Marmot Creek Research Basin Workshop

Presentation Abstracts:

Public Talk

Session 5: Watershed Disturbance and Management

Session 6: The Implications and Future of Marmot Creek

Poster Abstracts*:*

Introduction to the Marmot Creek Workshop: Overview and Objectives

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Marmot Creek Research Basin in the Kananaskis Valley, Alberta was established as an experimental basin in 1962 by the governments of Canada and Alberta. It became an outdoor research laboratory to examine the principles of mountain hydrology and how forest management could be used to influence streamflow generation. Research flourished for 25 years and provided the basis for a better understanding of hydrology, hydrochemistry and forest management that influenced headwater basin management for many years. In 2004, the basin was reactivated and has since been the subject of process hydrology, climatology, ecohydrology and hydrological modelling research that is underpinning the next generation of hydrological models and forest management strategies. The long term observations of mountain streamflow, precipitation, snowpack, groundwater, vegetation and meteorology in Marmot Creek makes it a unique laboratory for understanding and assessing environmental change in the Canadian Rockies.

This workshop celebrates the half century of knowledge and technology that has derived from Marmot Creek, reviews the challenges, designs and results of the early research period and of the recent period, and anticipates and plans for future science in the basin.

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Information from Marmot Creek Basin Still Making Waves after Half a Century

James P. (Jim) Bruce[1]

Initial instrumentation of Marmot Creek in 1962 was born out of a growing concern about water availability on the Canadian Prairies with growing population and irrigation needs. In 1960, the Prairie Provinces Water Board had estimated that 90% of the flow of the South Saskatewan River at Saskatoon originates in the 20% of the basin on the East Slopes of the Rockies. This region would thus have to be the best place to hope for augmentation of flow through forest management. This initiative also took place in a political climate highly favourable to multi-disciplinary science and scientific advice, particularly on hydrology and water. While initially established for logging experiments promoted by the Eastern Rockies Forest Conservation Board, Marmot Creek was quickly seized upon for other scientific purposes such as turbulence studies in forests and downslope areas, evaporation and wind studies.

Marmot Creek research basin was a forerunner of a series of such basins in Canada established during the 1965-75 International Hydrologic Decade. These research basins provided many benefits. For example, basins in the east yielded essential information for acid rain documentation and policy targets. Now a new generation of better equipped and ingenious researchers are using the 50-years of Marmot Creek records for assessing the changing climate and its impacts. WHO KNEW IN ’62?

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History of Marmot Creek Experimental Watershed
People, Places and Things Done

Richard Rothwell[1]

The Marmot Creek Experimental Watershed was one of the earliest if not the first long term paired-basin study in Canada designed to assess the effects of forest cover manipulation on water flows. This paper describes events leading to the start of Marmot Creek project, persons and agencies involved in the project and a legacy of continued hydrological research education and watershed management in western Canada. A history of the Eastern Rockies Forest Conservation Board, the East Slopes Watershed Research Program and research programs and studies following the Marmot project in Western Canada are provided.

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Marmot Creek Basin: Managing Forests for Water

Graham R. Hillman[1]

The Saskatchewan River supplies water to several large population centres in Alberta and Saskatchewan. The East Slopes of the Rocky Mountains, which are heavily forested, form the headwaters of the Saskatchewan River drainage system and, consequently, are important water conservation areas. In 1962, the Canadian and Alberta governments established Marmot Creek Basin in the Kananaskis Valley as an experimental watershed to examine the effects of forest cutting in the headwaters on streamflow. Marmot Creek Basin consists of three subbasins: Cabin Creek, Middle Creek and Twin Creek. In the experiments to be described, Middle Creek serves as an uncut control.

