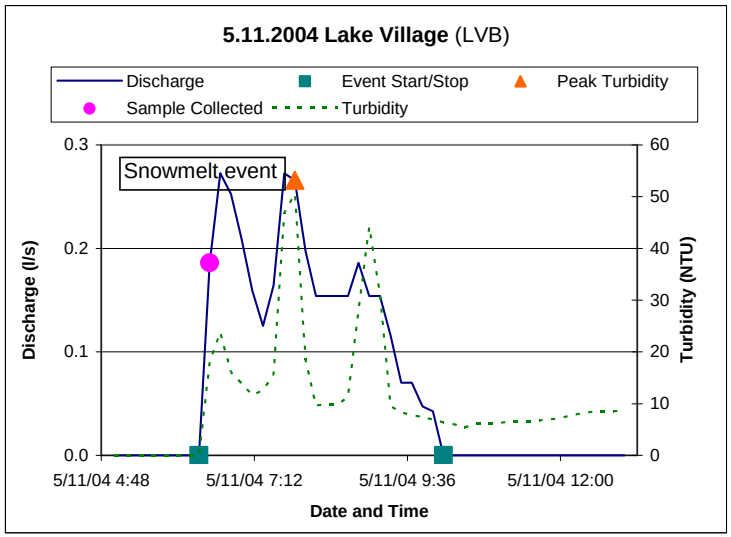
Event Date	Event Type	Data
11/9/2003	rain or rain/snow	No discharge data available
12/5/2003	rain or rain/snow	
12/6/2003	rain or rain/snow	
12/24/2003	rain on snow	
12/29/2003	rain on snow	
3/5/2004	snowmelt	
9/20/2004	snowmelt	
10/17/2004	rain or rain/snow	

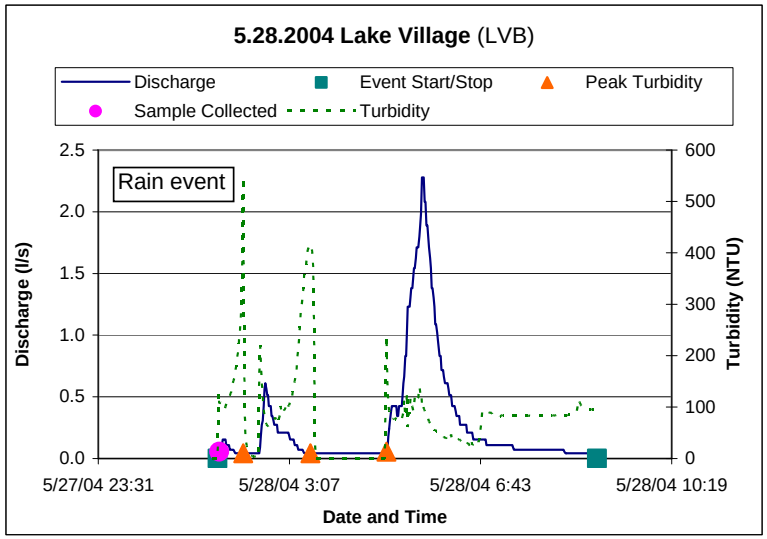
Lake Village Site B3 Pre-BMP Events

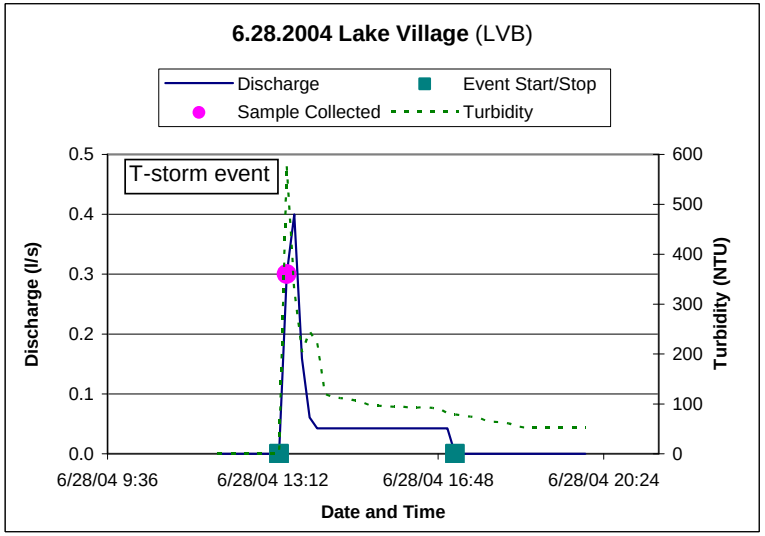


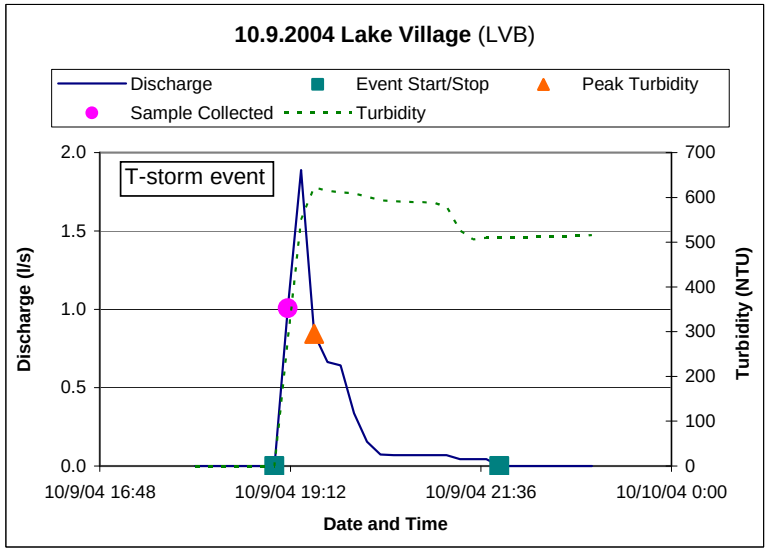


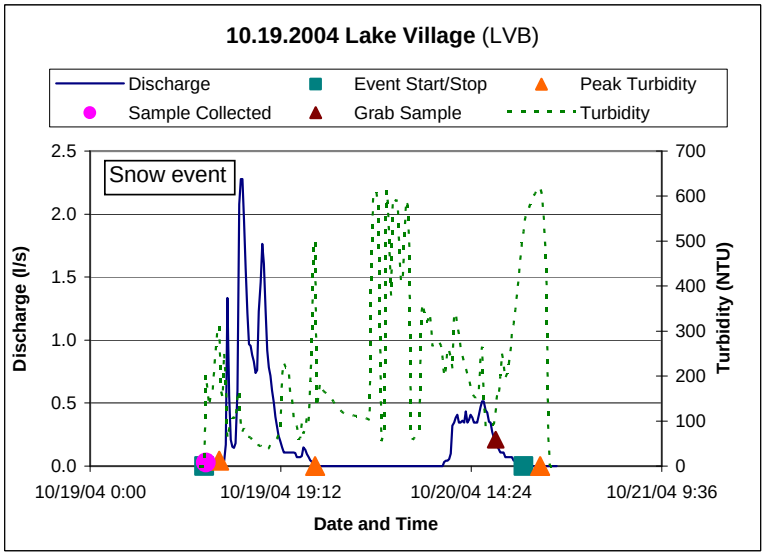


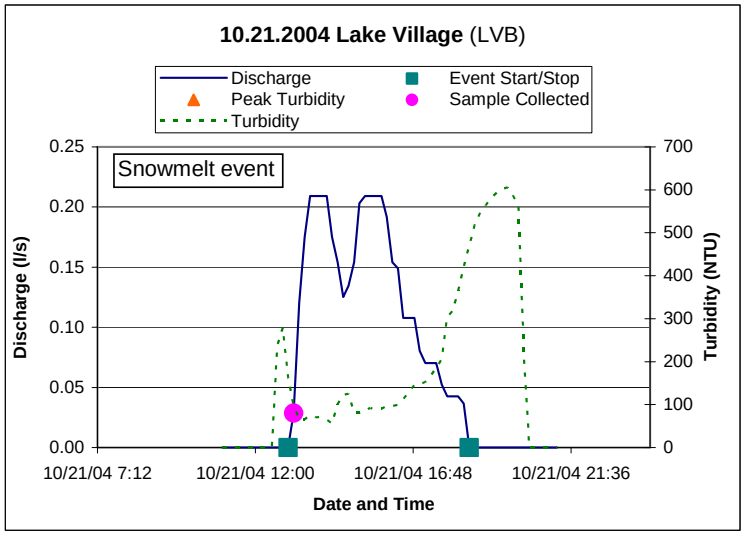


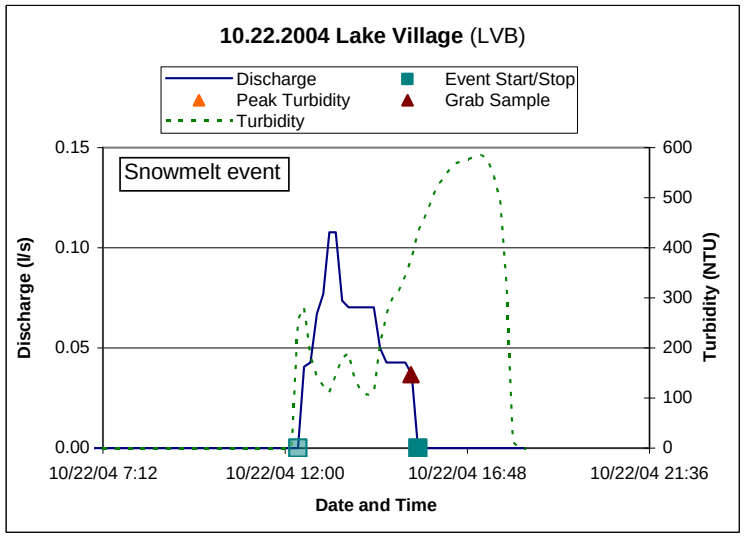

5.28.2004 Lake Village (LVB)
Discharge
Event Start/Stop
Peak Turbidity
Sample Collected
Turbidity
Rain event
Discharge (l/s)
Turbidity (NTU)
2.5
2.0
1.5
1.0
0.5
0.0
600
500
400
300
200
100
0
5/27/04 23:31
5/28/04 3:07
5/28/04 6:43
5/28/04 10:19
Date and Time

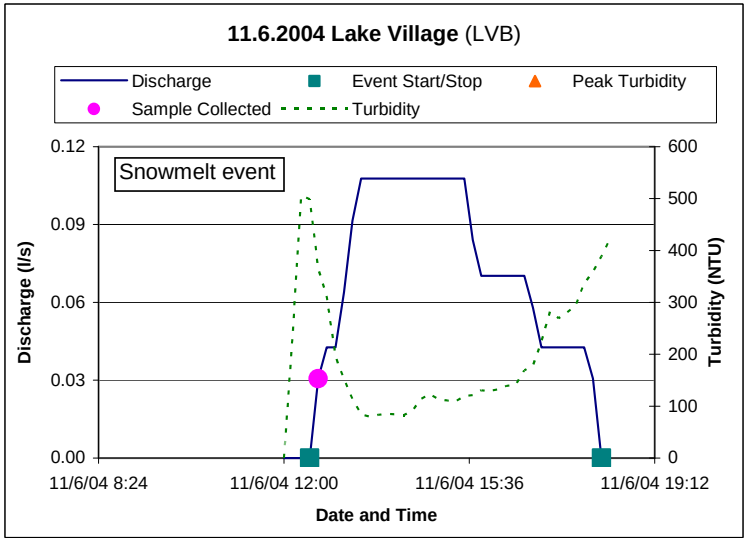

6.28.2004 Lake Village (LVB)
Discharge
Event Start/Stop
Sample Collected
Turbidity
T-storm event
Discharge (l/s)
Turbidity (NTU)
0.5
0.4
0.3
0.2
0.1
0.0
600
500
400
300
200
100
0
6/28/04 9:36
6/28/04 13:12
6/28/04 16:48
6/28/04 20:24
Date and Time

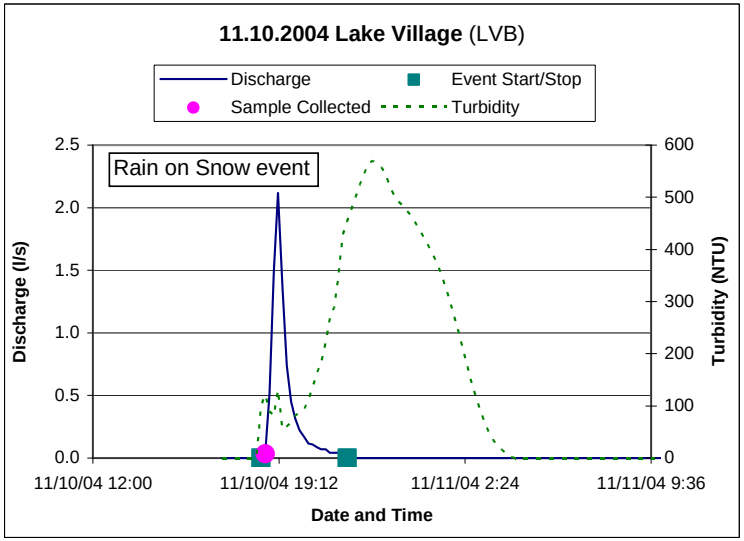

10.9.2004 Lake Village (LVB)
Discharge
Event Start/Stop
Peak Turbidity
Sample Collected
Turbidity
T-storm event
Discharge (l/s)
Turbidity (NTU)
2.0
1.5
1.0
0.5
0.0
700
600
500
400
300
200
100
0
10/9/04 16:48
10/9/04 19:12
10/9/04 21:36
10/10/04 0:00
Date and Time

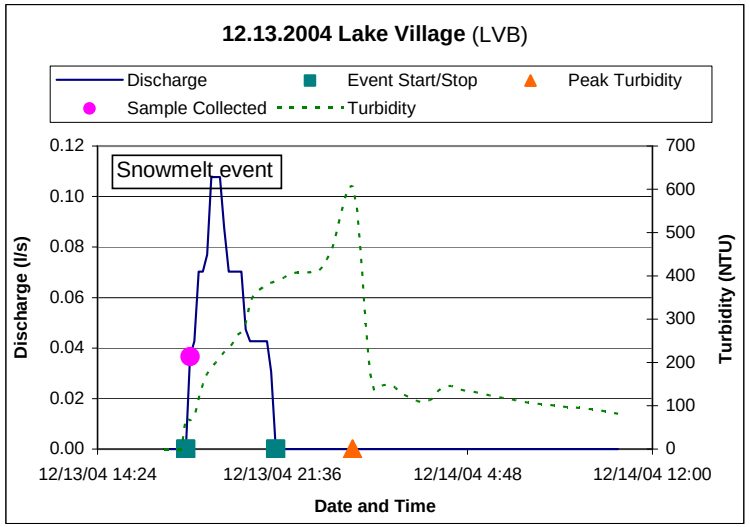

10.19.2004 Lake Village (LVB)
Discharge
Event Start/Stop
Peak Turbidity
Sample Collected
Grab Sample
Turbidity
Snow event
Discharge (l/s)
Turbidity (NTU)
2.5
2.0
1.5
1.0
0.5
0.0
700
600
500
400
300
200
100
0
10/19/04 0:00
10/19/04 19:12
10/20/04 14:24
10/21/04 9:36
Date and Time

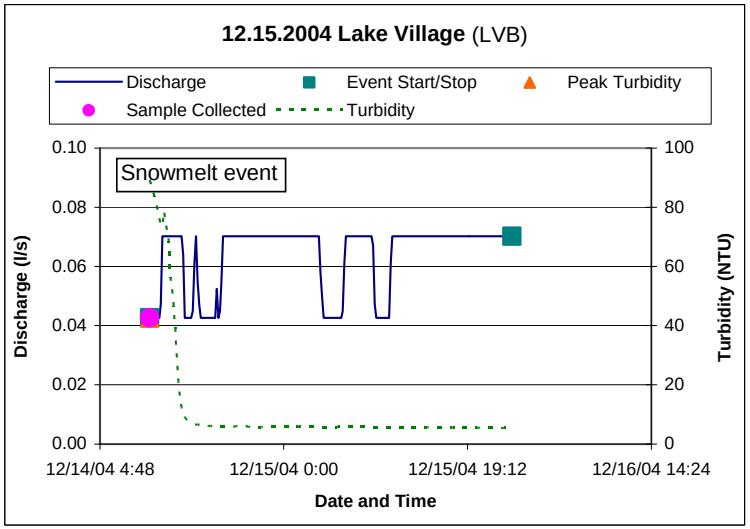

10.21.2004 Lake Village (LVB)
Discharge
Event Start/Stop
Peak Turbidity
Sample Collected
Turbidity
Snowmelt event
Discharge (l/s)
Turbidity (NTU)
0.25
0.20
0.15
0.10
0.05
0.00
700
600
500
400
300
200
100
0
10/21/04 7:12
10/21/04 12:00
10/21/04 16:48
10/21/04 21:36
Date and Time

