Sensitivity of Snowmelt Hydrology on Mountain Slopes to Forest Cover Disturbance

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CENTRE FOR HYDROLOGY

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- By -

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Executive Summary

Marmot Creek Research Basin was the subject of intense studies of snowmelt, water balance and streamflow generation in order to generate a five year database of precipitation inputs, snowpack dynamics and streamflow that could be used in hydrological model testing. A physically based hydrological model of the basin was constructed using the Cold Regions Hydrological Model and tested over four years of simulation. The model was found to accurately simulate snowpacks in forested and cleared landscapes and the timing and quantity of streamflow over the basin. The model was manipulated to simulate the impacts of forest disturbance on basin snow dynamics, snowmelt, streamflow and groundwater recharge. A total of 40 forest disturbance scenarios were compared to the current land use over the four simulation years. Disturbance scenarios ranged from the impact of pine beetle kill of lodgepole pine to clearing of north or south facing slopes, forest fire and salvage logging impacts.

Pine beetle impacts were small in all cases with increases in snowmelt of less than 10% and of streamflow and groundwater recharge of less than 2%. This is due to only 15% of the basin area being covered with lodgepole pine and this pine being at lower elevations which received much lower snowfall and rainfall than did higher elevations and so generated much less streamflow and groundwater recharge. Forest disturbance due to fire and clearing affected much large areas of the basin and higher elevations and were generally more than twice as effective in increasing snowmelt or streamflow. For complete forest cover removal with salvage logging a 45% increase in snowmelt was simulated, however this only translated into a 5% increase in spring and summer streamflow and a 7% increase in groundwater recharge. Forest fire with retention of standing burned trunks was the most effect forest cover treatment for increasing streamflow (up to 8%) due to minimizing both sublimation of winter snow and summer evaporation rates. Peak daily streamflow discharges responded more strongly to forest cover decrease than did seasonal streamflow with increases of over 20% in peak streamflow with removal of forest cover. It is suggested that the dysynchronization of snowmelt timing with forest cover removal resulted in an ineffective translation of changes in snowmelt quantity to streamflow. This resulted in a complementary increase in groundwater recharge as well as streamflow as forest cover was reduced. Presumably, a basin with differing soil characteristics, groundwater regime or topographic orientation would provide a differing hydrological response to forest cover change and the sensitivity of these changes to basin characterisation needs further examination.

1 Introduction

The Mountain Pine Beetle (MPB) epidemic in British Columbia is a natural disaster that has impacted forest canopy cover in many drainage basins, changing interception processes and the proportion of precipitation reaching the ground surface, as well as the energetics of snow melt. The beetle epidemic is moving eastward from British Columbia to Alberta, with major potential consequences for forests in the foothills of Alberta. MPB also threatens Alberta's forests, and subsequently could affect the timing and quality of water from the Rocky Mountains Eastern Slopes (RMES).

Water supplies in the rivers draining the RMES have been and are predicted to decline whilst demand increases due to rising population and increasing consumption from downstream agriculture and industry (St. Jacques *et al*., 2010). Decision-making for water supply protection and management requires an in-depth, science-based understanding of the risks and vulnerabilities of key water supply regions. Mountain runoff is highly sensitive to both variations in climate and forest disturbance. This is expected to be most severe in cold mountain environments that are dominated by snowmelt and frozen soils, such as the RMES. Recent temperature and precipitation shifts have led to a decrease in annual snow extent (Groisman *et al*., 1994), an earlier spring freshet (Cayan *et al*., 2001), and an increase in winter days with positive air temperature (Lapp *et al*., 2005). These changes have been associated with increased rates of forest disturbance due to wildfire (Fauria and Johnson 2006, 2008), insect infestation (Aukema *et al*., 2008), and disease (Woods *et al*., 2005). A comprehensive understanding of runoff generation in mountain headwater systems subject to forest change is thus critical to managing downstream water resources.

The Canadian forest industry has committed to achieving sustainable forest management, which identifies specific social, economic, and environmental values and sets objectives, indicators and targets to ensure that these values are maintained (CCFM, 2008). Water resources are one of the most important values of the RMES as they form the headwaters of the Saskatchewan and Athabasca River Basins, which support urban centres such as Edmonton, Calgary, Saskatoon, and Regina; the agricultural sector of the south-western Prairies; and oil sands mining operations. Water supply in this region is now exceeded by demand and ecosystem requirements; for example the South Saskatchewan basin has been closed to new water licenses. Water supply is further threatened by natural disturbance and subsequent forest management approaches.

Managing water supply from the RMES requires a good understanding of the interconnections between forest cover change and runoff generation from sub-humid, cold, continental mountain watersheds, and the impacts on water supply including the risk of extreme flows. Assessing the potential effects of headwaters forest disturbance has been identified as a priority for the Bow River Basin (BRBC, 2008) and others, particularly given the current mountain pine beetle infestation (Winkler *et al*., 2008). Therefore, there is a need for physically based hydrological models that are easy to use, have minimal data requirements, and that show forest change impacts on the timing, volume and duration of peak flow, and changes in flow regime (e.g. Silins, 2003).

Models must concurrently address alpine hydrology and forest hydrology in order to put the hydrological impact of forest change in the context of basin runoff generation and its variability. Physically based forest hydrology models have been developed for the boreal forest and more temperate coastal forests, but none exist for the cold, complex mountain headwater basins of the RMES consisting of montane, subalpine and alpine areas. There are currently no user-friendly models for predicting the effects of forest harvesting on water storage and runoff processes with variation in slope, aspect, and drainage area. Given the lack of user-friendly models, harvesting effects are routinely assessed by consultants at considerable expense to forest companies; this is often without a high degree of confidence due to the physical complexities of the RMES region. Non-stationarity and changing runoff processes due to climate variability and change add further uncertainty to such predictions. User-friendly tools that incorporate physiographic characteristics need to be used for more reliable basin assessments.

Hydrological response to forest management practices is highly variable, largely due to the inherent variability in management approaches across the wide range of climatic and vegetation regimes of Canadian forests. For example, while changing snow accumulation and melt dynamics can often be related to canopy radiative processes (Gelfan *et al*., 2004), these changes are rarely related to changes in soil moisture, forest floor organic layer moisture, subsurface flow pathways, or groundwater and runoff response (Monteith *et al*., 2006a). Stand-level and paired catchment research have been undertaken for many decades, yet results differ between specific environments given regional differences, notably, catchment wetness and topography. Buttle *et al*. (2005) state that despite work on forestry impacts, there remains a shortage of studies on disturbance impacts (both natural and anthropogenic) on water yields and peak/low flows in Canada's various forest landscapes. Thus models and system understanding developed in non-Canadian environments are sometimes applied in environments in Canada where they may not be valid (Swanson, 1998).

Questions regarding the basin-scale hydrological impacts of forest disturbance are often addressed with numerical models, which are less costly than intensive field monitoring and can be applied to basins for which field data are unavailable (Pomeroy *et al*., 1997, 2007; Whitaker *et al*., 2002; Schnorbus and Alila 2004). The Cold Regions Hydrological Model (CRHM) is a modular model that permits appropriate hydrological processes for the basin, selected from a library of process modules, to be linked to simulate the hydrological cycle (Pomeroy *et al*., 2007). From its inception, CRHM has focused on the incorporation of physically based descriptions of cold regions hydrological processes, which make it particularly appropriate to application in the RMES. Recent developments include treeline forest effects from alpine blowing snow (MacDonald *et al*., 2010), improved soil and fill and spill runoff generation (Fang *et al*., 2010) and enhanced forest modules (Ellis *et al*., 2010). Cold regions hydrological processes are represented in other models (e.g. Zhang *et al*., 2000; Bowling *et al*., 2004), but to our knowledge CRHM has the most complete range of processes for the RMES (direct and diffuse radiation to slopes, longwave radiation in complex terrain, intercepted snow, blowing snow, sub-canopy turbulent transfer, sublimation, energy balance snowmelt, infiltration to frozen soils, rainfall interception, combination-type evapotranspiration, infiltration to unfrozen soils, sub-surface flow, kinematic wave flow routing, etc.) and a wide-ranging selection of numerical process descriptions from conceptual to physically-based. It will be enhanced by linking to a groundwater flow model for simulating groundwater dynamics, more specifically by providing the top boundary flux to the flow model. CRHM uses an object-oriented structure to develop, support and apply dynamic model routines. Existing algorithms can be modified or new algorithms can be developed and added to the module library, which are coupled to create a purpose-built model, suited for the specific application. The model operates on the spatial unit of the Hydrological Response Unit (HRU) which has been found optimal for modelling in basins where there is a good conceptual understanding of hydrological behaviour, but incomplete detailed information to permit a fully distributed fine scale modelling approach to be employed (Dornes *et al*., 2008). CRHM participated in the recent Snowmip2 snow model intercomparison and did relatively quite well in modelling forest snowmelt at sites in Switzerland, USA, Canada, Finland and Japan (Rutter *et al*., 2009).

Needleleaf forest-cover dominates much of the mountain regions of the northern hemisphere where snowmelt is the most important annual hydrological event. We propose to develop CRHM to incorporate the primary hydrological processes in this region and their response to forest cover change. The retention of foliage by needleleaf forests during winter substantially lowers snow accumulation in forests due to interception of snow (Pomeroy and Schmidt, 1993; Lundberg and Halldin, 1994; Hedstrom and Pomeroy, 1998; Gelfan *et al*., 2004). This intercepted snow is exposed to high rates of turbulent transfer and radiation input and so sublimates rapidly (Pomeroy *et al*., 1998) resulting in greatly reduced snow accumulation on the ground at the time of snowmelt (Pomeroy and Gray, 1995). Uncertainty in snow unloading response to energy inputs requires further development of these algorithms for mountain slopes and may explain the wide range of sublimation losses noted in field studies in the West.