The first treatment, a "commercial" forest harvest, was imposed on Cabin Creek. The purpose of the experiment was to evaluate the effects of a commercial harvest on streamflow and sediment yield. Particular attention was to be paid to road design so as to minimize the effects of road construction on sediment yields in the creek. Logging haul roads were constructed in Cabin Creek subbasin during 1971–72. The commercial harvest was done between July and October 1974. Data for evaluating the effects of road construction alone on sediment production in Cabin Creek were obtained during the intervening period. Six blocks (45 ha) representing 50% percent of the forested area in the subbasin (21% of Cabin Creek subbasin) were clearcut. Regression and covariance analysis were used to determine the effects of cutting on Cabin Creek streamflow. The treatment produced an increase in annual water yield of 35.7 dam^3 or 6% greater than predicted if left uncut. There were no increases in sediment concentrations that could be attributed to roads or logging.

The purpose of the second treatment, implemented on Twin Creek subbasin, was to prolong recession flow from snowmelt and/or delay the time to peak runoff. This treatment took the form of a "honeycomb" pattern in which about 3000 small circular openings, 12.2 to 18.3 m in diameter, were cut in the forest. Some 62 ha or 24% of Twin Creek subbasin were cleared in this manner between 1977 and 1979. It had been ascertained in a related study that openings with diameter equal to the height of the surrounding trees captured the most snow while retaining it the longest in the spring. Between 1985 and 1987 the Nakiska resort and ski runs were built in the basin adjacent to Marmot Creek basin and opened for the 1986–87 ski season. Some of the ski runs intruded into the Twin Creek subbasin. It is not clear if the introduction of ski runs compromised the integrity of the experiment, or whether results for the Twin Creek treatment are available. Measurement of streamflow from the three subbasins of Marmot Creek basin was discontinued after 1986.

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The Impact of Climate Change and Forest Management on the Hydrometeorology of Marmot Creek Research Basin

Phillip Harder[1] and John Pomeroy[1]

The unique streamflow, groundwater level, snow accumulation, precipitation and temperature dataset spanning 1963-2012 from multiple elevations in the Marmot Creek Research Basin (MCRB), Alberta, Canada was examined for trends. Significant trends over time were identified for air temperature (annual minimum has increased 0.6°C to 1.8°C), low elevation peak snow accumulation (-55%), groundwater levels (-0.85m to +1.8m) and seasonal streamflow (-24%). No significant trends were identified in precipitation. These observations can be distinguished by elevation, which is unique in Canada and exceedingly rare in North America. The hydrometeorology at lower elevations (<1900m) is changing more rapidly than the upper elevations (>1900m) where few trends are observed or in the case of water table trends reverse direction. MCRB land cover was significantly altered through forest harvesting experiments (1962-1986) to increase water yield. Reanalysis of the streamflow response to forest management for this period shows that there were no significant changes to runoff though the land cover change may explain increased high elevation water table. The changes observed in MCRB hydrometeorology are primarily due to climate trends as the influences of land use change, and teleconnection forcings are not significant.

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An Outdoor Hydro-Climatic Laboratory for the 21st Century: 50+ Years of Research and Data Collection at the Reynolds Creek Experimental Watershed

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To understand how variations in climate, land use, and land cover will impact water, ecosystem, and natural resources in snow-dominated regions we must have access to long-term hydrologic and climatic databases. Data from watersheds that include significant human activities, such as grazing, farming, irrigation, and urbanization, are critical for determining the signature of human induced changes on hydrologic processes and the water cycle. One of the primary components of effective watershed research is a sustained, long-term monitoring and measurement program. Such an effort was undertaken when the Reynolds Creek Experimental Watershed (RCEW) was added to the USDA Agricultural Research Service watershed program in 1960. The RCEW, a 239 km^2 drainage in the Owyhee Mountains near Boise, Idaho, has been continuously monitored since the early 1960's and continues to the present. The vision for RCEW as an outdoor hydrologic laboratory in which watershed research would be supported by sustained, long-term monitoring of basic hydro-climatic parameters was described 1965 in the first volume of *Water Resources Research* [Robins *et al*., 1965] and the first 35 years of data presented in a series of papers in 2001 [Marks, 2001]. Research at the RCEW continues to be supported by monitoring at 9 weirs, 32 primary and 5 secondary meteorological measurement stations, 26 precipitation stations, 8 snow course and 5 snow study sites, 27 soil temperature and moisture measurement sites with 5 sub-surface hill-slope hydrology sites and 5 EC systems. These support a wide range of experimental investigations including snow hydrology and physics, cold season hydrology, water quality, model development and testing, water and carbon flux experiments, ecosystem processes, grazing effects, and mountain climate research. Active watershed manipulation allows fire ecology and hydrology, vegetation-climate interaction, watershed restoration, grazing and wildlife management, and invasive plant research.