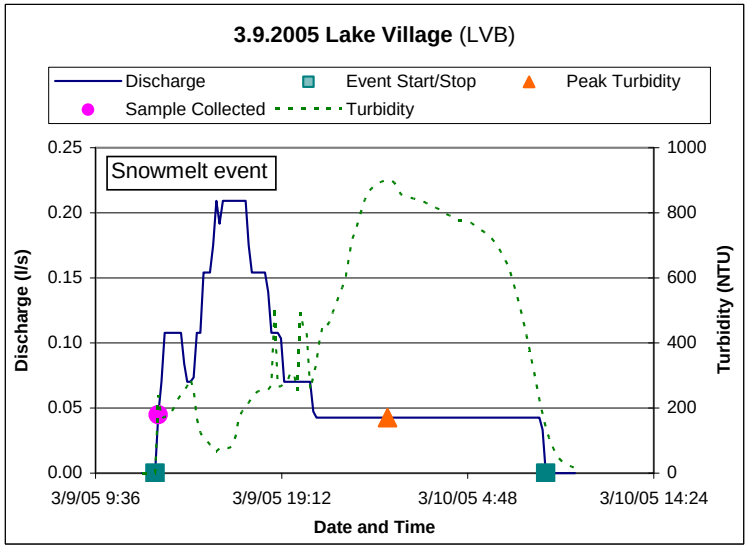

10.22.2004 Lake Village (LVB)
Discharge
Event Start/Stop
Peak Turbidity
Grab Sample
Turbidity
Snowmelt event
Discharge (l/s)
Turbidity (NTU)
0.15
0.10
0.05
0.00
600
500
400
300
200
100
0
10/22/04 7:12
10/22/04 12:00
10/22/04 16:48
10/22/04 21:36
Date and Time

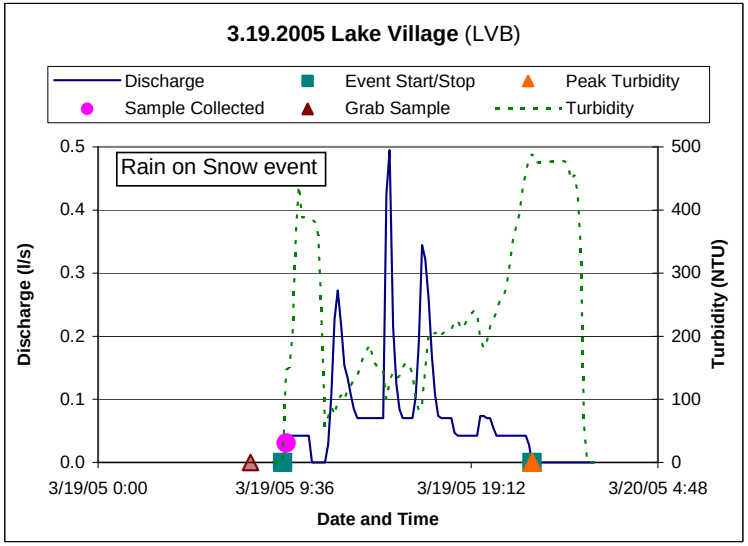

11.6.2004 Lake Village (LVB)
Discharge
Event Start/Stop
Peak Turbidity
Sample Collected
Turbidity
Snowmelt event
Discharge (l/s)
Turbidity (NTU)
0.12
0.09
0.06
0.03
0.00
600
500
400
300
200
100
0
11/6/04 8:24
11/6/04 12:00
11/6/04 15:36
11/6/04 19:12
Date and Time

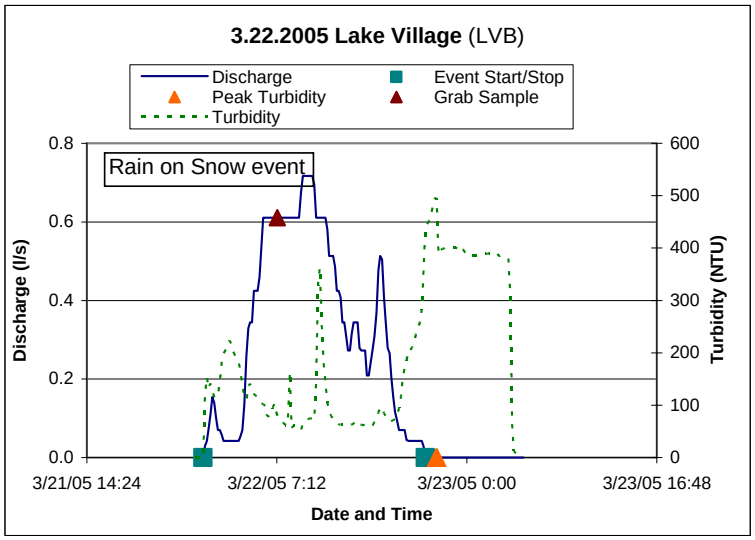

11.10.2004 Lake Village (LVB)
Discharge
Event Start/Stop
Sample Collected
Turbidity
Rain on Snow event
Discharge (l/s)
Turbidity (NTU)
2.5
2.0
1.5
1.0
0.5
0.0
600
500
400
300
200
100
0
11/10/04 12:00
11/10/04 19:12
11/11/04 2:24
11/11/04 9:36
Date and Time

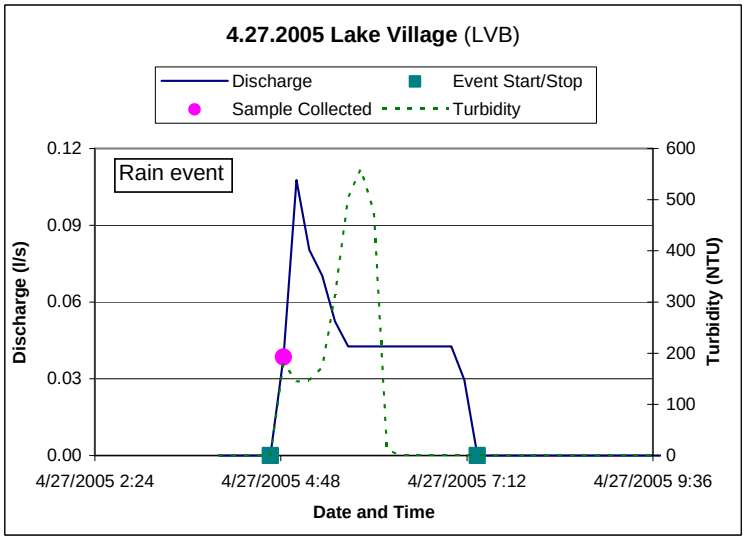

12.13.2004 Lake Village (LVB)
Discharge
Event Start/Stop
Peak Turbidity
Sample Collected
Turbidity
Snowmelt event
Discharge (l/s)
Turbidity (NTU)
0.12
0.10
0.08
0.06
0.04
0.02
0.00
700
600
500
400
300
200
100
0
12/13/04 14:24
12/13/04 21:36
12/14/04 4:48
12/14/04 12:00
Date and Time

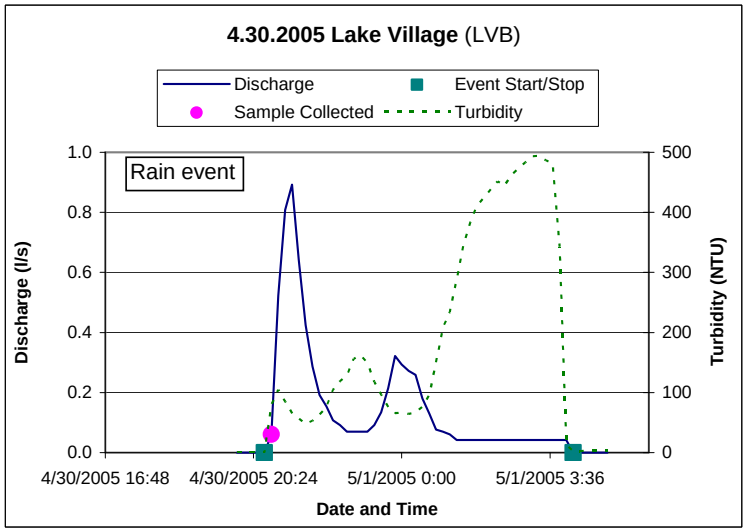

12.15.2004 Lake Village (LVB)
Discharge
Event Start/Stop
Peak Turbidity
Sample Collected
Turbidity
Snowmelt event
Discharge (l/s)
Turbidity (NTU)
0.10
0.08
0.06
0.04
0.02
0.00
100
80
60
40
20
0
12/14/04 4:48
12/15/04 0:00
12/15/04 19:12
12/16/04 14:24
Date and Time

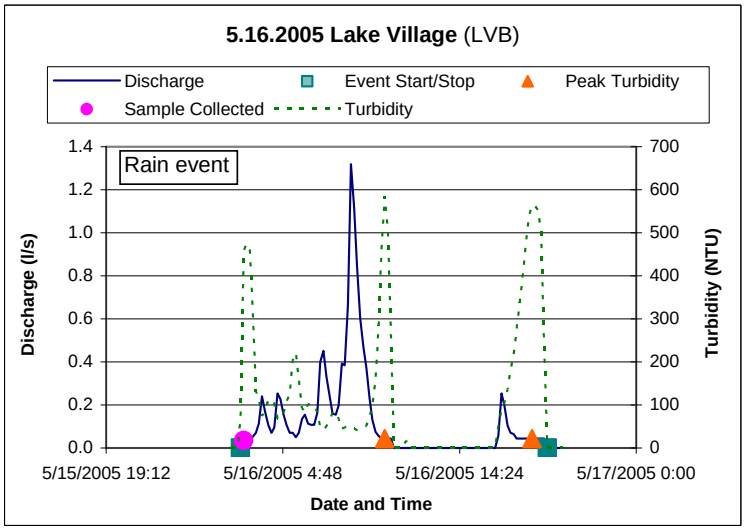

3.9.2005 Lake Village (LVB)
Discharge
Event Start/Stop
Peak Turbidity
Sample Collected
Turbidity
Snowmelt event
Discharge (l/s)
Turbidity (NTU)
0.25
0.20
0.15
0.10
0.05
0.00
1000
800
600
400
200
0
3/9/05 9:36
3/9/05 19:12
3/10/05 4:48
3/10/05 14:24
Date and Time

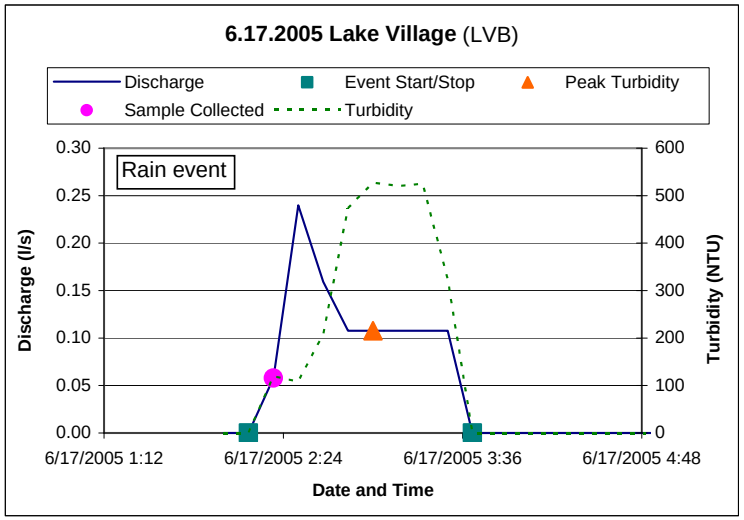

3.19.2005 Lake Village (LVB)
Discharge
Event Start/Stop
Peak Turbidity
Sample Collected
Grab Sample
Turbidity
Rain on Snow event
Discharge (l/s)
Turbidity (NTU)
0.5
0.4
0.3
0.2
0.1
0.0
500
400
300
200
100
0
3/19/05 0:00
3/19/05 9:36
3/19/05 19:12
3/20/05 4:48
Date and Time

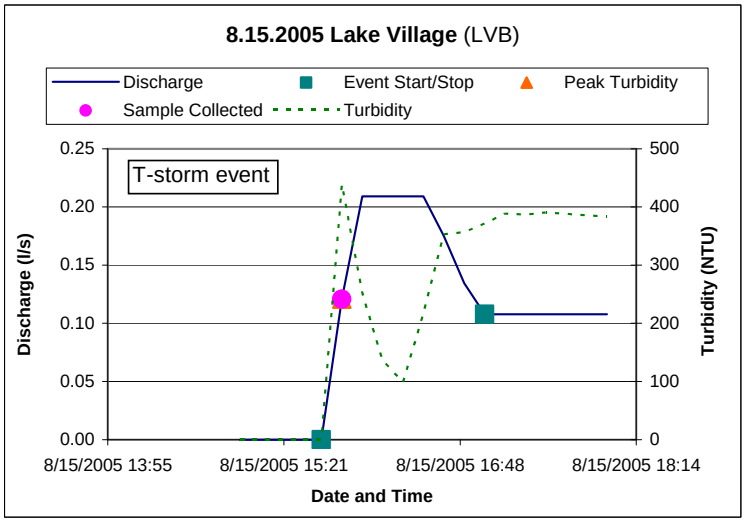

3.22.2005 Lake Village (LVB)
Discharge
Event Start/Stop
Peak Turbidity
Grab Sample
Turbidity
Rain on Snow event
Discharge (l/s)
Turbidity (NTU)
0.8
0.6
0.4
0.2
0.0
600
500
400
300
200
100
0
3/21/05 14:24
3/22/05 7:12
3/23/05 0:00
3/23/05 16:48
Date and Time

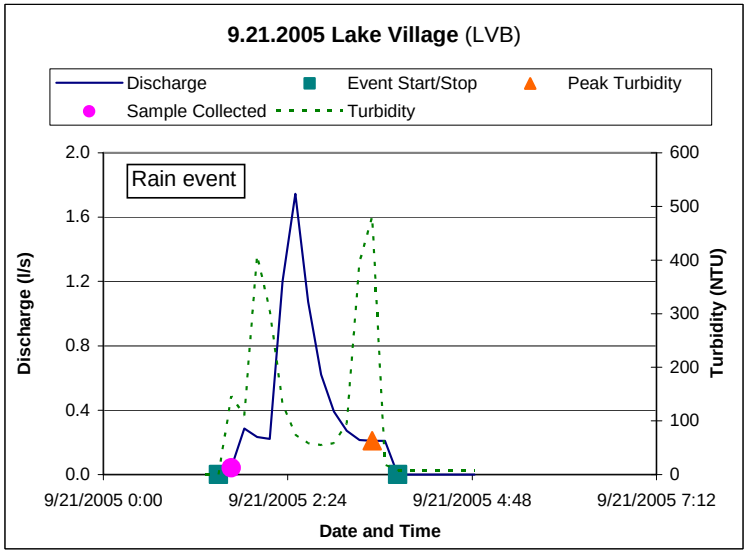

4.27.2005 Lake Village (LVB)
Discharge
Event Start/Stop
Sample Collected
Turbidity
Rain event
Discharge (l/s)
Turbidity (NTU)
0.12
0.09
0.06
0.03
0.00
600
500
400
300
200
100
0
4/27/2005 2:24
4/27/2005 4:48
4/27/2005 7:12
4/27/2005 9:36
Date and Time