Along with interception effects, needleleaf forest cover also influences energy exchanges to snow and therefore the timing and duration of snowmelt. The forest layer acts to decouple above- and sub-canopy atmospheres, resulting in a reduction of turbulent energy fluxes when compared with open snowfields (Harding and Pomeroy, 1996; Link and Marks, 1999). Consequently, energy to sub-canopy snow is dominated by radiation, itself modified by the canopy through shading of shortwave irradiance and longwave enhancement from forest emissions (Link *et al*., 2004; Pomeroy *et al*., 2009). As a result of the countering effects of reduced shortwave radiation and enhanced longwave radiation to snow as canopy density declines, there is no unique relationship between forest cover and snowmelt rates and even the direction of the response will differ with slope, aspect and cloud cover. Forest cover may also affect sub-canopy shortwave receipts by altering snow surface albedo through deposition of forest litter on snow (Hardy *et al*., 1997; Melloh *et al*., 2002). New algorithms for estimating shortwave fluxes through forests on slopes have been developed (Ellis and Pomeroy, 2007) but not coupled to enhanced longwave emissions from tree trunks (Pomeroy *et al*., 2009) and implemented in a modeling context.

Changes in mass and energy exchange between the atmosphere, canopy and ground surface expected as a result of forest disturbance have additional consequences for water storage in the vadose and phreatic zones and subsequent subsurface flow routing to streams. The removal of the forest canopy often (but not always) increases effective precipitation and snowmelt rates, leading to:

(i) higher water table levels after snowmelt, and during storms for several years after disturbance (Adams *et al*., 1991; Dhakal and Sidle, 2003) and
(ii) enhanced runoff via surface and near-surface pathways (Hetherington 1987; Monteith *et al*., 2006a), particularly immediately after harvesting (MacDonald *et al*., 2003).

Harvesting can lead to compaction of soils, resulting in decreased hydraulic conductivity and infiltration capacity (Startsev and McNabb, 2000) and reduces the role of macropores at the surface in delivering water to deeper soil layers. In addition, enhanced rain splash on disturbed soils may result in pore-clogging from detached fine materials. Hydrophobicity in forest soils has been identified as potentially important, reducing infiltration capacity when soils are dry and also related to fire occurrence (Letey, 2001). The impact of soil freezing on infiltration and runoff has been largely neglected in the RMES, yet work from other environments suggests that it can reduce infiltration during melt, promote runoff generation and overland flow (Stadler *et al*., 1996, Proulx and Stein, 1997; Pomeroy and Brun, 2001) and influence catchment-scale streamflow generation during spring (Pomeroy *et al*., 1999; Laudon *et al*., 2004; Smith *et al*., 2007). At the basin scale, Monteith *et al*. (2006b) observed a greater fraction of event water four years after harvest using classical hydrograph separation techniques, yet no differences in basin-wide residence times were observed. At larger scales, Buttle and Metcalfe (2000), in a comprehensive study of forest harvest on streamflow regimes in northern Ontario, suggest that the hydrologic impact of forest harvesting becomes equivocal due to the large natural variability of flows. Given the importance of the alpine zone in generating runoff in RMES and greater potential for groundwater storage in mountain compared to boreal shield environments, this needs careful assessment in the region to determine how sensitive basin hydrology really is to changes in forest cover.

Changes in groundwater storage due to forest disturbance are usually assessed through calculation of the residual in a water balance (e.g. Storr, 1974), as research on groundwater related to forest disturbance is scarce. Results from work in boreal locations show elevated water tables in the first five years following forest disturbance caused by a drop in evapotranspiration (e.g. Dubé *et al*., 1995; Elliot *et al*., 1998; Hetherington, 1998; Pothier *et al*., 2003). Smerdon *et al*. (2009) reviewed the effects of forest management on groundwater hydrology, with particular emphasis on British Columbia. Rex and Dubé (2006) suggest that in stands killed by mountain pine beetle, groundwater regimes are changing enough to result in wetting-up of sites that in turn may limit salvage-harvesting activities and forest regeneration success. While there are no published studies where groundwater recharge rates were directly measured, several have indicated increases in catchment water yield, which may result from higher groundwater recharge following harvesting. For example, Spittlehouse (2007) reports a 25% increase in drainage via a water balance model after harvest for the Okanagan Highlands, and Hubbart *et al*. (2007)

report a measured yield increase of 36% following a 50% areal harvest in north Idaho. The impact of forest management activities largely depends upon the location of the water table (uplands exhibit greater water table fluctuations than toe-slopes) and the time it takes for water to flow from the recharge areas. Time estimates for recovery range from 3 to >20 years, depending on climate, geology, intensity and extent of the disturbance (Moore and Wondzell, 2005), and rate of forest regrowth, which is relatively slow in cool subalpine forests (MacDonald and Stednick, 2003). Groundwater flow models solve the Richards equation for complex subsurface flow domains, and can be an effective tool for showing the dynamics of mountain groundwater regimes (Mirus *et al*., 2009) – if coupled to a surface hydrology calculation such as by CRHM they should be capable of demonstrating how changes in surface boundary conditions affect groundwater dynamics.

This study develops a physically-based hydrological model (CRHM) to allow forest managers to identify, measure, and compare risks and vulnerabilities of the RMES, a key water source for the Prairie Provinces. The model was applied and tested using snowmelt, groundwater, meteorology, and streamflow data collected from Marmot Creek Research Basin in the RMES. Marmot Creek is well situated for the study due to its Front Range location and history of research on forest management impacts on hydrology. The report is intended to provide information regarding the effects of forest change on water supply which will permit forest managers to more accurately determine allowable cut limits for protecting water supplies.

The following paragraphs provide the details about how the forest hydrology model was set up for the Marmot Creek Research Basin, including brief descriptions of study area, meteorological data collected and used, model structure and parameters setup. A description of forest disturbance scenarios is also provided. Results of model evaluation and the sensitivity of basin snowmelt hydrology to the scenarios are highlighted.

2 Site Description

The study was conducted at the Marmot Creek Research Basin (MCRB) (50˚57'N, 115˚09'W), located within the RMES (Figure 1). MCRB approximately comprises 9.4 km^2, composed of three sub-basins in the upper portion: Cabin Creek (2.35 km^2), Middle Creek (2.94 km^2), and Twin Creek (2.79 km^2). All three sub-basins merge into the Marmot Creek confluence (1.32 km^2). Elevation ranges from 1600 m.a.s.l at the Marmot Creek outlet to 2825 m.a.s.l at the peak of Mount Allan.

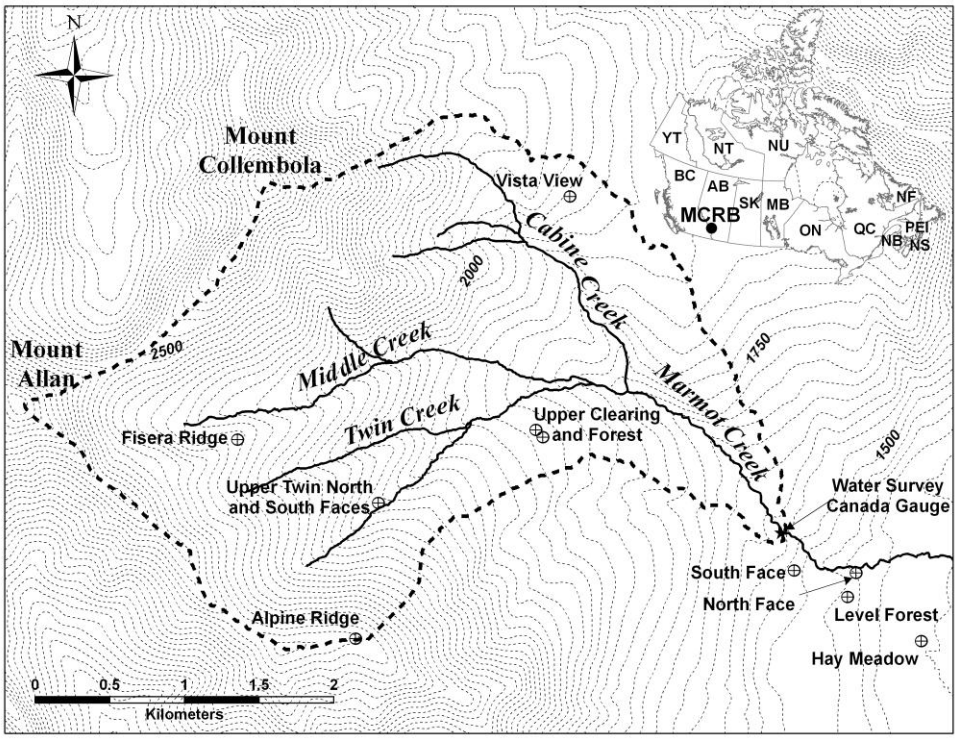


Figure 1. Map of the Marmot Creek Research Basin (MCRB) with the thick dot line donating the boundary of MCRB and thin dot line indicating contour. The locations of main hydrometeorological stations are indicated with crossing circles.

