



Southern Rockies Watershed Project

2nd Interim Report

Three year study results (2004-2006)
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Alberta Sustainable Resource Development
Alberta Environment
Alberta Innovation - Centre for Water Research
Canada Dept. of Fisheries & Oceans
Oldman Watershed Council

Prepared by

Dr. Uldis Silins, Dept. of Renewable Resources, University of Alberta
Michael Wagner, Dept. of Renewable Resources, University of Alberta

Collaborators/Co-investigators

Erin Kelly, Dept. of Biological Sciences, University of Alberta
Dr. Michael Stone, School of Planning, University of Waterloo
Dr. Monica Emelko, Dept. of Civil & Environmental Engineering, University of Waterloo
Dr. David Schindler, Dept. of Biological Sciences, University of Alberta
Dr. Thian Gan, Dept. of Civil & Environmental Engineering, University of Alberta
Dr. Kevin Devito, Dept. of Biological Sciences, University of Alberta
Dr. Carl Mendoza, Dept. of Earth & Atmospheric Sciences, University of Alberta
Dr. Richard Petrone, Dept. of Geography, Wilfred Laurier University

Executive summary

The 2003 Lost Creek wildfire in the Crowsnest Pass was one of the more severe forest fires in the upper eastern slopes in many decades. Given the high fire severity of the much of the area burned during fire, a wide range of watershed values from streamflow generation through aquatic ecology including a range of human values related to water (drinking water, water based recreation) are likely to be impacted. The Southern Rockies Watershed Project was initiated in March of 2004. The broad objectives of this research program are to evaluate both the initial effects of natural disturbance by wildfire on hydrology, water quality, aquatic ecology, and the early recovery of these values in front range headwater streams. The research is also providing crucial information on hydrology of high water yielding Rocky Mtn. watersheds that generate most of the water supply to settled regions of the province. The hydrology, water quality, aquatic ecology, and vegetation recovery will be studied during the 1st post-fire season (2004) through the subsequent 4 seasons to evaluate the magnitude of the initial effect on watershed values through 4 years of watershed recovery. The initial study design consisted of 3 burned watersheds (53-100 % burned) and two unburned (reference) watersheds for comparison. Two additional burned watersheds (58-82 % burned) that had been salvage logged were added to the study in early 2005. The study now comprises 7 fully instrumented watersheds.

Water production in the study watersheds is among the highest recorded in the province (up to 1200 mm/yr during 2004/06) due to very high annual precipitation (up to 1500 mm/yr in 2004/06), but also because of extremely high annual runoff ratios (approximately 80 % precipitation is routed as streamflow). Because the fire burned much of the forest crown cover, reduced winter snow and summer rainfall interception losses along with reduced summer transpiration by trees causes more water to be available for runoff after this type of severe burn. Reduction in snowpack interception losses has produced 2-3.5 times greater snowpacks in the burned areas during the 3 yrs. since the burn. While only limited inferences are possible without pre-disturbance streamflow data, small increases in snowmelt runoff and moderate increases in storm runoff (up to an average of 30 % for larger flow “events”) have been evident in the past 3 years.

Very large effects on most important water quality parameters have been observed during the 1st three post-fire seasons including 2-12 fold increases in sediment production in burned watersheds with substantially larger effects (2-75 fold) increases in burned & salvage logged watersheds. Similarly, concentration and stream water export of mobile forms of most nutrients (nitrogen, phosphorous, etc.) were between 2-22 times higher in burned and salvage logged compared to unburned watersheds. Though the burned and salvage logged streams have been monitored only since Jan. 2005, initial results indicate water quality may be more seriously affected than by wildfire alone. Elevated concentrations of mercury were also evident in the streams of burned watersheds during 2004-05; though generally below provincial and national water quality guidelines, mercury was periodically above both acceptable chronic and acute concentrations in 2004/05 and subsequent fish sampling indicated only smaller increases in mercury contamination of fish. These very large pulses of nutrients in streams, in turn, produced very dramatic increases in growth of algae; sometimes nearly choking some of the streams with dense algal mats. While recovery of water quality after 3 yrs was evident for nitrogen, little or no clear recovery has been evident for most other water quality parameters after 3 yrs. Vegetation surveys suggest adequate seedling regeneration has occurred in younger stands at the time of the burn, while older stands have relatively poor seedling establishment after 3 yrs.

Thus in the 3 seasons after this large wildfire, effects on some aspects of hydrology and very large effects on water quality were evident including large pulses of most nutrients, and some heavy metals (mercury) and these, in turn, produced nearly immediate effects on aquatic production in these streams at several trophic levels (primary and secondary producers) that have persisted for 3 yrs. Landscape recovery is likely to follow several different trajectories depending on the watershed “value” in question.

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1 Introduction

1.1 Background

The Southern Rockies region of Alberta's Eastern Slopes Forests forms the headwaters of the Oldman River; one of Alberta's most important river systems in terms of regional social and economic values. Hydrologically, the southern Rockies forest region constitutes a provincial end-member as the highest water yielding region of Alberta because as it has both the highest regional precipitation and the highest provincial runoff ratios (annual streamflow as a proportion of annual precipitation) which generate the majority of streamflow in the Oldman River. This feature along with the particular importance of the Oldman River to the water security of southern Alberta distinguishes the southern Rockies area from other forested regions in the province.

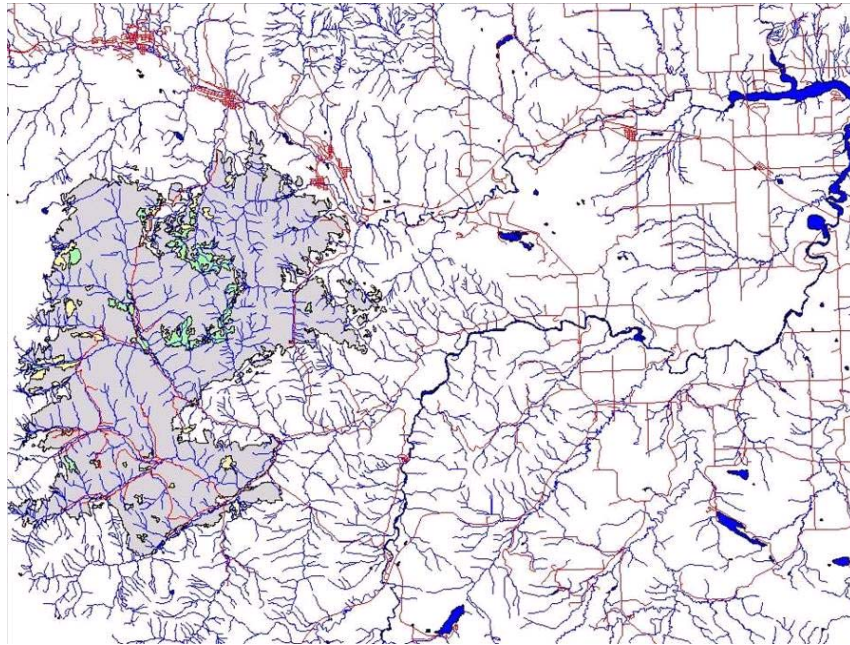
The Oldman River downstream of the southern Rockies area provides domestic water for many municipalities, supports a broad base of regional agriculture with irrigation and stock water, and with the local area provides for a broad range of water-based recreation, and supports what is arguably one of the provinces most economically valuable fisheries. However, the past decade of periodic droughts, potential effects of changing precipitation patterns and climate, recent wildfires, along with increased development in the forested region by the petrochemical, forestry, and municipal sectors raise important concerns about water quantity and quality in the headwater streams and rivers supporting the Oldman River system. Given the present near full allocation of water for human use in this watershed along with the possibility of longer-term limitations in water supply with continued episodic drought or longer term climate change, understanding and predicting how climatic and land use changes in this region are likely to affect production/timing of streamflow and water quality will be increasingly important to the region.

In July-Aug. of 2003, the Lost Creek fire in the Crowsnest pass burned 21,000 hectares (Figure 1) and was one of the most severe forest fires in the upper eastern slopes in many decades. The fire burned as a nearly contiguous crown fire consuming virtually all forest floor organic matter on the landscape. The fire burned the headwater regions of both the Castle and Crowsnest rivers. These two rivers represent an important headwater component of the Oldman River supporting a broad spectrum of human uses from domestic/agricultural water supply to water based recreation. Water quality issues are important for domestic water supply both within the municipality of Crowsnest Pass and further downstream. Provincial and federal government have serious concerns about how this fire might affect local and regional water-based resources. However, the lack of data at the smaller watershed scale (where effects are generally greatest) does not enable cumulative effects of such disturbances to be evaluated at present.

Changes to streamflow (increased yield, magnitude of peak flows, potential flood flows) and water quality deterioration (physical and chemical) are likely to occur as a result of the effect of the fire on several important hydrologic processes (evapotranspiration dynamics, runoff generation). In turn, changes to stream morphology, and in-stream habitats are also likely, thus impacting the aquatic ecology and fisheries within and downstream of the burn. From a landscape perspective, ecosystem productivity may also be affected for an extensive period given the extreme severity of the fire and its role in nutrient status of the landscape.

Figure 1

Map of the 2003 Lost Creek wildfire showing the Crowsnest River (north) and Castle River (south). The west end of the Oldman Dam is shown in the north-east portion. Grey areas indicate contiguous crown burn, yellow indicates partial crown burn, and green areas are fire skips.



The Lost Creek fire represents a unique opportunity from several important scientific perspectives:

1. Unique and Rare Research Opportunity - Since the effects of fire on hydrology and water quality are greatest in the period immediately after fire and then recover over time, this fire offers a rare opportunity to document the large initial pulses of nutrients/sediments expected and track the hydrologic recovery of the region over the next few years. Given the infrequent/random nature of wildfires, relatively few watershed studies have been conducted on fire effects in North America. In Alberta, no previous fire-watershed studies (Virginia Hills, Dogrib fires) have been able to document the initial fire effects on hydrology as they were initiated too late (up to several seasons) after the burns occurred.
2. The timing and location of this fire offers a unique opportunity to study and contrast natural (fire) and man caused (forest harvesting) forest disturbance effects on streamflow and water quality. This will be increasingly important to evaluate land use effects on water resources given broad adoption of "Natural Disturbance" based forest management planning in Alberta.
3. Unique or Special Hydrologic Setting – The Crowsnest pass region represents the highest water yielding region of Alberta along with the highest regional precipitation. The headwaters region (including the Castle, Crowsnest, and Oldman rivers) generate the vast majority (over 90-95 %) of surface water supplies for the Oldman River basin. While the importance of winter snow packs in regulating these water supplies is recognized in general, the runoff generation dynamics (i.e. direct runoff, groundwater inputs, water storage) in this region are poorly understood. These features will become increasingly important to understand and predict the influence of short- and long-term climatic fluctuations on surface water supplies and water security downstream. This feature along with the particular importance of the area to the water supply of southern Alberta distinguishes this research opportunity from others.

1.2 Goals & Objectives

Project Goals

1. Evaluate effects of natural disturbance by wildfire on hydrology (streamflow and timing of streamflows), water quality, and aquatic ecology of headwater streams affected by the 2003 Lost Creek wildfire. This includes characterizing the full hydrologic behaviour of snowpack dominated, high water yielding Rocky Mtn. watersheds which are not presently well described in Alberta yet supply the vast majority of usable water supplies for Alberta.
2. Evaluate the comparative effects of natural disturbance by wildfire and man made disturbances by forestry development on hydrology (streamflow and timing of streamflows), water quality, and aquatic ecology of headwaters streams in the Southern Rockies region.

Short term and long term research objectives

Short-term research objectives

The Southern Rockies Watershed Project (SRWP) is initially focused on describing the full suite of hydrologic effects of the 2003 Lost Creek wildfire (goal #1 above) in addition to providing some of the key empirical insights into hydrology of high water yielding Rocky Mtn. watersheds that does not presently exist in Alberta. Specific research objectives are to describe fire effects on streamflow (unit area streamflows, timing and magnitude of the spring snowmelt freshet, peak flows), key water quality parameters (physical and chemical), snow pack processes (accumulation, interception, re-distribution, melt dynamics), and watershed scale nutrient dynamics in several burned and burned & subsequently salvage logged watersheds relative to these same parameters in two un-burned (reference) watersheds. The trajectory of post-disturbance recovery of these watershed “values” is a major focus of this work. This study will be conducted over a 5 year period (2004-2009).

Longer-term research objectives

At the outset of this study, one of two longer term objectives was to evaluate the comparative effects of natural disturbance by wildfire with the effects of forest harvesting. However, beginning in 2004 the oncoming threat of potentially severe natural disturbance by catastrophic insect outbreak (Mountain Pine Beetle) was looming. It is likely that if this research continues beyond 2009, both Mtn. Pine Beetle hydrology and likely a range of management assisted control/recovery strategies would likely be crucial strategic issues to tackle in any possible future research in this area. A unique opportunity exists because the two undisturbed (reference) watersheds in the fire research will be fully calibrated with one another after 5 years of monitoring in the fire research which would enable a subsequent “paired watershed” study focused on either pine beetle or harvesting strategies and their effects on watershed processes. Paired watershed studies offer much more powerful insights into how watershed processes are affected by disturbance because the effects of climatic variability can be disentangled from those produced by disturbances such as fire or harvesting. One of these two watersheds could be harvested or otherwise treated and the other left as a true “control”. Along with the fire research, this will provide powerful insights into the comparative watershed effects of natural and man made disturbances on watershed function.

2 Materials & Methods

2.1 Study Area

Watersheds for this study were selected in a region that did not contain areas with significant confounding influence of logging disturbance prior to the 2003 Lost Creek wildfire. As much of the southern portion of the burn was previously harvested, study watersheds were selected in the northern end

of the fire. The study area is located immediately south of the Crowsnest Pass and includes the northern tip of the Flathead mountain range marking the British Columbia border on the western portion and stretches east across the Blairmore range including Willoughby and Hastings ridges to Turtle and Hillcrest mountains on the eastern edge.

Preliminary identification of research watersheds took place in Aug-Oct. 2003 with final site selection completed in March 2004 (Figure 2, Table 1). The study design initially consisted of 3 burned watersheds (upper Lynx Ck., South York Ck. & Drum Ck.) and 2 unburned (reference) watersheds (Star Ck. & North York Ck.). In early 2005, two additional burned and subsequently salvaged logged watersheds were added to the study (Lyons Ck. East-fork & Lyons Ck. West-fork). Salvage operations in these watersheds began in the winter of 2003/04 and continued through to the winter of 2004/05.

Lynx Ck. drains south into the Castle river drainage while the remaining 6 watersheds drain north into the Crowsnest River. All 7 watersheds have north to north-east aspect. The average watershed size is 8.3 km² (3.6-13.2 km²) with an average area-weighted mean elevation of 1820 m (1666-1931 m). The area burned ranges from 53-100 % in the burned watersheds, 58-82% in the burned-salvage logged watersheds, and 0-0.2 % in the reference watersheds. The fire stopped on almost precisely on the drainage divide between South and North York creeks consuming just under 2 ha of forest in North York watershed.

Figure 2 Map of study area showing research watersheds. Green indicates unburned (reference), black indicates burned, and red indicates burned & salvage-logged watersheds. Grey region indicates contiguous crown fire, yellow = crown scorched, green = fire skips. Study watersheds span 15 km from east-west, & 11 km north-south.

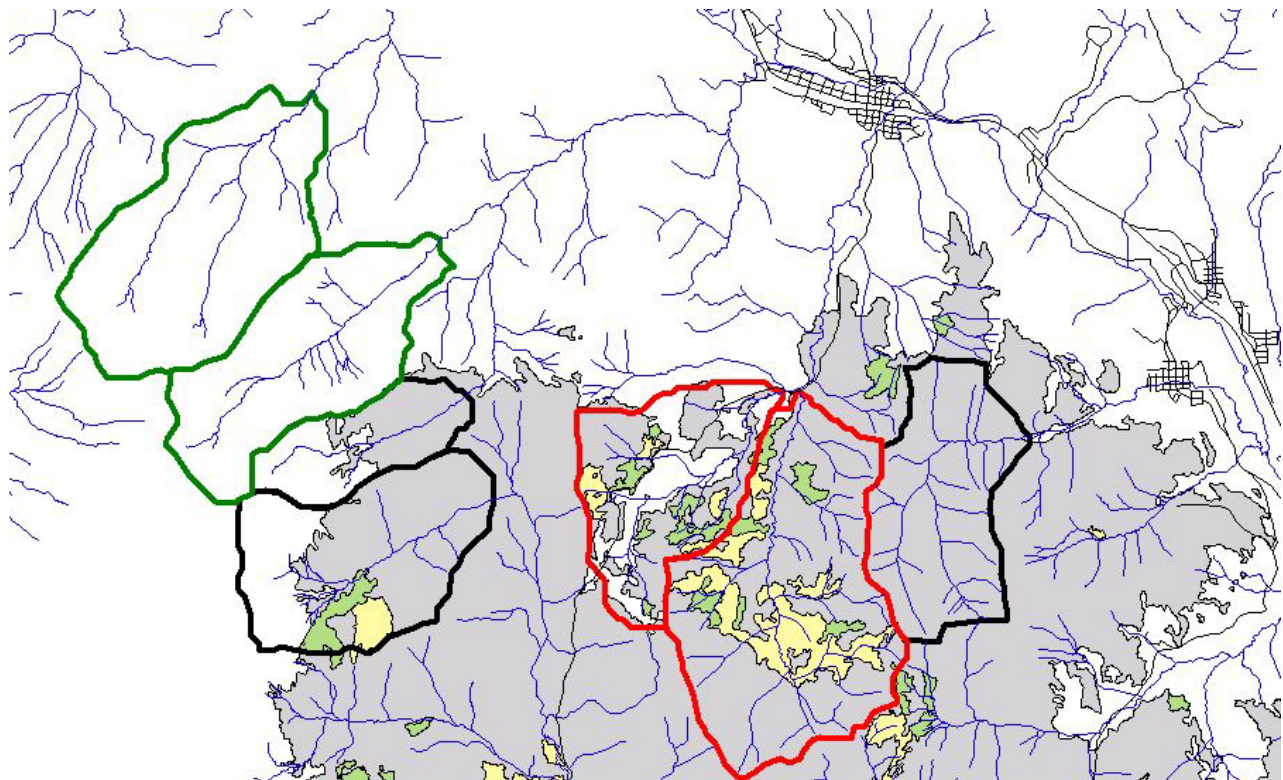


Table 1 Characteristics of study watersheds

Study watersheds

	Elevation (m)			Total area (ha)	Area Burned		
	mean	min	max		(ha)	(%)	
Unburned (reference)							
Star Ck.	1851	1479	2627	1059	0	0.0%	
North York Ck.	1931	1562	2633	829	2	0.2%	
Burned							
South York Ck.	1971	1691	2635	359	191	53.3%	
Lynx Ck	1906	1632	2629	821	553	67.3%	
Drum Ck.	1731	1432	2156	713	712	99.8%	
Burned + salvage logged							
Lyons Ck. East-fork	1685	1441	2027	1315	1072	81.5%	
Lyons Ck. West-fork	1666	1449	2059	707	413	58.4%	
*added spring 2005							

2.2 Hydrometric methods

Preliminary streamflow monitoring stations were established in March-May 2003 to capture the bulk of the 2004 spring snowmelt freshet in each of the 5 initial study watersheds, and have been expanded to include the 2 additional salvage logged watersheds as well as 2 additional sub-watersheds within Star Ck. Standard hydrometric techniques using stage-discharge relationships at natural control sections are used at all sites. Early in 2003, permanent benchmark and staff gauges were installed, followed by installation of stilling wells and electronic water level recorders for continuous measurement of stream stage (15 min. sampling interval). In the late summer/fall of 2003, the equipment at the preliminary gauging stations was replaced with more reliable (semi-permanent) stream gauging installations. Galvanized steel stilling sheds were erected at each site (well above the high water mark), followed by installation of DC powered compressed air bubbler systems (WaterLog) for continuous monitoring of stream stage over 2005-2009. These sheds and electronic data loggers will serve as the primary deployment platform for other stream monitoring equipment (water quality sondes & ISCO water samplers) that were deployed beginning in spring 2005.

Manual streamflow measurements were conducted using standard area-velocity techniques. Stream velocity was measured at 10 points for each cross-section using Global (FP-201) and Swoffer (2100) velocity meters. Current metering was performed approximately every 7-10 days during the snowmelt freshet and at 2 week intervals thereafter until the beginning of Nov. 2004. Over winter measurements were performed at 4-6 week intervals depending on ice conditions. Unique stage-discharge relationships are used to estimate continuous streamflow from the recorded stage data from all 7 watersheds.

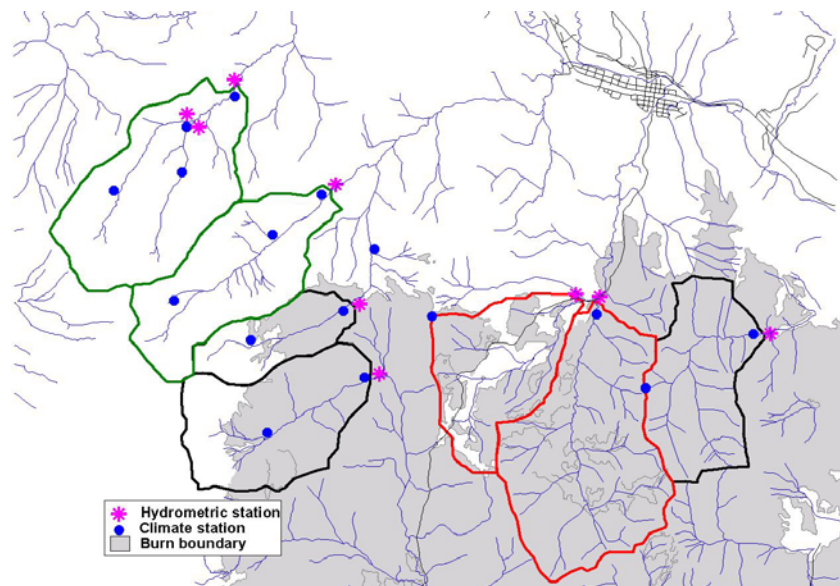
2.3 Meteorological

Precipitation stations were installed in beginning in late May 2004. Universal precipitation gauges equipped with alter shields were installed in the upper end of Star, N. York, Lynx, and Drum creeks, and tipping bucket rain gauges were installed at each of the five gauging sites. In the fall of 2004, tipping bucket rain gauges were fitted with an anti-freeze over-flow system to allow them to function as universal precipitation gauges through the fall and early winter of 2004/05. Precipitation data was collected at 2-3 week intervals during the summer-fall and in 1-2 month intervals during winter depending on snow pack conditions and access.