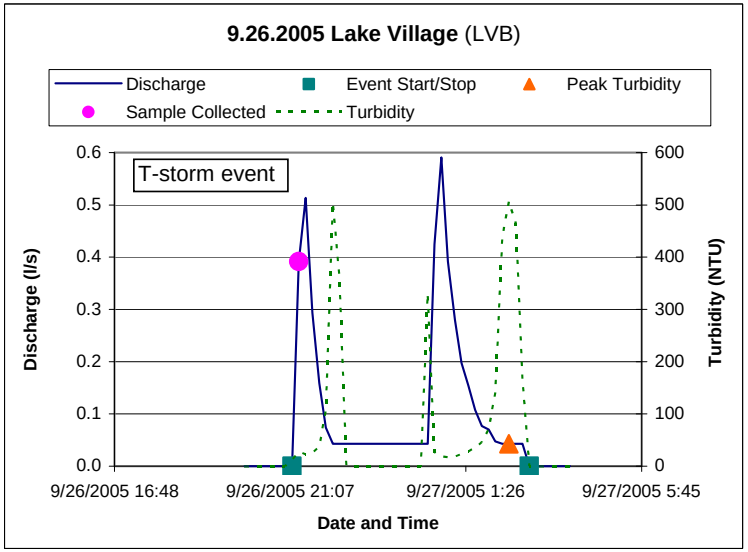

4.30.2005 Lake Village (LVB)
Discharge
Event Start/Stop
Sample Collected
Turbidity
Rain event
Discharge (l/s)
Turbidity (NTU)
1.0
0.8
0.6
0.4
0.2
0.0
500
400
300
200
100
0
4/30/2005 16:48
4/30/2005 20:24
5/1/2005 0:00
5/1/2005 3:36
Date and Time

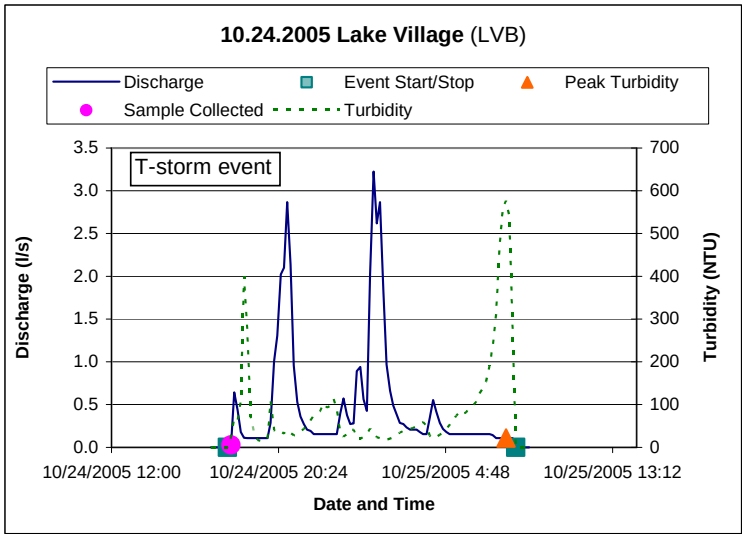

5.16.2005 Lake Village (LVB)
Discharge
Event Start/Stop
Peak Turbidity
Sample Collected
Turbidity
Rain event
Discharge (l/s)
Turbidity (NTU)
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
700
600
500
400
300
200
100
0
5/15/2005 19:12
5/16/2005 4:48
5/16/2005 14:24
5/17/2005 0:00
Date and Time

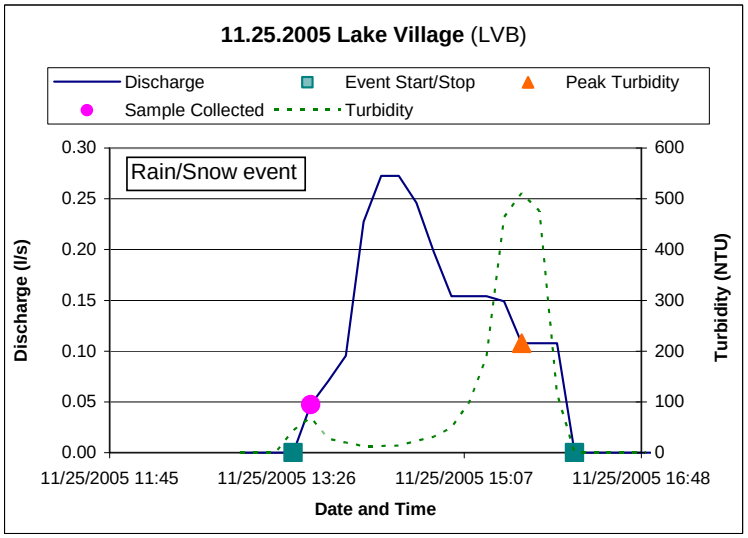

6.17.2005 Lake Village (LVB)
Discharge
Event Start/Stop
Peak Turbidity
Sample Collected
Turbidity
Rain event
Discharge (l/s)
Turbidity (NTU)
0.30
0.25
0.20
0.15
0.10
0.05
0.00
600
500
400
300
200
100
0
6/17/2005 1:12
6/17/2005 2:24
6/17/2005 3:36
6/17/2005 4:48
Date and Time

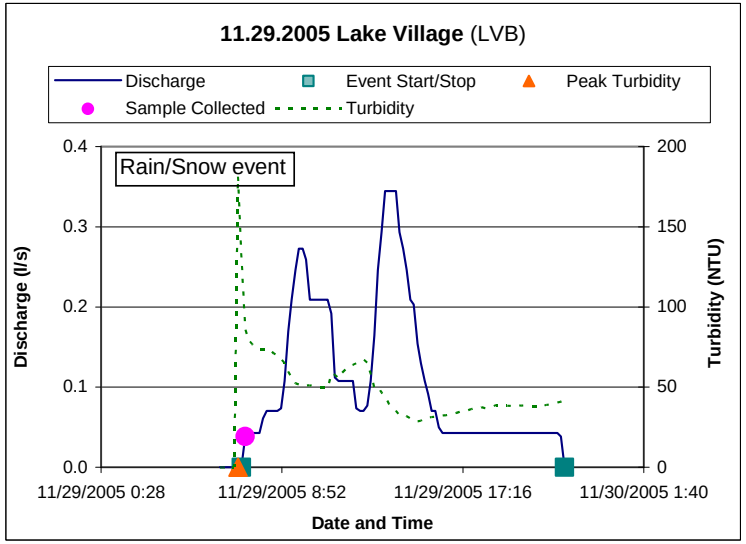

8.15.2005 Lake Village (LVB)
Discharge
Event Start/Stop
Peak Turbidity
Sample Collected
Turbidity
T-storm event
Discharge (l/s)
Turbidity (NTU)
0.25
0.20
0.15
0.10
0.05
0.00
500
400
300
200
100
0
8/15/2005 13:55
8/15/2005 15:21
8/15/2005 16:48
8/15/2005 18:14
Date and Time

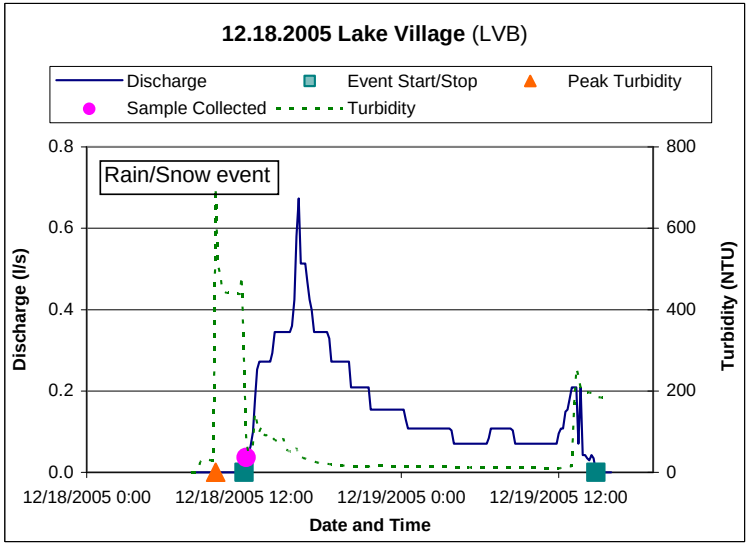

9.21.2005 Lake Village (LVB)
Discharge
Event Start/Stop
Peak Turbidity
Sample Collected
Turbidity
Rain event
Discharge (l/s)
Turbidity (NTU)
2.0
1.6
1.2
0.8
0.4
0.0
600
500
400
300
200
100
0
9/21/2005 0:00
9/21/2005 2:24
9/21/2005 4:48
9/21/2005 7:12
Date and Time

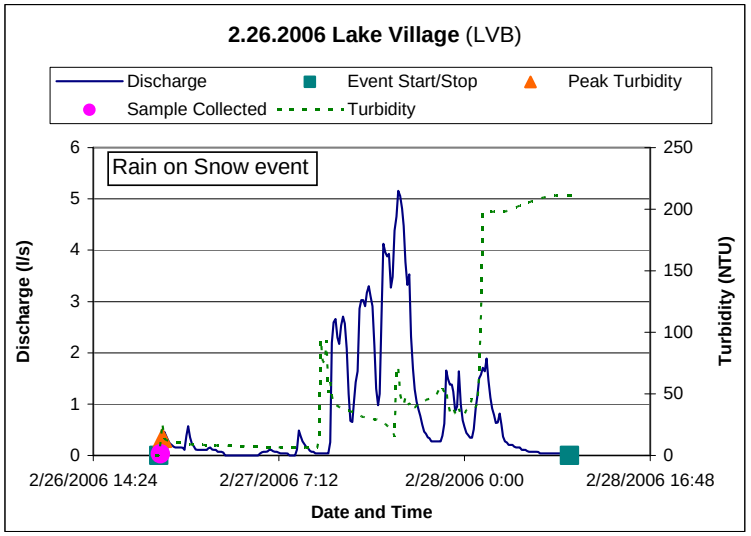

9.26.2005 Lake Village (LVB)
Discharge
Event Start/Stop
Peak Turbidity
Sample Collected
Turbidity
T-storm event
Discharge (l/s)
Turbidity (NTU)
0.6
0.5
0.4
0.3
0.2
0.1
0.0
600
500
400
300
200
100
0
9/26/2005 16:48
9/26/2005 21:07
9/27/2005 1:26
9/27/2005 5:45
Date and Time

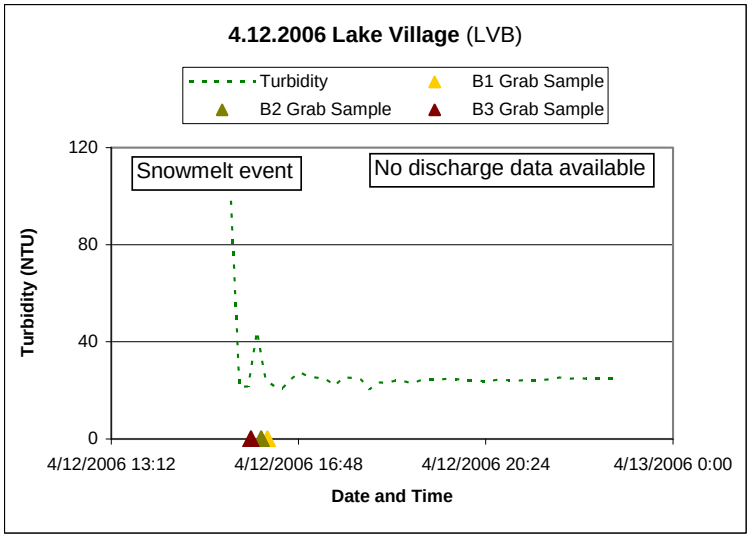

10.24.2005 Lake Village (LVB)
Discharge
Event Start/Stop
Peak Turbidity
Sample Collected
Turbidity
T-storm event
Discharge (l/s)
Turbidity (NTU)
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
700
600
500
400
300
200
100
0
10/24/2005 12:00
10/24/2005 20:24
10/25/2005 4:48
10/25/2005 13:12
Date and Time

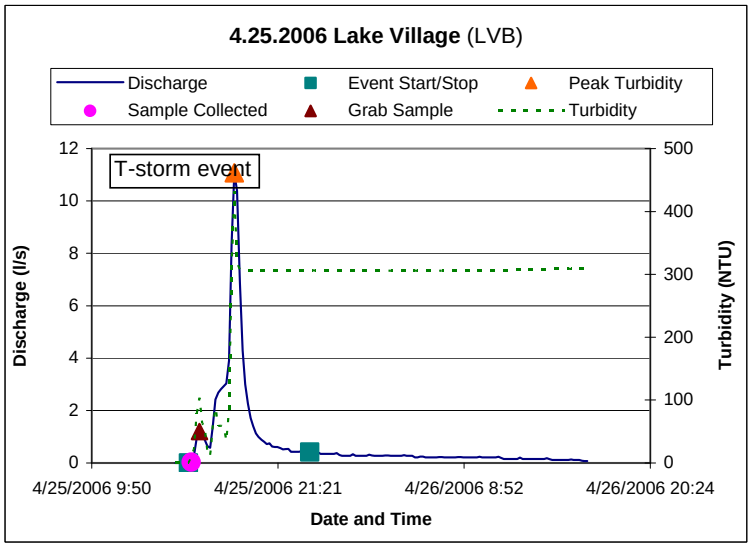

11.25.2005 Lake Village (LVB)
Discharge
Event Start/Stop
Peak Turbidity
Sample Collected
Turbidity
Rain/Snow event
Discharge (l/s)
Turbidity (NTU)
0.30
0.25
0.20
0.15
0.10
0.05
0.00
600
500
400
300
200
100
0
11/25/2005 11:45
11/25/2005 13:26
11/25/2005 15:07
11/25/2005 16:48
Date and Time

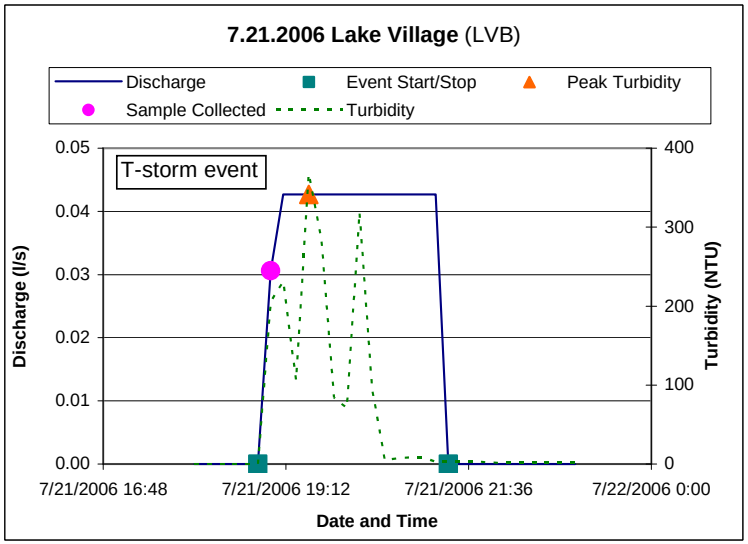

11.29.2005 Lake Village (LVB)
Discharge
Event Start/Stop
Peak Turbidity
Sample Collected
Turbidity
Rain/Snow event
Discharge (l/s)
Turbidity (NTU)
0.4
0.3
0.2
0.1
0.0
200
150
100
50
0
11/29/2005 0:28
11/29/2005 8:52
11/29/2005 17:16
11/30/2005 1:40
Date and Time


12.18.2005 Lake Village (LVB)
Discharge
Event Start/Stop
Peak Turbidity
Sample Collected
Turbidity
Rain/Snow event
Discharge (l/s)
Turbidity (NTU)
0.8
0.6
0.4
0.2
0.0
800
600
400
200
0
12/18/2005 0:00
12/18/2005 12:00
12/19/2005 0:00
12/19/2005 12:00
Date and Time

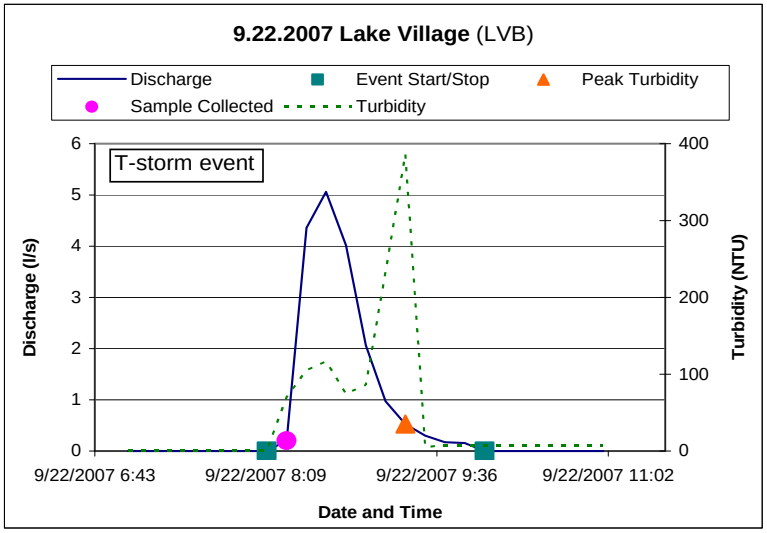

2.26.2006 Lake Village (LVB)
Discharge
Event Start/Stop
Peak Turbidity
Sample Collected
Turbidity
Rain on Snow event
Discharge (l/s)
Turbidity (NTU)
0
1
2
3
4
5
6
0
50
100
150
200
250
2/26/2006 14:24
2/27/2006 7:12
2/28/2006 0:00
2/28/2006 16:48
Date and Time