MCRB largely consists of needleleaf vegetation and is dominated by Engelmann spruce (*Picea engelmanni*) and subalpine fir (*Abies lasiocarpa*) in the higher part of basin, and the lower portion of basin is dominated by lodgepole pine (*Pinus contorta* var. Latifolia) (Kirby and Ogilvy, 1969). Exposed rock surface and talus are present in the high alpine part of basin (Figure 2). The surficial soils are primarily poorly developed mountain soils consisted of glaciofluvial and till surficial deposits (Beke, 1969). Relatively impermeable bedrock is found at the higher elevations and headwater area, and the rest of basin is covered by a deep layer of coarse and permeable soil allowing for rapid rainfall infiltration to deep subsurface layers (Green and Jones, 1961).

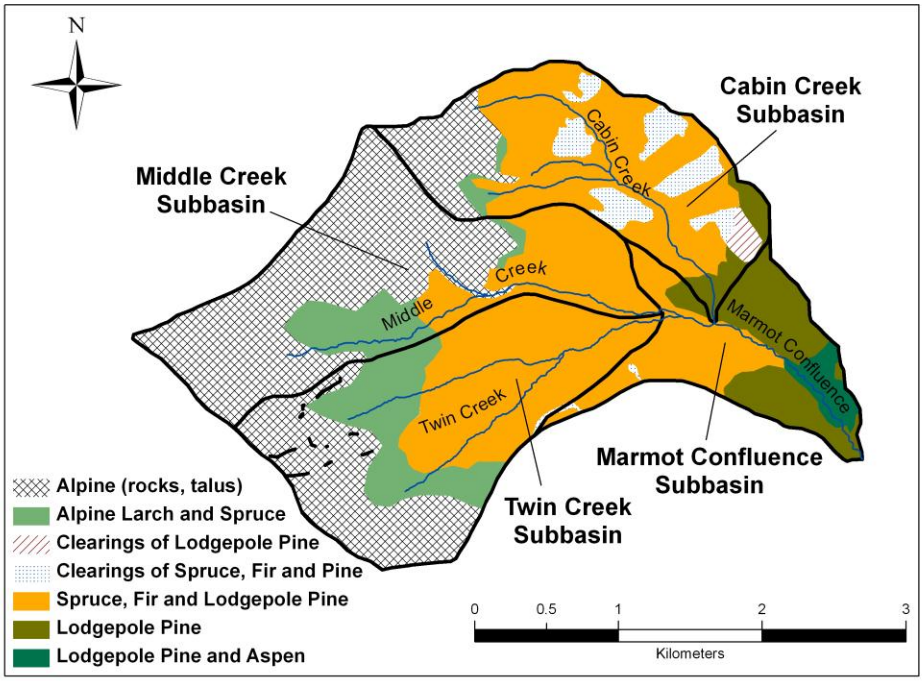


Figure 2. Landcovers at the sub-basins of the Marmot Creek Research Basin.: Cabin Creek, Middle Creek, Twin Creek, and Marmot Confluence.

Continental air masses control the weather in the region, which has long and cold winter and generally has cool and wet spring. A nearby weather station (51˚02'N, 115˚02'W, 1391 m.a.s.l) located at the University of Calgary Biogeoscience Institute Barrier Lake Station in the Kananaskis Country shows long-term (1939-2009) average seasonal air temperature values of -3.8˚C for the months from November to April, 10.9˚C for the months from May to July, and 9.2˚C for the months from August to October (Environment Canada, 2010), with the total seasonal precipitation of 214 mm, 254 mm, and 169 mm for the same monthly periods (Figures 3 and 4). In the MCRB, annual precipitation ranges from 600 mm at the lower altitude to more than 1100 mm at the higher elevations, and approximately from 70 to 75% occurs as snowfall with the percentage increasing with elevation (Storr, 1967). Mean monthly air temperature ranges from 14˚C in July to -10˚C in January.

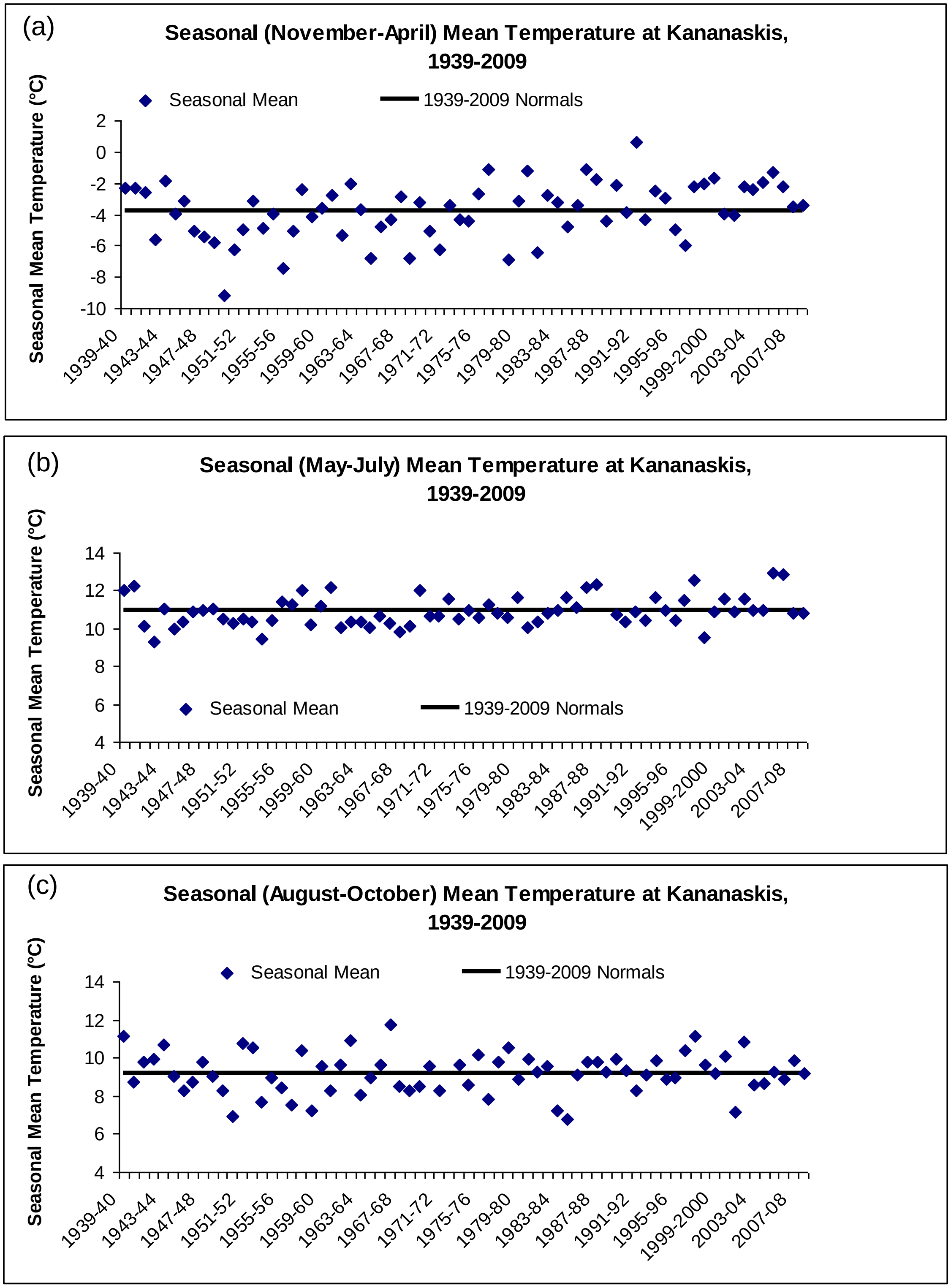


Figure 3. Long-term (1939-2009) seasonal average air temperature at the Kananaskis Country weather station (51˚02'N, 115˚02'W, 1391 m.a.s.l): (a) November-April seasonal average, (b) May-July seasonal average, and (c) August-October seasonal average.