The main meteorological station was installed in late fall 2004 at the top of South York Creek. South York Ck. was chosen as it is fairly central to all 7 watersheds. The main meteorological station was

located in an area close to the median elevation for all 7 watersheds (1839 m). In addition to the air temperature, RH, and precipitation instruments at the gauging sites, the main meteorological station includes instruments for net radiation, wind speed & direction, and snow pack depth. Radio towers (30-50 feet high) were installed at each gauging site in the fall of 2004 and most main gauging stations (5) are rigged with cellular telemetry systems for remote data collection. All variables are recorded as 10 min, hourly, and daily average values at the main met. station and the gauging stations. Additional meteorological variables are monitored at the Alberta Environment automated climate station on Willoughby ridge. Total summer and winter precipitation is also measured at the Alberta Sustainable Resource Development Sacramento precipitation gauge at the bottom of S. York Ck. Two additional climate stations were added in Star Ck, 1 in Lyons Ck., and 1 in N. York Ck. bringing the climate measurement network to 15 stations total in addition to the 9 hydrometric gauging stations.

Figure 3 Hydrological and meteorological network including 7 gauged watersheds + 2 gauged sub-catchments in Star Ck. (NW) and 15 climate stations.



Detailed snowpack surveys were conducted to provide insights into altered snowpack accumulation with burned areas due to post-fire reduction of snowpack interception losses by the forest canopy. These surveys have been conducted late Feb. / early March (near the timing of historic peak SWE) in 2005, 2006, & 2007 at the bottom of South York creek near the lower burn boundary in a lower sub-alpine stand of Sub-alpine fir and Englemann spruce. Five transects were established in similar burned and unburned portions of the same stand. Transects were oriented upslope extending along a west facing slope for 100 m. Snowpack depth was measured at 10 points (10 m apart) along each transect. Snowpack density and SWE was measured at the upper and lower end of each transect using Mt. Rose snow tubes. Additional snowpack surveys of salvage logged areas in Lyons Ck. were conducted in 2005.

The effect of loss of the forest canopy on rainfall interceptions losses is being studied using rainfall interception collection troughs to measure throughfall and stemflow gauges installed on tree trunks (range of diameter sizes) rigged with tipping bucket rain gauges. These instruments were installed early in 2006 in burned and unburned areas at the burn boundary between N. & S. York Cks. Data from this component is being analyzed for total interception loss and canopy storage capacity in burned/unburned stands. This empirical approach requires a large sample of independent rainfall events ranging in size from frequent small storms to less frequent larger storms in order to calculate these interception parameters. The summer of 2006 did not generate a sufficiently large sample of rain storms to estimate these interception components, thus at least one more season of measurements will likely be needed before these results can be reported on.

2.4 Water Quality Sampling

A 4-stage water quality sampling approach was employed to balance measurement of critical parameters needed to document effects of the fire on both the water quality and nutrient status of the landscape while constraining costs.

Level 1 – Automated continuous monitoring: water temp, dissolved O₂, electrical conductivity, pH, ORP, turbidity, & salinity using automated water quality sondes; continuous data (ice free periods; May-Oct)

Level 2 - Automated daily sampling using ISCO water samplers – 1 composite sample/day consisting of 4 x 250 ml sub-samples collected every 6 hr. Analysis for suspended sediment and turbidity.

Level 3 - Routine nutrients and cations/anions - nitrogen (TN, TDN, NH₄⁺, NO₃⁻), phosphorous (TDP, SRP, TP), K⁺, SO₄⁻, Ca²⁺, Mg²⁺, Na⁺, Fe²⁺, Al³⁺ Cl⁻, silica, DOC/DIC, dissolved & suspended solids: every 10 days during snowmelt freshet, every 14 days after the freshet during the ice-free periods, every 1-2 months during winter; also includes additional sampling during periodic storm events.

Level 4 - Full suite metals analysis (U.S. EPA metals) - 2-3 times/yr under a range of flow conditions (snowmelt, storms, baseflows).

In addition to this sampling program, total mercury was sampled in 2004 & 2005 in with analysis performed in cooperation with D. Schindler's laboratory at the University of Alberta. Owing to high mercury values recorded in some of our watersheds, additional sampling for mercury in water (methyl-mercury (sampled on twice during Aug 2005 [low flows]), fish tissue was sampled from regional creeks/rivers (Burned; Lost, Lynx, & Carbondale, Salvage Logged; Lyons, and Unburned; W. Castle & Blairmore Ck.), and aquatic insects were sampled for carbon and nitrogen isotopes and presence of mercury. Erin Kelly (Ph.D.) student is leading the analysis and publishing on this (and associated data).

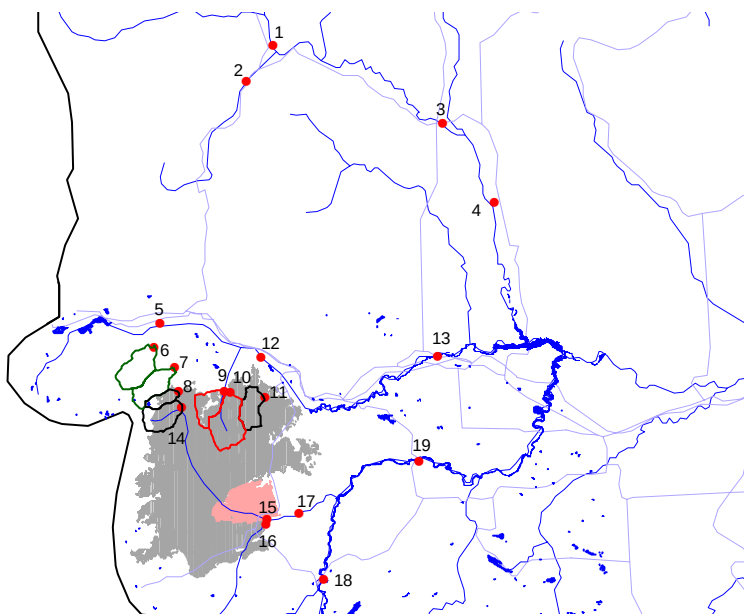
Lastly, additional oxygen isotope samples from precipitation and study streams have been collected during routine sampling since the outset of this study. Though these have not yet been analyzed (can be safely stored for several years), these samples will provide important insights into the relative surface water / groundwater components contributing to overall streamflow, and their temporal dynamics with and across seasons as the study progresses.

2.5 Regional Water Quality Scaling

During our 1st annual partner meeting in April 2005, at the request of the Oldman Watershed Council, we undertook a limited regional sampling program to describe regional patterns in water quality for a reduced number of water quality parameters in order to explore the impact of the wildfire on the on the larger headwaters regions of the Oldman River Basin.

We undertook a program to sample regional creeks/rivers within and outside of the burn in each of the major river systems comprising the headwaters of the Oldman River Basin (Castle R., Crowsnest R., and the Oldman R.). Including our study watersheds we sampled 19 sites during a range of dominant flow conditions (snowmelt freshet, stormflows, and summer baseflows) in 2005 & 2006 (Figure 4). Water quality parameters include TN, NH₄⁺, NO₃⁻, SRP, TP, SO₄⁻, DOC, Ca²⁺, Mg²⁺, electrical conductivity, pH, & TDS.

Figure 4 Location of regional sampling sites and SRWP research watersheds. The Lost Creek burn boundary is shown in grey, the Cherry Hill wildfire (4 yrs before Lost Ck) shown in pink.



2.6 Soils

Two soil surveys were conducted to capture basic soil nutrient information near the end of the summer and fall of 2004 and repeated in 2005.

The first soil survey was conducted on Aug 10, 2004 to capture basic soil nutrient information in a representative burned and unburned area of S. York creek. The sampling area was at the bottom of the burned area where comparable burned and unburned transects could be established in the same ecosite/elevation zone on slopes with similar slope and aspects. Transects were located on northerly facing hillslopes immediately above S. York creek and were lower elevation sub-alpine (just above the sub-alpine / montane eco-region boundary) sites dominated by Englemann spruce and sub-alpine fir. The forest floor in the unburned transects was dominated by feathermoss. Five transects extending from the riparian area adjacent to the creek running up the hillslope and over at bench in the valley bottom were established. Three sample points at each of the toe of the slope (bottom), mid-slope, and above the bench (top) were established in each of the 5 transects. Soil pits were excavated at each sample point for qualitative soil profile description. Gravimetric sampling was used to sample the LFH layer, along with the A and B soil horizons. Samples were bagged and frozen for transport to the laboratory. Two Root Simulator (PRSTM) cation/anion exchange probes were installed at each of the 3 sampling points in the middle transect (#3). These exchange probes provide a time-integrated sample of soil solution chemistry. One set of probes were sampled on Aug 28 (after 18 days) and the other set was sampled on Sept. 10, 2004 (after 31 days). Soil probes were washed with de-ionized water and returned to the laboratory for analysis.

A second soil survey was conducted during Oct. 5-7 2004 to provide broader insights into variability of soil nutrition across the 5 study watersheds. A similar study design (as above) was used. Five transects were established on each hillslope (running from the riparian area to upper slopes) to sample riparian soils (toe slope), mid-slope, and upper slope positions. Gravimetric soil samples were taken to sample the LFH, A and B horizons at each sample point. This was repeated to sample north facing slopes and south facing slopes in each of the 5 catchments. Soil samples were frozen for transport to the laboratory. Additional samples of live branch and foliar samples were harvested from N. York Ck. from a random sample of Lodgepole pine, White spruce, and Englemann spruce. These samples were

later burned (ashed) in a laboratory oven to estimate the nutrient concentration of wildfire ash from these tree species. This survey was repeated again in 2005. Analysis from the 1st soil survey was reported on in our 1st annual report. Analysis from the subsequent soil surveys will be reported on in a subsequent report.

2.7 Aquatic production

During early May 2004, it became evident that elevated nutrient concentrations in streamflow of the burned creeks was producing near-immediate effects on algal (periphyton) growth during the first post-fire snowmelt in these typically oligotrophic (nutrient poor) streams. Limited sampling for algal biomass on streambed rocks was conducted at the gauging sites on May 18, 2004. Four rocks were randomly selected from stream riffle sections and 3 fixed area sub-samples were scraped from each rock. Samples were amalgamated to provide a single integrated sample for each of the five study creeks. Samples were stored in scintillation vials and frozen. Samples were later analyzed for algal biomass. The intent with the 1st algal sampling was to provide an initial indication of differences in early algal growth among the study watersheds.

A 2nd set of algal sampling was conducted on July 6-8 to capture mid-summer algal production. On this set, a fixed area from three sample rocks were scraped and amalgamated at each of 4 replicate riffle sections. Samples were transferred to filter paper and stabilized with a small quantity of magnesium sulphate. Samples were later analyzed by AB. Env. labs for chlorophyll-a content.

A last set of aquatic biomass sampling was conducted on Oct. 13-15. In cooperation with Canadian Rivers Institute scientists, a number of sampling locations from the gauging sites to various headwaters tributaries were identified within each of the 5 watersheds. At each sample site, algae was collected by fixed-area scraping on 3-6 rocks within each of 3 riffle sections. Samples were amalgamated for each riffle and stored frozen in scintillation vials. Samples were later analyzed for chlorophyll-a content and algal biomass by laboratories at the National Water Research Institute (Saskatoon). Benthic invertebrate biomass and species composition was sampled using kick-sampling with a U-net to collect invertebrates from a fixed area from 3 separate riffle sections. Invertebrates were washed onto soil sieves and transferred to storage bottles (filled with 70% ETOH for stabilization) and shipped to University of New Brunswick for determination of biomass and species composition.

After our initial observations of dramatic increases in algal production with sampling by scraping fixed areas in 2004, we modified the sampling procedures for use in 2005 & 2006. We installed replicate groups of artificial stream substrate (3 replicate groups of 155 cm² unglazed porcelain tiles) for repeated scraping and measurement of algal production approximately every month during the growing season. Because of differences in both sampling and analysis between 2004 and 2005/06, only the 2005 & 2006 data are reported on here. The 2004 results were detailed in our 1st annual report

2.8 Vegetation Recovery

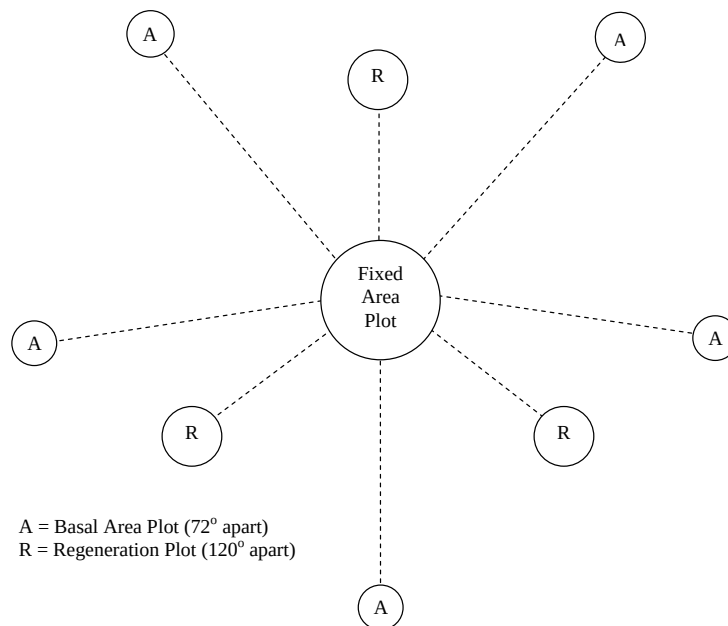
In 2006 (3rd growing season after the wildfire) we undertook a single synoptic vegetation survey to describe both regeneration/establishment of tree species and recovery of leaf area (leaf area index [LAI] m² leaf area / m² ground area). The purpose of this survey was not to do an extensive survey across the burned landscape, but rather, to conduct a synoptic survey across the major vegetation zones within the fire affected area.

The region was stratified by ecological sub-regions and stand surveys were conducted within the two dominant regions containing mature forest cover (montane, sub-alpine). Within each of these regions suitable stands were identified using AVI inventory data that were representative of stands in older & younger age classes at the time of the wildfire, and those occurring on strongly defined north and south facing hillslopes. These same stand selection criteria were used to identify similar groups of stands in representative unburned areas. The survey consisted of 2 burn categories (burned/unburned) x 2

ecological sub-regions (upper montane / sub-alpine; note: these are analogous to pine/spruce-fir dominated stands) x 2 age classes (younger/older) x aspect classes (north/south) = 18 stands. Within each stand, a central fixed area plot was established with plot area scaled to include at least 40-50 trees. Diameter at breast height (DBH), basal area, and total height was measured for every tree in the plot. Three seedling regeneration plots (1.73 m radius, 10 m²) were established 10 m from the fixed area plot centre and number, species, and height measured for every established seedling. Five additional basal area sweeps with prisms (BAF 4) were performed 15 m from fixed area plot centres.

Leaf area index was measured in each stand using 2 concurrent optical LAI measurement instruments (LiCor LAI-2000). One unit was set up outside of the stand in a nearby clearing with the other unit used to conduct the measurements. Fifty sample points were measured along randomly located transects within each stand. One set of 50 points were measured at ground level and the survey was repeated with measurements taken at breast height. This was done to allow separation of light interception due the presence of standing burned stems in the burned areas from the true leaf area present at ground level (instrument measures light interception due to both leaf area and standing burned trees). Only the regeneration data is resported on here (the LAI data will be reported on in a subsequent report). Our plan is to repeat this survey in two more years.

Figure 5 Vegetation sampling plot layout



2.9 Analysis

Due to the large volume of hydro-meteorological and water quality data, only a qualitative analysis is presented here. Results are shown as mean results with an appropriate expression of sample variance to illustrate variability and provide readers with a preliminary sense of statistical significance. Standard error of the mean is presented as the expression of variance. Generally speaking, where sample means +/- one standard error do not overlap, more rigorous statistical testing will usually show significant differences among sample populations with normal distributions.

Hydrometric and meteorological data in particular required considerable scrutiny to eliminate questionable values from the results. This data cleaning likely eliminated some “valid” extreme value results. Thus the hydrometric and meteorological data presented in this report can be considered as “conservative” with respect to differences between burned and unburned watersheds.

3 Results and Discussion

3.1 Hydrology

3.1.1 Total precipitation and snowpacks

Precipitation in the study area is generally very high and reflects some of the higher mountain precipitation occurring in Alberta's Rocky Mtn. region. Precipitation is also strongly variable across the study region with the highest precipitation occurring in watersheds in the Flathead range (Star, N. York, S. York, and Lynx Cks) and notably lower annual precipitation in catchments to the east including the two salvaged logged watersheds in the Lyons Ck. valley and Drum Ck. in the Blairmore range. Regional annual precipitation varied from 862 mm in 2004, 1112 mm in 2005, and 735 mm during 2006 (Table 2, Figure 6).

Table 2 Annual precipitation (mm) in study watersheds during 2004-2006 water years.

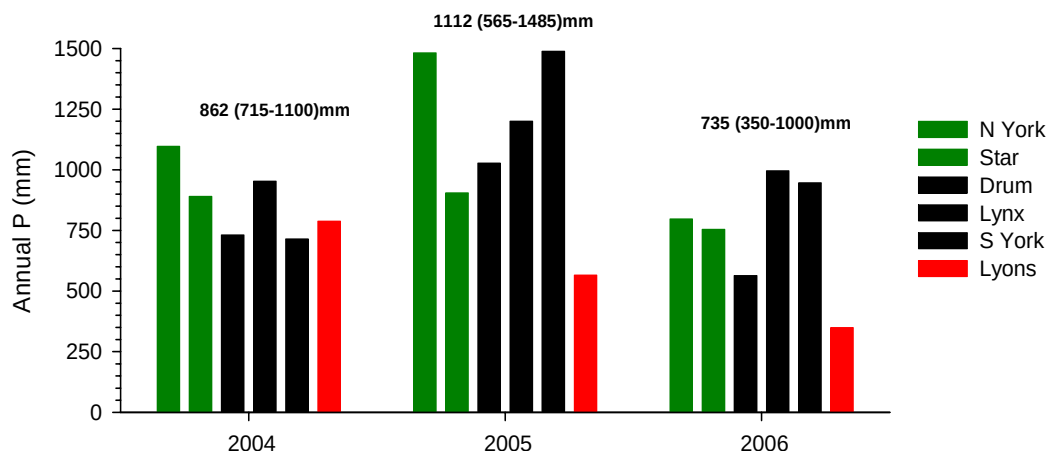
Precipitation (mm) (Nov 1 - Oct 31 water year)

	Unburned		Burned			Salvaged	
	N. York	Star	Drum	Lynx	S. York	Lyons E.	Lyons W.
2004	1096.8	890.8	731.2	952.6	715.0	787.7	787.7
2005	1482.0	905.4	1028.0	1200.0	1488.2	566.1	566.1
2006	797.2	754.8	564.0	996.0	946.4	349.9	349.9

While long-term records of precipitation are not available for the study region, the 3 study seasons are likely within the range of normal precipitation (perhaps a bit above average). Seven years of annual precipitation data at the Willoughby ridge automated station indicates a short-term average of approximately 800 mm/yr. Precipitation observed during the first 3 years of this study has been near average to slightly above average compared to this short-term record.

2004 was generally cool and moist but without notably large precipitation events. June of 2005 was particularly wet with 2 large rainfall events on June 2 and June 7. Approximately 150-175 mm of rain fell between Jun 1-8 across much of the study area. Because of this heavy precipitation, which thoroughly soaked the ground, smaller events of ~15-20 mm/day in the latter half of June also produced substantial streamflow response. 2006 was also unusual in that no measurable precipitation was observed after June 10 until well into Sept.

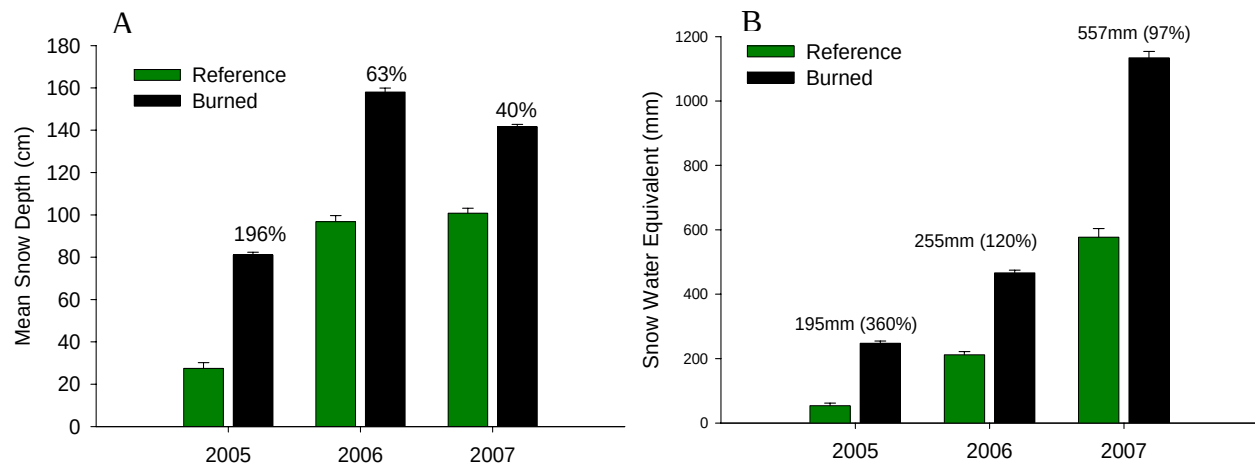
Figure 6 Annual precipitation (mm) during 2004-2006 water years (Nov 1 – Oct 31). Green=unburned, black=burned, red=burned & salvage logged. Group order is shown in legend. Regional annual mean values and ranges are shown above each year's group.



Based on nearby and regional AB. Env. snow pillow data, the winter of 2004/05 produced a normal to below normal (-35%) peak winter snowpack while 2005/06 and 2006/07 snowpacks were slightly above normal (~10-20%). Our snowpack sampling in late Feb – early Mar. 2005-2007 indicated 5-10 fold differences in snowpack depths, densities, and snow water equivalent between these 3 years. This past winter (2006/07), in particular, had the highest snowpack in burned & unburned areas with SWE 3-5 times greater than in 2004/05. Snowpacks near the top of our Flathead range watersheds have been 2.5-3 m deep during 2005/06 and 2006/07 with substantially less (0.3-1.6 m) near the bottom of the study watersheds.

The detailed snowpack survey in S. York generated some insights into how loss of snowpack interception processes with the burn are affecting winter hydrologic inputs into the watersheds. In the low snowpack year of 2004/05, mean snowpack depth near the time of peak SWE was nearly 3 times greater in the burned areas of S. York Ck. than in similar unburned areas (Figure 7). Similarly, mean SWE was nearly 3 times greater (representing an additional 142 mm) in burned areas. Though relative differences in mean snowpack depth and SWE between burned and unburned transects decreased in proportion to greater snowpack depths in 2005/06 and 2006/07, an additional 250 and 550 mm in snow water hydrologic inputs were observed in burned areas during these two years, respectively. These results are considerably higher than the estimated 37 % increase in SWE after wildfire (Lodgepole pine stands) in the Yellowstone reported by Farnes (1996). However, it should be noted that because spruce-fir type canopies have higher interception losses, burns in this forest stand type would be expected to produce greater relative changes in peak SWE than pine type forest stands.

Figure 7. Mean snowpack depths along snow transects (A), and mean SWE for burned and unburned areas near the bottom burn boundary at S. York Ck (B). Absolute values (mm) and % values indicate relative increase in snow packs in burned areas compared to unburned. Each bar n=50.