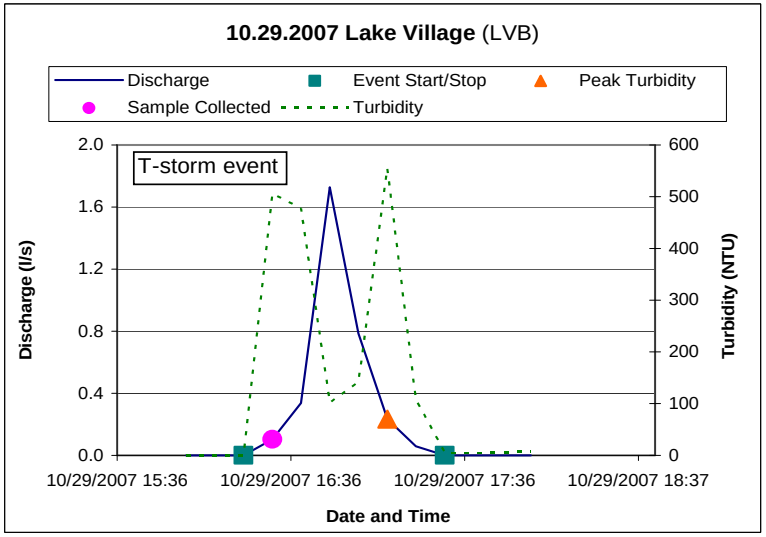

4.12.2006 Lake Village (LVB)
Turbidity
B1 Grab Sample
B2 Grab Sample
B3 Grab Sample
Snowmelt event
No discharge data available
Turbidity (NTU)
0
40
80
120
4/12/2006 13:12
4/12/2006 16:48
4/12/2006 20:24
4/13/2006 0:00
Date and Time

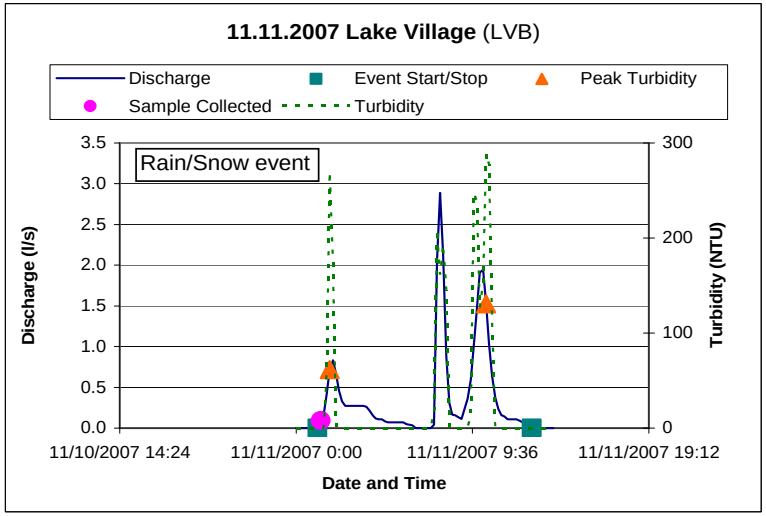

4.25.2006 Lake Village (LVB)
Discharge
Event Start/Stop
Peak Turbidity
Sample Collected
Grab Sample
Turbidity
T-storm event
Discharge (l/s)
Turbidity (NTU)
0
2
4
6
8
10
12
0
100
200
300
400
500
4/25/2006 9:50
4/25/2006 21:21
4/26/2006 8:52
4/26/2006 20:24
Date and Time

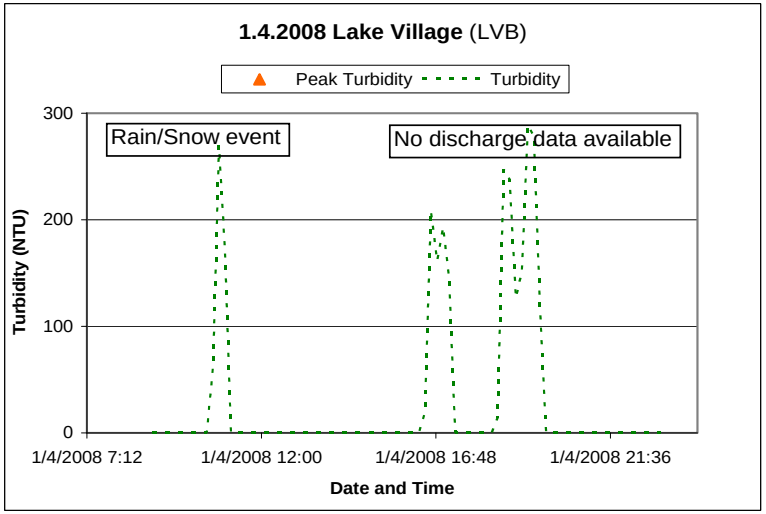

7.21.2006 Lake Village (LVB)
Discharge
Event Start/Stop
Peak Turbidity
Sample Collected
Turbidity
T-storm event
Discharge (l/s)
Turbidity (NTU)
0.00
0.01
0.02
0.03
0.04
0.05
0
100
200
300
400
7/21/2006 16:48
7/21/2006 19:12
7/21/2006 21:36
7/22/2006 0:00
Date and Time

Lake Village Site B Post-BMP Events









Nevada Tahoe Conservation District

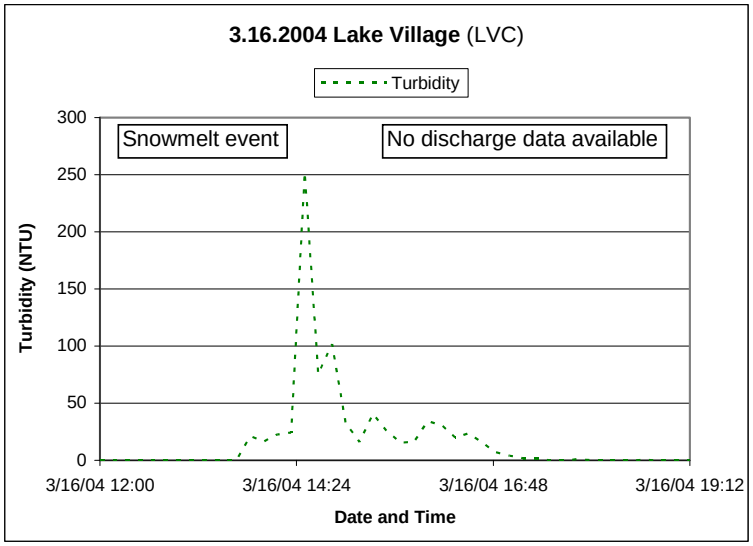
APPENDIX E

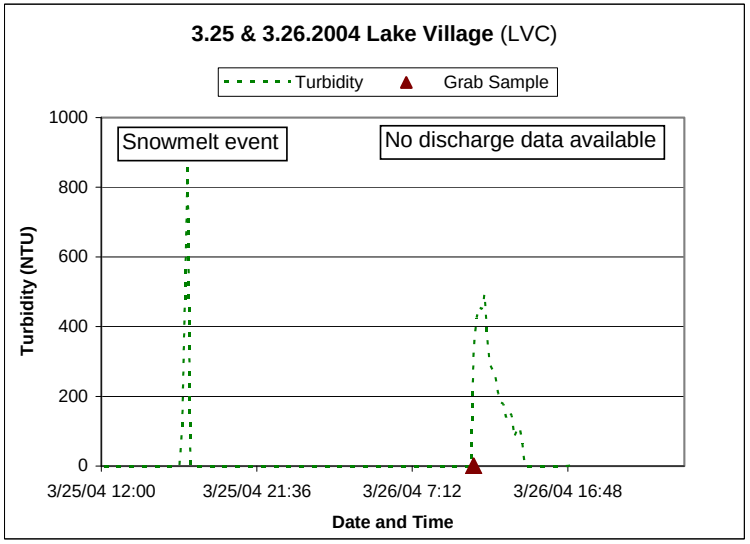
Hydrographs of Catchment C Events

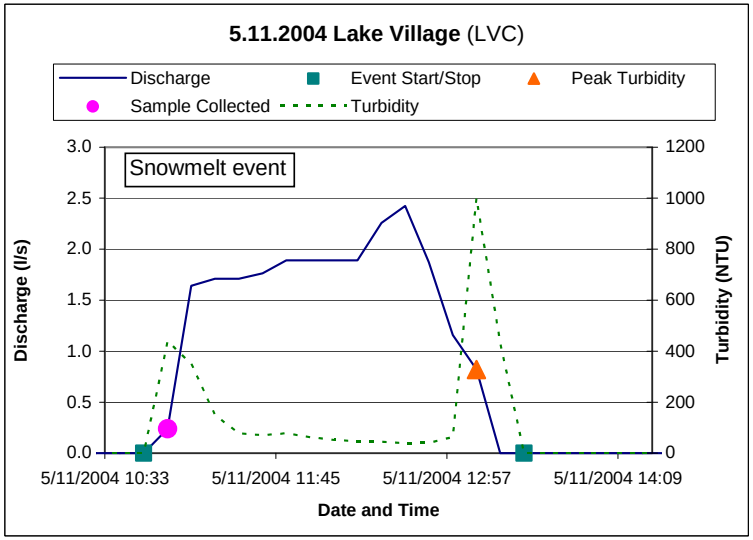
Lake Village Catchment C pre-BMP events with no discharge data

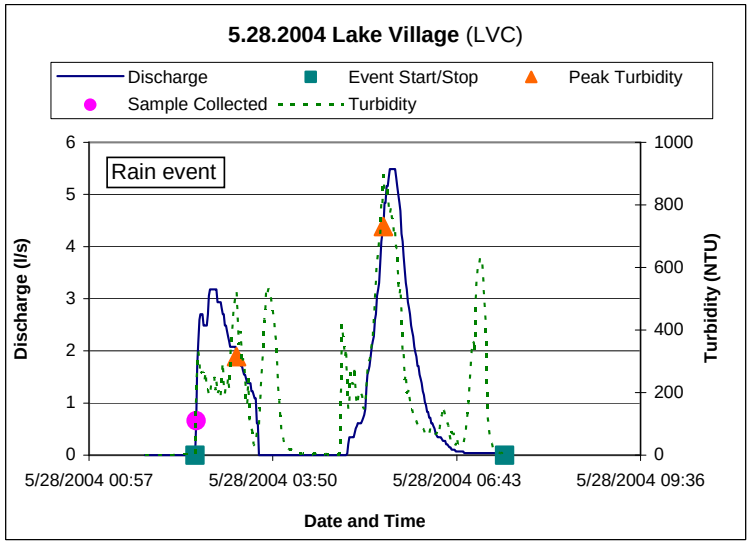
Event Date	Event Type	Data
11/9/2003	rain or rain/snow	No discharge data available
12/5/2003	rain or rain/snow	
12/6/2003	rain or rain/snow	
12/24/2003	rain on snow	
12/29/2003	rain on snow	
3/5/2004	snowmelt	
3/11/2004	snowmelt	
4/27/2005	rain or rain/snow	
4/30/2005	rain or rain/snow	
2/27/2006	rain on snow	
4/12/2006	snowmelt	