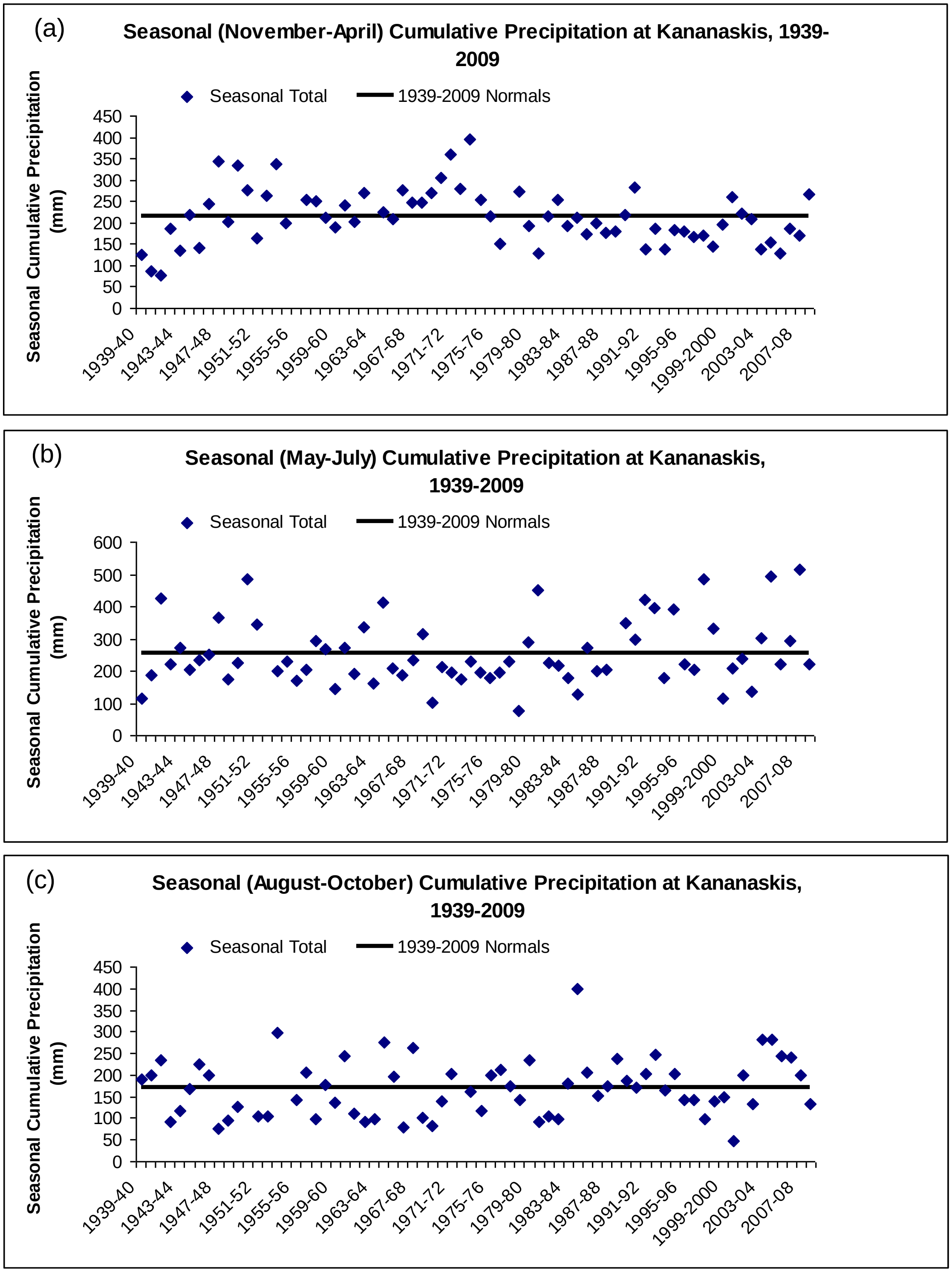


Figure 4. Long-term (1939-2009) seasonal cumulative precipitation at the Kananaskis Country weather station (51˚02'N, 115˚02'W, 1391 m.a.s.l): (a) November-April, (b) May-July, and (c) August-October.

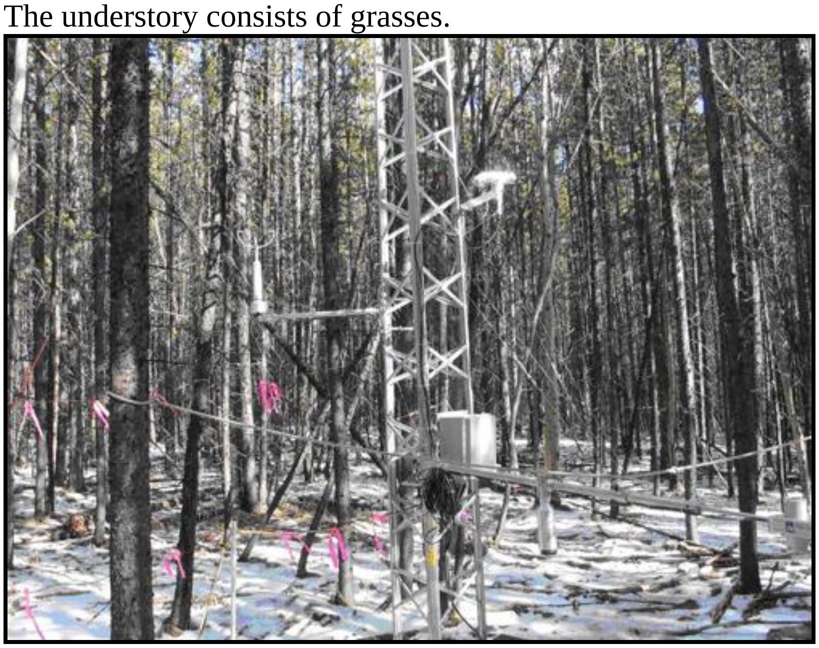
3 Field Observations

3.1 Description of Field Stations

The meteorological data were collected at the main hydrometeorological stations shown in Figure 1. Detailed information on the location and data collection is listed in Table 1. The following is a brief description of each field station.

Hay Meadow: the station is located on a large open grass-covered valley bottom terrace near the Kananaskis River.

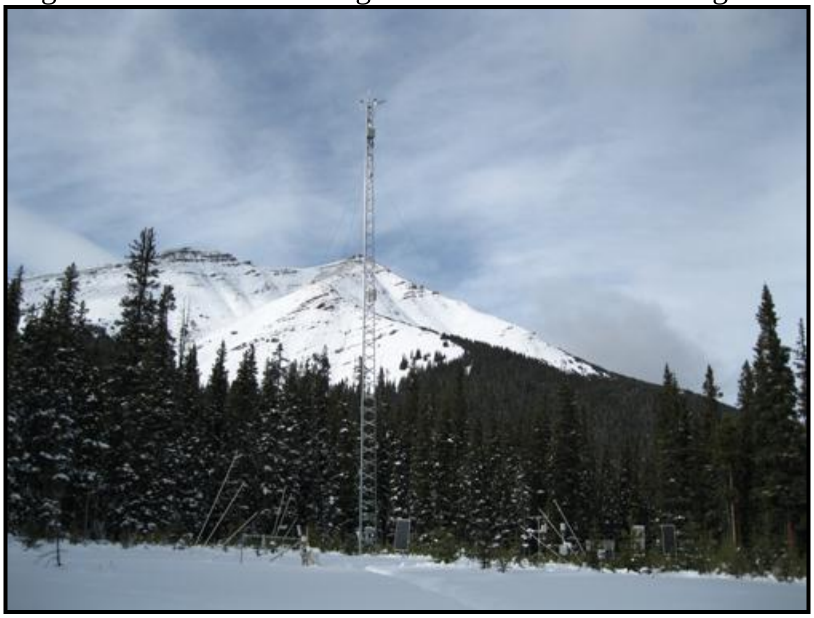
Level Forest: the station is in a level young lodgepole pine forest with a 9 m tall canopy. The understory consists of grasses.



North Face: the station is on a 29^{o} north facing slope covered with a young lodgepole pine forest. Ground cover is made up of heavy brush.

South Face: the station is on a 28^{o} south facing slope covered with a mature open, lodgepole pine forest with a grassy understory.

Upper Clearing: the station is a 100 m wide level clearing in a spruce and fir forest. Vegetation consist of short grasses and natural forest regeneration (<1.5 m tall).

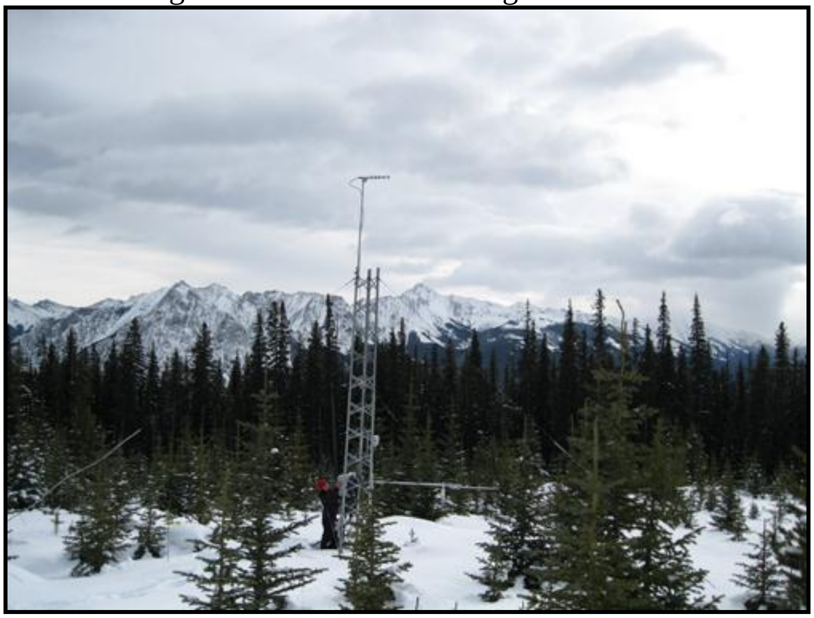


Upper Forest: the station located near the Upper Clearing, in a mature, relatively level, mixed forest stand of Douglas fir and Engelmann spruce.

Upper Twin North Face: the station is in a Douglas fir and Engelmann spruce sorest of approximately 14 m height on a slope of 25 to 30° north facing inclination.

Upper Twin South Face: the station is in a Douglas fir and Engelmann spruce forest of approximately 12 m height on a slope of 25 to 30° south facing inclination.

Vista View: the station is in a moderately sloping clear-cut block in Cabin Creek sub-basin. Vegetation on the site consists of grasses with the regeneration of pine and spruce trees that range from 0.5 – 2.0 m in height.



Fisera Ridge: the station is located above treeline. Vegetation consists of short grasses and dwarfed conifers (fir and larch).

Alpine: the station is located on Centennial Ridge, the top of Marmot Creek. Vegetation is sparse grasses and forbs.

The forcing dataset of air temperature, relative humidity, wind speed, precipitation, and incoming shortwave radiation is required for the hydrological modelling of Marmot Creek. The forcing data obtained at Alpine, Fisera Ridge, Vista View, Upper Clearing and Upper Forest, and Hay Meadow hydrometeorological stations were formatted in the CRHM observation file format. Any missing data gaps were filled using either station spatial correlations (long gaps) or temporal interpolation techniques (short gaps).