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Implications of Mountain Shading on Calculating Energy for Snowmelt using Unstructured Triangular Meshes

Chris Marsh[1,2], John Pomeroy[1], Raymond J. Spiteri[2,1]

In many parts of the world, the snowmelt energy balance is dominated by net solar shortwave radiation. This is the case in the Canadian Rocky Mountains, where clear skies dominate the winter and spring. In mountainous regions, irradiance at the snow surface is not only affected by solar angles, atmospheric transmittance, and the slope and aspect of immediate topography, but also by horizon-shadows, i.e., shadows from surrounding terrain. Many hydrological models do not consider such horizon-shadows and the accumulation of errors in estimating solar irradiance by neglecting horizon-shadows may lead to significant errors in calculating the timing and rate of snowmelt due to the seasonal storage of internal energy in the snowpack.

An unstructured triangular-mesh-based horizon-shading model is compared to standard self-shading algorithms in the Marmot Creek Research Basin (MCRB), Alberta, Canada. A systematic basin-wide over-prediction (basin mean expressed as phase change mass (assumed constant albedo of 0.8): 14 mm, maximum: 200 mm) in net shortwave radiation is observed when only self-shading is considered. The horizon-shadow model is run at a point scale at three sites throughout the MCRB to investigate the effects of topographic scale on the model results. In addition, the model results are compared to measurements of mountain shadows via orthorectified timelapse digital photographs and measured surface irradiance.

The horizon-model irradiance data are used to drive a point-scale energy balance model, SNOBAL, via The Cold Regions Hydrological Model, an HRU-based hydrologic model. Melt timing is shown to differ by up to four days by neglecting horizon-shadows. It is further hypothesized that the errors might be much larger in basins with more rugged topography. Finally, a consideration of the intersection of unstructured-mesh and HRU landscape representations is discussed.

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Progress Towards Understanding and Predicting Turbulent Heat Fluxes in the Canadian Rockies

Warren Helgason[1,2], and John Pomeroy[2]

Estimation of snowmelt rates in mountainous terrain is of great relevance for sustainable water management; yet it remains a formidable problem. In particular, complex wind flows associated with heterogeneous terrain complicate the prediction of the turbulent fluxes of sensible and latent heat. A micrometeorological investigation of the near surface atmospheric boundary layer was conducted within the Marmot Creek research basin, in order to improve the understanding of the processes affecting the rate of convective energy and mass exchange over an open snow field. It was found that low frequency wind gusts transport significant turbulent energy into the surface boundary layer, confounding commonly applied flux estimation approaches that are based on equilibrium boundary layer concepts such as fixed ratios of sensible and latent heat turbulent conductivity. As a result, the near surface turbulence scales on a local factor related to the wind shear as well as a non-local factor related to large eddies generated by the complex terrain. The results of this investigation suggest that new turbulence scaling approaches are required for application in mountain valleys. Further work is required to understand how boundary layer perturbations move from mountain tops to valleys, and to develop new ways of incorporating their effects into snow energy balance modeling techniques.