Lake Village Catchment C Pre-BMP Events

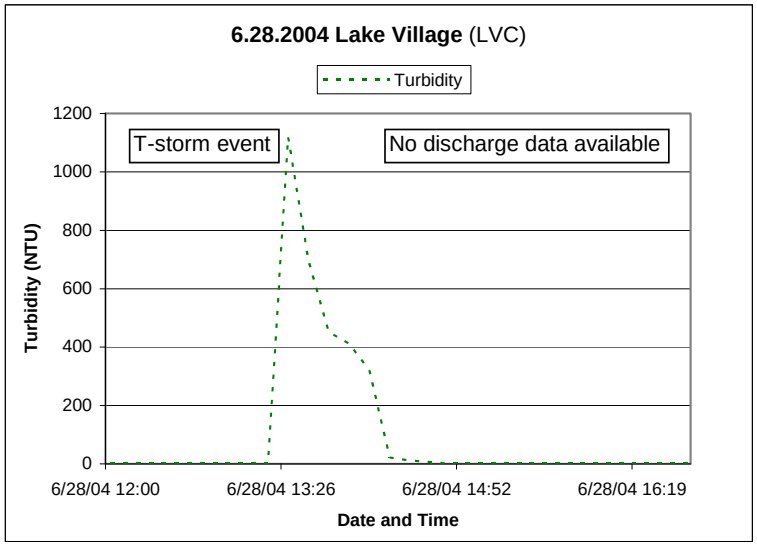


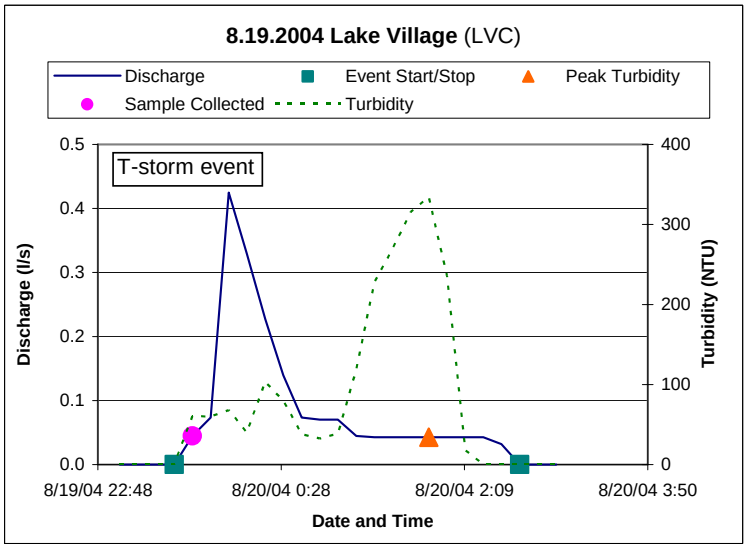


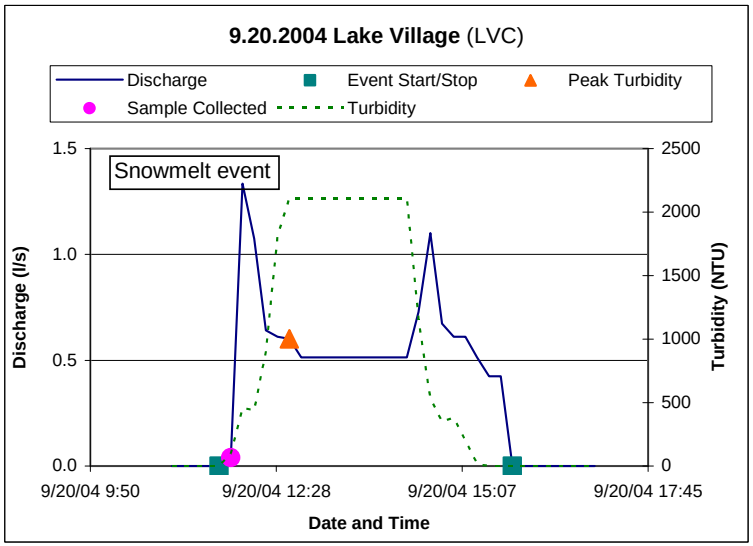


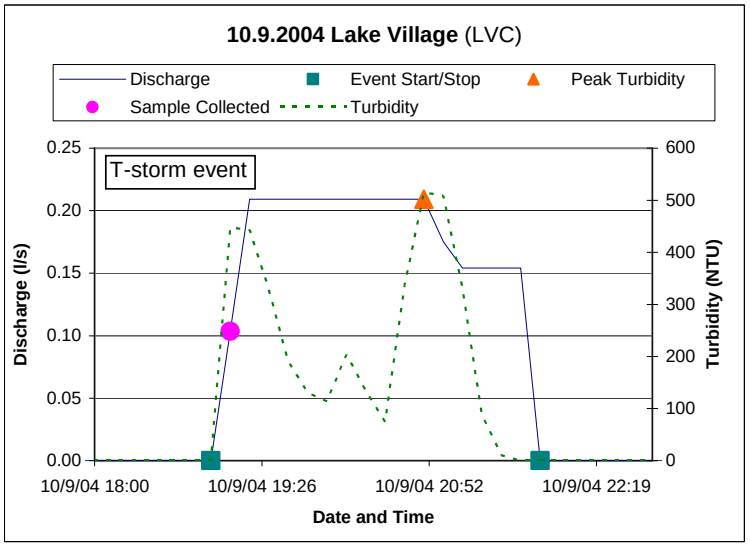


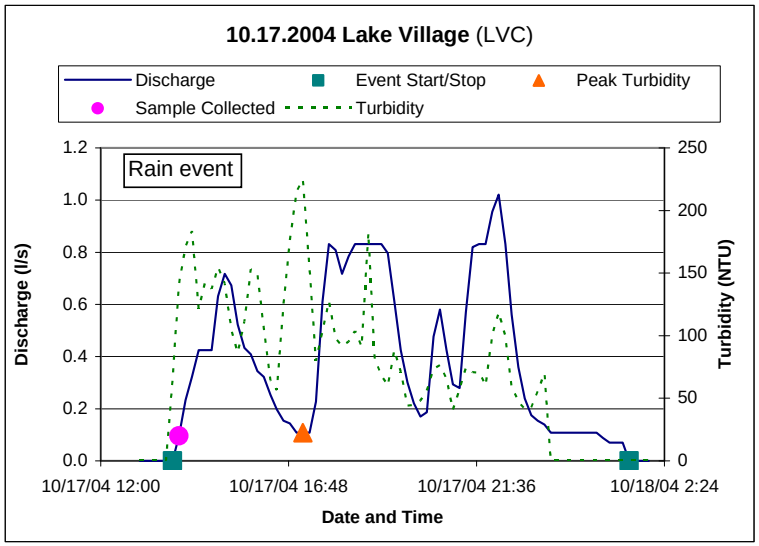
Nevada Tahoe Conservation District

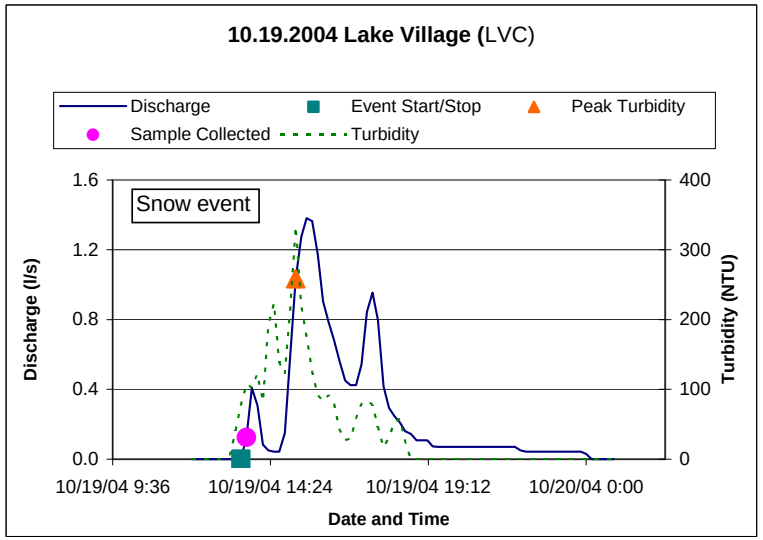

6.28.2004 Lake Village (LVC)
Turbidity
T-storm event
No discharge data available
Turbidity (NTU)
1200
1000
800
600
400
200
0
6/28/04 12:00
6/28/04 13:26
6/28/04 14:52
6/28/04 16:19
Date and Time

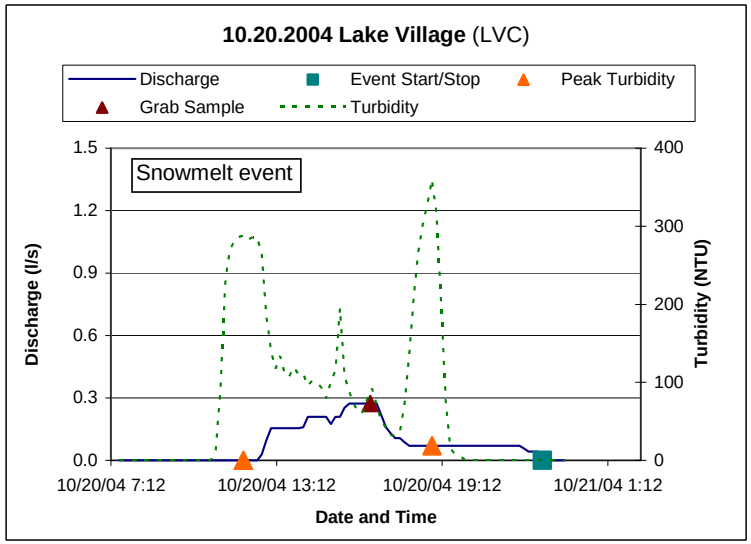

8.19.2004 Lake Village (LVC)
Discharge
Event Start/Stop
Peak Turbidity
Sample Collected
Turbidity
T-storm event
Discharge (l/s)
0.5
0.4
0.3
0.2
0.1
0.0
Turbidity (NTU)
400
300
200
100
0
8/19/04 22:48
8/20/04 0:28
8/20/04 2:09
8/20/04 3:50
Date and Time

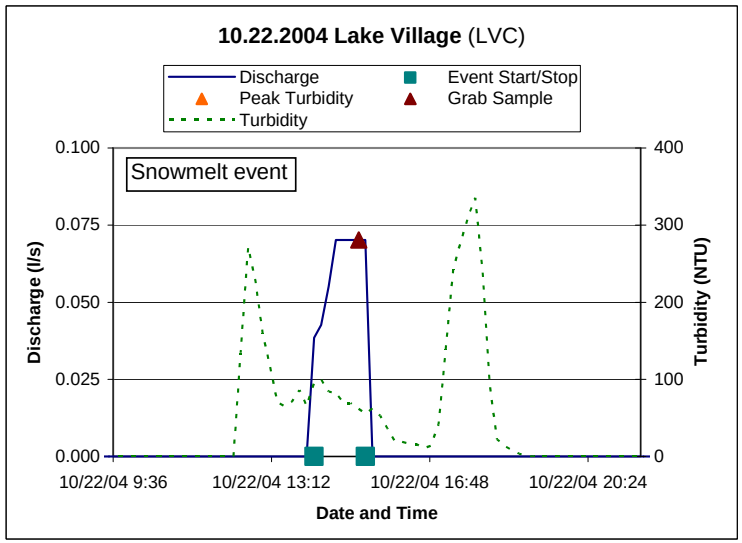

9.20.2004 Lake Village (LVC)
Discharge
Event Start/Stop
Peak Turbidity
Sample Collected
Turbidity
Snowmelt event
Discharge (l/s)
1.5
1.0
0.5
0.0
Turbidity (NTU)
2500
2000
1500
1000
500
0
9/20/04 9:50
9/20/04 12:28
9/20/04 15:07
9/20/04 17:45
Date and Time

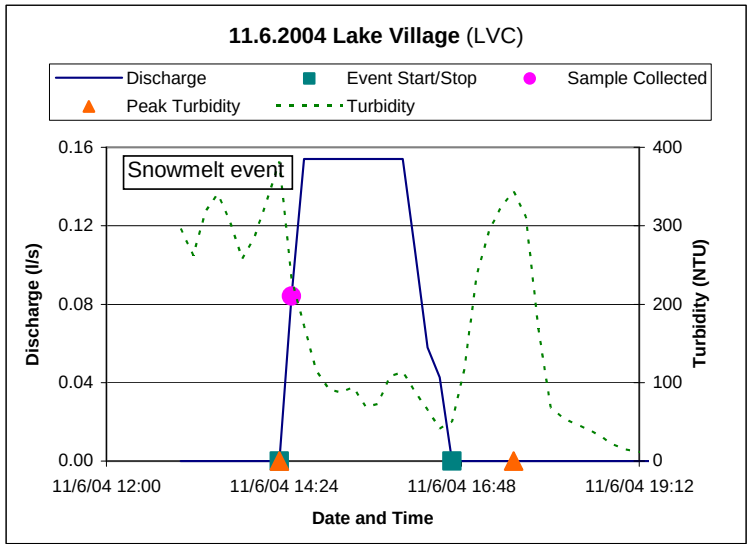

10.9.2004 Lake Village (LVC)
Discharge
Event Start/Stop
Peak Turbidity
Sample Collected
Turbidity
T-storm event
Discharge (l/s)
0.25
0.20
0.15
0.10
0.05
0.00
Turbidity (NTU)
600
500
400
300
200
100
0
10/9/04 18:00
10/9/04 19:26
10/9/04 20:52
10/9/04 22:19
Date and Time

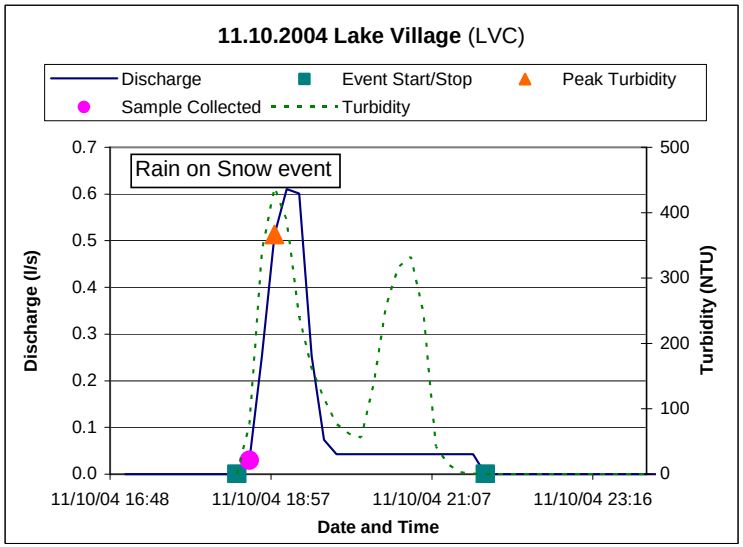

10.17.2004 Lake Village (LVC)
Discharge
Event Start/Stop
Peak Turbidity
Sample Collected
Turbidity
Rain event
Discharge (l/s)
Turbidity (NTU)
1.2
1.0
0.8
0.6
0.4
0.2
0.0
250
200
150
100
50
0
10/17/04 12:00
10/17/04 16:48
10/17/04 21:36
10/18/04 2:24
Date and Time

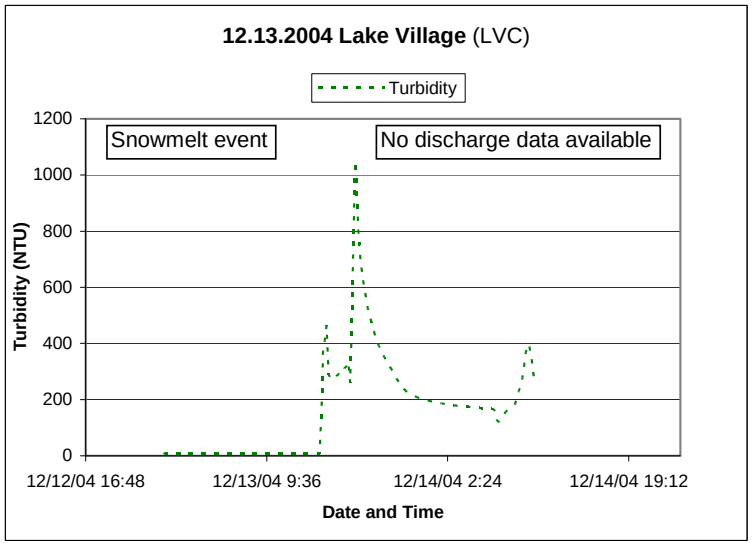

10.19.2004 Lake Village (LVC)
Discharge
Event Start/Stop
Peak Turbidity
Sample Collected
Turbidity
Snow event
Discharge (l/s)
Turbidity (NTU)
1.6
1.2
0.8
0.4
0.0
400
300
200
100
0
10/19/04 9:36
10/19/04 14:24
10/19/04 19:12
10/20/04 0:00
Date and Time

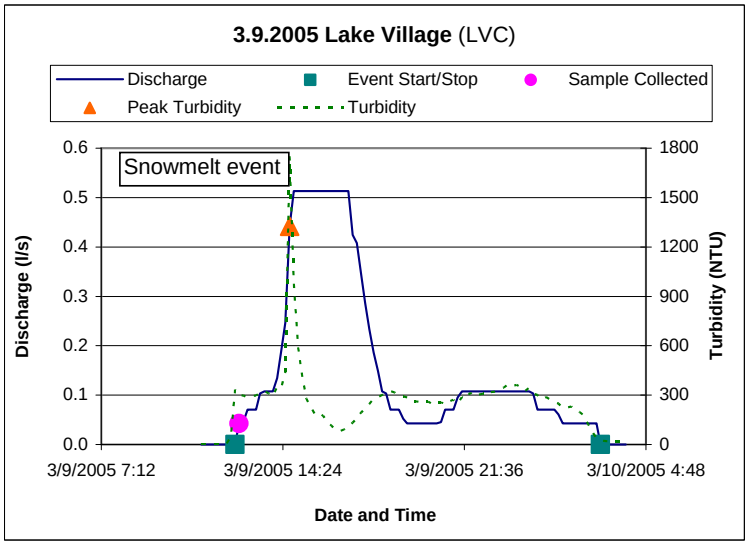

10.20.2004 Lake Village (LVC)
Discharge
Event Start/Stop
Peak Turbidity
Grab Sample
Turbidity
Snowmelt event
Discharge (l/s)
Turbidity (NTU)
1.5
1.2
0.9
0.6
0.3
0.0
400
300
200
100
0
10/20/04 7:12
10/20/04 13:12
10/20/04 19:12
10/21/04 1:12
Date and Time

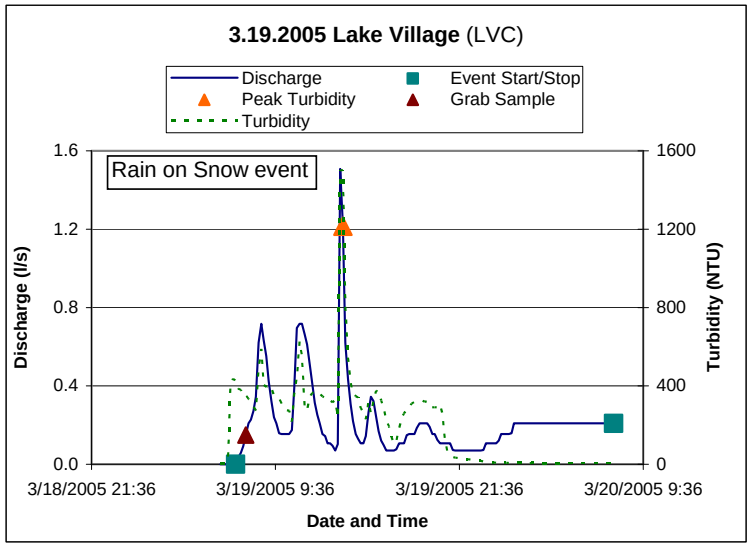

10.22.2004 Lake Village (LVC)
Discharge
Event Start/Stop
Peak Turbidity
Grab Sample
Turbidity
Snowmelt event
Discharge (l/s)
Turbidity (NTU)
0.100
0.075
0.050
0.025
0.000
400
300
200
100
0
10/22/04 9:36
10/22/04 13:12
10/22/04 16:48
10/22/04 20:24
Date and Time

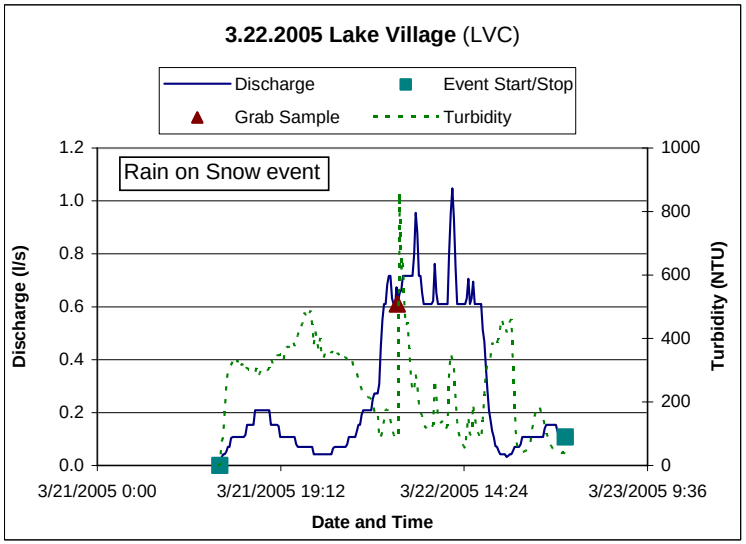

11.6.2004 Lake Village (LVC)
Discharge
Event Start/Stop
Sample Collected
Peak Turbidity
Turbidity
Snowmelt event
Discharge (l/s)
Turbidity (NTU)
0.16
0.12
0.08
0.04
0.00
400
300
200
100
0
11/6/04 12:00
11/6/04 14:24
11/6/04 16:48
11/6/04 19:12
Date and Time