3.2 Descriptions of Field Observations of Snow Survey and Streamflow Gauging

Regular snow surveys were conducted at all main sites: Hay Meadow, Level Forest, Upper Clearing and Upper Forest, Upper Twin North and South Faces, Vista View, and Fisera Ridge. Snow surveys typically consisted of >25 depth measurements spaced 5 m apart and >6 density measurements. The sites that have the most complete and continuous records of snow surveys are Upper Clearing and Upper Forest and Fisera Ridge, and the survey data from both sites were used to evaluate the model performance on snow accumulation and snowmelt.

In addition, the seasonal (April 1-October 31) streamflow is recorded by a Water Survey Canada gauge (05BF016) at the Marmot Creek outlet. This is a daily mean streamflow discharge and was used to evaluate model predictions of the basin streamflow. For the sub-basins, streamflows were gauged at the Cabin Creek outlet, lower and upper Middle Creek outlets, and Twin Creek outlet from the summer of 2007 using automated depth transducers. Rating curves were developed from velocity and depth profiles taken every few weeks from channel snowmelt until fall. Velocity was measured at 0.6 depth ever 10 cm across the channel using a Doppler sonic stream velocity gauge. Discharge was estimated using the velocity for each segment of the channel cross-section. At each sub-basin gauging site, hourly stage was recorded and hourly discharge was estimated using the rating curve between the stage and discharge. However, there are missing gaps in the various time periods and duration of the sub-basin gauging data varies from year to year; thus, the observed sub-basin streamflow discharge was not used for the model evaluation.

Table 1. Hydrometeorological Stations in the Marmot Creek Research Basin.

Site	Record History	Telemetry	UTM (11U)	Elevation (m)	Air Temperature	Relative Humidity	Incoming Longwave Radiation	Incoming Shortwave Radiation	Outgoing Shortwave Radiation	Incoming Shortwave Radiation	Incoming All-wave Radiation	Outgoing All-wave Radiation	Net Radiation	Wind Speed	Wind Direction	Snow Depth	Rainfall	Total Precipitation (rain&snow)	Soil Moisture	Soil Temperature	Soil heat flux	Canopy Temperature	Surface Temperature	Snow Temperature	Barometric Pressure
Hay Meadow	July 2006 - present	x	603742 5645259	1436	x	x	x	x	x	x				x	x	x	x	x[6]	x	x	x		x		x
Level Forest	March 2005 - present		630211 5645518	1557	x	x	x	x	x	x				x	x	x				x	x	x	x	x	
North Face	March 2005 - May 2007		630248 5645671	1467	x	x	x	x	x	x				x	x	x			x	x	x	x	x	x	
South Face	March 2005 - May 2007		629847 5645680	1552	x	x	x	x	x	x				x	x	x			x	x		x	x	x	
Upper Clearing	June 2005 - present	x	628150 5646577	1845	x	x					x	x		x	x	x	x	x	x	x	x[2]				
Upper Forest	June 2005 - present		628088 5646613	1848	x	x					x	x		x	x	x	x		x	x					
Upper Clearing Tower	Oct 2007 - present		628150 5646577	1845			x	x																	
Upper Twin North Face	Oct 2007 - present		627113 5648184	2008	x	x	x	x	x	x				x	x	x			x	x	x	x	x	x	
Upper Twin South Face	Oct 2007 - present		627049 5646138	2037	x	x	x	x	x	x				x	x	x			x	x	x	x	x	x	
Vista View	July 2006 present	x	628332 5648184	1956	x	x							x	x	x	x				x					
Fisera Ridge	Oct 2006 - present	x	626107 5646559	2325	x	x	x[3]	x[3]	x[3]	x[3]				x	x	x	x	x[4]		x[4]	x[5]				
Alpine	July 2005 - present	x	626896 5645231	2470	x	x					x	x		x	x	x				x					x[1]

Note: [1]instrument added October 2008
[2]instrument added October 2008
[3]instrument added October 2007
[4]instrument added October 2008
[5]instrument added August 2008
[6]instrument added July 2005

4 Model Structure and Parameter Setup

4.1 Model Description

The Cold Regions Hydrological Model platform (CRHM) was used to develop a basin model to simulate the dominant hydrological processes at the Marmot Creek Research Basin. CRHM is an object-oriented, modular and flexible platform for assembling physically based hydrological models. With CRHM, the user constructs a purpose-built model or "project", from a selection of possible basin spatial configurations, spatial resolutions, and physical process modules of varying degrees of physical complexity. Basin discretization is via dynamic networks of hydrological response units (HRUs) whose number and nature are selected based on the variability of basin attributes and the level of physical complexity chosen for the project. Physical complexity is selected by the user in light of hydrological understanding, parameter availability, basin complexity, meteorological data availability and the objective flux or state for prediction. Models are chosen depending on the dominant hydrological processes and controls on the basin. A full description of CRHM is provided by Pomeroy *et al.* (2007).

A set of physically based modules was linked in a sequential fashion to simulate the dominant hydrological processes for the MCRB. Figure 5 shows the schematic of these modules, and these modules include:

1. Observation module: reads the meteorological data (temperature, wind speed, relative humidity, vapour pressure, precipitation, and radiation), providing these inputs to other modules.

2. Garnier and Ohmura's radiation module (Garnier and Ohmura, 1970): calculates the theoretical global radiation, direct and diffuse solar radiation, as well as maximum sunshine hours based on latitude, elevation, ground slope, and azimuth, providing radiation inputs to sunshine hour module, energy-budget snowmelt module, net all-wave radiation module.

3. Sunshine hour module: estimates sunshine hours from incoming short-wave radiation and maximum sunshine hours, generating inputs to energy-budget snowmelt module, net all-wave radiation module.

4. Slope adjustment for short-wave radiation module: estimates incident short-wave for a slope using measurement of incoming short-wave radiation on the level surface. The measured incoming short-wave radiation from the observation module and the calculated direct and diffuse solar radiation from the Garnier and Ohmura's radiation module are used to calculate the ratio for adjusting the short-wave radiation on the slope.

5. Long-wave radiation module (Sicart *et al*., 2006): estimates incoming long-wave radiation using the measured short-wave radiation and provides long-wave radiation inputs to energy-budget snowmelt module.

6. Albedo module (Essery *et al*., 2001): estimates snow albedo throughout the winter and into the melt period and also indicates the beginning of melt for the energy-budget snowmelt module.

7. Forest snow mass- and energy-balance module (Ellis *et al*., 2010): estimates the snowfall and rainfall intercepted by forest canopy and updates the under-canopy snowfall and rainfall; also provides estimation for the adjusted short-wave and long-wave radiation

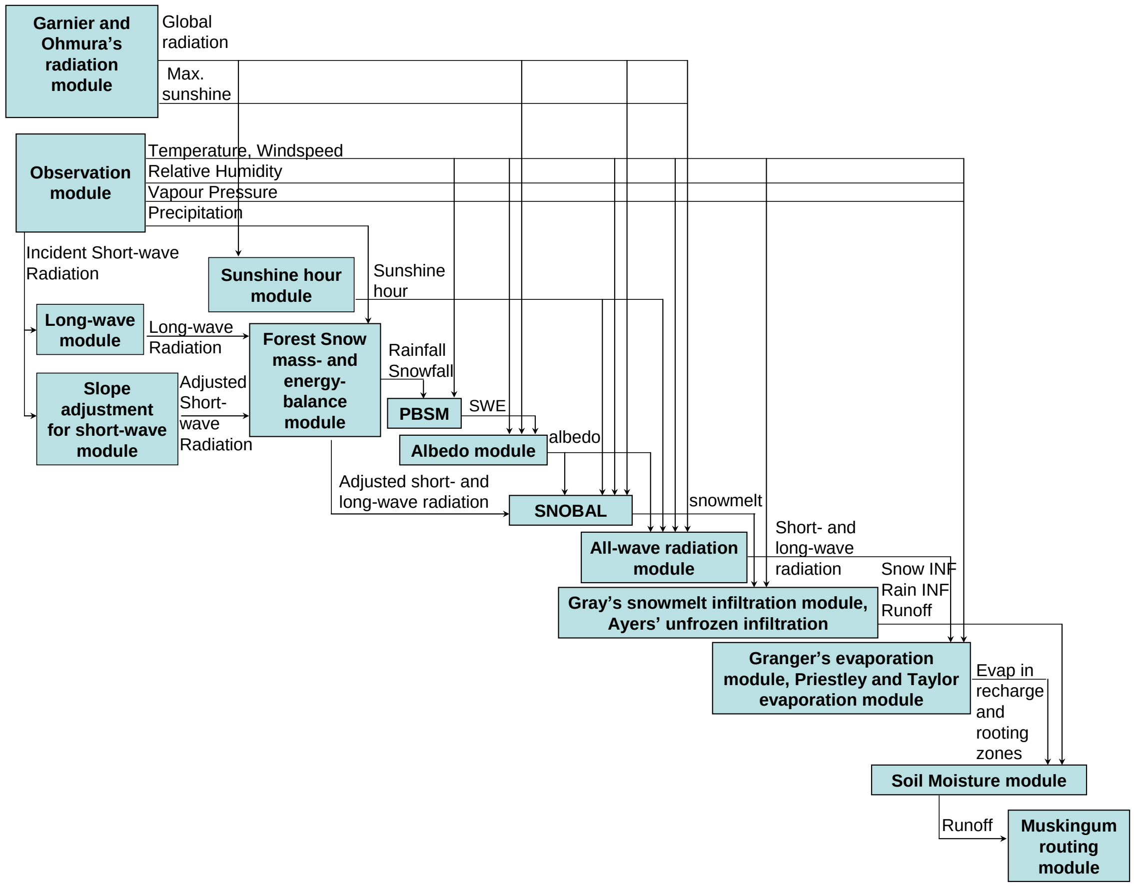


Figure 5. Flowchart of physically based hydrological modules for simulating hydrological processes at the MCRB.

underneath the forest canopy. This module generates inputs for both blowing snow module (PBSM) and energy-budget snowmelt module (SNOBAL) and has options for both alpine open environment (no canopy adjustment of snow mass and energy) and forest environment (adjustment of snow mass and energy from forest canopy).