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Simulating Areal Snowcover Depletion and Snowmelt Runoff in Alpine Terrain

Chris DeBeer[1], and John Pomeroy[2]

In the Canadian Rocky Mountains snowmelt runoff represents the greatest single contribution to the flow of streams and rivers. Concerns over future water resource stresses here require better understanding and prediction in some areas of alpine snow hydrology, such as representing spatial heterogeneity of snowcover distribution and melt, and scaling of processes within hydrological models over complex terrain. This work addressed these problems through a combination of field observations and model development and application, focusing on the upper alpine portion of the Marmot Creek Research Basin in the Kananaskis Valley, Alberta. Measurements included hydro-meteorological observations, snow surveys, remote sensing of snowcover (LiDAR snow depth measurement and daily terrestrial photography for snowcover mapping), and streamflow measurement. Model development included incorporating a new theoretical framework for areal snowcover depletion (SCD) and meltwater generation into the Cold Regions Hydrological Model (CRHM) platform. Predictions from the model were compared with observations of snowmelt and SCD at point, hillslope, and basin scales, along with runoff from the outlet of a ~1.2 km^2 basin. This provided evaluation of the model performance and shed insight on the scale dependence of snowmelt processes and their proper representation in hydrological models for alpine terrain.

The work led to several important findings, and provides useful tools for prediction outside of well-studied research basins. First, it was shown how the spatial and temporal variability in both pre-melt snow water equivalent (SWE) and snowmelt energetics control SCD during spring. The best results were achieved by considering separate SWE distributions on individual slope units and applying melt energetics separately to each unit. It was further shown that at certain times, such as early spring, the effects of differential warming, ripening, and melt over a heterogeneous snowcover on a single slope unit causes an "acceleration" of areal SCD due to the earlier and more rapid melt of areas with a relatively shallow snowpack. This is important to represent, and can be captured by considering different classes of SWE (with different mass and energy states) on each slope unit. The spatial extent of each class can be determined from the mean SWE and coefficient of variation (CV) of SWE using the lognormal distribution, which provides a simple yet robust means for applying the model in other basins. Finally, it was shown how the variability in meltwater inputs over the landscape influences the snowmelt hydrograph from alpine basins. Although realistic appearing hydrographs could be produced when considering only a single SWE distribution and average melt rates, the best hydrographs were achieved by representing the differential timing, location, and extent of source areas for snowmelt. By maintaining "internal correctness", such representation reduces predictive uncertainty under climate and landcover change scenarios, and provides more confidence in model applications outside of research basins.

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Impacts of Forest Clearing on Radiation and Snowmelt in Marmot Creek, Alberta, Canada

Chad Ellis[1, 2*], John Pomeroy[1], and Tim Link[3]

A physically-based model built upon extensive field observations of radiation dynamics and snow processes in cold regions forest environments was used to investigate the impacts of prescribed forest thinning treatments on spring snowmelt in the Marmot Creek Research Basin of the Canadian Rocky Mountains. Both field observations and model simulations showed that relative to small clear-cut gaps, canopy sublimation losses reduced forest snow accumulations by over one-half, resulting in a substantial increase in spring snowmelt in mountain forests thinned with patterned clear-cuts. In contrast, the impact of forest thinning on snowmelt timing was highly dependent on slope orientation; thinning accelerated snowmelt on south-facing slopes primarily through enhanced shortwave radiation, but retarded snowmelt on north-facing slopes primarily through reduced incoming longwave radiation. Consequently, forest thinning across opposing north-facing and south-facing mountain slopes acted to substantially extend the spring melt period over much of the basin, and illustrates the important hydrological control imparted by intact forest cover through its synchronization of snowmelt across complex terrain. Results strongly suggest that shifts in spring snowmelt runoff response from similar forest thinning treatments throughout mountain regions will depend on the slope and aspect at which they occur.