3.1.2 Streamflow

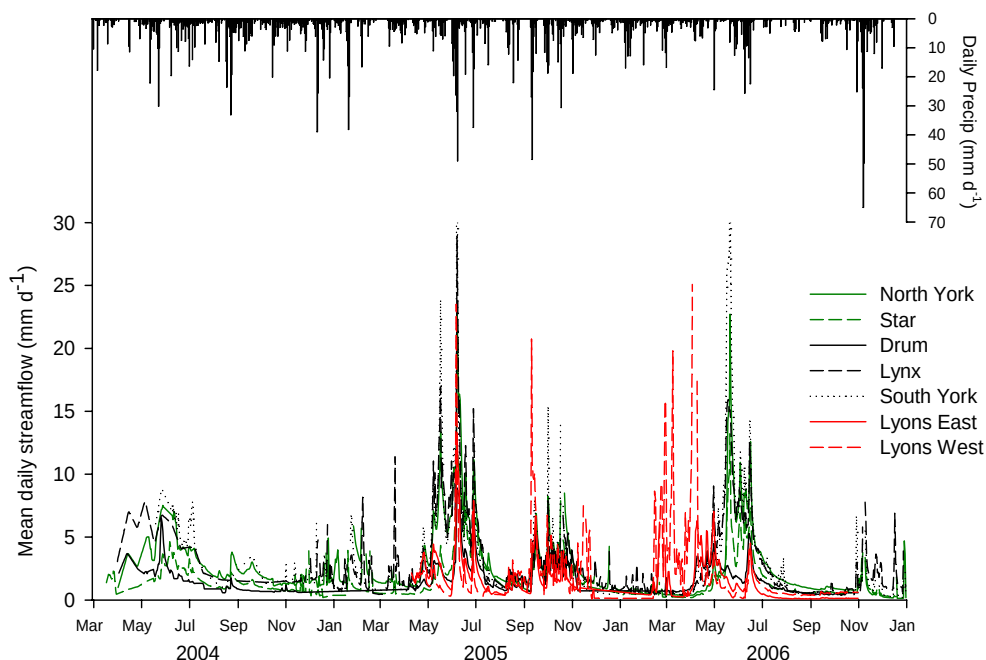
Stream discharges generally reflect extremely high water yielding runoff consistent with generally high regional precipitation and high relief physiographic setting of the study watersheds and the Southern Rockies in general. Total water yields generally reflected strong variation in watershed physiography among catchments and variation in climate among study years (Table 3) which are the dominant drivers of streamflow production and watershed runoff behaviour. Annual water yields ranged from approx. 1150 mm/yr in the highest yielding Flathead range catchments to approximately 450 mm in the lower relief Lyons Ck. valley during the 2005 water year (annual runoff ratios ranged from 60-80% with highest ratios observed in steeper-higher yielding watersheds). Water yields were approximately 30% lower during the drier 2006 water year.

Table 3 Annual water yield (mm) in study watersheds during 2005 & 2006 water years.

Streamflow (mm)	(Nov 1 - Oct 31 water year)						
	Unburned		Burned			Salvaged	
	N. York	Star	Drum	Lynx	S. York	Lyons E.	Lyons W.
2004							
2005	1137.8	699.2	617.8	1140.9	1147.1	429.1	448.7
2006	730.9	468.0	431.1	799.3	881.9	356.9	572.7

Mean daily unit area streamflow during the peak snowmelt freshet ranged from 5-10 mm/day (non-storm) dropping to 1-3 mm/day during non-storm base flow periods later in the summer (Figure 8). Stormflows during these periods typically produce mean daily discharges from 5-50 mm/day depending on antecedent soil moisture storage conditions. All streams responded quickly to rain storm events with very rapid time to rise and steep post-peak flow recession limbs evident in most of the storm hydrographs. While the mean daily discharges illustrated in Figure 8 have a considerable muting effect on the storm hydrographs (i.e. maximum instantaneous discharges are usually well above those shown on mean daily discharge hydrographs), storms during the snowmelt freshet of 2005 and 2006 produced very high mean daily unit area discharges of over 50-75 mm/day. The spring snowmelt freshet typically begins almost a month earlier in lower elevation watersheds in Drum, Lyons East, and Lyons West Cks. (Figure 8 & 9).

Figure 8 Mean daily precipitation & unit area stream discharges (mm/day) 2004-2006

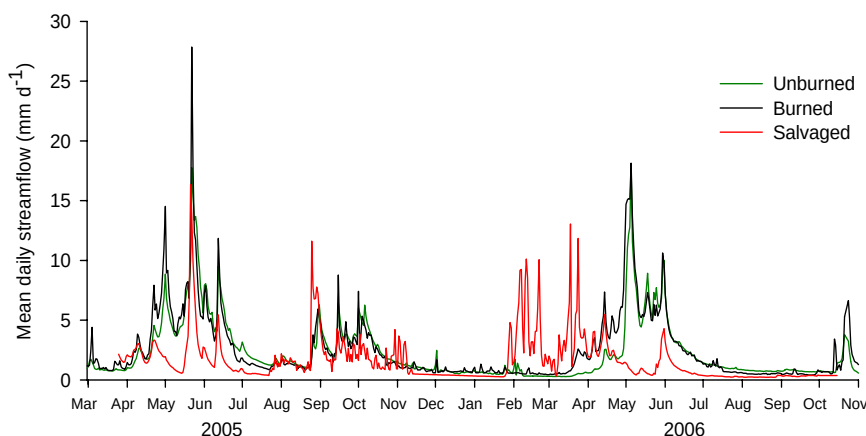


Periodic rain on snowpack events are a common feature of this area (not shown due to inherent errors in under ice streamflow gauging methods) but constitutes some of the more extreme flows observed during 2004-2006. While the heavy rains during June 2005 did produce very high discharges, no severe flooding was observed likely because of rapid recovery of post-wildfire water repellency typically observed in severely burned watersheds (see review in short manuscript appearing in appendix).

Because of the inherent differences in runoff dynamics between undisturbed watersheds, runoff behaviour is usually highly unique for individual catchments. For example, the higher discharges evident in Figure 8 from N. York Ck. compared to Star creek (both unburned) likely reflect a combination of differences in precipitation, relief ratio, and physiographic/geologic setting. Because of the lack of pre-disturbance streamflow data for the study catchments, few strong inferences can be drawn on burn effects on streamflow based on 3 yrs of streamflow data. However, mean annual hydrographs for 2005/06 among

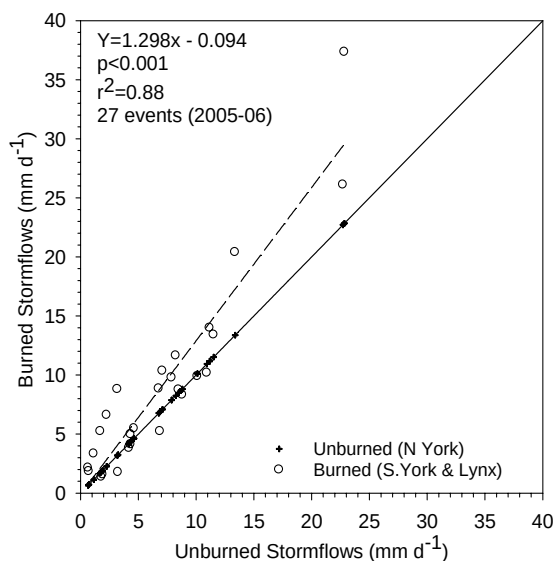
treatments do illustrate some important sources of hydrologic variability (Figure 9) in the study area. For example, the differences in both timing of the snowmelt freshet and lower summer baseflows because of less groundwater influence in the lower elevation, lower relief Lyons Ck. valley (salvage logged).

Figure 9 Mean daily streamflow from unburned, burned, & salvage logged watersheds (2005-06)



Due to the strongly confounding factors of differences in the climate & physiography among catchments among unburned, burned, and salvage logged watersheds, empirical comparison of streamflow among catchments does not support defensible scientific inferences on how these conditions affect catchment hydrology. However, restricting empirical comparisons to a small sub-set of matched stormflows from 3 adjacent and physiographically similar catchments (burned; Lynx & S. York, and unburned; N York Cks.) can provide some reasonably defensible inferences on how the severe burn in these watershed may be affecting stormflow generation processes. Twenty-seven matched peak mean daily discharges from N. York Ck. during 2005 & 2006 were regressed against matching mean peakflows from Lynx & S. York Cks (Figure 10). These results suggest a possible increase in stormflow generation from burned watersheds. Interestingly and contrary to other published research on stormflows from disturbed watersheds), little effect of fire was evident for smaller peakflows but an increase in the effect size appears evident as the size of the peakflow increases ($p < 0.001$). At the higher range of stormflows, the mean stormflows of burned watersheds was 30% greater than in similar unburned watersheds.

Figure 10 Matched mean stormflow peaks from hydro-climatically similar burned & unburned Flathead Range watersheds. Deviation of the dashed regression line indicates the effect of the burn on stormflows (function of “event” size).



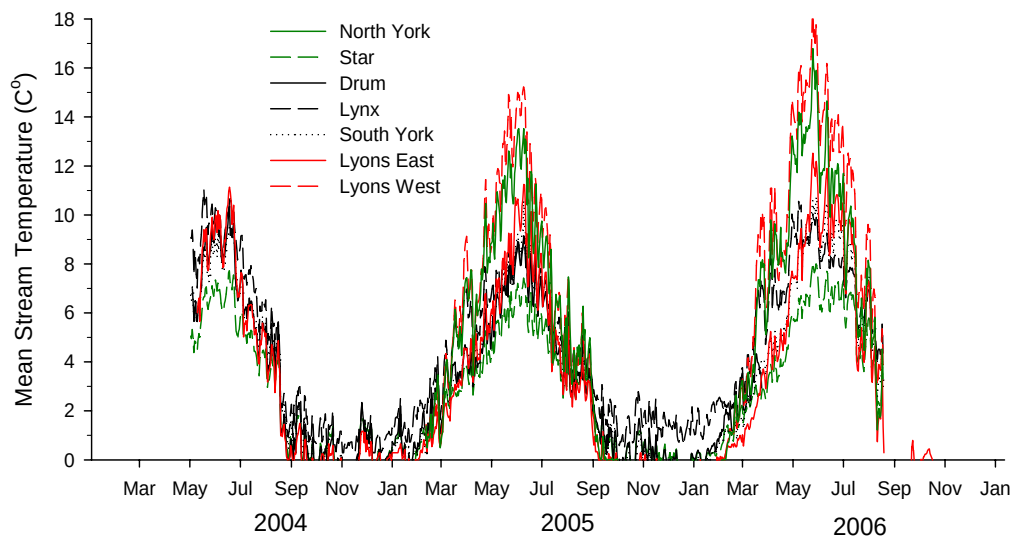
It should be re-emphasized that despite these results, no severe flood causing flows were observed following the June 2005 rains, thus caution is suggested in drawing any inferences regarding burn effects on extreme flows at this stage. While these results are consistent with work by others suggesting that peakflows can increase well beyond the natural range of variability observed in similar unburned watersheds after wildfire (Neary et al. 2003), additional analysis will be needed to support stronger inferences on peakflow generation. Additional stormflow comparisons will be performed in the coming year to further explore these relationships.

3.2 Water Quality

3.2.1 Physical water quality

Stream temperatures reached their annual maximum in June-July and declined to just above freezing by late Sept. (Figure 11). Consistent with results for streamflow, no clear pattern in temporal dynamics of stream temperature was evident for any of the burned streams. Again, this variability is largely due to strong climatic-physiographic differences among the 7 catchments, which drives strong differences in the degree of radiation versus groundwater discharge controls over stream thermal regimes (Moore *et al.*, 2005).

Figure 11 Mean daily stream temperature

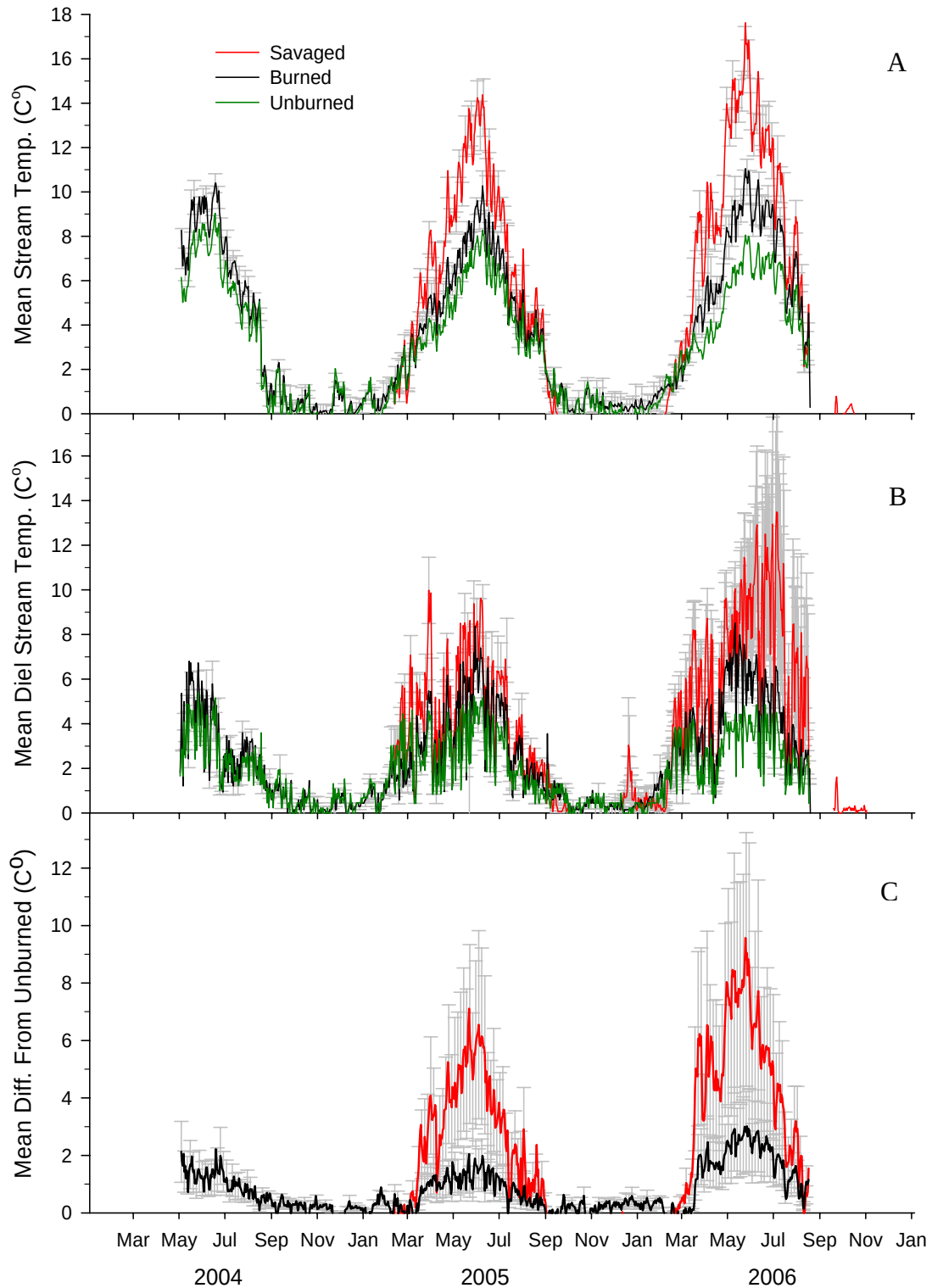


Mean daily stream temperatures were generally similar among years in unburned watersheds with peak summer temperatures in burned watersheds reaching approximately 2 °C warmer in 2004/2005 and 3 °C warmer during the hotter dry summer of 2006 (Figure 12). Salvage logged catchments were warmer yet with mean peak differences of 6-7 °C in 2005 & 8-9 °C in 2006 (some of the salvage logged streams in the Lyons Ck. valley approach daily maxima of approx. 25°C during 2006). These differences paralleled a similar pattern of differences in the diurnal range of temperature fluctuation among watersheds with higher temperature amplitude in burned & salvage logged watersheds than in unburned streams.

While moderate differences in stream thermal regimes were evident, as with streamflow generation, it should be re-emphasized that differences among disturbance types are confounded with variation in hydro-climatic condition. Conclusions regarding these effects should be considered with caution as both changes in radiation flux from burned riparian areas and strong variation in groundwater controls on

stream thermal regimes are likely driving the observed patterns in water temperature we have observed in 2004-2006 (Johnson and Jones 2000, Moore *et al.* 2005).

Figure 12 Mean daily stream temperature (A), diel temperature (B), and mean difference between burned & burned-salvaged streams with unburned streams (C).



Suspended sediment concentrations varied strongly with flow condition within and among years and disturbance types across the study region (Figures 13 & 14). Sediment production was strongly affected by wildfire and salvage logging with mean concentrations 2-15 x greater in burned watersheds and mean total sediment export 2-12 x higher than in unburned watersheds with the largest differences evident during the snowmelt freshet and during stormflows. Salvage logging produced much greater impacts that wildfire alone with mean concentrations 2-75 x greater in salvage logged watersheds and mean total sediment export 2-110 x higher than in unburned watersheds. Summary results for mean sediment concentration, export and yield are presented in the appendix.

Figure 13 Mean suspended sediment concentrations (A) and sediment export (B) in 2004-2006. % values indicate relative increases over unburned values.

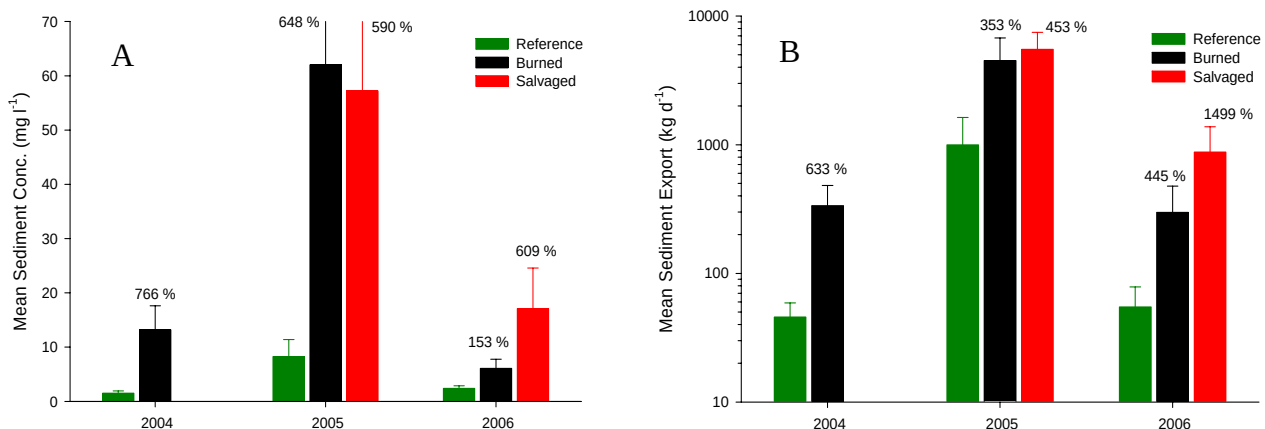
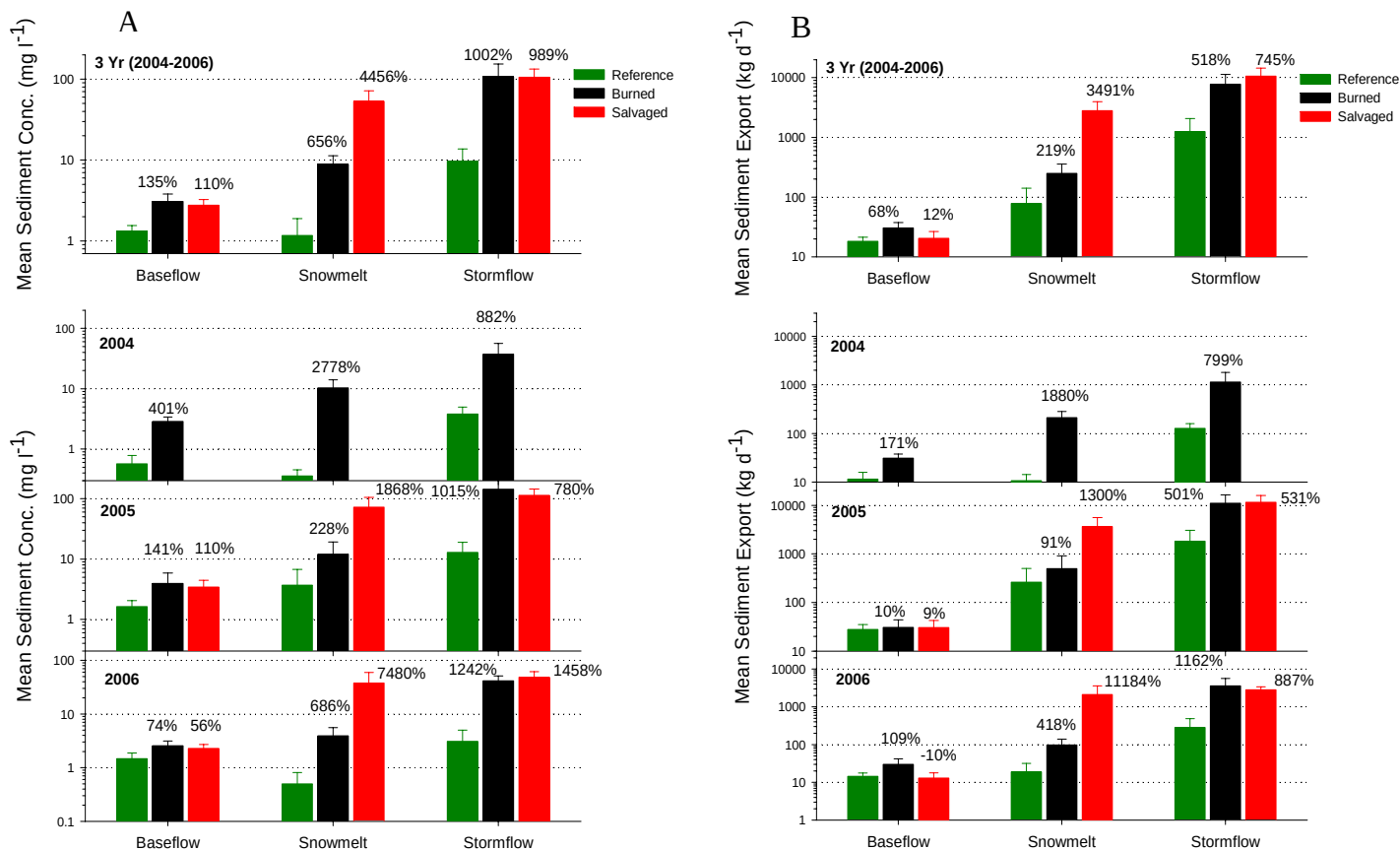


Figure 14 Mean suspended sediment concentrations (A) and sediment export (B) by flow condition in 2004-2006. % values indicate relative increases over unburned values.