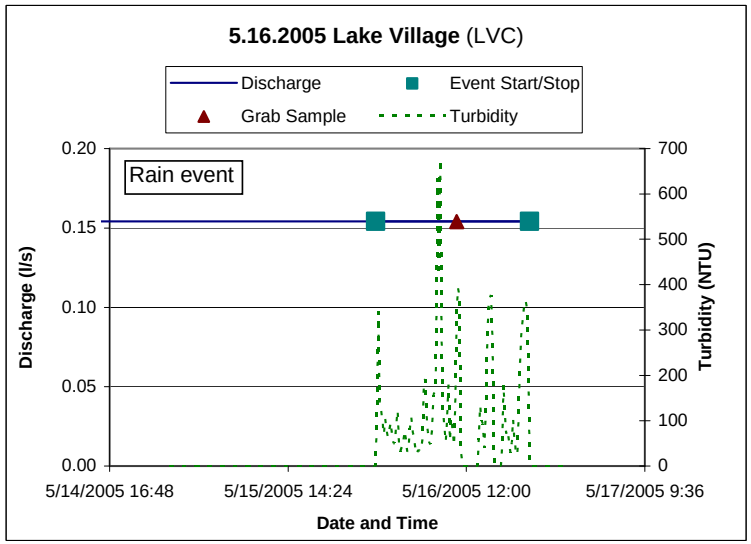

11.10.2004 Lake Village (LVC)
Discharge
Event Start/Stop
Peak Turbidity
Sample Collected
Turbidity
Rain on Snow event
Discharge (l/s)
Turbidity (NTU)
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
500
400
300
200
100
0
11/10/04 16:48
11/10/04 18:57
11/10/04 21:07
11/10/04 23:16
Date and Time

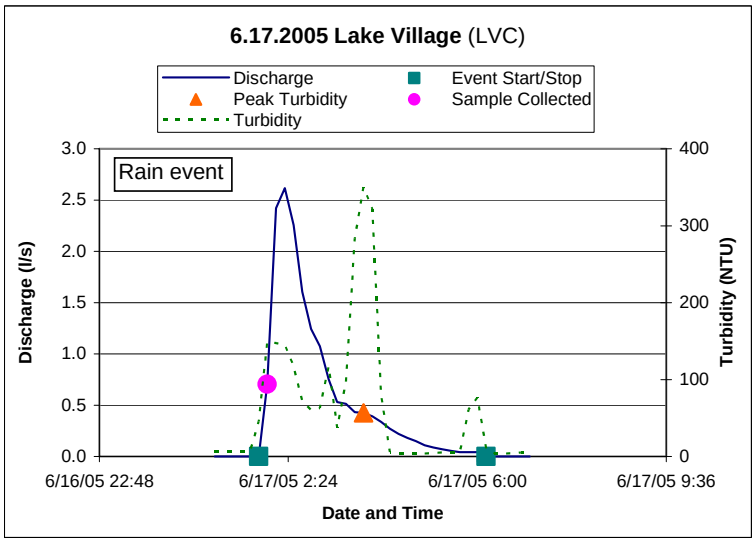

12.13.2004 Lake Village (LVC)
Turbidity
Snowmelt event
No discharge data available
Turbidity (NTU)
1200
1000
800
600
400
200
0
12/12/04 16:48
12/13/04 9:36
12/14/04 2:24
12/14/04 19:12
Date and Time

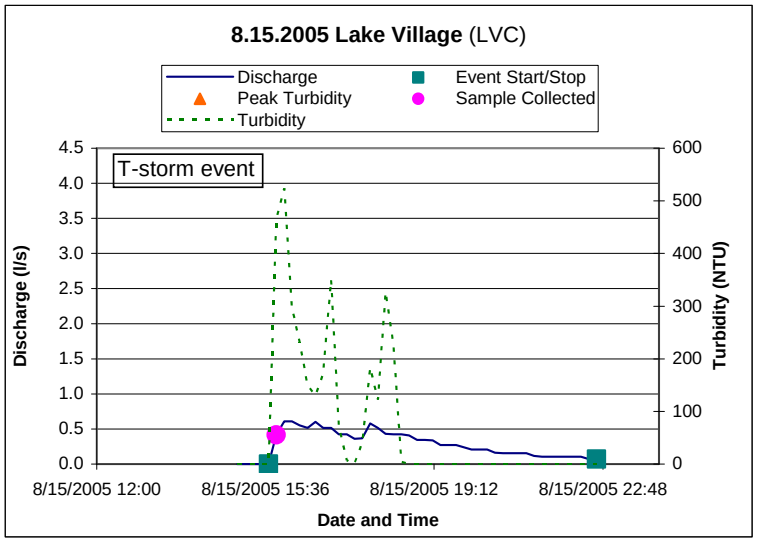

3.9.2005 Lake Village (LVC)
Discharge
Event Start/Stop
Sample Collected
Peak Turbidity
Turbidity
Snowmelt event
Discharge (l/s)
Turbidity (NTU)
0.6
0.5
0.4
0.3
0.2
0.1
0.0
1800
1500
1200
900
600
300
0
3/9/2005 7:12
3/9/2005 14:24
3/9/2005 21:36
3/10/2005 4:48
Date and Time

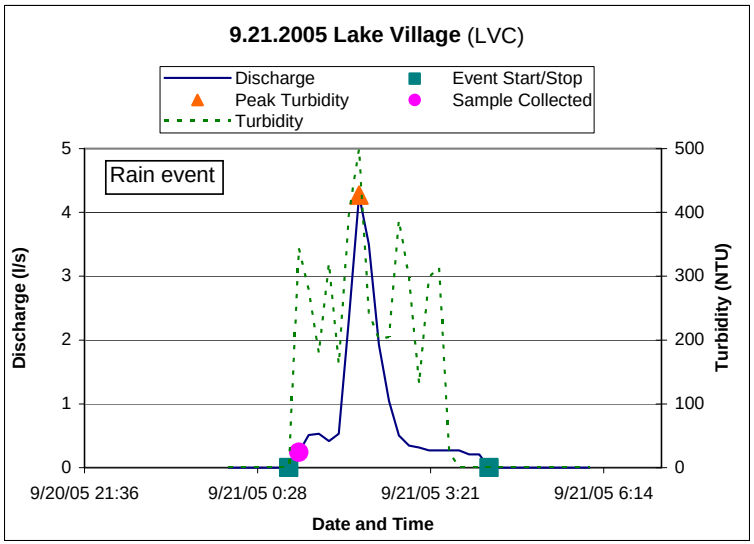

3.19.2005 Lake Village (LVC)
Discharge
Event Start/Stop
Peak Turbidity
Grab Sample
Turbidity
Rain on Snow event
Discharge (l/s)
Turbidity (NTU)
1.6
1.2
0.8
0.4
0.0
1600
1200
800
400
0
3/18/2005 21:36
3/19/2005 9:36
3/19/2005 21:36
3/20/2005 9:36
Date and Time

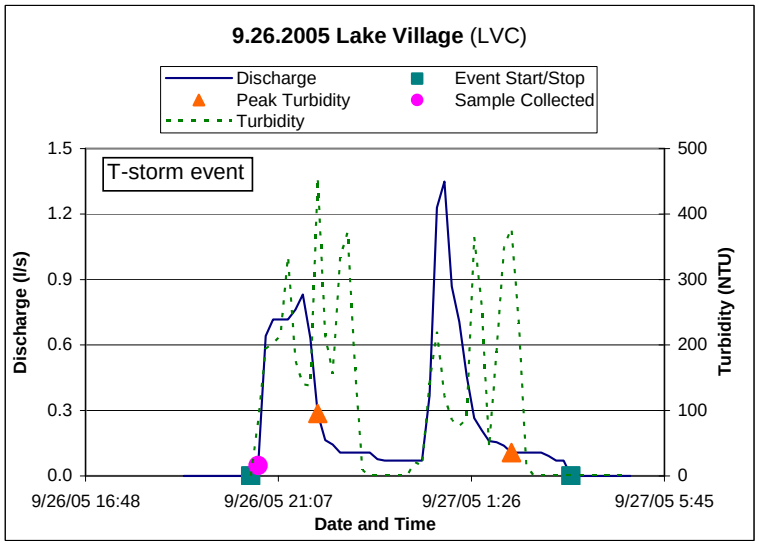

3.22.2005 Lake Village (LVC)
Discharge
Event Start/Stop
Grab Sample
Turbidity
Rain on Snow event
Discharge (l/s)
Turbidity (NTU)
1.2
1.0
0.8
0.6
0.4
0.2
0.0
1000
800
600
400
200
0
3/21/2005 0:00
3/21/2005 19:12
3/22/2005 14:24
3/23/2005 9:36
Date and Time

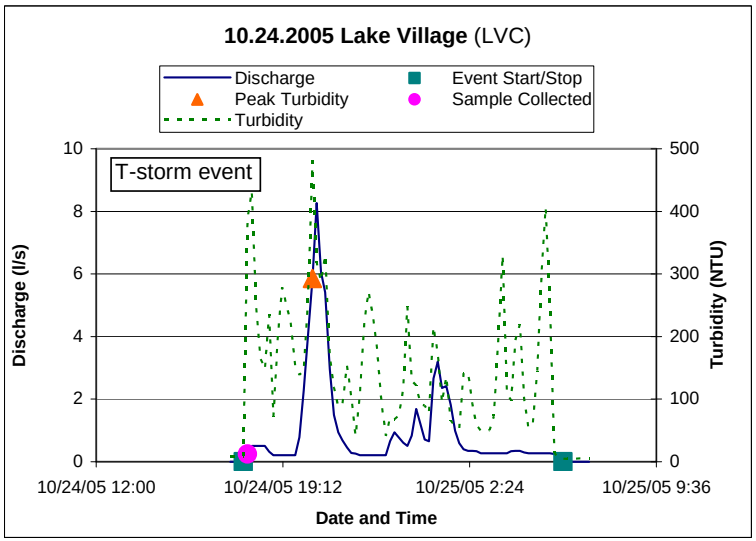

5.16.2005 Lake Village (LVC)
Discharge
Event Start/Stop
Grab Sample
Turbidity
Rain event
Discharge (l/s)
Turbidity (NTU)
0.20
0.15
0.10
0.05
0.00
700
600
500
400
300
200
100
0
5/14/2005 16:48
5/15/2005 14:24
5/16/2005 12:00
5/17/2005 9:36
Date and Time

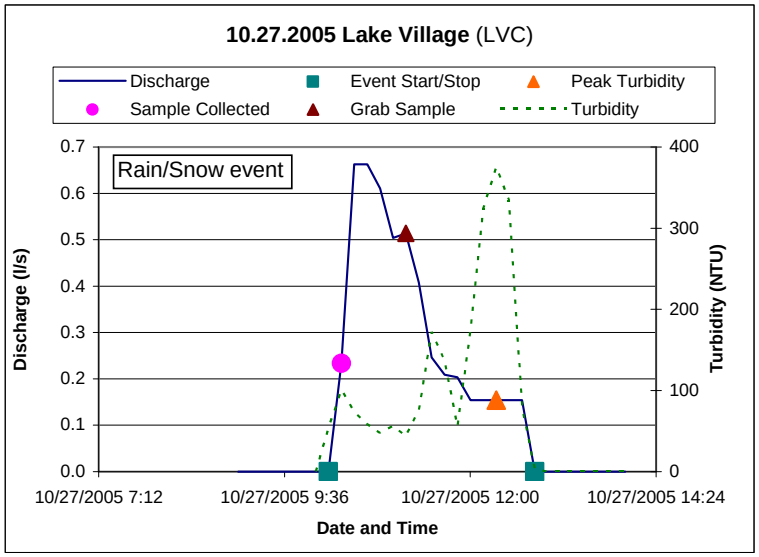

6.17.2005 Lake Village (LVC)
Discharge
Event Start/Stop
Peak Turbidity
Sample Collected
Turbidity
Rain event
Discharge (l/s)
Turbidity (NTU)
3.0
2.5
2.0
1.5
1.0
0.5
0.0
400
300
200
100
0
6/16/05 22:48
6/17/05 2:24
6/17/05 6:00
6/17/05 9:36
Date and Time

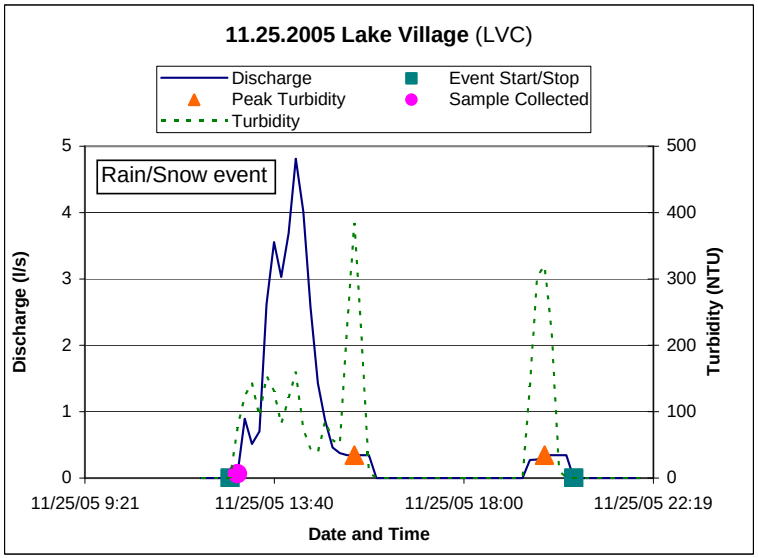

8.15.2005 Lake Village (LVC)
Discharge
Peak Turbidity
Turbidity
Event Start/Stop
Sample Collected
T-storm event
Discharge (l/s)
Turbidity (NTU)
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
600
500
400
300
200
100
0
8/15/2005 12:00
8/15/2005 15:36
8/15/2005 19:12
8/15/2005 22:48
Date and Time

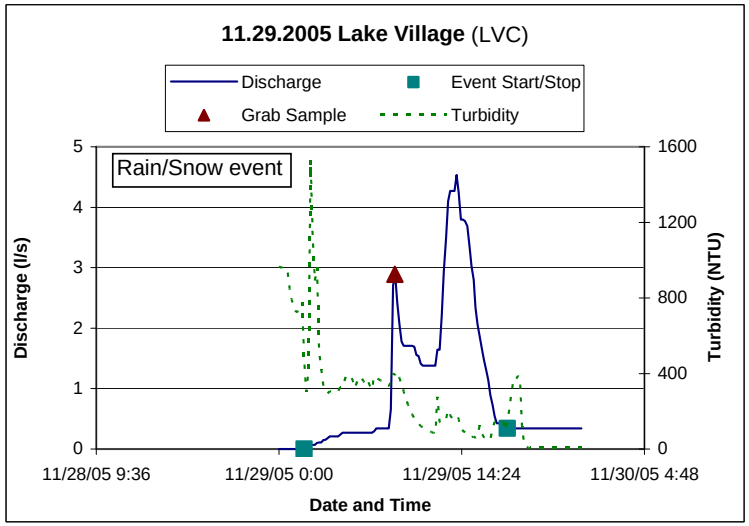

9.21.2005 Lake Village (LVC)
Discharge
Peak Turbidity
Turbidity
Event Start/Stop
Sample Collected
Rain event
Discharge (l/s)
Turbidity (NTU)
5
4
3
2
1
0
500
400
300
200
100
0
9/20/05 21:36
9/21/05 0:28
9/21/05 3:21
9/21/05 6:14
Date and Time