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A Sensitivity Study of Radiant Energy During Snowmelt in Small Canopy Gaps

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In mountainous, forested environments, snowcover dynamics exert a strong control on hydrologic and atmospheric processes. Snowcover ablation patterns in forests are controlled by a complex combination of depositional patterns coupled with radiative and turbulent heat flux patterns related to topographic and canopy cover variations. Quantification of small-scale variations of radiant energy in forested environments in necessary to expand on early research at the Marmot Creek Research Basin to advance understanding of how canopy structure affects snowcover energetics. Incoming shortwave and longwave radiation were measured and modeled across small forest clearings along a transect spanning the North American Cordillera. Results indicate that reductions in solar radiation at the snow surface are partially balanced by increased longwave radiation from the forest canopy, relative to open locations. The differences between the transfer processes for shortwave and longwave radiation can produce an environment where all-wave radiation is less than in both open and closed canopy forests. The optimal gap size to minimize radiation to snow was estimated to have a diameter between 1 and 2 times the surrounding vegetation height. The low-radiation paradox is most pronounced early in the winter, at high latitudes and on north-facing slopes due to low solar elevation angles relative to the ground. The empirical results coupled with theoretical modeling indicates that the effects of forest canopies on the radiative regimes at the snow surface are controlled by complex interactions of slope, aspect, gap sizes, canopy height, canopy density, canopy temperature, snow surface temperature and snowcover albedo. These radiation differences coupled with decreased turbulent fluxes due to lower wind velocities and reduced snow water due to canopy interception losses help to explain small-scale patterns of snowmelt in non-uniform forested areas and suggest that gap harvest patterns may be used to retain snow on the landscape and prolong seasonal runoff.

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Modelling the Effects of climate variability on hydrological processes in Marmot Creek: Approach and Initial Results

Evan Siemens[1] and John Pomeroy[1]

Climate influences the type and rate of hydrological processes in mountain basins. The effect of climate variability on hydrological processes in a catchment basin is important in determining the resilience of future water resources. Through the use of a cold regions hydrological process model, water balance components can be estimated using meteorological data. By modelling both measured and unmeasured water balance components such as snowfall, rainfall, evapotranspiration, sublimation, storage and runoff, changes in a basins hydrology can be simulated over time.

A historical data set containing meteorological variables such as air temperature, relative humidity, precipitation and wind speed was derived from Marmot Creek in the Kananaskis region of the Canadian Rockies. Starting at various time periods in the 1960's, this data was used in calculating hydrological processes over an observed period of climate change and variability.

Water balance components for daily and seasonal time periods were estimated using the calculated processes and can be compared to measured streamflow and climate indices including seasonal temperature and precipitation. Construction of a dataset that is complete enough to run a hydrological process model proved to be a challenging task with numerous gaps and variability in the measurement techniques and observation locations. Initial results from the model from 1968 to 1987 show a decline in both snowpacks and streamflow over time as a result of substantial changes in hydrological processes during this time period in Marmot Creek.

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Global Climate Change and Canada's Water

J. P. (Jim) Bruce[1]

As is now well established scientifically, human actions are changing the chemical composition of the global atmosphere. This is changing the energy balance at earth's surface resulting in general warming and increased storminess. Indications are that, without world-wide changes in energy use, these trends will accelerate in coming decades. Implications are profound for water in both solid phases, snow and ice, and as liquid. In some already dry areas such as the southern Prairies, water supplies are expected to continue to decline. Surprisingly, both flash floods and devastating droughts are projected to be more severe. Water quality degradation will worsen in many lake systems. Research in basins vital for water supply, is essential to prepare for the future and adapt to the changes. Marmot Creek is one such basin on the East Slopes of the Rockies. Much climate change adaptation needs to be undertaken at a community level, involving all citizens.

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Fire Regime and Risk in the Kananaskis Valley

Brad Hawkes[1] and Rick Arthur[2]

The Kananaskis valley has experienced many forest fires since the end of the last ice age. Fire frequency, type, intensity, size, shape, and severity have varied over time and space due to changing climate, a complex topography, variable ignition probability, location of non-vegetated fire breaks, forest structure and fuel load. First Nations have long been a part of this landscape with the later arrival of explorers, surveyors, lumber and hydro company personnel, hunters, recreational users, and tourists. The fire regime and its influence on the forest ecosystems of the Kananaskis valley have been studied by many university and government researchers and consultants over the last 30 years.