The vast majority of sediment production occurred during the snowmelt period and with periodic stormflows when sediment export averaged 3.5 to 11.5 tons/day in burned and salvage logged watersheds compared to approximately 0.03 tons/day in unburned watersheds. Though sediment concentrations were low during baseflows, differences in sediment regimes among disturbance types were still evident during these low flows.

Given the relatively strong differences in precipitation between years, along with strong differences in sediment concentration/export between disturbance types still evident 3 yrs after the wildfire, the temporal pattern of sediment production for the past 3 years does not suggest any likely post-disturbance recovery for sediment production. Indeed, collapse of streambanks-hillslopes and the additional soil disturbance that occurred with salvage logging (particularly with linear feature such as skid-trails and in-block roads) will likely remain as significant sediment sources for many years.

Hillslope-bank collapse occurring in Lyons Ck.

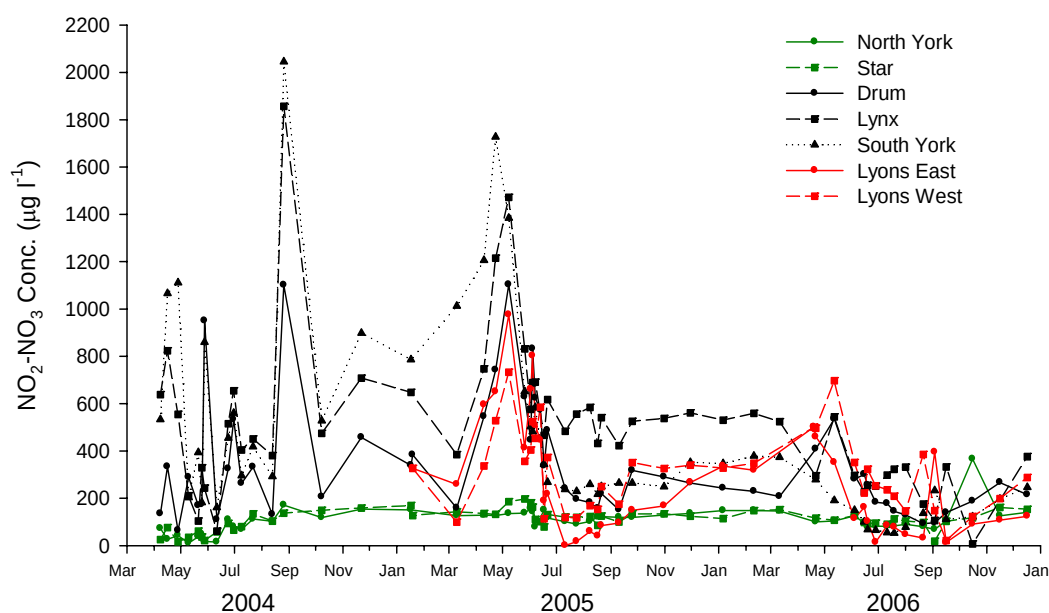


3.2.2 Chemical water quality

Owing to the very large number of chemical water quality parameters measured, and the very large differences in these parameters observed between burned and unburned watersheds in this study, only a very reduced set of these parameters (particularly those showing differential rates of apparent recovery) is presented here. With a few minor exceptions, all of the water chemistry summaries (mean concentrations, export, and total yield) are presented in the appendix of this report. In very general terms, these water quality parameters can be described as; those in mobile form that are relatively easily transported to streams by surface/sub-surface flowpaths (many important nutrient species, some heavy metals), less mobile forms with periodic weaker transport (some metals & nutrients such as NH_4), and species under hillslope-geologic controls (i.e. many base cations/anions, SO_4).

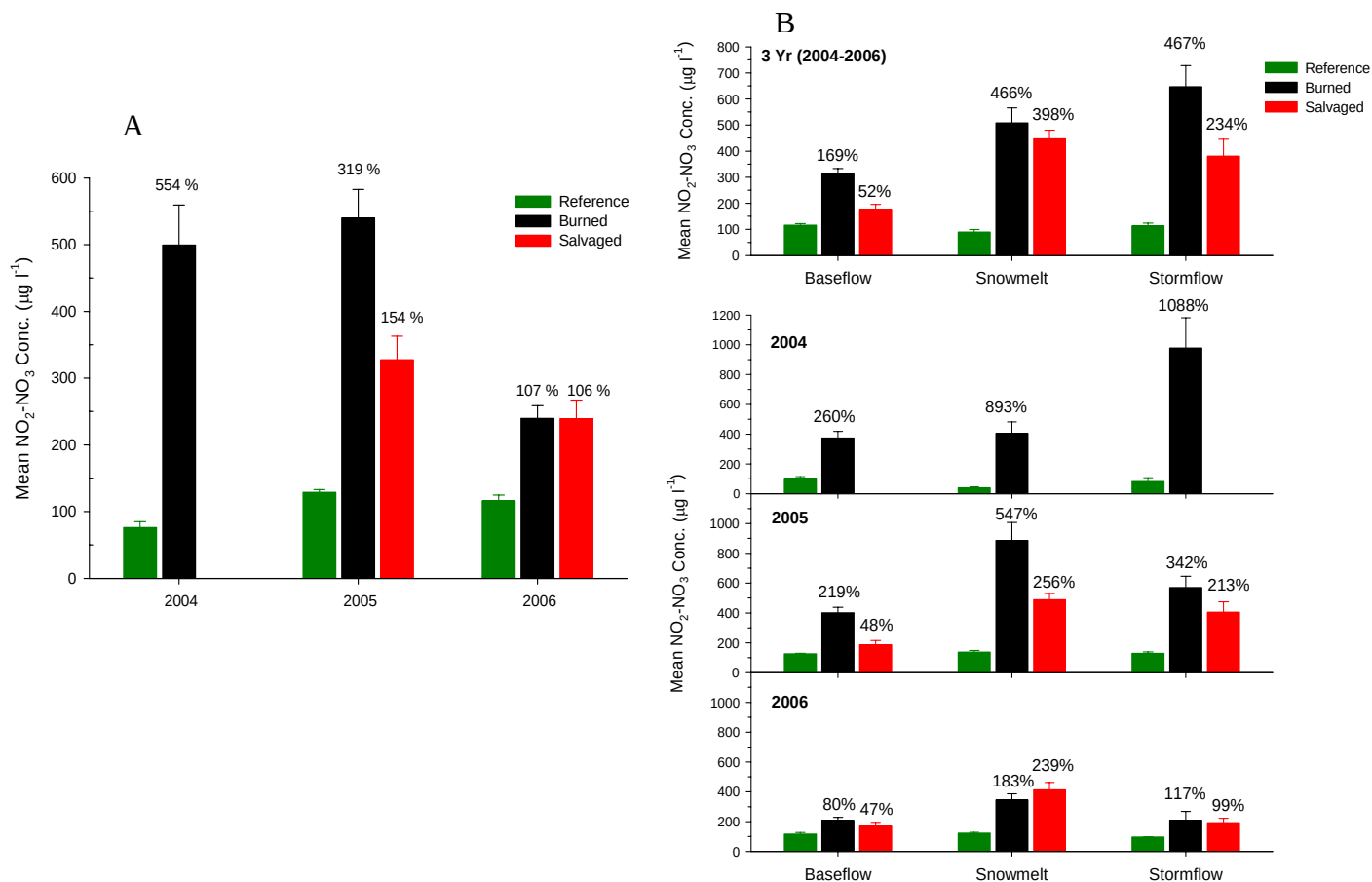
NO_2 - NO_3 nitrogen is a good example of an important mobile nutrient species. Strong differences among unburned, burned, and salvage logged watersheds have been observed over the previous 3 years (Figure 15).

Figure 15 Nitrate-nitrite concentrations for study watershed during 2004-2006.



While $\text{NO}_2\text{-NO}_3$ concentrations are strongly flow dependent (highest during snowmelt and stormflows, lowest during baseflows), concentrations were generally low in unburned watersheds over the 3 years. Concentrations were approx. 5-10 x higher in burned and salvage logged watersheds, particularly during the 2004-05 snowmelt periods. Concentrations were slightly greater during the 2005 snowmelt period owing the greater over-winter snowpack during that year. The largest stormflow peaks were observed during the 1st post-burn growing season of 2004 when a moderate sized storm was sampled in late Aug. In contrast, by the following year, the June 2005 high flows did not produce concentration peaks because of the dilution effect of high flows on concentration (total exports and yields were high during that “event”).

Figure 16 Mean $\text{NO}_2\text{-NO}_3$ concentrations (A) and $\text{NO}_2\text{-NO}_3$ concentrations (B) by flow condition in 2004-2006. % values indicate relative increases over unburned values.

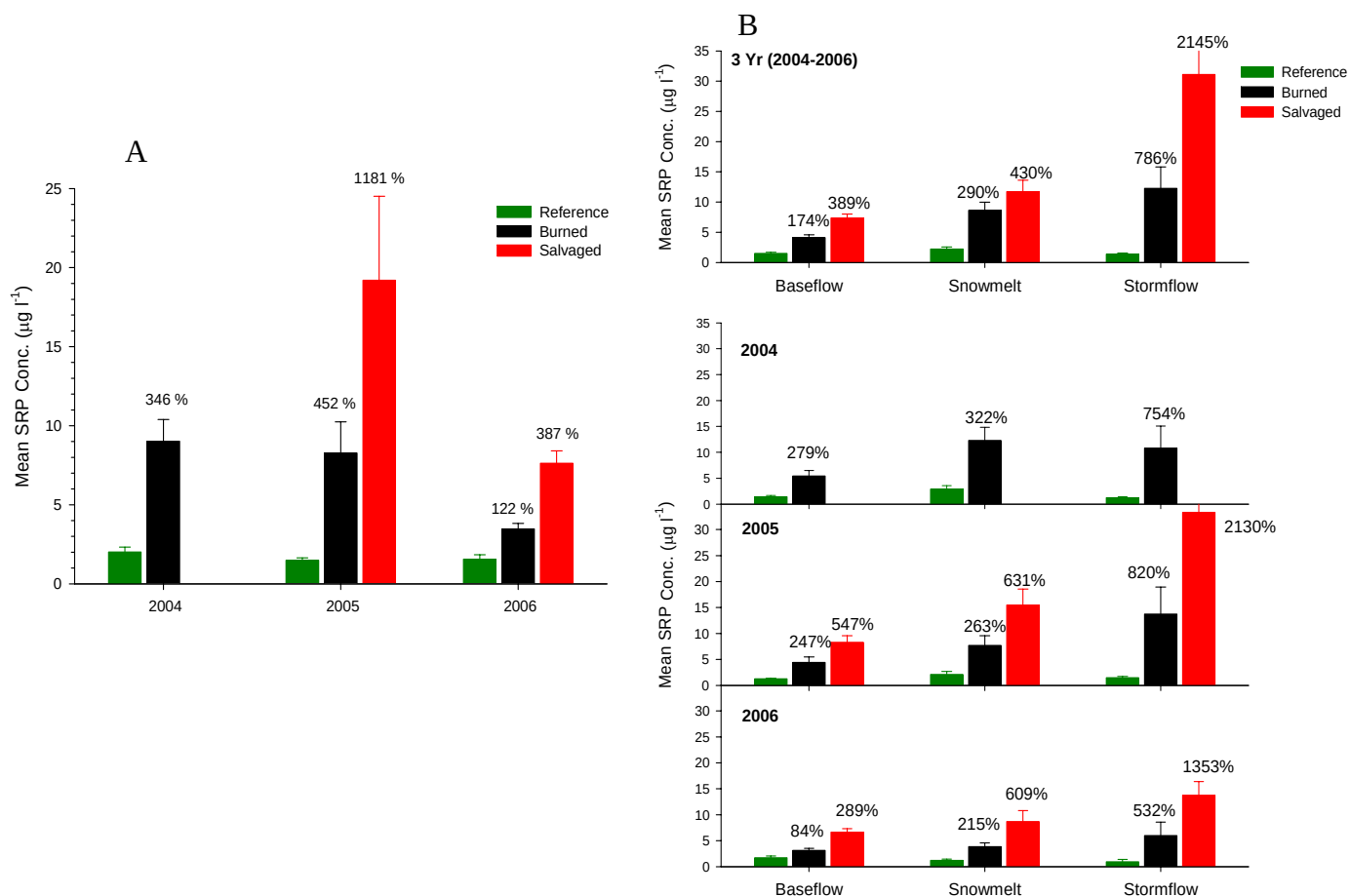


Elevated nitrate-nitrite concentrations were generally lower in salvage logged watersheds compared to burned watersheds during most flow periods in 2005 & 2006. Though concentrations were slightly greater during the 2nd year after the burn, this largely reflected higher snowmelt period streamflows during that year. While concentrations were still elevated in burned and salvage logged watersheds in 2006, the magnitude of differences between unburned, burned, and salvage logged watersheds has strongly declined over the 1st 3 growing seasons after the wildfire.

Though differences among disturbance types was somewhat greater for total export and yield, the general pattern of differences among watersheds and changes over the past 3 years is generally similar as that shown above for $\text{NO}_2\text{-NO}_3$ concentrations. Similarly, the general patterns evident for ammonium, total dissolved nitrogen, and total nitrogen are generally similar as above with most nitrogen species showing evidence of relatively strong post-disturbance recovery 3 years after the burn (see Appendix).

Soluble reactive phosphorous (SRP) concentrations were also highly variable with flow condition especially in burned and salvage logged watersheds and showed seasonal patterns generally consistent with those observed for nitrate (data not shown). SRP concentrations were high during both the snowmelt and storm flows in 2004 & 2005 (Figure 17). Though SRP concentrations were lower during drier season of 2006, relative differences in concentration (& export-yield) between unburned & burned or salvage logged watersheds remained relatively high 3 yrs. after the fire.

Figure 17 Mean SRP concentrations (A) and SRP concentrations (B) by flow condition in 2004-2006. % values indicate relative increases over unburned values.



In contrast to nitrogen, salvage logged watersheds showed consistently higher SRP concentrations across major flow periods during both 2005 and 2006 with particularly strong differences evident during periodic stormflows. Relative differences in mean SRP concentration were 6-21 times greater in salvage logged watersheds than in unburned watersheds during 2005/06 compared to 2-8 fold differences evident for burned watersheds during the same periods. Though differences among disturbance types is somewhat great for total export and yield, the general pattern among watersheds and changes over the past 3 years is generally similar as that shown above for SRP concentrations.

Also in contrast to nitrogen, SRP has not shown a clear pattern of recovery over the 1st three years after the wildfire. Again, the general patterns evident for total dissolved phosphorous, and total phosphorous are generally similar as above with greater effects evident for salvage logged that burned watersheds and little evidence of post-disturbance recovery after 3 growing seasons. (see Appendix).

Other nutrient water chemistry parameters (see Appendix) showed general similarity to the seasonal patterns described for nitrate and SRP (total N, total P, DOC). Most major cations (calcium,

magnesium, potassium) showed a lower concentrations in burned watersheds during snowmelt and only slightly elevated concentrations during storm flows and baseflows. Higher yield of these cations from burned watersheds likely reflected the slightly higher water yields from burned watersheds. Lastly, some parameters showed only weak variance with flow condition or difference between burned and unburned watersheds (pH, EC).

Though important differences exist between these results and others reported previously in the literature (i.e. this study has documented a much broader/robust set of water chemistry data after fire than any other previous study I am aware of), our results are generally consistent with the findings of other researchers studying post-wildfire water chemistry. Though large sediment (Troendle and Bevenger, 1996) and nutrient pulses (Robinson and Minshall, 1996, Brass *et al.* 1996, Spencer *et al.* 2003) following wildfire in the Rocky Mountains has been reported, our results for nutrient flux in particular show higher concentrations and greater relative increases compared to similar unburned watersheds than previously described. This study also shows slower rates of post-disturbance recovery than these previous studies. This is likely due to a combination of factors including differences in climate, hydrology and the fact that our sampling began immediately with the 1st large hydrologic event after the Lost Creek fire and captured a much greater range of flow conditions than these previous authors. Our results provide substantial new insights into relationships between water quality effects with precipitation and streamflow variation during the 1st three years of post-fire watershed behavior. Because most studies do not measure streamflow and other hydrologic parameters along with water chemistry results, our work is the first (to my knowledge) to show elevated nutrient yields beyond the range of concentration increases for most of these parameters.

3.2.3 Heavy metals

Total mercury concentrations were generally not strongly variable in unburned watersheds but were highly variable with flow condition in burned and salvage logged watersheds during the 2 post-disturbance years in which mercury was sampled (Figure 18; note: broken y axis). Though variable among burned and salvage logged watersheds, generally high (periodically above AB and CCME chronic water quality guidelines) concentrations were observed during the snowmelt period, with much larger total mercury pulses evident during stormflows (periodically above acute water quality guidelines). Drum Ck. (100% burned) & both salvage logged watersheds were strongly and consistently elevated in total Hg.

Figure 18 Total mercury concentrations during 2004/05. Numeric value = confirmed conc. in Lyons Ck. during June high flows. AB water quality guidelines shown with broken line.

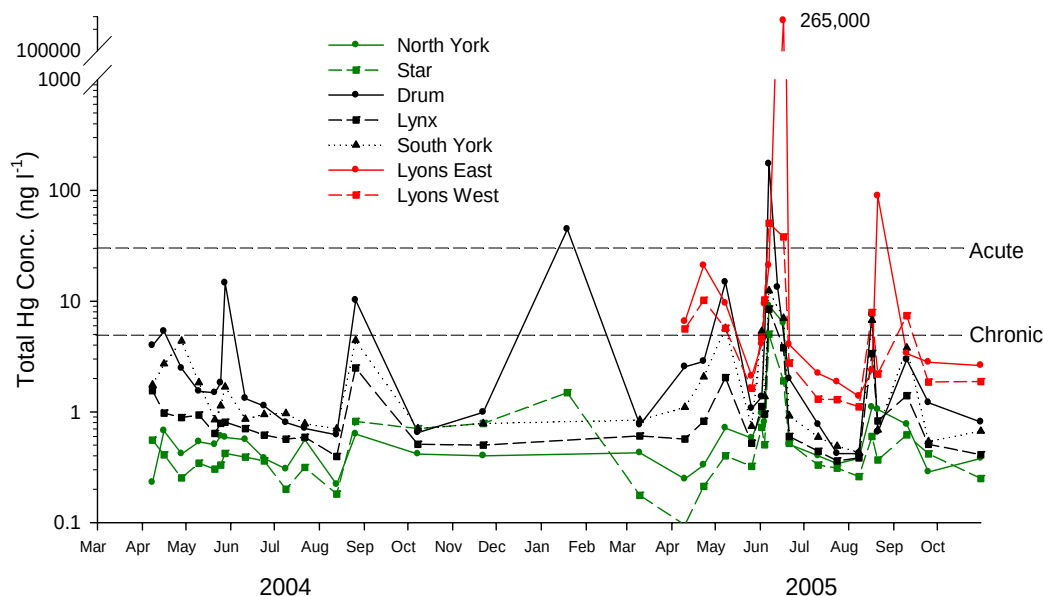


Figure 19 Total mercury export during 2004/05. Numeric value = confirmed conc. in Lyons Ck. during June high flows.

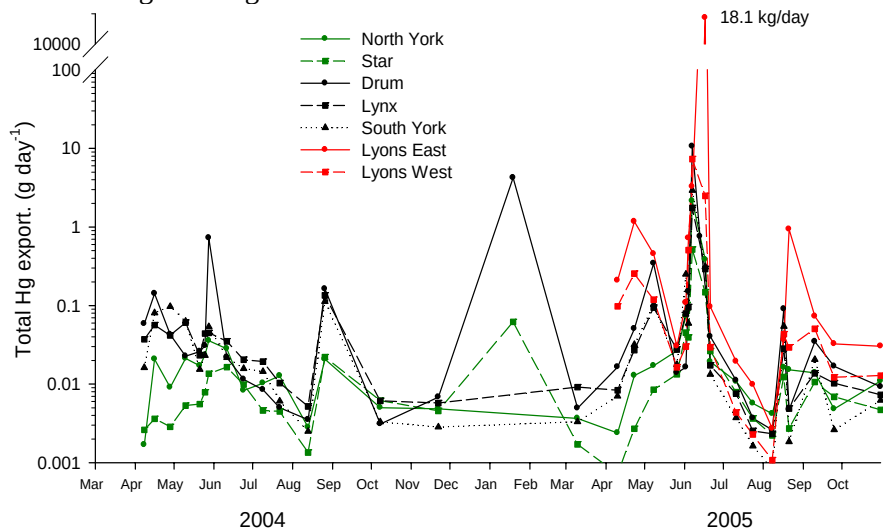
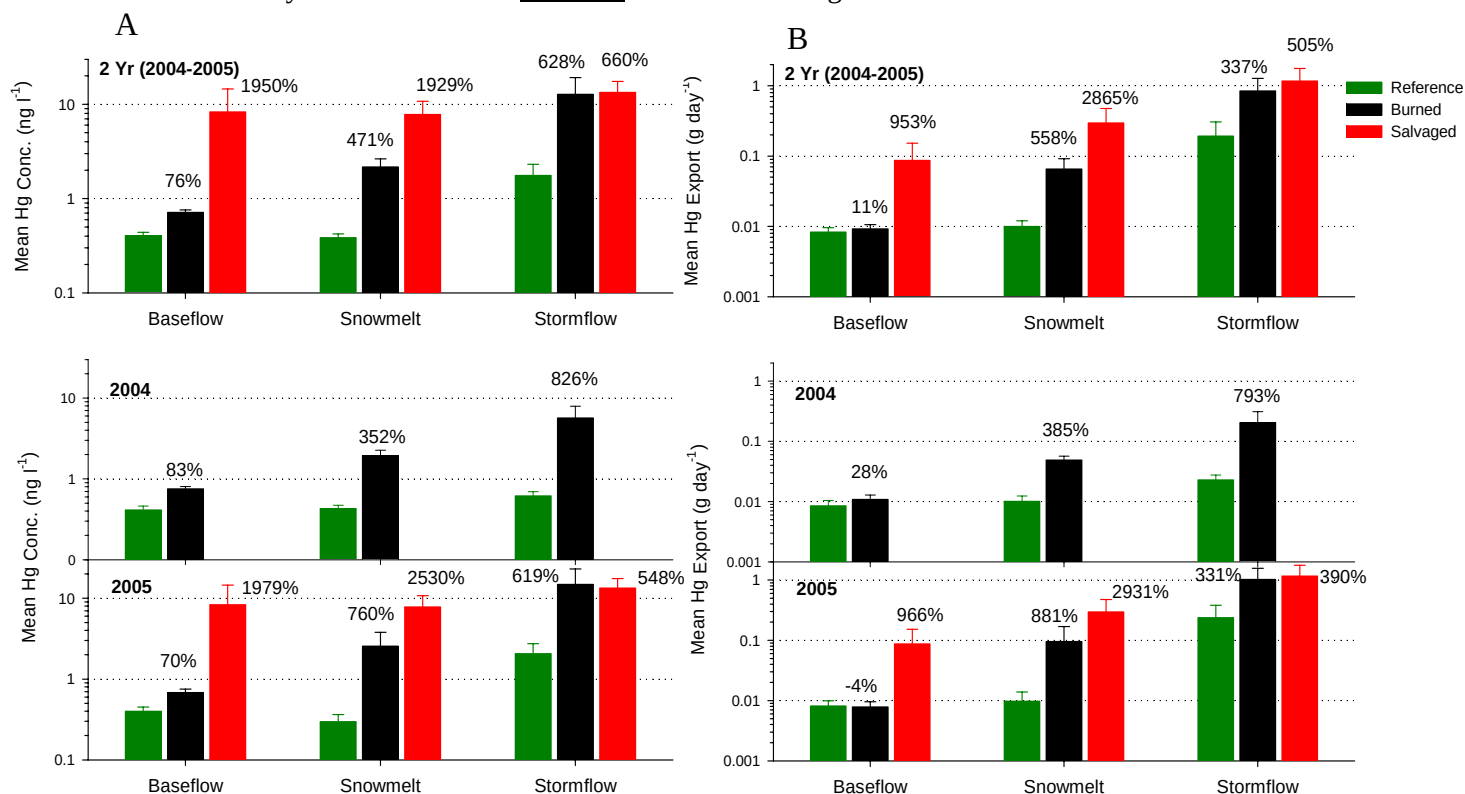


Figure 20 Mean total mercury concentrations (A) and export (B) by flow condition in 2004-2005. % values indicate relative increases over unburned values. **Note:** the extreme value from Lyons Ck. in 2005 is excluded from these averages.