8. PBSM module or Prairie Blowing Snow Model (Pomeroy and Li, 2000): simulates the wind redistribution of snow and estimates snow accumulation and density changes throughout the winter period.

9. SNOBAL module or Energy-Budget Snowmelt Model (Marks *et al*., 1998): this is a point version of the spatially distributed ISNOBAL model (Marks *et al*., 1999) and is developed to simulate snowmelt in the mountain forest environment. This module estimates snowmelt by calculating the energy balance of radiation, sensible heat, latent heat, ground heat, advection from rainfall, and change in internal energy for two layers of snowpack: a top active layer and layer underneath it.

10. All-wave radiation module: calculates net all-wave radiation from the short-wave radiation and provides inputs to the evaporation module.

11. Infiltration module (two types): Gray's parametric snowmelt infiltration (Zhao and Gray, 1999) estimates snowmelt infiltration into frozen soils; Ayers' infiltration

(Ayers, 1959) estimates rainfall infiltration into unfrozen soils based on soil texture and ground cover. Both infiltration algorithms update moisture content in the soil column from soil moisture balance module.

12. Evaporation module (two types): Granger's evaporation expression (Granger and Gray, 1989) estimates actual evaporation from unsaturated surfaces; Priestley and Taylor evaporation expression (Priestley and Taylor, 1972) estimates evaporation from saturated surfaces or water body. Both evaporation update moisture content in the soil column, and Priestley and Taylor evaporation also updates moisture content in the channel.

13. Soil moisture balance module: This module was modified (Dornes *et al*., 2008) from an original soil moisture balance routine developed by Leavesley *et al*., (1983) and calculates soil moisture balance and drainage for two soil column layers; the top layer is called the recharge layer. Inputs to the soil column layers are derived from infiltration from both snowmelt and rainfall. Evapotranspiration withdraws moisture from both soil column layers. Evaporation only occurs from the recharge zone, and water for transpiration is taken out of the entire soil column. This module also estimates the surface depression storage and its effect on the surface drainage, which is a specific hydrological character in the prairie pothole region (Fang *et al*., 2010).

14. Muskingum routing module: the Muskingum method is based on a variable discharge-storage relationship (Chow, 1964) and is used to route the runoff between HRUs in the sub-basins. The routing storage constant is estimated from the averaged length of HRU to main channel and averaged flow velocity; the average flow velocity is calculated by Manning's equation (Chow, 1959) based on averaged HRU length to main channel, averaged change in HRU elevation, overland flow depth and HRU roughness.

4.2 Model Parameter Estimation

4.2.1 Basin physiographic parameters

A CRHM modelling structure termed "representative basin" (RB) was used to simulate the hydrological processes for sub-basins at the MCRB. In a RB, a set of physically based modules are assembled with a number of HRUs; the RB can be repeated as necessary in a basin, with each sub-basin possessing the same modules but varying parameter sets and varying numbers of HRU. MCRB was divided into four sub-basins that are represented by four RBs (Figure 6); a modelling structure comprising of Muskingum routing was used to route the streamflow output from these RBs along the main channels at MCRB: Cabin Creek, Middle Creek, Twin Creek, and Marmot Creek. At the MCRB, HRUs were decided based on forest cover, aspect, and slope. The forest cover types were derived from the existing basin forest cover type map by Alberta Forest Service (1963) and recent changes were updated from site visits. Figure 2 shows the updated cover types including alpine talus, alpine forest, mix forest of spruce and lodgepole pine, mix of lodgepole pine and aspen, lodgepole pine, and forest clearings. A terrain pre-processing GIS analysis using 2008 LiDAR 8-m DEM was conducted to extract elevation, aspect, and slope for the basin. The extracted elevation, aspect, and slope were then intersected with the basin forest cover feature in ArcGIS, which generates the HRUs based on aspect, slope, and forest cover (Figure 7). 12 HRUs were created for the Cabin Creek sub-basin; seven

HRUs were extracted for both Middle Creek and Twin Creek sub-basin, and eight HRUs were produced for the Marmot Creek confluence sub-basin. Area and the averaged values of elevation, aspect, and slope for these HRUs are listed in Table 2.

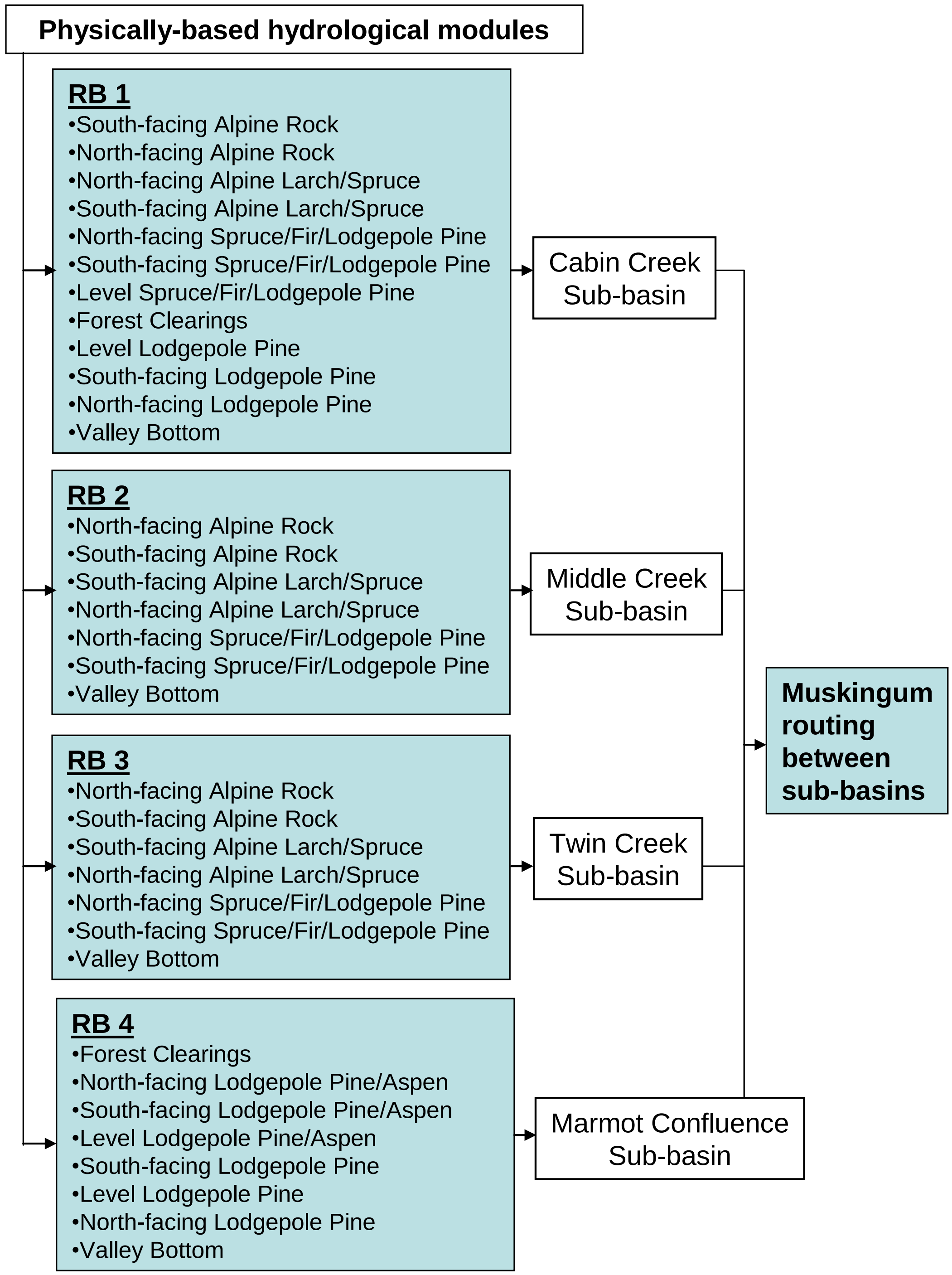


Figure 6. CRHM modelling structure. Four sub-basins are simulated by modelling structure "Representative Basin" (RB); modelling structure of Muskingum routing connects all four RBs.