A synthesis of past fire regime studies and an examination of the current fire risk are presented. An understanding of fire's role in the ecosystems within the Marmot basin could assist with future hydrologic modeling studies of fire disturbance and guide the design and application of future experimental treatments. Quantification of fire risk within and surrounding the Marmot basin would assist in determining if mitigation actions are needed to reduce the probability of wildfires negatively impacting long-term study objectives.

Fire history studies have documented short interval overlap of historic wildfires in the Kananaskis valley which have impacted surface woody debris mass, forest floor depths, and stand density which potentially reduced crown fire initiation and spread for decades in these areas. Early surveyor's high resolution photographs have provided a valuable historic snapshot of forest stand and spatial disturbance patterns which have assisted in understanding current stand and fuel conditions.

The most recent large high-intensity crown fires in the Kananaskis valley were in 1920 and 1936. There needs to be a recognition and assessment of the potential for wildfire to impact the Marmot basin in future research and management planning. Recent hydrologic modeling of fire disturbance in the Marmot watershed have shown significant changes in stream flow and timing supporting the need to consider fire in future plans.

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Mountain hydrology and disturbance in the Elk Valley, British Columbia: Utilizing Marmot Creek Research Basin for process understanding

Sean K Carey[1]

The Elk Valley of British Columbia has headwaters ~ 50km south of Marmot Creek Research Basin, and has similar climate, topographic, geological and vegetation characteristics. In the Elk Valley, surface coal mining is a major driver of land use change. As part of a new research program, several instrumented watersheds are being developed to understand the impact of surface mining on hydrological and hydrochemical processes. Principal research objectives are to assess the impact of surface mining on the timing and magnitude of water balance components, runoff pathways, and residence times. A secondary objective is to explore the utility of numerical models (including the Cold Region Hydrological Model) to better understand the impact of surface mining on headwater catchments. As Marmot Creek represents the most intensively studied long-term facility in the region, future work will explore complementary methods of understanding and modelling watersheds in the southeastern Rockies.

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Managing for Watershed Function as a Priority

Kevin Van Tighem[1]

Watershed protection and water yield have been the policy priorities for Alberta's Eastern Slopes since the late 1880s. This priority for watershed health was originally established by William Pearce, assigned by the Minister of Interior to deal with land use matters in the Railway Belt of what were then the Northwest Territories of Canada. It has been reaffirmed through repeated changes of administration including the 1979 and 1984 Policy for Resource Management of the Eastern Slopes.

A Regional Advisory Council for the 2011 first phase of planning process for a South Saskatchewan Regional Plan, in spite of struggling to find consensus on many issues, was unanimous in re-emphasizing the critical need to subordinate or modify other land uses in the Eastern Slopes to the overwhelming strategic importance of managing the headwaters for optimal watershed function. Limited water availability has already led to a moratorium on new water licenses in the South Saskatchewan Basin, and population growth is projected to double in the next quarter century; water is southern Alberta's single most critical strategic issue.

Given a century and a quarter of consistent policy direction, it would be reasonable to expect that the headwaters of Alberta's rivers would be in good shape. They are not.

In practice, multiple-use and compromise have trumped watershed management at the expense of water production, water quality, river health and critical summer flows.

Research findings from Marmot Basin and other studies of forestry, hydroelectric dam operations, recreation and other land uses spotlight several ways in which existing management practices can, and should, be changed in light of growing water shortages and the confounding threats arising from the regional effects of climate change. Three of those changes will be discussed.

The management changes that would be required to deliver optimal water yield, water quality and water timing from Alberta's headwater landscapes would also yield important secondary benefits. These include enhanced habitat for grizzly bears, elk and native trout, as well as improved recreational amenity values that can contribute to the quality of life for Albertans and the attractiveness of Alberta as a place for businesses to locate.