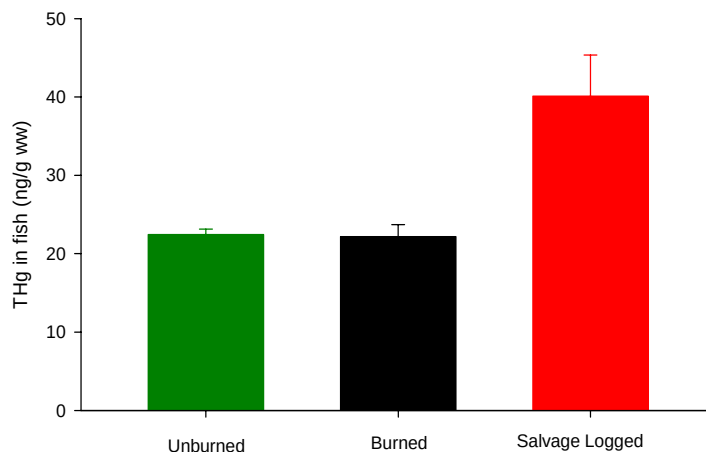


Export of total mercury from burned or salvage logged catchments were periodically above 1 g Hg day⁻¹ (Figure 19). An extremely high mercury concentration was sampled from Lyons Creek East Fork on June 17, 2005 when a small-moderate rainstorm (approx. 20mm) on top of already saturated ground from the extreme rains 10 days earlier, produced a very high stormflow. Because of the extreme mercury concentration in this sample, the remaining sample was also sent to Flett Labs (Winnipeg) for confirmation. The final confirmed value of 265,000 ng/L Hg is likely one of the highest mercury concentrations sampled in Canadian flowing waters (B. Flett personal comm.). This storm produced an estimated flow weighted mercury export of 18.1 kg of mercury per day. Based on measured mercury conc. and streamflow in Lyons E. & W. Ck.s, along with Water Survey of Canada measured mean daily flows in the Crowsnest R. at Frank (downstream of the confluence with Lyons Ck.), estimated mixing ratios with the Crowsnest R. would have still produced a mercury concentration in the main stem of the river of 9910 ng/litre and an estimated Hg load of 18.16 kg/day downstream of Frank, AB. This extreme value is omitted from analysis of mean responses (below). Caution is urged in inferences concerning general impact of salvage logging on mercury production. Considering both the extreme value and chronically elevated values of Hg in Lyons Ck., differences in geology among watersheds (Lyons Ck. has a higher proportion of marine shales than the other catchments), other factors such as previously undescribed mercury bearing formations in that valley may be involved in the patterns we have observed.

Patterns of mean mercury concentrations and total exports were generally similar (Figure 20) and were 3.5-8 x higher in burned watersheds during higher flows in 2004/05 and 5.5-30 x greater in salvaged logged watersheds in 2005. Two sets of samples for methyl-mercury were taken from study watersheds in late 2005 when flows had already declined. By this time, concentrations were very low near detection limits for these samples (0.1-0.8 ng/litre, data not shown).

Because of the potential for mercury to bio-amplify up the aquatic food chain from algae to invertebrate herbivores to invertebrate predators, and finally to predatory fish, sampling for fish within and outside of areas affected by the burn was conducted in late 2005 with AB. SRD Fish & Wildlife. Fish were sampled by electroshocking in burned creeks (Carbondale R., Lost Ck., & lower Lynx. Ck), salvage logged (Lyons Ck.), and nearby creeks unaffected by the burn (W. Castle R. and Blairmore Ck.) and muscle tissue from replicate fish ranging in size (n=12-15) were analyzed for total mercury (Figure 21).

Figure 21 Total mercury concentration in fish muscle tissue collected in Aug. 2005

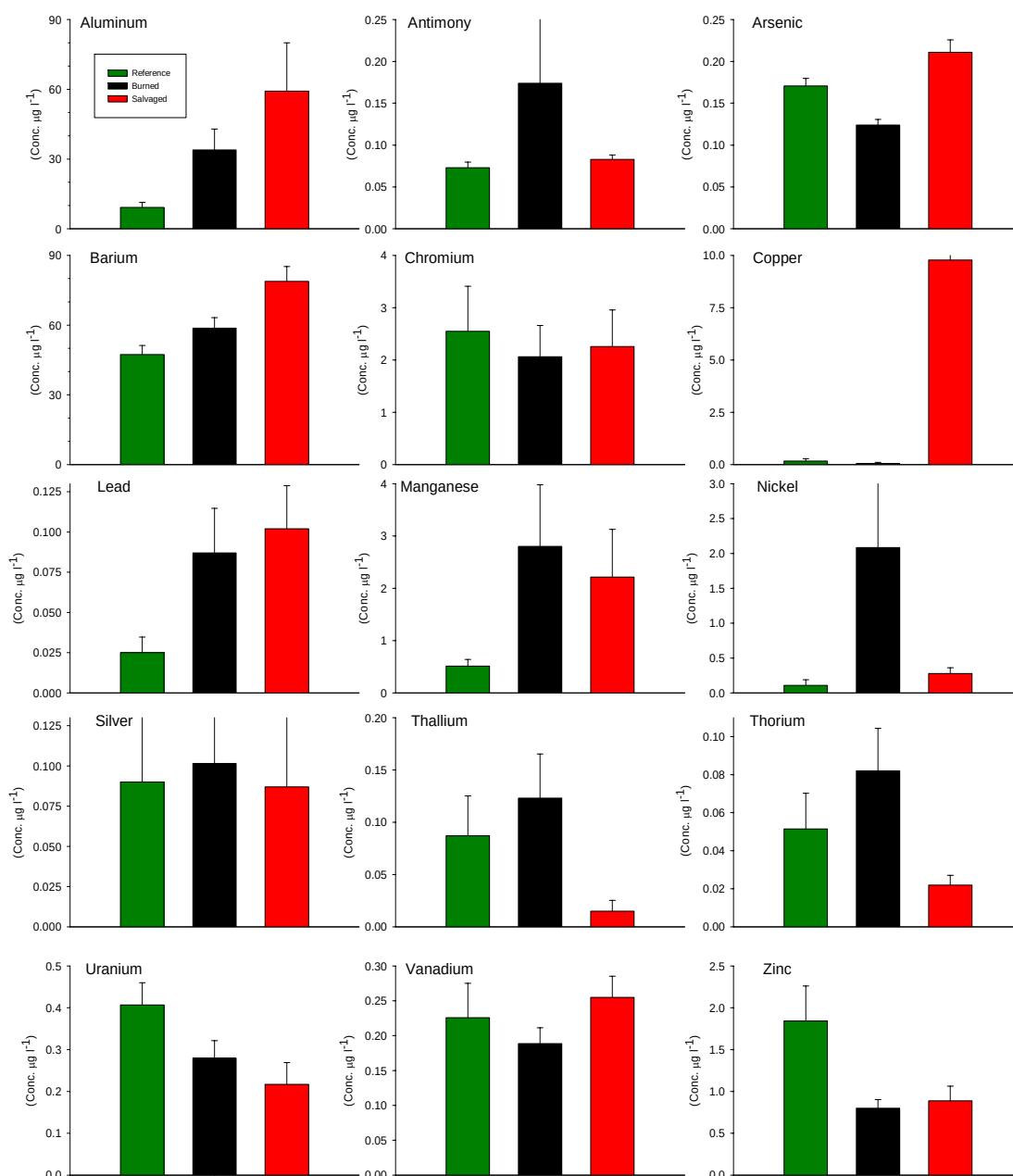


Fish from the salvage logged creek had higher total mercury in their muscle tissue, while the mean of the burned creeks was no different from the unburned creeks. While fish from the Carbondale R. had elevated Hg. (31 ng/g w/w), the mean of fish from Lynx & Lost Cks. were considerably lower thus the overall group mean was not different from the unburned group. Furthermore, the concentration of mercury in fish tissue, though elevated in some creeks, was not sufficient to warrant fish consumption concerns for

regional anglers. A full research manuscript on mercury results from this work (water, insects, & fish) is in preparation by Erin Kelly and will be submitted for publication in the summer of 2007.

Full suite metal analysis also suggested some likely effect of wildfire and fire + salvage logging on concentrations of these metal species (Figure 22 & appendix). Somewhat consistent patterns of elevated aluminum, barium, copper, lead, and manganese were evident in burned and salvage logged watersheds. Given our observation of elevated mobile lead in soil sampling conducted during 2004 (reported on in the 1st annual report) the finding of elevated lead concentrations in stream water may be a possible concern. However, given the very small sample size (2-3 samples under a range of flow condition in each year), these data should only be considered preliminary and do not support any inferences on disturbance effects at this time. Additional sampling in the next two years will provide more solid insights.

Figure 22 Mean full suite U.S. EPA metals from 2004-2006



3.3 Regional Water Quality

Analysis to provide interpretation of the regional water quality results has turned out to be one of the more challenging datasets we have collected over the past 3 years. Putting these results in context of major changes in background hydrology, physiology, climate, disturbance, and changing patterns of wildland, urban, and rural land use as one moves from the headwater regions of the 3 major river systems in the upper Oldman Basin downstream towards the Oldman Dam presents a profoundly difficult cumulative effects assessment challenge. Both the Castle R. and Crowsnest R. are partially affected by the wildfire, while the upper Oldman R. is not. While we are exploring a range of analytical approaches to more effectively summarize these results, only a preliminary analysis is presented here. For this report, we present the data for the 3 main river systems longitudinally beginning in the upper main stem section of the rivers (beginning above the burn in the case of the Castle/Crowsnest)

Water quality parameters in all of the river systems were highly flow dependent with the greatest concentrations, yields, and export values during the snowmelt and stormflow periods (Tables 4 & 5). While concentrations and unit area total yields of nitrogen and phosphorous generally remained similar in the main stem of the 3 river systems moving in the downstream direction, while total export or loading generally increased substantially due to the combined effect of generally similar concentrations but strongly increasing downstream river discharges in these rivers.

Increases in nitrogen and phosphorous concentrations are evident between either, unburned upstream sections of the Crowsnest/Castle rivers & unburned SRWP study watersheds, when compared to downstream sections of these rivers within, or strongly affected by the burn. Further downstream, concentrations were generally similar or decline likely because of the dilution effect of strongly increasing discharge. While this does indicate impact of the burn in the larger river systems, these changes in concentration are also strongly confounded with changing land use conditions in the downstream direction which (at present) limits strong inferences as to the changing cumulative effect of the wildfire as the % of the watershed area affected by the burn decreases in the downstream direction. Because concentrations remain relatively constant or only marginally decrease in downstream reaches despite strong increases in discharge, this indicates likely strong inputs from other sources is acting to maintain the concentration signal. Again, we are exploring alternate analysis techniques to attempt to disentangle these confounding factors in order to provide stronger quantitative insights into cumulative effects of this disturbance further downstream.

However, these results show reasonably strong differential scaling patterns evident in each of these river systems. For example, in the upper Oldman R. and Racehorse Ck. where no or little permanent development exists, both total N & P are relatively low. However, a very large increase in both parameters occurs between the gap in the Livingstone Mtn. range and Maycroft and continued P & N increases are evident below this point to the Olin bridge. While no substantial cultivation of agricultural lands exists in this area, the region is used for extensive (as opposed to intensive) grazing. Similarly, moderate increases in N and much larger increases in P occur in the Crowsnest R. during the dominant flow periods (melt freshet & baseflows) at the town of Frank (below much of the burn, plus the town of Blairmore & the Crowsnest Golf Course) and increase substantially again at Lundbreck (below primary municipal sewage treatment at Frank and Hillcrest). Nitrogen and phosphorous concentrations, yields, and exports appear lower in the Castle R. within the forest reserve, but increase substantially at Hwy. 507 where agricultural land use (grazing, forage and other crops under cultivation) comprises a dominant feature of the landscape east of the forest reserve boundary. Similar spatial/temporal patterns are also evident with nitrate-nitrite, ammonium, soluble reactive phosphorous, sulphate, dissolved organic carbon, and total dissolved solids (appendix).

Figure 23 Sampling locations

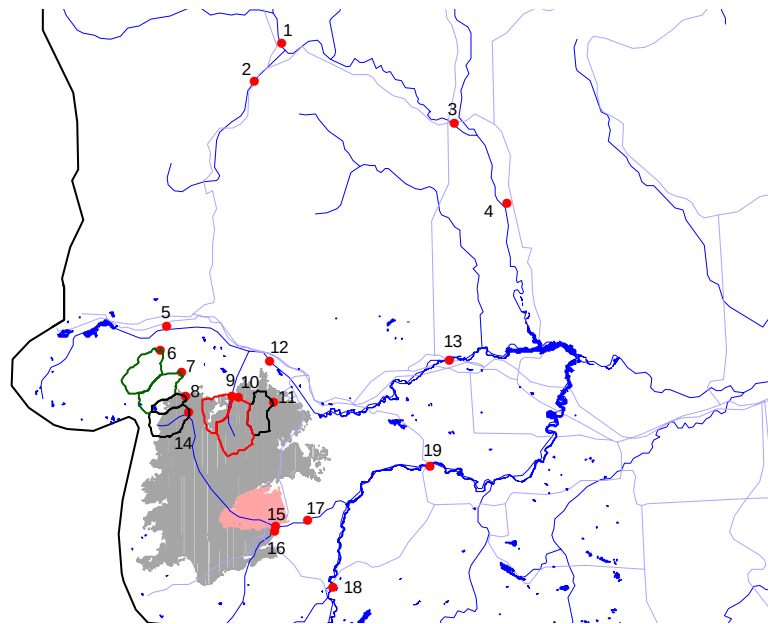


Table 4 Total nitrogen concentration & flow weighted yields and export

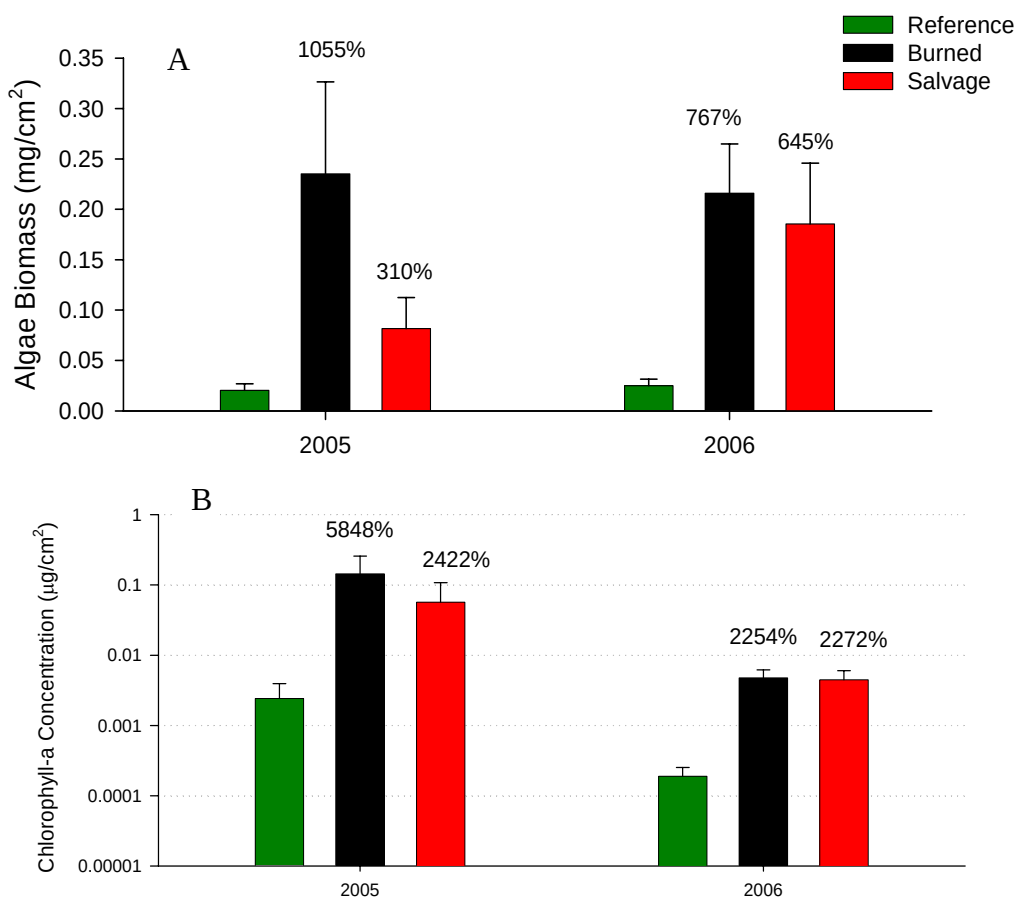
Oldman R.	Site	Area (km ²)	% Burned	Site #	Total Nitrogen Conc. (µg/l)			Total Nitrogen Yield (kg/ha/yr)			Total Nitrogen Export (kg/d)		
					Baseflow	Snowmelt	Stormflow	Baseflow	Snowmelt	Stormflow	Baseflow	Snowmelt	Stormflow
	Racehorse Creek	896.3	0%	2	259	203	704	0.69	2.09	27.41	41	126	1653
	Upper Oldman	220.1	0%	1	311	211	828	1.05	0.80	23.52	258	195	5777
	Oldman at Maycroft	1441.2	0%	3	228	195	952	0.78	1.08	36.17	309	427	14280
	Oldman at Olin Bridge	1826.6	0%	4	541	363	778	1.53	1.83	28.40	764	918	14215
Crowsnest R.													
	Crowsnest above Star Ck.	158.5	0%	5	251	309	757	1.88	3.59	33.31	82	156	1446
	Star Creek	10.6	0%	6	352	263	464	5.72	4.64	12.25	17	13	36
	North York Creek	8.3	0%	7	274	221	536	4.52	8.13	33.36	10	18	76
	South York Creek	3.6	53%	8	293	307	1178	4.40	12.25	114.16	4	12	112
	Lyons West	7.1	58%	9	582	523	1265	2.44	1.58	55.03	5	3	107
	Lyons East	13.2	82%	10	403	410	1259	1.80	1.27	32.40	6	5	117
	Drum Creek	7.1	100%	11	661	398	1481	5.49	1.93	30.19	11	4	59
	Crowsnest at Frank	382.4	6%	12	262	478	544	1.33	4.37	13.41	139	458	1405
	Crowsnest at Lundbreck	661.7	8%	13	255	598	851	1.04	4.04	17.14	189	732	3107
Castle R.													
	Castle at Ranger Stn.	372.5	0%	18	98	179	333	0.46	4.10	15.13	47	419	1544
	Lynx Creek	8.2	67%	14	523	392	1356	6.57	10.93	65.38	15	25	147
	Lynx at Mouth	105.1	71%	15	369	383	893	0.74	4.50	25.69	21	130	740
	Carbondale above Lynx Ck.	150.3	37%	16	253	598	467	0.79	11.73	38.69	33	483	1593
	Carbondale below Adinack Rd	291.7	45%	17	239	398	618	4.41	18.93	18.72	352	1512	1496
	Castle at Hwy 507	819.3	16%	19	138	293	479	0.55	4.40	21.55	124	987	4837

Table 5 Total phosphorous concentration & flow weighted yields and export

	Site	Area (km ²)	% Burned	Site #	Total Phosphorous Conc. (µg/l)			Total Phosphorous Yield (kg/ha/yr)			Total Phosphorous Export (kg/d)		
					Baseflow	Snowmelt	Stormflow	Baseflow	Snowmelt	Stormflow	Baseflow	Snowmelt	Stormflow
Oldman River													
	Racehorse Creek	896.3	0%	2	9.6	15.3	67.1	0.034	0.153	3.463	2.0	9.2	208.8
	Upper Oldman	220.1	0%	1	6.5	12.7	49.9	0.022	0.049	1.873	5.4	12.0	459.9
	Oldman at Maycroft	1441.2	0%	3	6.7	12.7	424.1	0.023	0.071	24.352	9.1	27.9	9615.6
	Oldman at Olin Bridge	1826.6	0%	4	12.8	22.3	427.2	0.042	0.097	20.148	21.2	48.5	10083.0
Crowsnest River													
	Crowsnest above Star Ck.	158.5	0%	5	7.5	15.8	33.6	0.071	0.151	1.716	3.1	6.6	74.5
	Star Creek	10.6	0%	6	2.8	2.6	20.0	0.036	0.046	0.654	0.1	0.1	1.9
	North York Creek	8.3	0%	7	6.7	5.4	26.1	0.109	0.199	2.390	0.2	0.5	5.4
	South York Creek	3.6	53%	8	9.5	8.5	67.9	0.144	0.339	11.546	0.1	0.3	11.4
	Lyons West	7.1	58%	9	18.8	8.9	152.3	0.086	0.027	10.284	0.2	0.1	19.9
	Lyons East	13.2	82%	10	23.8	14.6	100.0	0.123	0.045	3.210	0.4	0.2	11.6
	Drum Creek	7.1	100%	11	18.6	10.5	442.7	0.157	0.051	12.612	0.3	0.1	24.6
	Crowsnest at Frank	382.4	6%	12	7.2	31.2	78.3	0.037	0.273	2.360	3.8	28.6	247.3
	Crowsnest at Lundbreck	661.7	8%	13	16.4	61.1	119.6	0.095	0.409	3.185	17.3	74.1	577.4
Castle R.													
	Castle at Ranger Stn.	372.5	0%	18	3.9	9.8	37.7	0.038	0.208	1.774	3.9	21.2	181.0
	Lynx Creek	8.2	67%	14	4.4	9.4	35.2	0.053	0.262	2.840	0.1	0.6	6.4
	Lynx at Mouth	105.1	71%	15	7.6	16.9	90.1	0.037	0.199	2.884	1.1	5.7	83.0
	Carbondale above Lynx Ck.	150.3	37%	16	8.3	17.3	43.9	0.056	0.337	3.554	2.3	13.9	146.3
	Carbondale below Adinack Rd	291.7	45%	17	4.0	20.0	62.0	0.074	0.808	1.411	5.9	64.6	112.8
	Castle at Hwy 507	819.3	16%	19	3.6	17.6	96.8	0.023	0.263	4.675	5.2	59.1	1049.3

3.4 Aquatic Production

Figure 23 Algal biomass (A) and algal chlorophyll-a content (B) during 2005/06. % values indicate relative increases over unburned values.