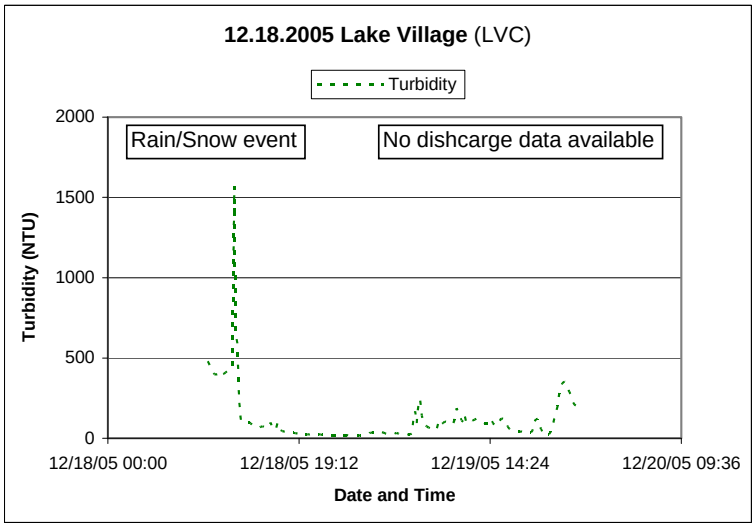

9.26.2005 Lake Village (LVC)
Discharge
Peak Turbidity
Turbidity
Event Start/Stop
Sample Collected
T-storm event
Discharge (l/s)
Turbidity (NTU)
1.5
1.2
0.9
0.6
0.3
0.0
500
400
300
200
100
0
9/26/05 16:48
9/26/05 21:07
9/27/05 1:26
9/27/05 5:45
Date and Time

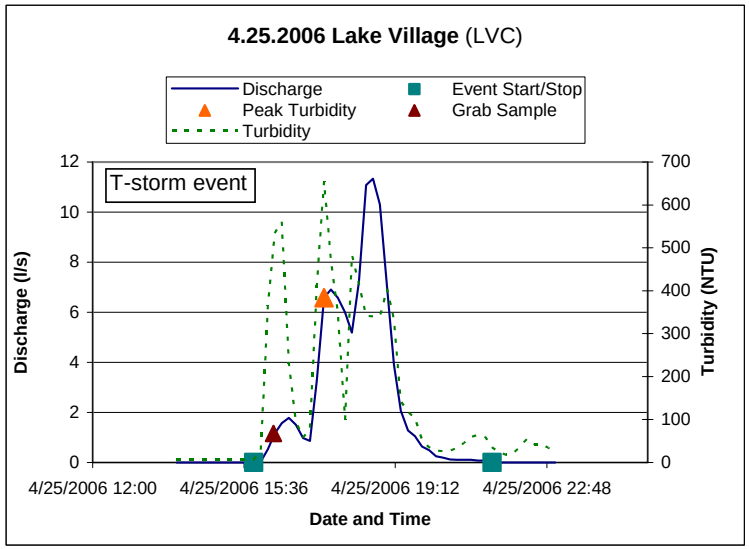

10.24.2005 Lake Village (LVC)
Discharge
Peak Turbidity
Turbidity
Event Start/Stop
Sample Collected
T-storm event
Discharge (l/s)
Turbidity (NTU)
10
8
6
4
2
0
500
400
300
200
100
0
10/24/05 12:00
10/24/05 19:12
10/25/05 2:24
10/25/05 9:36
Date and Time

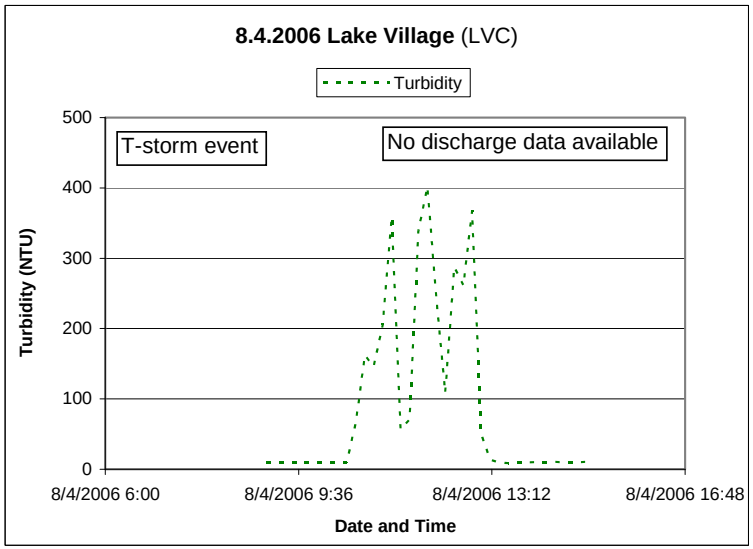

10.27.2005 Lake Village (LVC)
Discharge
Event Start/Stop
Peak Turbidity
Sample Collected
Grab Sample
Turbidity
Rain/Snow event
Discharge (l/s)
Turbidity (NTU)
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
400
300
200
100
0
10/27/2005 7:12
10/27/2005 9:36
10/27/2005 12:00
10/27/2005 14:24
Date and Time

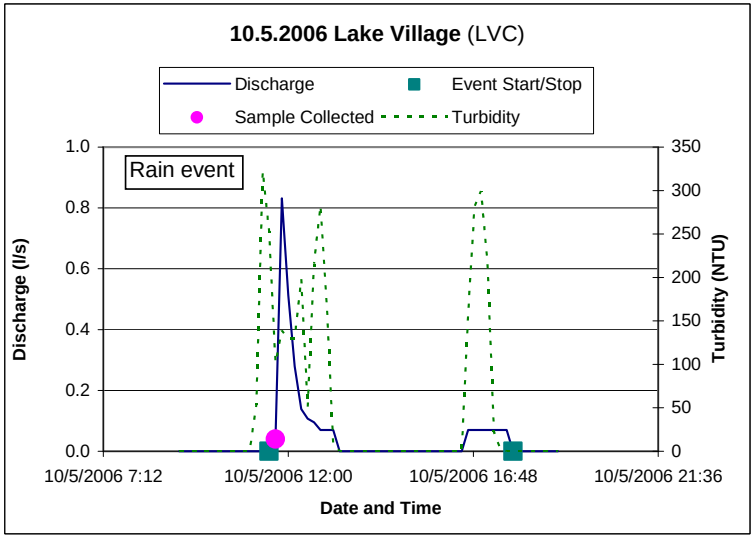

11.25.2005 Lake Village (LVC)
Discharge
Event Start/Stop
Peak Turbidity
Sample Collected
Turbidity
Rain/Snow event
Discharge (l/s)
Turbidity (NTU)
5
4
3
2
1
0
500
400
300
200
100
0
11/25/05 9:21
11/25/05 13:40
11/25/05 18:00
11/25/05 22:19
Date and Time

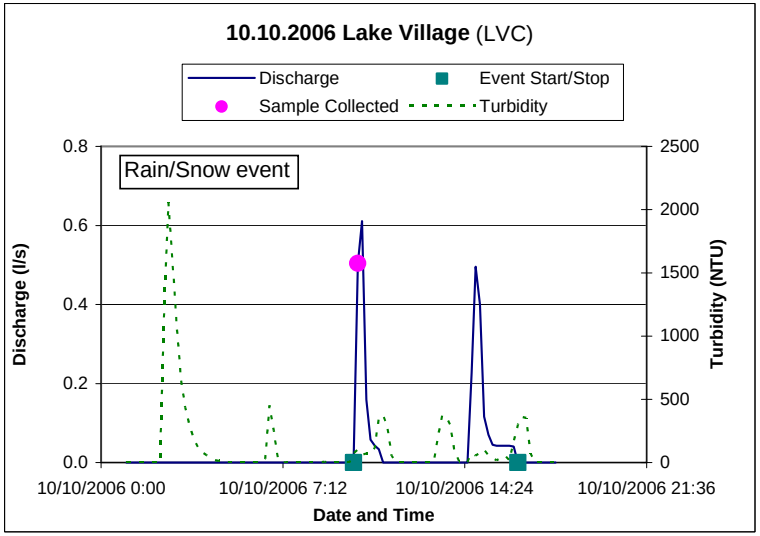

11.29.2005 Lake Village (LVC)
Discharge
Event Start/Stop
Grab Sample
Turbidity
Rain/Snow event
Discharge (l/s)
Turbidity (NTU)
5
4
3
2
1
0
1600
1200
800
400
0
11/28/05 9:36
11/29/05 0:00
11/29/05 14:24
11/30/05 4:48
Date and Time


12.18.2005 Lake Village (LVC)
Turbidity
Rain/Snow event
No dishcarge data available
Turbidity (NTU)
2000
1500
1000
500
0
12/18/05 00:00
12/18/05 19:12
12/19/05 14:24
12/20/05 09:36
Date and Time

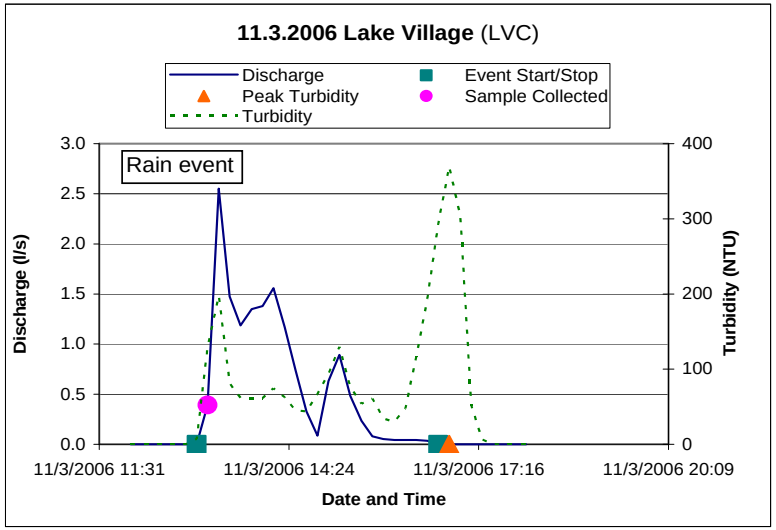


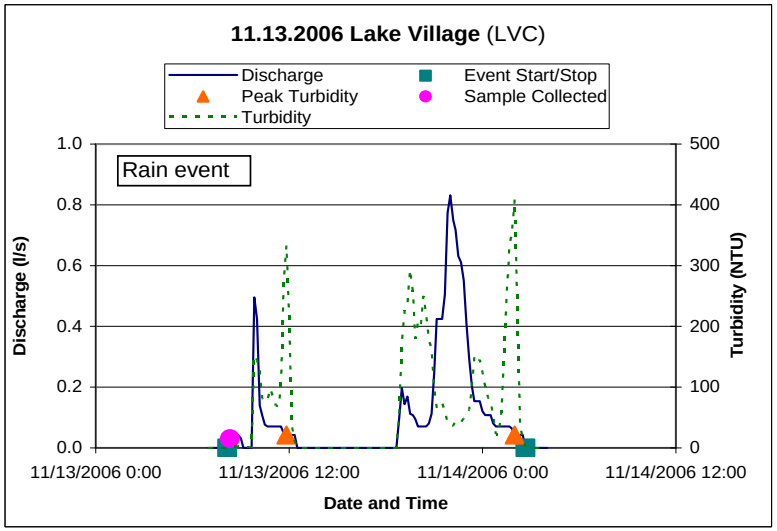


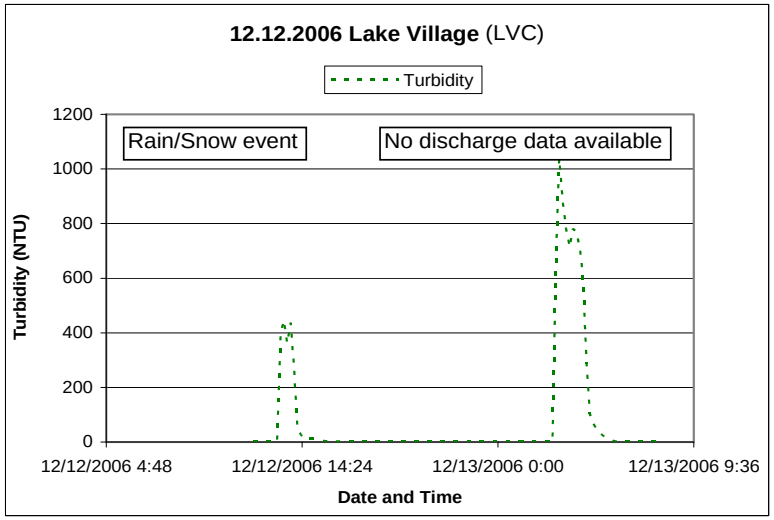


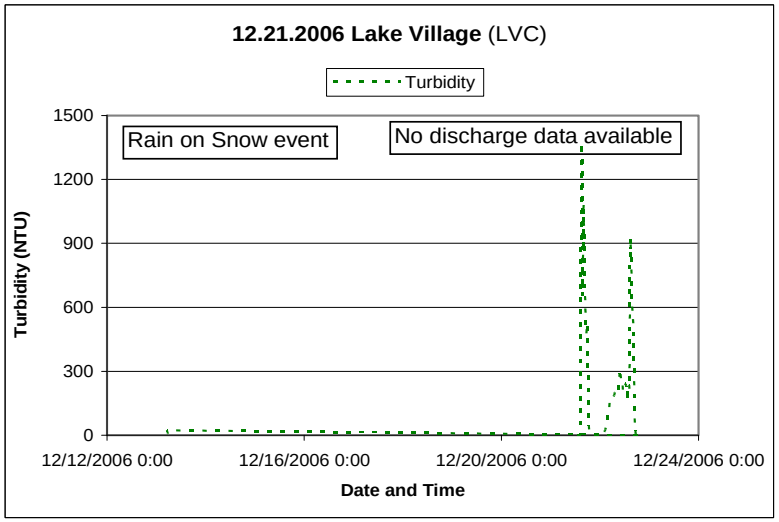


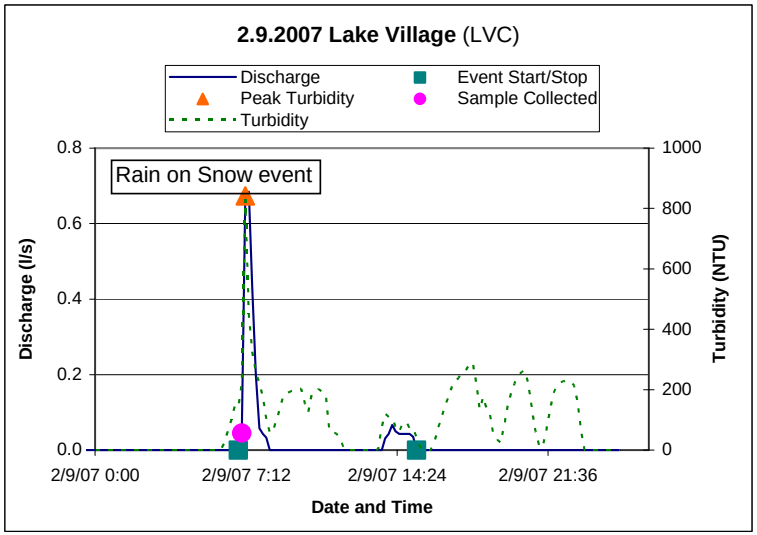
Lake Village Catchment C Post-BMP Events

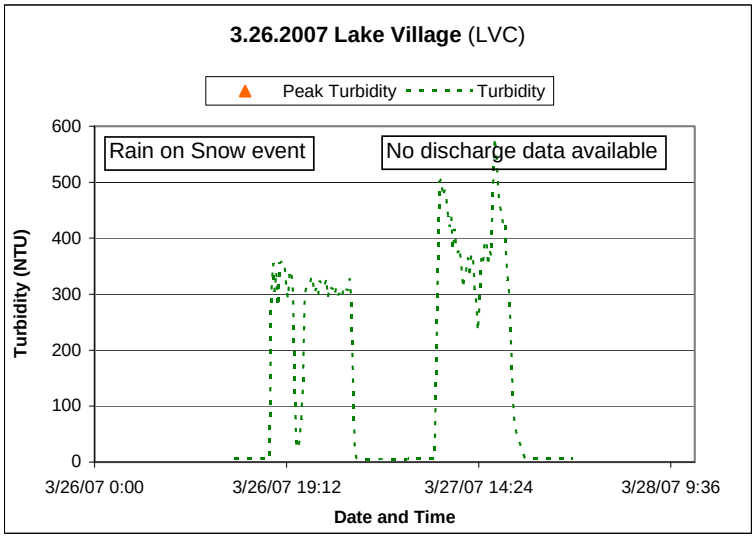

11.3.2006 Lake Village (LVC)
Discharge
Peak Turbidity
Turbidity
Event Start/Stop
Sample Collected
Rain event
Discharge (l/s)
Turbidity (NTU)
3.0
2.5
2.0
1.5
1.0
0.5
0.0
400
300
200
100
0
11/3/2006 11:31
11/3/2006 14:24
11/3/2006 17:16
11/3/2006 20:09
Date and Time