For the required changes to be effective and persist over time, new business models and investment strategies will be needed. Given the certain resistance of some vested interests, government leadership, public education and political fortitude will be no less critical.

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Sensitivity of Marmot Creek Snow Hydrology to Future Climate Change and Forest Disturbance

John Pomeroy[1], Xing Fang[1], Chad Ellis[1], Matt MacDonald[2] and Tom Brown[1]

A model including snow redistribution, interception, melt energetics, infiltration to frozen soils and runoff formation was developed using the Cold Regions Hydrological Modelling platform, parameterised with minimal calibration, and manipulated to simulate the impacts of climate warming and forest disturbance on the snow hydrology of Marmot Creek. Climate warming scenarios involved raising the air temperature from that measured in recent years and showing the effect on precipitation phase, snow redistribution, sublimation, melt and runoff generation. These scenarios showed the alpine snow regime to be extremely sensitive to further warming because much current snowfall occurs in spring and so with further warming will tend to change phase to rainfall. Earlier melt with warming results in slower melt and reduced snowmelt runoff. The forest snow hydrology regime is only moderately sensitive to warming because of reduced snow interception and sublimation losses, partly compensating for reduced winter snowfall. Whilst runoff was reduced under warming, the major transformation was the dramatic increase in rainfall-runoff and decrease in snowmelt-runoff mechanisms.

Forest disturbance scenarios examined the possible impacts of pine beetle kill of lodgepole pine, clear-cutting of north or south facing slopes, forest fire and salvage logging. Pine beetle mortality increased in snowmelt volume by less than 10% and streamflow volume by less than 2%. This small impact is attributed to the low and relatively dry elevations of lodgepole pine forests in the basin. Forest disturbances due to fire and clear-cutting affected much larger areas and higher elevations of the basin and were generally more than twice as effective as pine beetle in increasing snowmelt or streamflow. For complete forest cover removal by burning and salvage logging, a 45% increase in snowmelt volume was simulated; however, this only translated into a 5% increase in spring and summer streamflow volume. Retention of standing burned trunks increased streamflow volume up to 8% due to its minimizing of winter snow sublimation. Peak daily streamflow discharges responded more strongly to forest cover disturbance than did seasonal streamflow volumes, with increases of almost 25% in peak streamflow from removal of forest canopy by fire and retention of standing burned trunks. Peak flow was most effectively increased by forest removal on south facing slopes and level sites. Increases in streamflow from forest disturbance were almost entirely due to reductions in intercepted snow sublimation with decreasing canopy coverage.

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Marmot Creek and the Saskatchewan River Basin Project – a Large-scale Observatory for New Water Science

Howard Wheater[1]

The water environment world-wide faces unprecedented pressures. Water resources are under stress from population growth, economic development and pollution, and extreme events threaten increasing numbers of people and economic activity. There is also recognition that 'stationarity is dead'; with widespread changes to land use and land management, and major uncertainties surrounding current and future climate, past records are no longer an adequate guide to the future. There is therefore an urgent need to improve our level of understanding of environmental change, and develop improved models and methodological approaches to aid in the management of uncertain water futures. Critical to this is the need for long-term, high quality research basins, to provide the underpinning data that are essential for understanding and modelling change, and the focal point for integration of scientific effort to address these issues.

All of the above management pressures are found in the Saskatchewan River Basin (SaskRB). The SaskRB experiences one of the most extreme climates in the world, embodies biomes of major Canadian and global importance, and has a history of extreme floods and drought. It is home to the majority of Canadian agriculture, important natural resources and the fastest growing economies in Canada, yet its water resources are fully allocated in southern Alberta, and its water quality is degraded.

The key to water futures in the SaskRB lies in the Rocky Mountains, which are the dominant water source for the Prairie Provinces, and indeed for all of the major rivers in Western Canada. The unprecedented hydrological record from Marmot Creek, and the associated science that had been developed to improve our understanding and modelling capability of Rocky Mountain hydro-ecological and cryospheric processes, provide a unique and vitally-important resource, and an important springboard for a new generation of world-leading research activities. Marmot Creek is therefore at the heart of a major new initiative to provide large-scale research infrastructure to support international science and the regional needs of Western Canada.