Consistent with our observations of dramatically increased algal production in 2004 (reported on in the 1st annual report), algal production remained high during the 2005/06 growing season (Figure 23). Though the seasonal timing of peak algal growth varied between 2005 and 2006, the relative differences in algal biomass and chlorophyll-a between burned and salvage logged watersheds was relatively consistent within each of these seasons (see appendix). Algal biomass production was 10.5 & 7.6 x greater in burned creeks during 2005 & 2006 respectively, while only 3.1-6.5 x greater in salvage logged watersheds during this same period. Chlorophyll-a showed larger relative differences among disturbance conditions with 58 & 22.5 x greater production in burned creeks during 2005 & 2006 and 24 & 22 x greater production in salvage logged catchments during this period.

Our observations of greatly increased algal biomass in burned and burned/salvage logged streams is consistent with our observations of strongly elevated nitrogen and phosphorus in these streams. Stream water nutrient status is generally considered a primary limitation to algal production in typically oligotrophic (nutrient) poor headwater mountain streams characteristic of the study area. Therefore small changes in stream nutrient status will often have substantial effects on algal production. Our findings of somewhat lower algal production in salvage logged streams is likely related to the much higher sediment regime in these watersheds. Indeed, the streambeds in both Lyons East and West Forks shows clear signs of heavy sediment intrusion which along with decreased light penetration from chronically higher turbidities both likely limits algal production in these creeks. The likely association of increased production with elevated phosphorous in particular is evidenced by the association of high SRP,

dissolved, and total phosphorus with continued high algal production in 2006 (despite no storm activity from June onward) when nitrogen export had already begun to decline by 2006. This may also indicate phosphorous leaching into local groundwater systems has occurred over the past several years which could explain the continued high phosphorous concentrations in these creeks in 2006.

Figure 23 Algal growth in Lynx creek still evident during low flows in Aug. 2006. Dark areas in photo on left are submerged algal mats.



Similar results have been reported after large wildfires in Glacier national park (Spencer et al. 2003), while other studies have reported variable results (Earl and Blinn, 2003). Spencer et. al. (2003) suggested increases in stream nutrients followed by increased algal production can cause a shift in functional invertebrate feeding groups. Headwater streams are often dominated by detritivores and predators owing to light limitations on aquatic plant production in these small shaded streams. After wildfire which produced both increased radiation to streams and increased nutrient concentrations, increased plant production can stimulate increased density of herbivores potentially altering the invertebrate community structure. The effect of post-fire increases in invertebrate biomass on fish production is unclear at present, but our results for fish age - growth rates, along with carbon nitrogen isotope ratios (not presented here but will be reported on in upcoming manuscript focused on mercury and a subsequent SRWP report) suggest increase in stream productivity at several trophic levels has occurred after the wildfire.

3.5 Vegetation Recovery

The immediate post-fire year of 2004 was ideal for seedling germination and establishment as climatic conditions were generally cool and moist with frequent small rain showers throughout the summer. Considerable growth of herbaceous vegetation (dominated by fireweed) has also occurred establishing by both seed germination, but also by suckering from areas of the landscape with less severe burn conditions.

Early on in 2004 we observed generally high densities of spruce seed on burned soils, but noted a general absence (or very low densities) of lodgepole pine seed on the forest floor (Figure 24). Given the limited synoptic survey we conducted, only limited inferences can be supported by our survey data but these do agree strongly with our field-based observations over the previous 3 yrs. Though strong differences in the regenerating species were observed depending on the species composition of the fire killed stands sampled (stand type at the time of burn), generally speaking, we observed 2000-20000 total established seedlings/ha across the survey though a large number of stands had no plots with any established seedlings present. However, because of the high number of plots with no seedling

establishment present, stand means are limited in their suitability to describe “average” conditions observed in the survey. Median values (with upper/lower quartiles & min/max range) are likely more descriptive of variability in regeneration survey results (median of 0 indicates more than ½ of the plots within a comparison group had 0 seedlings present).

Figure 24 Spruce seed/cones on forest floor - fall 2003 (left), Fireweed establishment - 2005 (centre), pine seedling establishment – 2006 (right)



Figure 25 Box & whisker plots (median, quartiles, max/min) of regeneration by species (each group represents different establishment spp.) in 2 pre-burn stand age classes x two pre-burn species dominance classes.

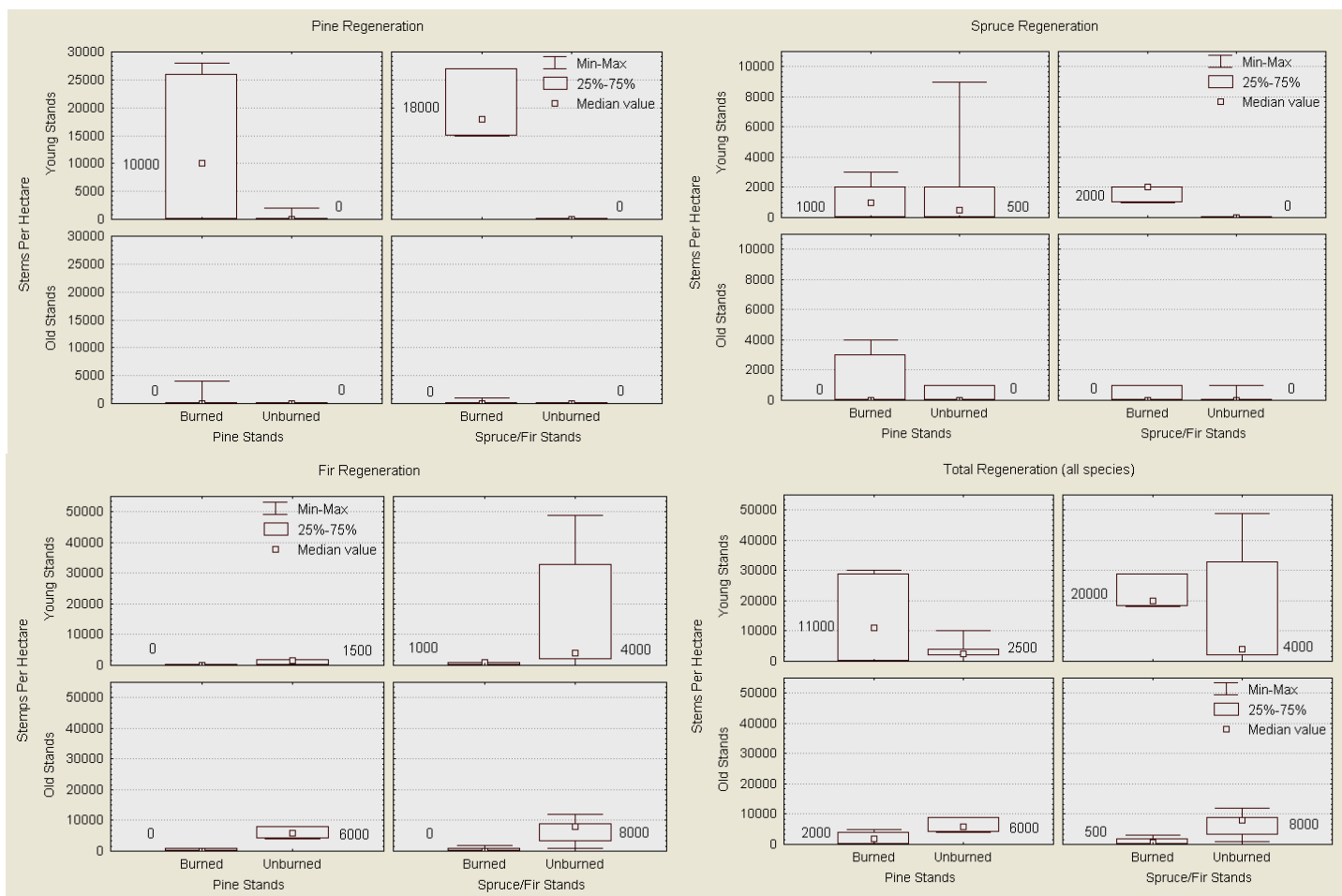


Table 6 Stand attributes of stands (burned=fire killed trees) selected in establishment survey

Site Description				Stand Characteristics				
Treatment	Species Class	Age Class	Aspect	Stand age	Density (sph)	Mean Height (m)	Mean DBH (cm)	BA/ha (m2/ha)
Burned	Pine	Old	North	126	1105	17.2	23.2	55
Burned	Pine	Old	South	116	2404	11.9	16.3	61
Burned	Pine	Young	North	86	2079	13.6	18.9	70
Burned	Pine	Young	South	86	4838	10.2	11.9	66
Burned	Spruce/Fir	Old	North	126	893	10.9	17.8	37
Burned	Spruce/Fir	Old	South	116	2735	9.8	13.7	48
Burned	Spruce/Fir	Young	North	86	2185	8.4	12.4	32
Burned	Spruce/Fir	Young	South					
Unburned	Pine	Old	North	136	2476	12.4	16.1	69
Unburned	Pine	Old	South	136	2260	9.7	12.2	35
Unburned	Pine	Young	North	76	8754	10.8	9.4	93
Unburned	Pine	Young	South	76	7512	11.8	10.7	91
Unburned	Spruce/Fir	Old	North	76	923	14.1	22.6	46
Unburned	Spruce/Fir	Old	South	136	7074	7.4	8.8	52
Unburned	Spruce/Fir	Young	North	76	9196	8.3	9.3	63
Unburned	Spruce/Fir	Young	South	76	10964	4.3	5.0	56

Over most of the stands sampled, seedling establishment was dominantly spruce-fir seedlings (Table 6 & 7). For lodgepole pine stands, we observed a very strong association of establishment with previous stand age with few if any pine seedlings in old stands but a median of 10000-18000 seedlings/ha in younger pine stands at the time of the fire. However, because of spruce-fir establishment in burned old pine sites, the total establishment in these stand types had a median value of 2000 seedlings/ha. Spruce-fir establishment was more uniform across the burn ranging from 500-2000 seedlings per ha in younger stands at the time of the fire, with similarly little establishment in older stands. Our LAI data was not available for summary at the time report preparation but will be reported on in subsequent reports.

Given the dominance of older stand ages in the study region, these figures may be some concern (acknowledging the limitations of this dataset). While 10,000-20,000 pine seedlings per ha is likely reasonable initial stocking after a wildfire, the very low median and mean values we observed in the older burned stands (indicating a high proportion of un-stocked stands) may be a concern for hydrologic recovery in the coming decades and stand composition further into the future. However, the generally high proportion of spruce & fir seedling establishment across the survey may be a promising leading indicator of future species composition when considered in light of likely severe Mtn. Pine Beetle disturbance to lodgepole pine dominated montane stands in the coming decade.

Table 7 Mean establishment of regenerating seedlings (3 yr. old) in 2006

Site Description				Regeneration				
Treatment	Species Class	Age Class	Aspect	Density (sph)	Mean Height (cm)	% Fir	% Pine	% Spruce
Burned	Pine	Old	North	3000	5.07	11	44	44
Burned	Pine	Old	South	2000	3.80	25	0	75
Burned	Pine	Young	North	1000	0.67	0	0	100
Burned	Pine	Young	South	26667	7.34	0	93	7
Burned	Spruce/Fir	Old	North	0	0.00	0	0	0
Burned	Spruce/Fir	Old	South	2000	5.55	50	17	33
Burned	Spruce/Fir	Young	North	22333	4.05	3	90	7
Burned	Spruce/Fir	Young	South					
Unburned	Pine	Old	North	14000	12.50	96	0	4
Unburned	Pine	Old	South	9500	24.16	95	0	5
Unburned	Pine	Young	North	3000	8.07	67	33	0
Unburned	Pine	Young	South	7500	59.81	20	0	80
Unburned	Spruce/Fir	Old	North	6000	5.88	100	0	0
Unburned	Spruce/Fir	Old	South	23000	7.62	100	0	0
Unburned	Spruce/Fir	Young	North	8000	42.36	100	0	0
Unburned	Spruce/Fir	Young	South	84000	27.34	100	0	0

4 References

- Brass, J.A., Ambrosia, V.G., Riggan, P.J., and Sebesta, P.D., 1996, Consequences of fire on aquatic nitrate and phosphorous dynamics in Yellowstone national park., *Ecol. Imp. of Fire in the Greater Yellowstone 1988*, IAWF.
- Earl, S.R., and Blinn, D.W., 2003, Effects of wildfire ash on water chemistry and biota in South-Western U.S.A. streams., *Freshwater Biol.* 48:1015-1030.
- Farnes, P.E., 1996, Impact of the 1988 Yellowstone fires on snowmelt water yields. *Ecol. Imp. of Fire in the Greater Yellowstone 1988*, IAWF.
- Garcia, E., and Carignan, R., 1999, Impact of wildfire and clear-cutting in the boreal forest on methyl mercury in zooplankton., *Can. J. Fish & Aquat. Sci.* 56:339-345
- Johnson, S.L., and Jones, J.A., 2000, Stream temperature responses to forest harvest and debris flows in the western Cascades, Oregon., *Can. J. Fish & Aquatic Sci.*, 57 (supl. 2): 30-39.
- Moore, R.D., Sutherland, P., Gomi, T. and Dhakal, A. 2005. Thermal regime of a headwater stream within a clearcut, coastal British Columbia, Canada. *Hydrological Processes* (in press).
- Neary, D.G., Gottfried, G.J., and Ffolliott P.F., 2003, Post-Wildfire Watershed Flood Responses, 2nd Int. Wildland Fire Ecology & Fire Management Congress and 5th Symp. on Fire Forest Meteorology. American Meteorology Society. Orlando, FL. 16-20 November.
- Robinson, C.T., and Minshall, G.W., 1996, Physical and chemical response of streams in Yellowstone national park following the 1988 wildfires. *Ecol. Imp. of Fire in the Greater Yellowstone 1988*, IAWF.
- Rudd, J.W.M., 1995, Sources of methyl-mercury in freshwater ecosystems: a review. *Water Air & Soil Poll.* 80:697-713.
- Spencer, C.N., Gabel, O.K., and Hauer, F.R., 2003, Wildfire effects on stream food webs and nutrient dynamics in Glacier national park, U.S.A., *For. Ecol. & Mgt.* 178: 141-153

5 Appendix – Water chemistry summary tables

Nitrogen

Nitrogen - Concentrations

Year	Flow condition	Total Nitrogen (µg/L)					Nitrate-Nitrite (µg/L)					Ammonium (µg/L)				
		Reference	Burned	Diff (rel. unburned)	Burned & Salvaged	Diff (rel. unburned)	Reference	Burned	Diff (rel. unburned)	Burned & Salvaged	Diff (rel. unburned)	Reference	Burned	Diff (rel. unburned)	Burned & Salvaged	Diff (rel. unburned)
2004	Baseflow	197.0	722.9	267%			104.2	374.7	260%			4.8	7.2	52%		
	Snowmelt	208.2	1311.9	530%			40.9	406.3	893%			4.3	10.3	141%		
	Stormflow	211.3	1417.7	571%			82.4	978.3	1088%			12.0	9.8	-18%		
	Mean 2004	203.9	1074.0	427%			76.4	499.7	554%			5.9	8.9	50%		
2005	Baseflow	270.5	612.3	126%	419.0	55%	126.0	401.5	219%	187.0	48%	2.2	1.8	-19%	4.3	96%
	Snowmelt	349.2	1010.2	189%	878.7	152%	137.1	886.8	547%	488.6	256%	4.1	7.7	90%	8.9	120%
	Stormflow	435.8	1051.0	141%	920.4	111%	129.2	571.0	342%	405.1	213%	3.9	18.6	376%	22.2	468%
	Mean 2005	342.7	832.2	143%	697.6	104%	129.0	539.9	319%	327.5	154%	3.1	8.7	180%	12.0	285%
2006	Baseflow	199.3	274.5	38%	300.3	51%	115.9	208.9	80%	170.3	47%	2.3	2.3	-1%	7.3	221%
	Snowmelt	303.8	570.0	88%	803.9	165%	122.0	345.7	183%	414.0	239%	6.1	10.4	71%	9.6	58%
	Stormflow	328.0	537.3	64%	774.0	136%	96.6	209.3	117%	192.0	99%	1.0	3.9	294%	9.8	878%
	Mean 2006	229.7	356.3	55%	466.5	103%	116.2	239.9	107%	239.2	106%	3.0	4.2	38%	8.1	165%
3-yr Mean	Baseflow	222.5	494.2	122%	351.2	58%	116.5	312.9	169%	177.4	52%	2.8	3.3	16%	6.0	113%
	Snowmelt	273.1	1013.9	271%	837.1	207%	89.9	508.2	466%	447.2	398%	4.7	9.7	104%	9.3	95%
	Stormflow	367.9	1102.8	200%	904.2	146%	114.2	646.9	467%	381.4	234%	5.8	15.0	160%	20.8	262%

** % Differences are % increase in parameter relative to value in reference watersheds
[(treatment-reference)/reference]

Nitrogen - Area-Discharge Weighted Yield

Year	Flow condition	Total Nitrogen (kg/ha/yr)					Nitrate-Nitrite (kg/ha/yr)					Ammonium (kg/ha/yr)				
		Reference	Burned	Diff (rel. unburned)	Burned & Salvaged	Diff (rel. unburned)	Reference	Burned	Diff (rel. unburned)	Burned & Salvaged	Diff (rel. unburned)	Reference	Burned	Diff (rel. unburned)	Burned & Salvaged	Diff (rel. unburned)
2004	Baseflow	1.74	7.16	311%			0.69	2.92	325%			0.05	0.06	32%		
	Snowmelt	1.84	24.29	1220%			0.32	8.18	2482%			0.02	0.17	796%		
	Stormflow	3.18	30.43	857%			1.08	20.80	1824%			0.16	0.15	-7%		
	Mean 2004	2.05	17.95	776%			0.62	8.24	1225%			0.06	0.12	103%		
2005	Baseflow	2.39	3.76	57%	1.49	-38%	1.06	2.47	134%	0.69	-35%	0.02	0.01	-47%	0.01	-34%
	Snowmelt	6.26	14.65	134%	12.47	99%	1.77	12.23	591%	6.54	269%	0.04	0.13	213%	0.09	121%
	Stormflow	13.86	43.43	213%	28.72	107%	3.08	21.26	591%	10.94	256%	0.11	0.60	447%	0.80	635%
	Mean 2005	7.13	19.59	175%	13.96	96%	1.90	10.71	465%	5.71	201%	0.06	0.24	332%	0.33	497%
2006	Baseflow	1.13	1.90	68%	0.76	-33%	0.49	1.20	145%	0.36	-27%	0.01	0.01	18%	0.01	81%
	Snowmelt	2.94	7.06	140%	8.54	191%	1.31	4.07	211%	3.73	185%	0.06	0.16	152%	0.08	30%
	Stormflow	10.68	22.64	112%	17.55	64%	3.22	8.28	157%	4.26	33%	0.03	0.18	443%	0.22	555%
	Mean 2006	2.06	4.24	106%	3.85	87%	0.82	2.25	173%	1.51	84%	0.02	0.05	146%	0.04	107%
3-yr Mean	Baseflow	1.69	3.77	123%	1.07	-37%	0.73	2.03	180%	0.50	-31%	0.02	0.02	6%	0.01	-36%
	Snowmelt	3.31	16.71	405%	10.29	211%	0.99	7.96	706%	4.98	404%	0.04	0.15	311%	0.09	130%
	Stormflow	10.80	38.15	253%	27.48	154%	2.57	19.99	678%	10.20	297%	0.12	0.44	280%	0.74	533%

** % Differences are % increase in parameter relative to value in reference watersheds
[(treatment-reference)/reference]

Total Dissolved Nitrogen - available on request

Flow weighted export (kg/day) available on request for all water quality parameters

Phosphorous

Phosphorous - Concentrations

Year	Flow condition	Total Phosphorous (µg/L)					Total Dissolved Phosphorous (µg/L)					Soluable Reactive Phosphorous (µg/L)				
		Reference	Burned	Diff (rel. unburned)	Burned & Salvaged	Diff (rel. unburned)	Reference	Burned	Diff (rel. unburned)	Burned & Salvaged	Diff (rel. unburned)	Reference	Burned	Diff (rel. unburned)	Burned & Salvaged	Diff (rel. unburned)
2004	Baseflow	3.9	13.3	244%			2.4	7.0	190%			1.4	5.4	279%		
	Snowmelt	4.1	35.9	785%			2.8	13.9	398%			2.9	12.3	322%		
	Stormflow	8.7	93.0	976%			3.9	18.6	378%			1.3	10.8	754%		
	Mean 2004	4.8	36.7	660%			2.8	11.8	315%			2.0	9.0	346%		
2005	Baseflow	2.9	11.3	290%	20.2	598%	1.4	5.2	274%	9.5	587%	1.3	4.5	247%	8.3	547%
	Snowmelt	6.0	25.7	331%	91.5	1431%	2.2	8.7	294%	18.9	754%	2.1	7.7	263%	15.5	631%
	Stormflow	18.4	146.8	697%	143.5	679%	2.2	16.4	657%	38.1	1660%	1.5	13.7	820%	33.3	2130%
	Mean 2005	9.0	61.7	589%	80.7	802%	1.8	9.7	440%	22.2	1132%	1.5	8.3	452%	19.2	1181%
2006	Baseflow	3.4	7.8	126%	14.6	324%	2.1	3.7	74%	8.1	277%	1.7	3.2	84%	6.7	289%
	Snowmelt	3.2	13.2	308%	54.2	1582%	1.7	5.4	222%	12.0	616%	1.2	3.9	215%	8.7	609%
	Stormflow	5.0	54.6	986%	73.0	1354%	1.5	8.5	466%	20.9	1282%	1.0	6.0	532%	13.8	1353%
	Mean 2006	3.5	11.7	235%	28.8	728%	2.0	4.4	118%	9.9	393%	1.6	3.5	122%	7.6	387%
3-yr Mean	Baseflow	3.4	10.3	206%	17.0	406%	2.0	5.0	155%	8.7	344%	1.5	4.1	174%	7.4	389%
	Snowmelt	4.3	26.5	516%	70.8	1545%	2.3	10.0	335%	15.1	553%	2.2	8.6	290%	11.7	430%
	Stormflow	14.7	124.5	746%	135.7	822%	2.6	16.3	536%	36.2	1314%	1.4	12.3	786%	31.1	2145%