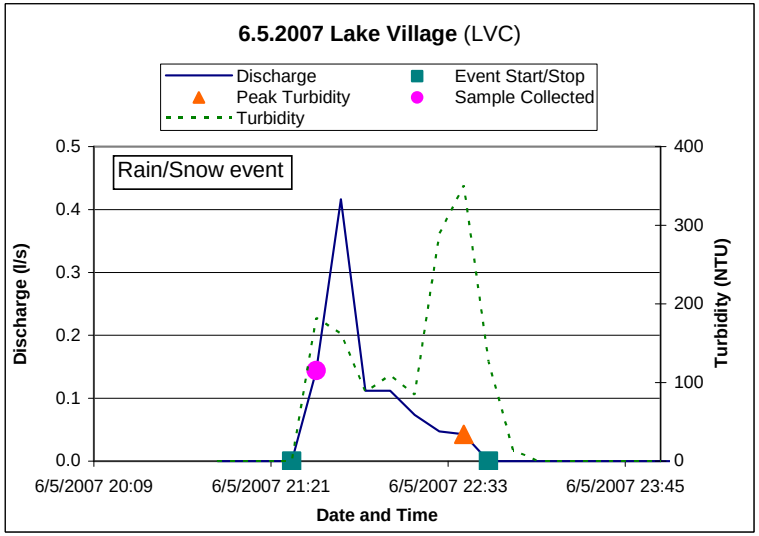

11.13.2006 Lake Village (LVC)
Discharge
Peak Turbidity
Turbidity
Event Start/Stop
Sample Collected
Rain event
Discharge (l/s)
Turbidity (NTU)
1.0
0.8
0.6
0.4
0.2
0.0
500
400
300
200
100
0
11/13/2006 0:00
11/13/2006 12:00
11/14/2006 0:00
11/14/2006 12:00
Date and Time

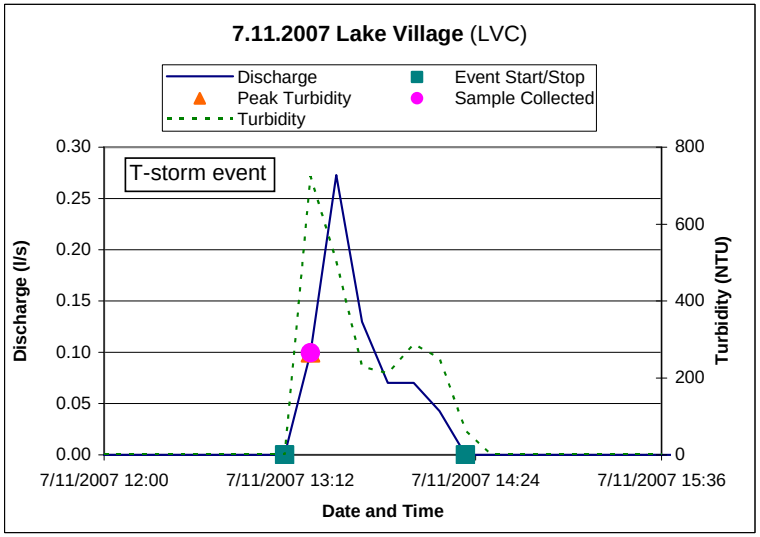

12.12.2006 Lake Village (LVC)
Turbidity
Rain/Snow event
No discharge data available
Turbidity (NTU)
1200
1000
800
600
400
200
0
12/12/2006 4:48
12/12/2006 14:24
12/13/2006 0:00
12/13/2006 9:36
Date and Time

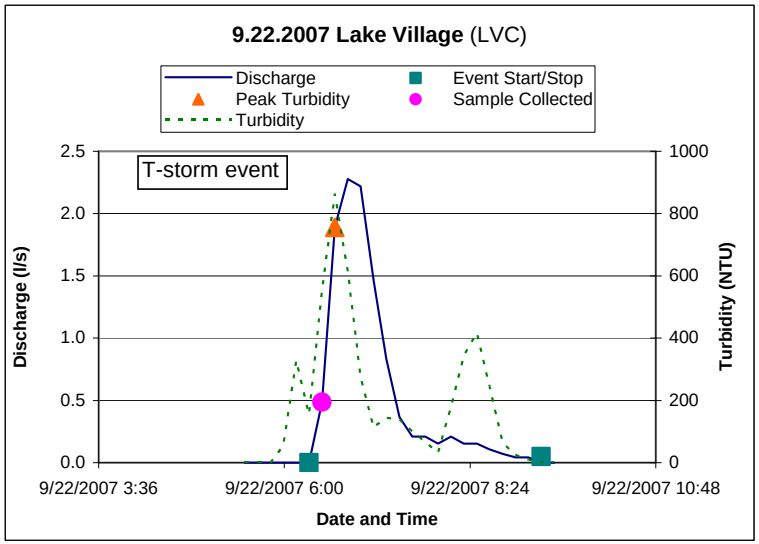

12.21.2006 Lake Village (LVC)
Turbidity
Rain on Snow event
No discharge data available
Turbidity (NTU)
1500
1200
900
600
300
0
12/12/2006 0:00
12/16/2006 0:00
12/20/2006 0:00
12/24/2006 0:00
Date and Time

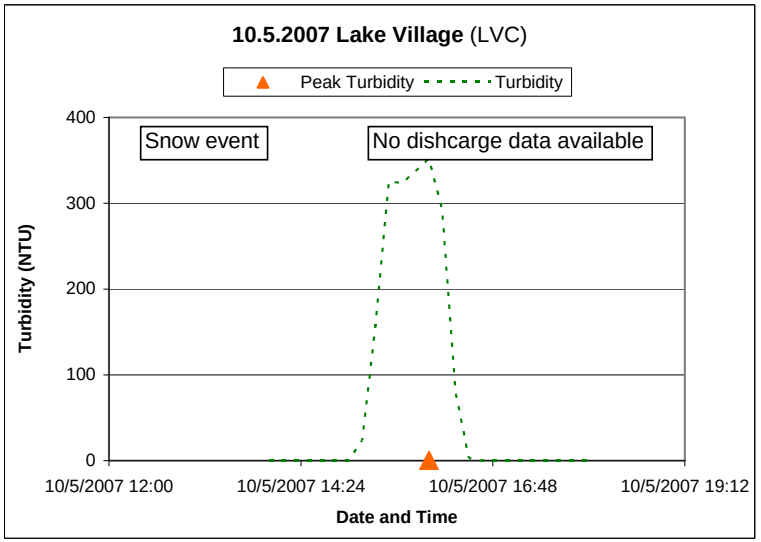

2.9.2007 Lake Village (LVC)
Discharge
Peak Turbidity
Turbidity
Event Start/Stop
Sample Collected
Rain on Snow event
Discharge (l/s)
Turbidity (NTU)
0.8
0.6
0.4
0.2
0.0
1000
800
600
400
200
0
2/9/07 0:00
2/9/07 7:12
2/9/07 14:24
2/9/07 21:36
Date and Time

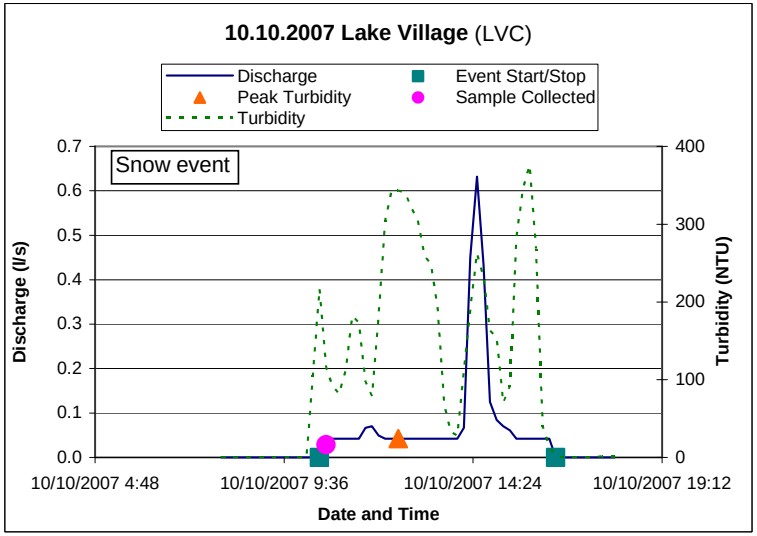

3.26.2007 Lake Village (LVC)
Peak Turbidity
Turbidity
Rain on Snow event
No discharge data available
Turbidity (NTU)
600
500
400
300
200
100
0
3/26/07 0:00
3/26/07 19:12
3/27/07 14:24
3/28/07 9:36
Date and Time

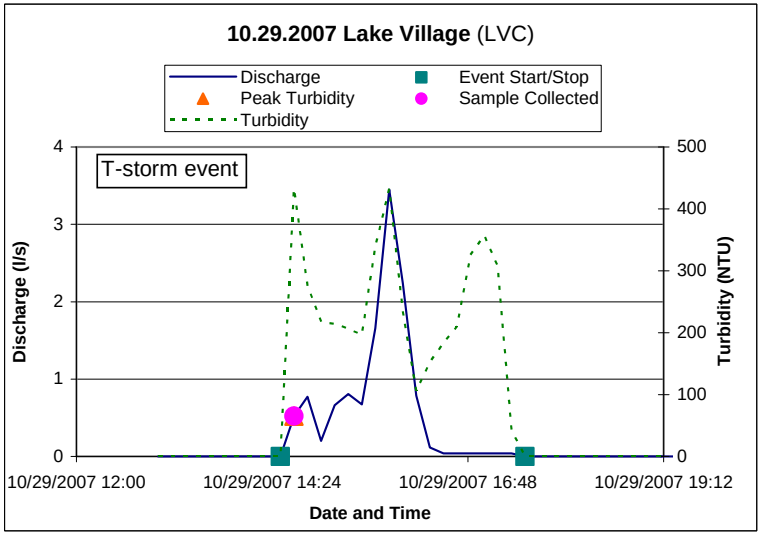

6.5.2007 Lake Village (LVC)
Discharge
Peak Turbidity
Turbidity
Event Start/Stop
Sample Collected
Rain/Snow event
Discharge (l/s)
Turbidity (NTU)
0.5
0.4
0.3
0.2
0.1
0.0
400
300
200
100
0
6/5/2007 20:09
6/5/2007 21:21
6/5/2007 22:33
6/5/2007 23:45
Date and Time

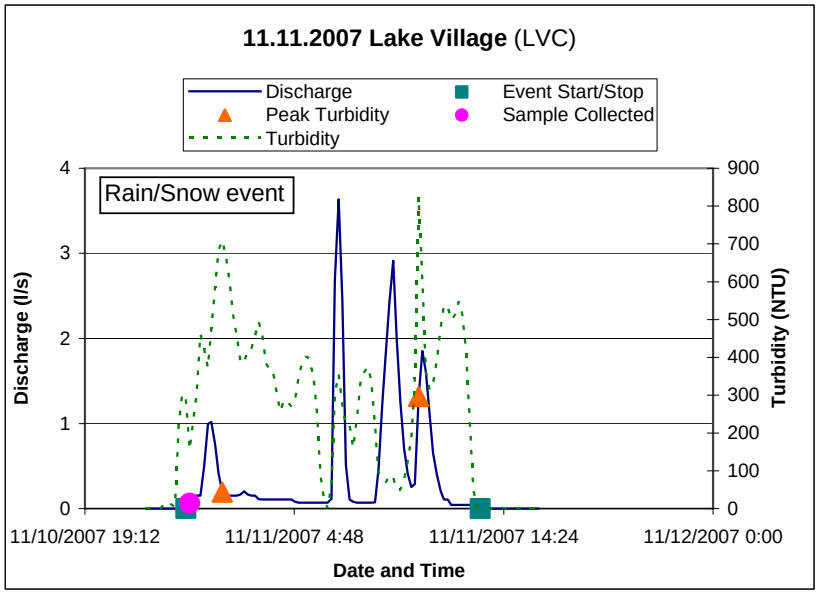

7.11.2007 Lake Village (LVC)
Discharge
Peak Turbidity
Turbidity
Event Start/Stop
Sample Collected
T-storm event
Discharge (l/s)
Turbidity (NTU)
0.30
0.25
0.20
0.15
0.10
0.05
0.00
800
600
400
200
0
7/11/2007 12:00
7/11/2007 13:12
7/11/2007 14:24
7/11/2007 15:36
Date and Time

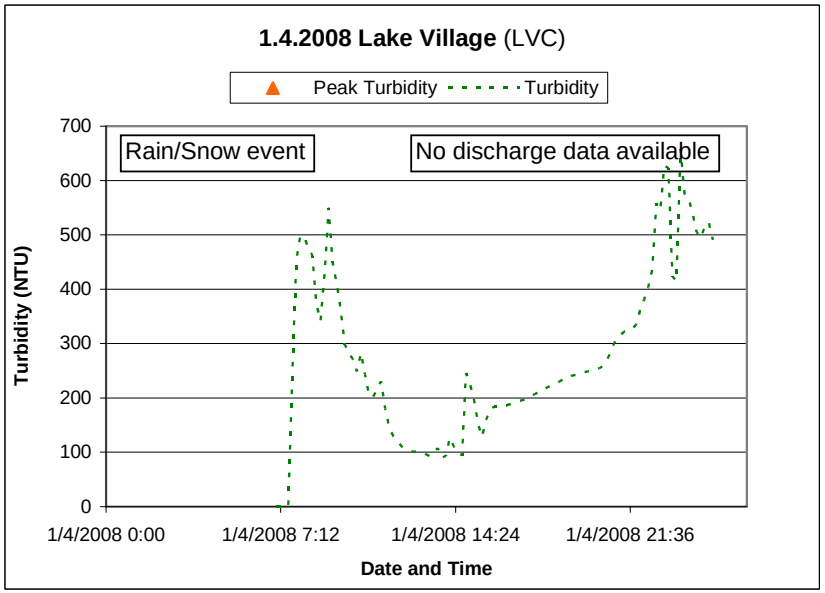

9.22.2007 Lake Village (LVC)
Discharge
Peak Turbidity
Turbidity
Event Start/Stop
Sample Collected
T-storm event
Discharge (l/s)
Turbidity (NTU)
2.5
2.0
1.5
1.0
0.5
0.0
1000
800
600
400
200
0
9/22/2007 3:36
9/22/2007 6:00
9/22/2007 8:24
9/22/2007 10:48
Date and Time


10.5.2007 Lake Village (LVC)
Peak Turbidity
Turbidity
Snow event
No dishcarge data available
Turbidity (NTU)
400
300
200
100
0
10/5/2007 12:00
10/5/2007 14:24
10/5/2007 16:48
10/5/2007 19:12
Date and Time


10.10.2007 Lake Village (LVC)
Discharge
Peak Turbidity
Turbidity
Event Start/Stop
Sample Collected
Snow event
Discharge (l/s)
Turbidity (NTU)
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
400
300
200
100
0
10/10/2007 4:48
10/10/2007 9:36
10/10/2007 14:24
10/10/2007 19:12
Date and Time


10.29.2007 Lake Village (LVC)
Discharge
Peak Turbidity
Turbidity
Event Start/Stop
Sample Collected
T-storm event
Discharge (l/s)
Turbidity (NTU)
4
3
2
1
0
500
400
300
200
100
0
10/29/2007 12:00
10/29/2007 14:24
10/29/2007 16:48
10/29/2007 19:12
Date and Time


11.11.2007 Lake Village (LVC)
Discharge
Peak Turbidity
Turbidity
Event Start/Stop
Sample Collected
Rain/Snow event
Discharge (l/s)
Turbidity (NTU)
0
1
2
3
4
0
100
200
300
400
500
600
700
800
900
11/10/2007 19:12
11/11/2007 4:48
11/11/2007 14:24
11/12/2007 0:00
Date and Time


1.4.2008 Lake Village (LVC)
Peak Turbidity
Turbidity
Rain/Snow event
No discharge data available
Turbidity (NTU)
0
100
200
300
400
500
600
700
1/4/2008 0:00
1/4/2008 7:12
1/4/2008 14:24
1/4/2008 21:36
Date and Time

APPENDIX F

Sample and Analysis Plan