The Global Institute for Water Security has developed a large scale observatory based on the SaskRB, recently recognised by the World Climate Research Programme's GEWEX project as a Regional Hydroclimate Project, the only active RHP in North America. A key science focus is on understanding and predicting impacts of environmental change on climate, ecology, hydrology, and water quality at local to large catchment scales, and the associated development and application of a new generation of modelling tools to support decision making under conditions of deep uncertainty.

This paper will outline plans and progress for this new initiative, and the critical role of Marmot Creek in addressing the challenges of understanding and predicting environmental change across multiple scales, and the development of new and improved models to support local, regional and global modelling and the management of water future in Western Canada.

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Interplay Between Field Observations and Numerical Modeling in Understanding Tree Root Throw Processes

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This investigation explores the adoption of a combined methodological approach that relies on the interplay between field observations and numerical modeling. Tree root throw is now widely recognized as an agent of soil bioturbation and sediment transport, and it may also result in a distinct pit-mound microtopography. Much of the root throw literature has focused on locations with pronounced pit-mound microtopography, especially in eastern and mid-western USA. The notable microtopography observed in these landscapes makes the potential significance of root throw in affecting soil bioturbation and sediment transport readily discernible. Less certain is the significance of root throw as an agent of soil bioturbation and sediment transport in locations with less pronounced pit-mound microtopography, such as subalpine forests of the Canadian Rockies. The idea guiding the present study is that what we observe on the landscape may be a function of *when* we look at the landscape. Following on from this idea, it would be expected that soil bioturbation and sediment transport due to root throw are also temporally variable but that they may still be significant processes at certain times during forest dynamics. To study processes related to the concepts describe above, field measurements over temporal scales ranging from order-of-magnitude 10^1 to 10^2 years are preferred. However, these temporal scales are generally too long for direct observation due to various practical limitations and yet do not always lend themselves readily to other options (e.g., longer-term dating techniques). Herein, we rely on a combination of: (i) field observations of root throw and creep-type processes to guide and drive exploratory numerical modeling work; and (ii) sensitivity analysis within a numerical modeling framework to identify potential variables to which the system is most sensitive and for which further field observations are required. Results show that the magnitude of a pit/mound feature and choice of creep-type formula to simulate pit/mound degradation influence pit/mound longevity; when this information is connected to a tree population dynamics model (calibrated with field observations), the pulsing over time of root throw events and associated processes can be better understood.

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There is No Way Up: High Elevation Tree Cover Advance Severely Limited by Geomorphic Processes

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The transition between subalpine forests and alpine areas (commonly known as altitudinal treeline) is attributed to reduced development of plant tissue due to low growing season temperatures. Recent and forecast climate warming raises interest on whether trees have advanced and/or will advance into non-forested areas. However, global meta-analyses based on site studies report mixed, often contradictory responses to recent warming. Processes other than the direct effect of temperature on plant physiology have been proposed to be important in these regions, such as those related with geomorphology and geology. However, their effect on the landscape has not been quantified. Here we show that temperature alone cannot realistically explain high elevation tree cover over a >100km^2 area in the Canadian Rockies and that geologic/geomorphic processes are fundamental to understand the heterogeneous landscape tree distribution. Furthermore, we show that upslope tree advance in a warmer scenario will be severely limited by availability of sites with adequate geomorphic/topographic characteristics that do not depending on short (yearly/decadal) but on long (centuries/millennia) timescales. Treeline research focuses on specific sites deemed to be temperature-sensitive. However, the implications of this site selection practice are not accounted in regional assessments. Our results demonstrate that accounting for slope processes fundamentally modifies future tree cover projections in mountains and warns against directly using results from temperature-focused treeline research to predict future tree cover at a landscape scale.

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