** % Differences are % increase in parameter relative to value in reference watersheds
[(treatment-reference)/reference]

Phosphorous - Area-Discharge Weighted Yield

Year	Flow condition	Total Phosphorous (kg/ha/yr)					Total Dissolved Phosphorous (kg/ha/yr)					Soluable Reactive Phosphorous (kg/ha/yr)				
		Reference	Burned	Diff (rel. unburned)	Burned & Salvaged	Diff (rel. unburned)	Reference	Burned	Diff (rel. unburned)	Burned & Salvaged	Diff (rel. unburned)	Reference	Burned	Diff (rel. unburned)	Burned & Salvaged	Diff (rel. unburned)
2004	Baseflow	0.03	0.10	200%			0.02	0.05	152%			0.01	0.04	236%		
	Snowmelt	0.04	0.53	1181%			0.03	0.22	701%			0.03	0.19	632%		
	Stormflow	0.12	1.63	1212%			0.06	0.36	471%			0.02	0.18	907%		
	Mean 2004	0.05	0.55	925%			0.02	0.12	559%			0.02	0.12	559%		
2005	Baseflow	0.02	0.06	135%	0.07	200%	0.01	0.03	194%	0.04	285%	0.01	0.02	135%	0.03	183%
	Snowmelt	0.13	0.46	256%	1.42	993%	0.03	0.13	274%	0.29	744%	0.02	0.10	452%	0.23	1172%
	Stormflow	0.82	6.39	678%	7.33	793%	0.08	0.74	879%	2.27	2900%	0.03	0.60	1700%	2.02	5970%
	Mean 2005	0.33	2.37	625%	3.10	848%	0.02	0.24	1119%	0.82	4093%	0.02	0.24	1119%	0.82	4093%
2006	Baseflow	0.02	0.05	143%	0.04	85%	0.01	0.02	62%	0.02	54%	0.01	0.01	92%	0.01	102%
	Snowmelt	0.04	0.18	306%	0.89	1910%	0.02	0.07	228%	0.14	591%	0.01	0.04	392%	0.10	1070%
	Stormflow	0.17	2.50	1380%	1.65	880%	0.05	0.32	538%	0.49	871%	0.03	0.21	660%	0.33	1087%
	Mean 2006	0.03	0.22	543%	0.36	978%	0.01	0.03	261%	0.06	541%	0.01	0.03	261%	0.06	541%
3-yr Mean	Baseflow	0.02	0.06	159%	0.05	114%	0.01	0.03	126%	0.03	100%	0.01	0.02	150%	0.02	127%
	Snowmelt	0.06	0.41	525%	1.12	1630%	0.03	0.15	456%	0.21	666%	0.02	0.13	556%	0.16	739%
	Stormflow	0.58	4.78	721%	6.70	1051%	0.07	0.60	758%	2.07	2844%	0.03	0.45	1476%	1.83	6250%

** % Differences are % increase in parameter relative to value in reference watersheds
[(treatment-reference)/reference]

Flow weighted export (kg/day) available on request for all water quality parameters

Potassium, Sulphate, Dissolved Organic Carbon

Potassium, Sulfate, Dissolved Organic Carbon - Concentrations

Year	Flow condition	Potassium (mg/L)					Sulphate (mg/L)					DOC (mg/L)				
		Reference	Burned	Diff (rel. unburned)	Burned & Salvaged	Diff (rel. unburned)	Reference	Burned	Diff (rel. unburned)	Burned & Salvaged	Diff (rel. unburned)	Reference	Burned	Diff (rel. unburned)	Burned & Salvaged	Diff (rel. unburned)
2004	Baseflow	0.34	0.51	50%			10.8	12.1	12%			1.66	2.33	41%		
	Snowmelt	0.40	0.62	56%			9.1	18.9	108%			1.73	3.10	80%		
	Stormflow	0.32	0.59	84%			8.9	12.5	39%			1.81	3.54	96%		
	Mean 2004	0.36	0.57	58%			9.8	14.7	50%			1.71	2.85	66%		
2005	Baseflow	0.43	0.45	6%	0.70	64%	11.9	10.3	-13%	9.8	-17%	1.28	1.76	37%	4.48	249%
	Snowmelt	0.59	0.65	10%	0.74	25%	8.8	11.7	32%	9.9	12%	1.74	2.73	57%	5.69	227%
	Stormflow	0.40	0.68	72%	0.81	104%	8.6	10.1	18%	9.6	12%	2.55	3.60	41%	8.86	247%
	Mean 2005	0.44	0.56	28%	0.75	69%	10.2	10.5	3%	9.7	-4%	1.81	2.57	42%	6.38	252%
2006	Baseflow	0.39	0.43	10%	0.67	70%	10.3	23.9	133%	8.7	-15%	1.11	1.31	18%	3.10	179%
	Snowmelt	0.40	0.46	14%	0.62	55%	9.0	7.9	-12%	7.4	-18%	2.48	1.61	-35%	5.24	111%
	Stormflow	0.29	0.43	48%	0.65	124%	5.9	5.7	-3%	5.6	-6%	1.53	4.23	176%	8.90	480%
	Mean 2006	0.39	0.43	12%	0.65	69%	9.7	19.2	98%	8.1	-16%	1.44	1.54	7%	4.02	179%
3-yr Mean	Baseflow	0.39	0.46	17%	0.68	74%	10.9	16.5	51%	9.2	-16%	1.30	1.70	31%	3.69	185%
	Snowmelt	0.45	0.58	29%	0.67	51%	9.0	13.8	53%	8.5	-6%	1.95	2.56	31%	5.44	179%
	Stormflow	0.37	0.63	73%	0.79	115%	8.4	10.3	23%	9.1	8%	2.27	3.64	60%	8.86	290%

** % Differences are % increase in parameter relative to value in reference watersheds
 $[(\text{treatment-reference})/\text{reference}]$

Potassium, Sulfate, Dissolved Organic Carbon - Area-Discharge Weighted Yield

Year	Flow condition	Potassium (kg/ha/yr)					Sulphate (kg/ha/yr)					DOC (kg/ha/yr)				
		Reference	Burned	Diff (rel. unburned)	Burned & Salvaged	Diff (rel. unburned)	Reference	Burned	Diff (rel. unburned)	Burned & Salvaged	Diff (rel. unburned)	Reference	Burned	Diff (rel. unburned)	Burned & Salvaged	Diff (rel. unburned)
2004	Baseflow	2.7	4.2	57%			74.8	91.5	22%			15.8	21.8	38%		
	Snowmelt	3.2	10.7	233%			71.8	310.4	332%			15.4	54.4	252%		
	Stormflow	4.7	11.2	140%			127.1	230.6	81%			26.9	69.5	159%		
	Mean 2004	3.2	7.9	145%			83.5	199.7	139%			17.8	43.0	142%		
2005	Baseflow	3.1	2.5	-20%	2.1	-34%	96.4	59.2	-39%	31.6	-67%	10.0	10.2	2%	16.2	62%
	Snowmelt	6.8	8.8	29%	9.3	37%	110.6	174.5	58%	122.3	11%	31.7	40.2	27%	84.1	166%
	Stormflow	10.3	23.6	129%	25.1	144%	167.8	251.3	50%	204.3	22%	78.5	158.2	101%	313.7	299%
	Mean 2005	6.3	11.0	75%	12.2	94%	124.3	146.0	17%	114.7	-8%	38.1	67.5	77%	142.5	274%
2006	Baseflow	1.6	2.3	41%	1.6	-1%	43.2	139.7	223%	17.9	-59%	5.6	8.0	42%	8.2	46%
	Snowmelt	3.6	5.5	56%	5.0	41%	73.5	79.3	8%	50.7	-31%	28.4	24.1	-15%	67.2	137%
	Stormflow	9.5	19.0	100%	14.7	54%	190.9	210.1	10%	127.8	-33%	51.2	187.2	266%	198.1	287%
	Mean 2006	2.5	4.0	59%	3.3	31%	58.2	130.0	124%	33.1	-43%	13.2	21.8	65%	35.1	166%
3-yr Mean	Baseflow	2.4	2.8	19%	1.8	-23%	68.3	101.2	48%	23.8	-65%	9.4	12.0	27%	11.6	23%
	Snowmelt	4.2	8.7	105%	6.9	63%	82.4	207.1	151%	82.5	0%	23.5	41.8	78%	74.7	218%
	Stormflow	8.8	19.9	127%	23.9	173%	159.2	242.2	52%	195.8	23%	62.7	137.3	119%	300.8	380%

** % Differences are % increase in parameter relative to value in reference watersheds
 $[(\text{treatment-reference})/\text{reference}]$

Flow weighted export (kg/day) available on request for all water quality parameters

Base Cations/Anions

Base cations/anions - Concentrations

Year	Flow condition	Calcium (mg/L)					Magnesium (mg/L)					Chloride (mg/L)				
		Reference	Burned	Diff (rel. unburned)	Burned & Salvaged	Diff (rel. unburned)	Reference	Burned	Diff (rel. unburned)	Burned & Salvaged	Diff (rel. unburned)	Reference	Burned	Diff (rel. unburned)	Burned & Salvaged	Diff (rel. unburned)
2004	Baseflow	38.8	39.7	2%			9.6	10.1	6%			0.38	0.71	88%		
	Snowmelt	41.7	36.7	-12%			10.2	8.7	-14%			1.22	1.78	45%		
	Stormflow	36.9	36.6	-1%			8.7	9.0	4%			0.45	0.80	78%		
	Mean 2004	39.5	38.0	-4%			9.6	9.4	-3%			0.71	1.13	59%		
2005	Baseflow	42.2	39.1	-7%	30.1	-29%	11.0	10.2	-7%	5.5	-50%	0.46	0.58	27%	0.77	69%
	Snowmelt	42.1	36.5	-13%	24.1	-43%	10.0	8.4	-16%	4.3	-57%	0.40	0.65	62%	0.93	130%
	Stormflow	35.6	31.8	-11%	21.1	-41%	8.5	8.1	-4%	3.9	-54%	0.42	0.67	62%	1.07	157%
	Mean 2005	39.9	36.1	-9%	25.5	-36%	9.9	9.2	-7%	4.7	-53%	0.43	0.63	44%	0.92	111%
2006	Baseflow	41.9	39.1	-7%	35.0	-16%	10.3	10.0	-3%	7.1	-31%	0.38	0.44	16%	0.51	34%
	Snowmelt	46.2	36.3	-21%	24.6	-47%	11.5	9.1	-21%	4.6	-60%	0.39	0.48	23%	0.55	42%
	Stormflow	35.3	29.3	-17%	19.8	-44%	7.7	6.8	-12%	3.6	-53%	0.33	0.39	20%	0.44	34%
	Mean 2006	42.5	37.9	-11%	31.3	-26%	10.4	9.6	-8%	6.2	-41%	0.38	0.45	17%	0.52	36%
3-yr Mean	Baseflow	41.3	39.3	-5%	32.9	-20%	10.3	10.1	-2%	6.4	-38%	0.41	0.55	36%	0.62	53%
	Snowmelt	43.1	36.5	-15%	24.4	-43%	10.5	8.8	-17%	4.5	-58%	0.76	1.11	45%	0.72	-6%
	Stormflow	35.9	32.9	-8%	20.9	-42%	8.5	8.2	-3%	3.8	-55%	0.42	0.68	63%	1.00	140%

** % Differences are % increase in parameter relative to value in reference watersheds
[(treatment-reference)/reference]

Base cations/anions - Area-Discharge Weighted Yield

Year	Flow condition	Calcium (kg/ha/yr)					Magnesium (kg/ha/yr)					Chloride (kg/ha/yr)				
		Reference	Burned	Diff (rel. unburned)	Burned & Salvaged	Diff (rel. unburned)	Reference	Burned	Diff (rel. unburned)	Burned & Salvaged	Diff (rel. unburned)	Reference	Burned	Diff (rel. unburned)	Burned & Salvaged	Diff (rel. unburned)
2004	Baseflow	310.0	334.9	8%			74.3	80.8	9%			3.1	6.6	112%		
	Snowmelt	353.2	652.0	85%			85.9	152.1	77%			12.9	29.3	128%		
	Stormflow	541.5	708.2	31%			126.7	167.5	32%			6.3	15.6	149%		
	Mean 2004	369.6	523.8	42%			88.5	123.8	40%			7.4	16.8	128%		
2005	Baseflow	348.5	230.9	-34%	90.0	-74%	88.1	59.3	-33%	16.9	-81%	3.7	3.4	-8%	2.4	-34%
	Snowmelt	543.1	486.1	-11%	278.0	-49%	123.7	113.4	-8%	50.2	-59%	5.6	9.1	61%	11.0	94%
	Stormflow	878.5	997.3	14%	415.3	-53%	196.5	229.6	17%	75.6	-62%	11.3	20.4	80%	35.5	213%
	Mean 2005	570.2	544.0	-5%	249.7	-56%	132.8	128.4	-3%	45.6	-66%	6.7	10.3	53%	16.6	147%
2006	Baseflow	186.5	211.2	13%	80.7	-57%	45.3	51.6	14%	15.1	-67%	1.6	2.2	33%	1.5	-10%
	Snowmelt	428.8	457.4	7%	160.2	-63%	101.5	106.0	4%	30.5	-70%	3.5	6.3	82%	4.0	17%
	Stormflow	1164.3	1336.5	15%	442.3	-62%	250.0	295.9	18%	81.1	-68%	10.7	16.2	51%	9.2	-14%
	Mean 2006	294.7	330.6	12%	122.9	-58%	69.2	77.7	12%	23.0	-67%	2.5	3.9	54%	2.6	3%
3-yr Mean	Baseflow	269.3	247.0	-8%	84.7	-69%	66.4	61.1	-8%	15.9	-76%	2.6	3.6	36%	1.9	-29%
	Snowmelt	424.9	552.1	30%	212.5	-50%	100.3	128.6	28%	39.2	-61%	8.2	17.3	111%	7.1	-13%
	Stormflow	815.5	950.7	17%	418.3	-49%	182.9	219.0	20%	76.2	-58%	10.0	18.8	88%	32.6	227%

** % Differences are % increase in parameter relative to value in reference watersheds
[(treatment-reference)/reference]

Flow weighted export (kg/day) available on request for all water quality parameters

Total Mercury, Sediment, Turbidity

Total mercury, suspended sediment, turbidity - Concentrations

Year	Flow condition	Total mercury (ng/L)					Suspended sediment (mg/l)					Turbidity (NTU)				
		Reference	Burned	Diff (rel. unburned)	Burned & Salvaged	Diff (rel. unburned)	Reference	Burned	Diff (rel. unburned)	Burned & Salvaged	Diff (rel. unburned)	Reference	Burned	Diff (rel. unburned)	Burned & Salvaged	Diff (rel. unburned)
2004	Baseflow	0.41	0.75	83%			0.57	2.85	401%			0.43	0.85	99%		
	Snowmelt	0.43	1.95	352%			0.36	10.31	2778%			0.38	2.08	444%		
	Stormflow	0.61	5.69	826%			3.80	37.31	882%			1.12	4.45	296%		
	Mean 2004	0.42	1.77	323%			1.52	13.21	766%			0.54	1.99	267%		
2005	Baseflow	0.40	0.68	70%	8.32	1979%	1.63	3.93	141%	3.42	110%	0.40	1.00	152%	3.84	861%
	Snowmelt	0.30	2.56	760%	7.83	2530%	3.68	12.08	228%	72.48	1868%	1.63	4.83	197%	22.48	1280%
	Stormflow	2.07	14.88	619%	13.40	548%	12.94	144.24	1015%	113.80	780%	5.30	23.66	346%	45.00	748%
	Mean 2005	0.89	5.37	503%	7.68	761%	8.29	62.03	648%	57.21	590%	2.37	9.66	307%	23.00	869%
2006	Baseflow						1.47	2.56	74%	2.29	56%	0.41	0.79	96%	2.54	526%
	Snowmelt						0.50	3.93	686%	37.90	7480%	0.70	1.91	175%	13.71	1873%
	Stormflow						3.10	41.60	1242%	48.30	1458%	1.30	13.00	904%	23.00	1676%
	Mean 2006						2.42	6.12	153%	17.12	609%	0.52	1.74	234%	6.78	1205%
3-yr Mean	Baseflow	0.41	0.72	76%	8.32	1950%	1.31	3.09	135%	2.76	110%	0.41	0.88	115%	3.08	653%
	Snowmelt	0.39	2.17	461%	7.83	1929%	1.17	8.84	656%	53.27	4456%	0.77	2.72	255%	17.61	2199%
	Stormflow	1.76	12.84	628%	13.40	660%	9.70	106.88	1002%	105.62	989%	3.86	17.63	356%	42.41	997%

** % Differences are % increase in parameter relative to value in reference watersheds
 $[(\text{treatment-reference})/\text{reference}]$

Total mercury & suspended sediment - Discharge weighted total export

Year	Flow condition	Total mercury (g/day)					Suspended sediment (kg/day)				
		Reference	Burned	Diff (rel. unburned)	Burned & Salvaged	Diff (rel. unburned)	Reference	Burned	Diff (rel. unburned)	Burned & Salvaged	Diff (rel. unburned)
2004	Baseflow	0.009	0.011	28%			11.5	31.1	171%		
	Snowmelt	0.010	0.049	385%			10.7	211.6	1880%		
	Stormflow	0.023	0.206	793%			127.4	1146.0	799%		
	Mean 2004	0.011	0.052	369%			45.8	335.8	633%		
2005	Baseflow	0.008	0.008	-4%	0.087	966%	27.9	30.7	10%	30.4	9%
	Snowmelt	0.010	0.096	881%	0.296	2931%	261.4	499.3	91%	3659.0	1300%
	Stormflow	0.239	1.029	331%	1.170	390%	1834.0	11025.6	501%	11567.2	531%
	Mean 2005	0.102	0.414	306%	0.552	441%	996.6	4517.8	353%	5510.1	453%
2006	Baseflow						14.3	30.1	109%	13.0	-10%
	Snowmelt						18.8	97.3	418%	2120.2	11184%
	Stormflow						286.0	3608.6	1162%	2822.1	887%
	Mean 2006						54.8	298.5	445%	876.1	1499%
3-yr Mean	Baseflow	0.008	0.009	11%	0.087	943%	18.2	30.5	68%	20.5	12%
	Snowmelt	0.010	0.066	558%	0.296	2865%	78.1	249.2	219%	2804.1	3491%
	Stormflow	0.193	0.846	337%	1.170	505%	1254.2	7756.0	518%	10595.5	745%

** % Differences are % increase in parameter relative to value in reference watersheds
 $[(\text{treatment-reference})/\text{reference}]$

Total mercury & suspended sediment - Discharge-Area weighted total yield

Year	Flow condition	Total mercury (g/ha/yr)					Suspended sediment (kg/ha/yr)				
		Reference	Burned	Diff (rel. unburned)	Burned & Salvaged	Diff (rel. unburned)	Reference	Burned	Diff (rel. unburned)	Burned & Salvaged	Diff (rel. unburned)
2004	Baseflow	3.1	4.0	28%			4.8	22.6	373%		
	Snowmelt	3.7	17.9	385%			4.5	141.6	3044%		
	Stormflow	8.4	75.1	793%			48.5	651.7	1244%		
	Mean 2004	4.1	19.0	369%			17.9	202.0	1028%		
2005	Baseflow	3.0	2.9	-4%	31.8	966%	11.5	17.2	50%	11.0	-4%
	Snowmelt	3.6	35.0	881%	108.0	2931%	91.5	261.7	186%	1167.6	1177%
	Stormflow	87.1	375.4	331%	427.0	390%	768.2	6627.7	763%	4808.9	526%
	Mean 2005	37.2	151.0	306%	201.4	441%	413.1	2708.0	556%	2217.5	437%
2006	Baseflow						5.8	17.3	196%	4.6	-20%
	Snowmelt						7.7	60.9	694%	713.6	9199%
	Stormflow						122.0	1998.9	1539%	1049.6	760%
	Mean 2006						22.9	167.8	634%	301.5	1219%
3-yr Mean	Baseflow	3.0	3.4	11%	31.8	943%	7.5	18.5	148%	7.4	-1%
	Snowmelt	3.6	24.0	558%	108.0	2865%	28.0	147.4	427%	915.4	3171%
	Stormflow	70.6	308.7	337%	427.0	505%	524.2	4637.4	785%	4391.2	738%

** % Differences are % increase in parameter relative to value in reference watersheds
 $[(\text{treatment-reference})/\text{reference}]$

U.S. EPA Heavy Metals

Aluminum (µg/L Al)	Reference	s.e.	Burned	s.e.	Salvaged	s.e.
2004	8.8	1.1	45.7	14.2		
2005	14.0	7.5	40.4	25.4	27.5	10.1
2006	6.1	1.1	20.3	6.3	80.4	32.2
Mean (2004-06)	9.2	2.2	33.9	8.9	59.2	20.8

Antimony (µg/L Sb)	Reference	s.e.	Burned	s.e.	Salvaged	s.e.
2004	0.068	0.005	0.090	0.016		
2005	0.078	0.006	0.063	0.010	0.075	0.006
2006	0.073	0.016	0.320	0.250	0.088	0.007
Mean (2004-06)	0.073	0.007	0.174	0.100	0.083	0.005

Arsenic (µg/L As)	Reference	s.e.	Burned	s.e.	Salvaged	s.e.
2004	0.163	0.007	0.140	0.009		
2005	0.180	0.022	0.107	0.008	0.195	0.018
2006	0.170	0.016	0.125	0.013	0.222	0.021
Mean (2004-06)	0.171	0.009	0.124	0.007	0.211	0.015

Barium (µg/L Ba)	Reference	s.e.	Burned	s.e.	Salvaged	s.e.
2004	40.0	6.0	59.9	8.2		
2005	48.0	7.6	58.3	10.0	83.3	0.7
2006	51.7	6.5	58.0	6.9	75.8	11.0
Mean (2004-06)	47.3	3.9	58.7	4.5	78.8	6.5

Beryllium (µg/L Be)	Reference	s.e.	Burned	s.e.	Salvaged	s.e.
2004	All below detection limits					
2005						
2006						
Mean (2004-06)						

Cadmium (µg/L Cd)	Reference	s.e.	Burned	s.e.	Salvaged	s.e.
2004	0.000	0.000	0.000	0.000		
2005	0.000	0.000	0.000	0.000	0.000	0.000
2006	0.000	0.000	0.009	0.009	0.000	0.000
Mean (2004-06)	0.000	0.000	0.004	0.004	0.000	0.000

Chromium (µg/L Cr)	Reference	s.e.	Burned	s.e.	Salvaged	s.e.
2004	0.56	0.04	0.59	0.04		
2005	0.69	0.08	0.69	0.06	0.59	0.08
2006	5.12	1.48	4.18	1.17	3.37	0.92
Mean (2004-06)	2.55	0.86	2.06	0.60	2.26	0.70

Cobalt (µg/L Co)	Reference	s.e.	Burned	s.e.	Salvaged	s.e.
2004	0.000	0.000	0.023	0.016		
2005	0.000	0.000	0.062	0.062	0.023	0.014
2006	0.000	0.000	0.006	0.006	0.038	0.019
Mean (2004-06)	0.000	0.000	0.028	0.019	0.032	0.013