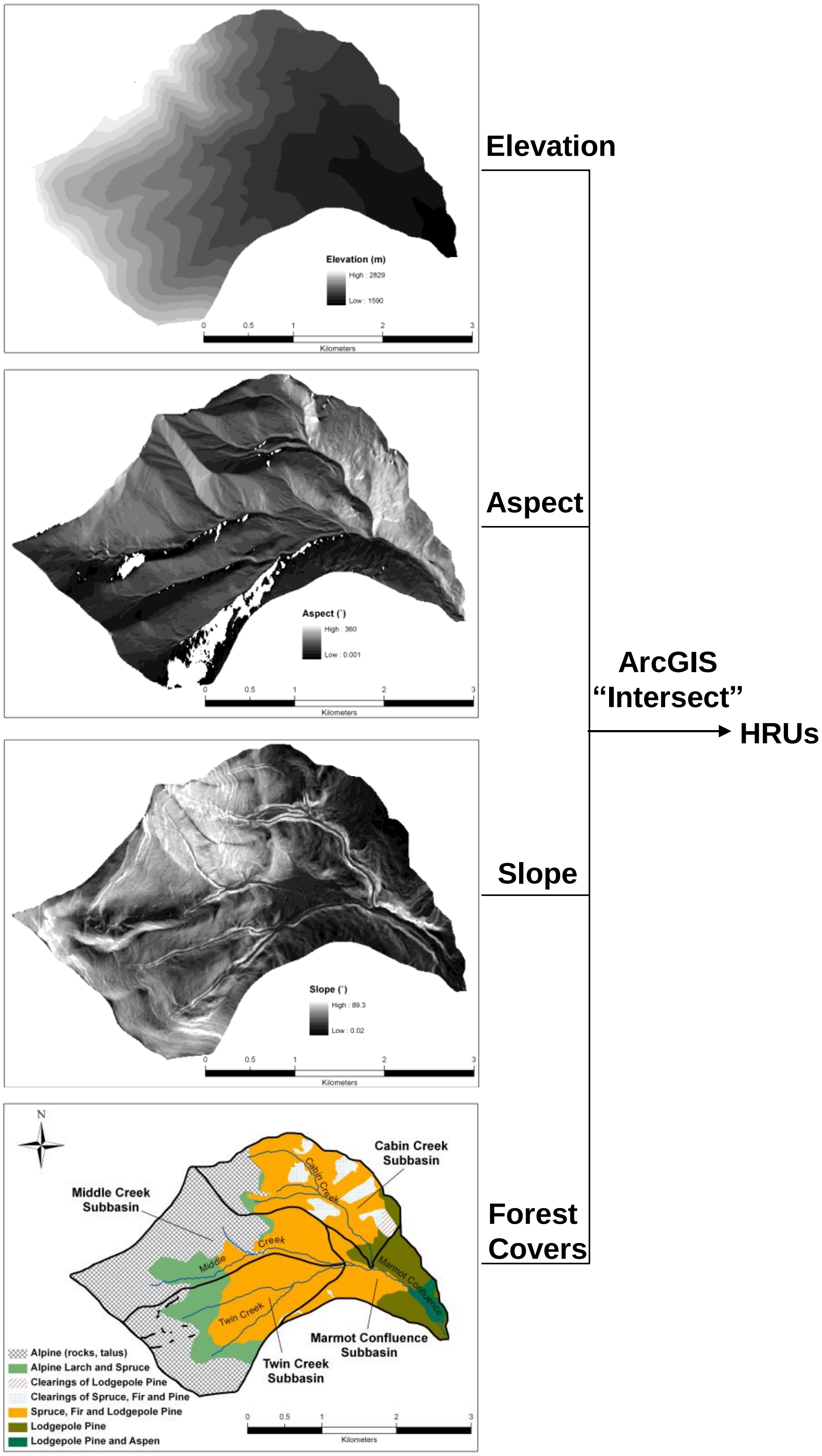


Figure 7. Pre-processing procedure for generating HRUs at the Marmot Creek Research Basin.

Table 2. Area and mean elevation, aspect, and slope for HRUs at the Marmot Creek Research Basin. Note that the aspect is in degree clockwise from North.

HRU	Area (km^2)	Mean Elevation (m)	Mean Aspect (˚)	Mean Slope (˚)
Cabin Creek Sub-basin				
South-facing Alpine Rock	0.23	2387	122	36
North-facing Alpine Rock	0.17	2379	69	37
North-facing Alpine Larch/Spruce	0.02	2222	60	35
South-facing Alpine Larch/Spruce	0.02	2194	115	32
North-facing Spruce/Fir/Lodgepole Pine	0.35	2046	62	24
South-facing Spruce/Fir/Lodgepole Pine	0.93	1972	151	18
Level Spruce/Fir/Lodgepole Pine	0.05	1931	0	4
Forest Clearings	0.40	1927	140	11
Level Lodgepole Pine	0.05	1882	0	3
South-facing Lodgepole Pine	0.07	1798	204	18
North-facing Lodgepole Pine	0.01	1780	76	25
Valley Bottom	0.04	1951	135	18
Middle Creek Sub-basin				
North-facing Alpine Rock	0.52	2462	82	31
South-facing Alpine Rock	1.37	2422	148	30
South-facing Alpine Larch/Spruce	0.26	2246	138	20
North-facing Alpine Larch/Spruce	0.08	2211	46	18
North-facing Spruce/Fir/Lodgepole Pine	0.16	1995	76	21
South-facing Spruce/Fir/Lodgepole Pine	0.52	1953	134	22
Valley Bottom	0.03	2057	115	16
Twin Creek Sub-basin				
North-facing Alpine Rock	0.79	2386	67	28
South-facing Alpine Rock	0.15	2380	106	22
South-facing Alpine Larch/Spruce	0.28	2228	116	23
North-facing Alpine Larch/Spruce	0.28	2182	37	22
North-facing Spruce/Fir/Lodgepole Pine	0.64	1966	34	17
South-facing Spruce/Fir/Lodgepole Pine	0.60	2014	113	21
Valley Bottom	0.04	1988	119	16
Marmot Confluence Sub-basin				
Forest Clearings	0.01	1903	55	11
North-facing Lodgepole Pine/Aspen	0.38	1786	54	13
South-facing Lodgepole Pine/Aspen	0.24	1725	159	13
Level Lodgepole Pine/Aspen	0.04	1688	0	4
South-facing Lodgepole Pine	0.44	1752	172	17
Level Lodgepole Pine	0.02	1724	0	4
North-facing Lodgepole Pine	0.15	1687	71	14
Valley Bottom	0.02	1664	163	8

4.2.2 Blowing snow parameters

The values of vegetation density in the alpine talus and forest HRUs were decided by MacDonald *et al*. (2010); the values of the density for the other forest HRUs were estimated from site observations during field work. The vegetation height for alpine talus and forest HRUs was determined by MacDonald *et al*. (2010), and a uniform height of 10 m was given to other forest cover HRUs. This is the average height to represent the various forest covers and was estimated from site observation. For the blowing snow fetch distance, 300 m (minimum value) was used for all HRUs in the basin due to the short upwind distance. The blowing snow sequence was decided based on the predominant wind direction in the basin. For the Cabin Creek sub-basin, blowing snow initiates from the south-facing alpine talus HRU then to the north-facing alpine talus HRU, and snow is redistributed to the north-facing alpine forest HRU and then blown to the south-facing alpine forest HRU where the redistribution of snow ends. For both Middle Creek and Twin Creek sub-basins, snow is transported from the north-facing alpine talus HRU to south-facing alpine talus HRU, and snow is subsequently redistributed to the south-facing alpine forest HRU, from which snow is blown to the north-facing alpine forest HRU. For other HRUs in the lower elevation part of basin including the mix of spruce, fir, and lodgepole pine HRUs and all HRUs in the Marmot Confluence sub-basin, blowing snow is inhibited.

4.2.3 Forest snow mass- and energy-balance model parameters

For the forest cover HRUs, a LAI value of 2.2 was assigned, and this is comparable to the values estimated by Ellis *et al*. (2010) and to previous findings (Hedstrom and Pomeroy, 1998). A LAI value of 1.1 was given for the forest clearings HRUs as regenerated forest cover is present in the clearings, and this value is similar to the reported values for the forest regeneration (Bewley *et al*., 2010). For the canopy snow interception load capacity, 6.6 kg/m^2 was assigned to lodgepole pine and alpine forest HRUs; this is value found for the similar forest type (Schmidt and Gluns, 1991; Hedstrom and Pomeroy, 1998). A higher value of 8.8 kg/m^2 was given to spruce forest, and mixed spruce and lodgepole pine forest HRUs. This was derived from trial-and-error runs by comparing the simulated and observed snow accumulation in those HRUs at Upper Clearing and Upper Forest sites in 2008. A lower value of 3.3 kg/m^2 was assigned to the forest clearing HRU. The parameter of unloading temperatures as snow and water set the temperature boundaries for the intercepted snow to unload as either snow or liquid water. The values are site specific depending on the local climate; that is, coastal mountain forests have different values than forests in the Rockies. For the MCRB, -3 ˚C was estimated as the temperature when canopy snow is unloaded as snow, and 6 ˚C was estimated as the temperature when canopy snow is unloaded as meltwater (drip). Those values were derived from field observations and trial-and-error runs by comparing the simulated and observed snow accumulation in those HRUs at Upper Clearing and Upper Forest sites in 2008.

4.2.4 Long-wave radiation model parameter

The terrain view factor parameter was calculated using the inverse relationship with the sky view factor. The sky view factor was measured for the alpine environment at the

MCRB by DeBeer and Pomeroy (2009) and was measured for the forest environment by (Essery *et al*., 2008).

4.2.5 Soil infiltration parameters

For the parameters in the Gray's parametric infiltration into frozen soils (Zhao and Gray, 1999), initial soil saturation and initial soil temperature were taken from the measured values prior to snowmelt at various stations at the MCRB. For the surface saturation, 1 was given as the surface is likely to be fully covered by melting water when snowmelt starts. Infiltration opportunity time was calculated by the model runs. For the Ayers' infiltration into unfrozen soil (Ayers, 1959), soil texture parameter was decided by the Marmot Creek soil analysis conducted by Beke (1969), and surface cover parameter was determined based on the forest cover type at the MCRB.