Copper (µg/L Cu)	Reference	s.e.	Burned	s.e.	Salvaged	s.e.
2004	0.00	0.00	0.00	0.00		
2005	0.00	0.00	0.00	0.00	23.40	23.40
2006	0.38	0.26	0.15	0.11	0.69	0.47
Mean (2004-06)	0.16	0.12	0.06	0.04	9.77	9.32

Lead (µg/L Pb)	Reference	s.e.	Burned	s.e.	Salvaged	s.e.
2004	0.008	0.008	0.073	0.032		
2005	0.058	0.024	0.095	0.066	0.050	0.021
2006	0.015	0.010	0.091	0.048	0.137	0.037
Mean (2004-06)	0.025	0.010	0.087	0.028	0.102	0.027

Manganese (µg/L Mn)	Reference	s.e.	Burned	s.e.	Salvaged	s.e.
2004	0.62	0.26	3.56	1.24		
2005	0.59	0.34	4.50	3.77	1.16	0.41
2006	0.38	0.14	0.96	0.29	2.92	1.48
Mean (2004-06)	0.51	0.13	2.80	1.18	2.22	0.91

Molybdenum (µg/L Mo)	Reference	s.e.	Burned	s.e.	Salvaged	s.e.
2004	0.43	0.07	0.91	0.22		
2005	0.50	0.08	0.82	0.18	0.70	0.16
2006	0.49	0.11	0.77	0.17	0.84	0.32
Mean (2004-06)	0.47	0.05	0.83	0.10	0.77	0.17

Nickel (µg/L Ni)	Reference	s.e.	Burned	s.e.	Salvaged	s.e.
2004	0.00	0.00	0.21	0.14		
2005	0.00	0.00	0.00	0.00	0.18	0.04
2006	0.25	0.18	5.05	4.84	0.35	0.13
Mean (2004-06)	0.11	0.08	2.08	1.94	0.28	0.08

Selenium (µg/L Se)	Reference	s.e.	Burned	s.e.	Salvaged	s.e.
2004	0.000	0.000	0.000	0.000		
2005	0.000	0.000	0.000	0.000	0.000	0.000
2006	0.000	0.000	0.000	0.000	0.163	0.104
Mean (2004-06)	0.000	0.000	0.000	0.000	0.098	0.065

Silver (µg/L Ag)	Reference	s.e.	Burned	s.e.	Salvaged	s.e.
2004	0.023	0.010	0.032	0.020		
2005	0.038	0.034	0.020	0.018	0.000	0.000
2006	0.170	0.107	0.215	0.099	0.145	0.133
Mean (2004-06)	0.090	0.048	0.102	0.044	0.087	0.080

Thallium (µg/L Tl)	Reference	s.e.	Burned	s.e.	Salvaged	s.e.
2004	0.073	0.038	0.125	0.086		
2005	0.200	0.117	0.113	0.085	0.000	0.000
2006	0.022	0.010	0.129	0.065	0.025	0.016
Mean (2004-06)	0.087	0.038	0.123	0.042	0.015	0.010

Thorium (µg/L Th)	Reference	s.e.	Burned	s.e.	Salvaged	s.e.
2004	0.038	0.021	0.070	0.040		
2005	0.095	0.059	0.065	0.039	0.018	0.003
2006	0.032	0.016	0.104	0.040	0.025	0.008
Mean (2004-06)	0.051	0.019	0.082	0.022	0.022	0.005

Uranium (µg/L U)	Reference	s.e.	Burned	s.e.	Salvaged	s.e.
2004	0.463	0.075	0.290	0.064		
2005	0.488	0.074	0.320	0.080	0.248	0.028
2006	0.315	0.100	0.241	0.076	0.197	0.087
Mean (2004-06)	0.406	0.054	0.280	0.042	0.217	0.052

Vanadium (µg/L V)	Reference	s.e.	Burned	s.e.	Salvaged	s.e.
2004	0.170	0.025	0.210	0.031		
2005	0.158	0.033	0.172	0.055	0.235	0.042
2006	0.308	0.108	0.185	0.036	0.268	0.045
Mean (2004-06)	0.226	0.049	0.189	0.023	0.255	0.030

Zinc (µg/L Zn)	Reference	s.e.	Burned	s.e.	Salvaged	s.e.
2004	2.355	1.068	0.937	0.203		
2005	2.218	0.662	0.993	0.190	1.163	0.336
2006	1.252	0.544	0.553	0.124	0.705	0.170
Mean (2004-06)	1.843	0.416	0.800	0.103	0.888	0.174

Total Dissolved Solids, Electrical Conductivity, pH

Total dissolved solids, conductivity, pH - Concentrations

Year	Flow condition	TDS (mg/L)					Conductivity					pH				
		Reference	Burned	Diff (rel. unburned)	Burned & Salvaged	Diff (rel. unburned)	Reference	Burned	Diff (rel. unburned)	Burned & Salvaged	Diff (rel. unburned)	Reference	Burned	Diff (rel. unburned)	Burned & Salvaged	Diff (rel. unburned)
2004	Baseflow	178.0	172.3	-3%			263.8	273.7	4%			8.23	8.26	0%		
	Snowmelt	162.5	152.4	-6%			286.3	260.4	-9%			8.19	8.13	-1%		
	Stormflow	145.5	157.7	8%			251.3	257.4	2%			8.19	8.15	-1%		
	Mean 2004	166.1	162.1	-2%			269.9	265.6	-2%			8.21	8.19	0%		
2005	Baseflow	154.8	160.1	3%	120.4	-22%	270.1	250.3	-7%	186.6	-31%	8.32	8.30	0%	8.25	-1%
	Snowmelt	148.0	126.0	-15%	93.1	-37%	301.3	257.3	-15%	174.3	-42%	8.30	8.21	-1%	8.06	-3%
	Stormflow	141.7	146.4	3%	116.7	-18%	245.3	222.0	-10%	148.4	-40%	8.34	8.26	-1%	7.98	-4%
	Mean 2005	149.0	149.8	1%	113.6	-24%	266.5	241.4	-9%	169.7	-36%	8.32	8.27	-1%	8.11	-3%
2006	Baseflow	169.7	160.4	-5%	158.9	-6%	285.4	273.1	-4%	239.7	-16%	8.20	8.20	0%	8.10	-1%
	Snowmelt	201.9	162.5	-20%	122.4	-39%	308.8	250.1	-19%	168.7	-45%	8.25	8.18	-1%	8.06	-2%
	Stormflow	79.0	120.7	53%	124.0	57%	230.5	198.7	-14%	137.1	-41%	8.22	8.09	-2%	7.89	-4%
	Mean 2006	171.8	158.6	-8%	146.8	-15%	287.6	263.7	-8%	214.3	-25%	8.21	8.19	0%	8.08	-2%
3-yr Mean	Baseflow	166.7	163.1	-2%	142.4	-15%	275.3	265.6	-4%	217.0	-21%	8.24	8.25	0%	8.16	-1%
	Snowmelt	170.4	148.8	-13%	109.4	-36%	296.8	256.5	-14%	171.2	-42%	8.24	8.17	-1%	8.06	-2%
	Stormflow	137.2	147.1	7%	117.7	-14%	245.6	229.3	-7%	147.1	-40%	8.29	8.21	-1%	7.97	-4%

** % Differences are % increase in parameter relative to value in reference watersheds
[(treatment-reference)/reference]

Total Dissolved Solids - Area-Discharge Weighted Yield

Year	Flow condition	TDS (kg/ha/yr)				
		Reference	Burned	Diff (rel. unburned)	Burned & Salvaged	Diff (rel. unburned)
2004	Baseflow	1524	1419	-7%		
	Snowmelt	1381	2610	89%		
	Stormflow	1950	2877	48%		
	Mean 2004	1550	2139	38%		
2005	Baseflow	1205	923	-23%	382	-68%
	Snowmelt	1896	1678	-12%	1364	-28%
	Stormflow	4010	4082	2%	2833	-29%
	Mean 2005	2322	2238	-4%	1618	-30%
2006	Baseflow	801	877	9%	371	-54%
	Snowmelt	1904	2152	13%	954	-50%
	Stormflow	2575	5307	106%	2714	5%
	Mean 2006	1145	1417	24%	663	-42%
3-yr Mean	Baseflow	1105	1020	-8%	376	-66%
	Snowmelt	1669	2239	34%	1136	-32%
	Stormflow	3348	3871	16%	2819	-16%

** % Differences are % increase in parameter relative to value in reference watersheds
[(treatment-reference)/reference]

Flow weighted export (kg/day) available on request for all water quality parameters

Other parameters measured not reported on (available on request)

Nutrient species: Total dissolved nitrogen
Cations/anions: Sodium, iron, silica, calcium carbonate, carbonate, bicarbonate
Other parameters: Dissolved inorganic carbon

Regional Sampling – Nitrate-Nitrite, Soluble Reactive Phos., Sulphate

Oldman R.	Site	Area (km ²)	% Burned	Site #	Nitrate-Nitrite Conc. (µg/l)			Nitrate-Nitrite Yield (kg/ha/yr)			Nitrate-Nitrite Export (kg/d)		
					Baseflow	Snowmelt	Stormflow	Baseflow	Snowmelt	Stormflow	Baseflow	Snowmelt	Stormflow
	Racehorse Creek	896.3	0%	2	2.6	19.6	25.3	0.009	0.073	0.439	2.2	18.0	107.8
	Upper Oldman	220.1	0%	1	4.5	10.8	36.8	0.016	0.109	1.565	0.9	6.6	94.4
	Oldman at Maycroft	1441.2	0%	3	3.0	7.4	35.1	0.010	0.043	1.355	4.1	16.9	535.2
	Oldman at Olin Bridge	1826.6	0%	4	5.9	6.8	36.6	0.021	0.032	1.236	10.5	16.1	618.7
Crowsnest R.													
	Crowsnest above Star Ck.	158.5	0%	5	100.6	105.2	108.3	0.913	1.069	4.643	39.6	46.4	201.6
	Star Creek	10.6	0%	6	113.4	127.0	153.1	1.540	2.239	3.226	4.5	6.5	9.4
	North York Creek	8.3	0%	7	99.3	126.0	119.2	1.628	4.634	5.482	3.7	10.5	12.5
	South York Creek	3.6	53%	8	166.4	150.0	816.6	2.491	5.986	62.408	2.5	5.9	61.4
	Lyons West	7.1	58%	9	312.7	352.0	569.9	1.336	1.061	18.426	2.6	2.1	35.7
	Lyons East	13.2	82%	10	116.0	115.0	762.2	0.729	0.355	17.252	2.6	1.3	62.2
	Drum Creek	7.1	100%	11	334.9	281.0	852.8	3.000	1.361	15.441	5.9	2.7	30.2
	Crowsnest at Frank	382.4	6%	12	125.0	196.2	177.6	0.634	1.735	4.781	66.4	181.8	500.9
	Crowsnest at Lundbreck	661.7	8%	13	74.4	236.2	210.0	0.412	1.573	4.120	74.8	285.2	747.0
Castle R.													
	Castle at Ranger Stn.	372.5	0%	18	26.2	56.6	53.5	0.227	1.070	2.427	23.2	109.2	247.7
	Lynx Creek	8.2	67%	14	434.3	297.0	950.4	5.440	8.284	41.497	12.2	18.6	93.3
	Lynx at Mouth	105.1	71%	15	161.0	178.9	445.7	0.569	2.089	12.146	16.4	60.1	349.6
	Carbondale above Lynx Ck.	150.3	37%	16	15.2	415.4	134.7	0.089	8.243	11.079	3.6	339.3	456.1
	Carbondale below Adinack Rd	291.7	45%	17	77.8	203.0	238.8	1.435	11.074	7.396	114.7	885.0	591.0
	Castle at Hwy 507	819.3	16%	19	29.1	137.2	116.3	0.198	1.927	5.299	44.5	432.5	1189.4
Oldman R.	Site	Area (km ²)	% Burned	Site #	SRP Conc. (µg/l)			SRP Yield (kg/ha/yr)			SRP Export (kg/d)		
					Baseflow	Snowmelt	Stormflow	Baseflow	Snowmelt	Stormflow	Baseflow	Snowmelt	Stormflow
	Racehorse Creek	896.3	0%	2	3.10	2.12	5.50	0.010	0.008	0.171	2.57	1.99	41.97
	Upper Oldman	220.1	0%	1	3.29	2.41	6.80	0.011	0.024	0.282	0.66	1.46	17.02
	Oldman at Maycroft	1441.2	0%	3	2.40	2.17	9.70	0.008	0.012	0.510	3.26	4.81	201.57
	Oldman at Olin Bridge	1826.6	0%	4	1.45	1.62	11.05	0.004	0.007	0.480	2.17	3.62	240.40
Crowsnest R.													
	Crowsnest above Star Ck.	158.5	0%	5	1.34	1.00	0.60	0.013	0.008	0.023	0.55	0.34	1.00
	Star Creek	10.6	0%	6	0.70	1.02	1.37	0.010	0.018	0.026	0.03	0.05	0.07
	North York Creek	8.3	0%	7	1.65	0.50	1.13	0.027	0.018	0.052	0.06	0.04	0.12
	South York Creek	3.6	53%	8	1.25	1.79	7.60	0.019	0.071	1.186	0.02	0.07	1.17
	Lyons West	7.1	58%	9	8.08	2.36	14.17	0.036	0.007	0.654	0.07	0.01	1.27
	Lyons East	13.2	82%	10	7.78	4.48	22.10	0.046	0.014	0.620	0.16	0.05	2.23
	Drum Creek	7.1	100%	11	7.67	4.70	37.77	0.065	0.023	1.007	0.13	0.04	1.97
	Crowsnest at Frank	382.4	6%	12	1.50	1.45	4.30	0.008	0.012	0.151	0.80	1.31	15.83
	Crowsnest at Lundbreck	661.7	8%	13	1.00	1.60	9.20	0.005	0.010	0.216	0.85	1.90	39.12
Castle R.													
	Castle at Ranger Stn.	372.5	0%	18	1.15	1.47	5.20	0.008	0.027	0.228	0.77	2.77	23.24
	Lynx Creek	8.2	67%	14	1.66	3.23	6.23	0.021	0.090	0.430	0.05	0.20	0.97
	Lynx at Mouth	105.1	71%	15	1.52	1.98	9.25	0.006	0.024	0.297	0.18	0.68	8.55
	Carbondale above Lynx Ck.	150.3	37%	16	1.59	2.36	0.75	0.009	0.046	0.066	0.39	1.91	2.70
	Carbondale below Adinack Rd	291.7	45%	17	1.50	2.32	5.65	0.028	0.093	0.127	2.21	7.42	10.13
	Castle at Hwy 507	819.3	16%	19	1.10	1.63	5.05	0.006	0.024	0.250	1.29	5.41	56.10
Oldman R.	Site	Area (km ²)	% Burned	Site #	Sulfate Conc. (mg/l)			Sulfate Yield (kg/ha/yr)			Sulfate Export (kg/d)		
					Baseflow	Snowmelt	Stormflow	Baseflow	Snowmelt	Stormflow	Baseflow	Snowmelt	Stormflow
	Racehorse Creek	896.3	0%	2	22.0	12.8	5.8	74.2	49.0	120.4	18219	12025	29579
	Upper Oldman	220.1	0%	1	14.5	7.9	6.9	46.6	76.5	244.0	2807	4611	14714
	Oldman at Maycroft	1441.2	0%	3	26.1	13.1	9.0	89.5	74.6	334.9	35349	29437	132227
	Oldman at Olin Bridge	1826.6	0%	4	20.5	13.6	9.7	65.3	63.6	301.5	32685	31845	150861
Crowsnest R.													
	Crowsnest above Star Ck.	158.5	0%	5	26.8	38.8	34.5	241.6	347.5	1396.0	10488	15087	60614
	Star Creek	10.6	0%	6	9.9	6.8	6.8	126.8	119.6	155.7	368	347	452
	North York Creek	8.3	0%	7	7.3	5.1	5.9	119.5	189.3	275.3	271	430	625
	South York Creek	3.6	53%	8	6.1	3.9	5.2	93.7	156.2	478.5	92	154	471
	Lyons West	7.1	58%	9	7.8	6.5	9.4	33.9	19.5	324.6	66	38	629
	Lyons East	13.2	82%	10	8.3	7.1	10.0	39.4	21.8	257.7	142	79	928
	Drum Creek	7.1	100%	11	13.6	12.8	15.8	110.5	61.8	339.1	216	121	662
	Crowsnest at Frank	382.4	6%	12	37.4	28.7	24.2	189.9	267.9	609.4	19892	28072	63851
	Crowsnest at Lundbreck	661.7	8%	13	31.4	28.5	24.2	159.9	202.6	447.9	28991	36740	81197
Castle R.													
	Castle at Ranger Stn.	372.5	0%	18	9.6	10.5	7.0	75.3	194.1	317.3	7688	19803	32380
	Lynx Creek	8.2	67%	14	5.6	4.4	6.3	69.0	123.9	313.9	155	279	706
	Lynx at Mouth	105.1	71%	15	7.2	5.4	6.9	26.5	63.1	188.2	762	1818	5417
	Carbondale above Lynx Ck.	150.3	37%	16	6.8	6.2	4.7	34.8	119.8	399.9	1434	4933	16460
	Carbondale below Adinack Rd	291.7	45%	17	9.0	5.3	5.7	165.4	218.5	189.9	13220	17460	15173
	Castle at Hwy 507	819.3	16%	19	9.5	8.3	6.7	59.3	123.6	290.2	13307	27750	65129

Regional Sampling – DOC, TDS

					DOC Conc. (mg/l)			DOC Yield (kg/ha/yr)			DOC Export (kg/d)		
	Site	Area (km ²)	% Burned	Site #	Baseflow	Snowmelt	Stormflow	Baseflow	Snowmelt	Stormflow	Baseflow	Snowmelt	Stormflow
Oldman R.	Racehorse Creek	896.3	0%	2	2.8	3.6	12.2	9.5	14.0	405.0	2328	3442	99455
	Upper Oldman	220.1	0%	1	2.7	4.3	10.7	8.9	44.5	434.1	537	2682	26176
	Oldman at Maycroft	1441.2	0%	3	3.0	3.7	10.0	10.3	20.2	455.3	4050	7990	179790
	Oldman at Olin Bridge	1826.6	0%	4	2.8	3.9	10.0	9.0	17.3	379.5	4491	8646	189897
Crowsnest R.	Crowsnest above Star Ck.	158.5	0%	5	1.2	1.5	2.4	11.1	13.6	115.2	483	588	5001
	Star Creek	10.6	0%	6	1.5	7.8	2.5	21.7	138.4	67.2	63	401	195
	North York Creek	8.3	0%	7	1.0	1.1	2.7	16.8	40.6	191.6	38	92	435
	South York Creek	3.6	53%	8	1.3	1.8	3.7	19.2	72.3	490.8	19	71	483
	Lyons West	7.1	58%	9	4.8	3.1	10.9	22.3	9.4	451.9	43	18	875
	Lyons East	13.2	82%	10	4.8	4.1	8.1	23.1	12.5	223.8	83	45	806
	Drum Creek	7.1	100%	11	2.3	1.7	5.6	20.3	8.2	125.4	40	16	245
	Crowsnest at Frank	382.4	6%	12	1.8	2.3	6.0	9.4	20.2	187.6	980	2116	19651
Crowsnest at Lundbreck	661.7	8%	13	1.9	2.6	6.3	9.8	17.8	141.1	1769	3225	25590	
Castle R.	Castle at Ranger Stn.	372.5	0%	18	1.0	1.0	2.7	9.2	19.6	123.4	943	1999	12594
	Lynx Creek	8.2	67%	14	1.4	1.6	3.8	17.2	43.9	240.7	39	99	541
	Lynx at Mouth	105.1	71%	15	1.8	2.0	4.8	7.2	23.2	143.8	209	667	4139
	Carbondale above Lynx Ck.	150.3	37%	16	1.4	2.0	4.0	7.6	39.2	323.6	312	1614	13320
	Carbondale below Adinack Rd	291.7	45%	17	2.0	1.9	4.5	36.2	91.3	122.5	2895	7298	9787
	Castle at Hwy 507	819.3	16%	19	1.1	1.6	4.9	6.6	22.8	233.7	1472	5122	52464
	Site	Area (km ²)	% Burned	Site #	TDS Conc. (mg/l)			TDS Yield (kg/ha/yr)			TDS Export (kg/d)		
					Baseflow	Snowmelt	Stormflow	Baseflow	Snowmelt	Stormflow	Baseflow	Snowmelt	Stormflow
Oldman R.	Racehorse Creek	896.3	0%	2	187.0	166.0	114.0	631.2	560.3	3006.1	155003	137597	738220
	Upper Oldman	220.1	0%	1	188.0	148.0	123.0	498.4	1267.9	4930.8	30050	76455	297320
	Oldman at Maycroft	1441.2	0%	3	214.0	163.0	156.0	735.2	1077.5	6007.9	290287	425453	2372224
	Oldman at Olin Bridge	1826.6	0%	4	113.0	164.0	152.0	323.2	896.1	5767.5	161737	448458	2886357
Crowsnest R.	Crowsnest above Star Ck.	158.5	0%	5	98.8	138.0	138.0	754.7	1707.7	5139.5	32770	74146	223153
	Star Creek	10.6	0%	6	123.0	154.0	114.7	1348.2	2715.4	3225.4	3912	7878	9358
	North York Creek	8.3	0%	7	101.5	155.0	144.7	1648.6	5700.0	10481.4	3744	12946	23806
	South York Creek	3.6	53%	8	100.5	143.0	154.5	1568.9	5706.8	17683.9	1543	5613	17393
	Lyons West	7.1	58%	9	112.0	140.0	147.0	385.1	422.1	7578.0	746	818	14678
	Lyons East	13.2	82%	10	86.5	131.0	57.0	240.7	404.3	1482.3	867	1457	5340
	Drum Creek	7.1	100%	11	161.0	183.0	191.0	1206.1	886.3	4903.9	2356	1731	9579
	Crowsnest at Frank	382.4	6%	12	224.0	122.5	125.5	1136.0	1235.7	3936.0	119025	129467	412392
Crowsnest at Lundbreck	661.7	8%	13	131.5	219.0	176.0	553.1	1750.1	3158.7	100278	317278	572653	
Castle R.	Castle at Ranger Stn.	372.5	0%	18	69.3	97.0	59.5	339.3	2710.1	2615.0	34628	276566	266864
	Lynx Creek	8.2	67%	14	123.0	162.0	104.0	1492.4	4518.3	5870.8	3357	10163	13205
	Lynx at Mouth	105.1	71%	15	89.5	68.0	120.5	192.8	753.8	2983.7	5550	21700	85890
	Carbondale above Lynx Ck.	150.3	37%	16	79.3	126.0	70.0	259.0	2302.3	6137.8	10660	94774	252657
	Carbondale below Adinack Rd	291.7	45%	17	159.0	90.0	126.0	2932.2	1201.9	3807.9	234338	96053	304319
	Castle at Hwy 507	819.3	16%	19	77.8	119.0	110.0	315.2	2120.4	4861.9	70759	475935	1091301

Other parameters available on request - NH₄⁺, Ca²⁺, Mg²⁺, electrical conductivity, pH

Algal biomass (ash free dry mass) chlorophyll-a concentrations in 2005/06