4.2.6 Soil moisture model parameters

The current version of CRHM has a less conceptual module for estimating groundwater flows, which is one of most important water balance elements at the MCRB. Hence, to incorporate active groundwater flow regime into the current basin model, 5 m was assigned as total depth for the soil column layer. This is much deeper than the conventional soil column layers found in other environment such as the Prairies. 0.25 m was set for the soil recharge layer, which is the top of soil column layer; this layer represents the most active subsurface flow regime. 1 mm was given to the surface depression capacity – "*Sd_max*". The small valued *Sd_max* represent a conceptual connection between surface and groundwater flow regimes. That is, having 1 mm of *Sd_max* allows excessive surface water to flow quickly down to the groundwater layer through "macropores". The rate of this excessive surface water to groundwater is controlled by a depression storage drainage factor – "*Sd_gw_K*". A CRHM modelling feature "Macro" was developed to adjust the value of *Sd_gw_K*. In the Macro, *Sd_gw_K* was assigned to be zero in the early season when the "macropores" are still closed due to frost layers; *Sd_gw_K* grew linearly in the summer when the "macropores" gradually open up during thaw. The value for the *Sd_gw_K* growing rate was estimated using trial-and-error runs by comparing the simulated and observed basin hydrographs in 2007. In addition, the drainage factors in the soil column and groundwater layers control the rates of flow in these layers and were estimated from the groundwater level analysis using the historical groundwater well observation data at the MCRB. 32 mm day^{-1} was given to both parameters.

4.2.7 Routing parameters

4.2.7.1 Surface runoff and channel flow routing

Figure 8 illustrates the routing sequence for surface runoff and channel flow at the MCRB. In each RB, all non-channel HRUs including alpine rock and forest, and other forest, and forest clearing are routing to the valley bottom HRU. The valley bottom HRU represents the deep incised surface and the runoff from the valley bottom HRU is routing along the main channel in each RB: Cabin Creek, Middle Creek, Twin Creek, and Marmot Creek. Then, the channel flows from Cabin Creek, Middle Creek, and Twin Creek at the upper basin merge to the Marmot Creek, which subsequently flows out of the basin.

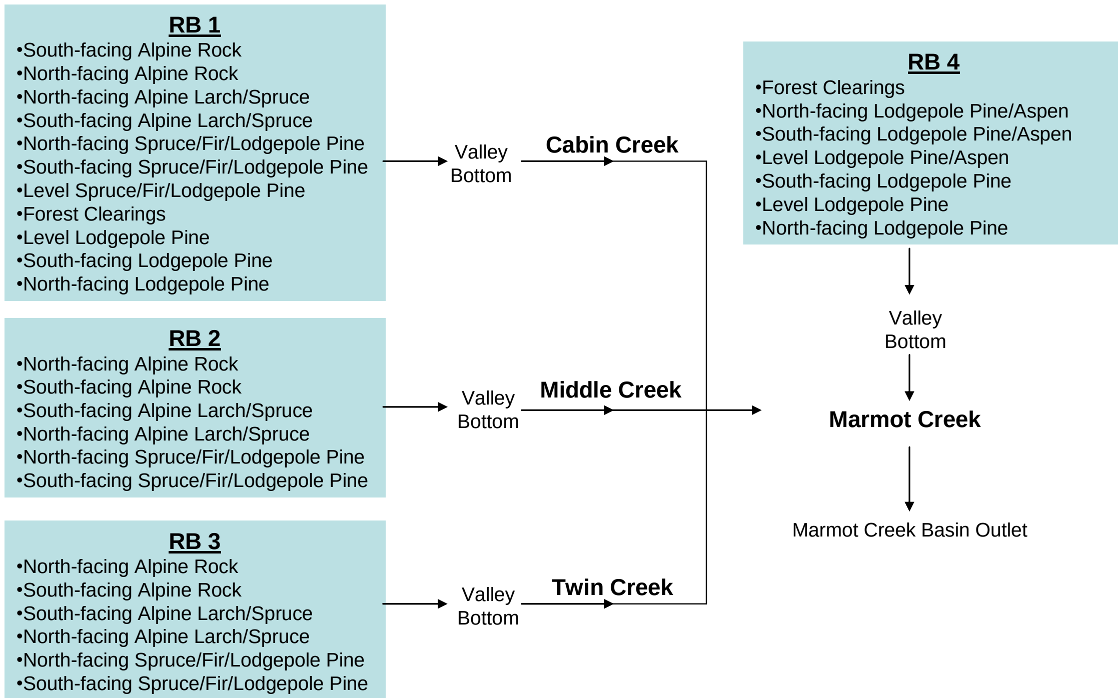


Figure 8. Routing sequence for surface runoff and channel flow at the Marmot Creek Research Basin.

The Muskingum routing module (Chow, 1964) was used for both routing within and between RBs. For the routing between RBs, the routing length is the total length of main channel in each sub-basin, which was estimated from the terrain pre-processing GIS analysis using 2008 LiDAR DEM. For the routing within RBs, the routing length is the distance from each HRU to the main channel in each sub-basin, which was calculated from the Hack's law length (Hack, 1957) based on the HRU area as outlined by Pomeroy *et al*. (2010). Manning's equation (Chow, 1959) was used to estimate the average flow velocity, and parameters used in the equation include longitudinal channel slope, Manning's roughness coefficient, and hydraulic radius. The longitudinal channel slope of a HRU or a sub-basin was estimated from the averaged slope of the corresponding HRU or sub-basin. The averaged slope was derived from the terrain pre-processing GIS analysis using 2008 LiDAR DEM. Manning's roughness coefficient was assigned based on the surface cover and channel condition using the Manning's roughness lookup table (Mays, 2001). Hydraulic radius was determined from the lookup table using channel shape and depth of channel as criteria; channel shape was set as parabolic and was decided from field observation, and channel depth was measured in the field. From the average flow velocity and routing length, the storage constant was calculated. The dimensionless weighting factor controls the level of attenuation, ranging from 0 (maximum attenuation) to 0.5 (no attenuation), which can be determined by a number of methods (Wu *et al*., 1985; Kshirsagar *et al*., 1995). However, information for approximating this parameter is lacking from the existing data, so a medium value, 0.25 was used for the basin.

4.2.7.2 Subsurface flow routing

The flow in the subsurface layer is less well known and was simulated with a simpler and less physically based model due to the uncertainty in estimating routing parameters. Thus, the subsurface runoff storage constant – "*ssrKstorage*" was used to control the routing in the subsurface layer. Trial-and-error runs by comparing the simulated and observed hydrographs in 2007 were conducted to derive the *ssrKstorage* values. 1 day, 2 days and 0 day were estimated for alpine rock, forest, and valley bottom HRUs, respectively.

5 Model Performance Evaluation

Model simulations on snow accumulation and snowmelt were evaluated by comparing the simulations and observations in both forest and alpine environments during 2007-08 and 2008-09 seasons. The comparisons were conducted at the Upper Clearing and Upper Forest site for evaluation in the forest environment; comparisons made at Fisera Ridge site were used as evaluation for the alpine environment. In addition, model predictions on the basin streamflow discharge were assessed by comparing the simulated and observed basin streamflow during 1 May to 30 September in 2006, 2007, 2008, and 2009. To assess the performance of model, two statistical measures: root mean square difference (RMSD) and model bias (MB) were calculated as:

$$RMSD = \frac{1}{n}\sqrt{\sum (X_s - X_o)^2} \quad (1)$$

$$MB = \frac{\sum X_s}{\sum X_o} - 1 \quad (2)$$

where n is number of samples, X_o, and X_s are the observed and simulated values, respectively. The RMSD is a weighted measure of the difference between observation and simulation and has the same units as the observed and simulated values. The MB indicates the ability of model to reproduce the water balance; a positive value or a negative value of MB implies model overprediction or underprediction, respectively.

5.1 Snow Accumulation Tests

Snow accumulation is the primary driver of streamflow timing, magnitude and duration in Marmot Creek. In order to evaluate the predictions of snow accumulation, simulations for appropriate HRUs were compared to the results of long surveys of snow depth and density taken approximately 15 times each snow season in landscapes representative of specific HRUs. Evaluations were conducted at middle elevations in the Upper Clearing and Upper Forest Site and at high elevations for a forest, ridgetop, and north and south facing slopes near Fisera Ridge for the winters of 2007-2008 and 2008-2009. Snow accumulation was much higher for the Fisera Ridge sites than for the Upper Clearing/Upper Forest sites. Table 3 shows root mean square differences between observations and predictions over the snow season. Figure 9 through 12 show the observed and predicted snow accumulations over the course of the snow accumulation and ablation periods. The RMSD are small compared to the snow accumulations, ranging from 2% to 17% of seasonal mean snow accumulations.

Table 3. Evaluation of snow accumulations with the root mean square difference (RMSD, mm SWE) at Upper Clearing/Forest and Fisera Ridge, Marmot Creek Research Basin.

	Upper Clearing/Forest		Fisera Ridge				
	Upper Forest	Upper Clearing	North-facing Slope	Ridge Top	Top South-facing Slope	Bottom South-facing Slope	Larch Forest
2007-08	4.3	7.6	12.6	13.5	16.5	11.9	22.8
2008-09	5.1	9.5	14.1	14.0	13.8	26.2	27.7

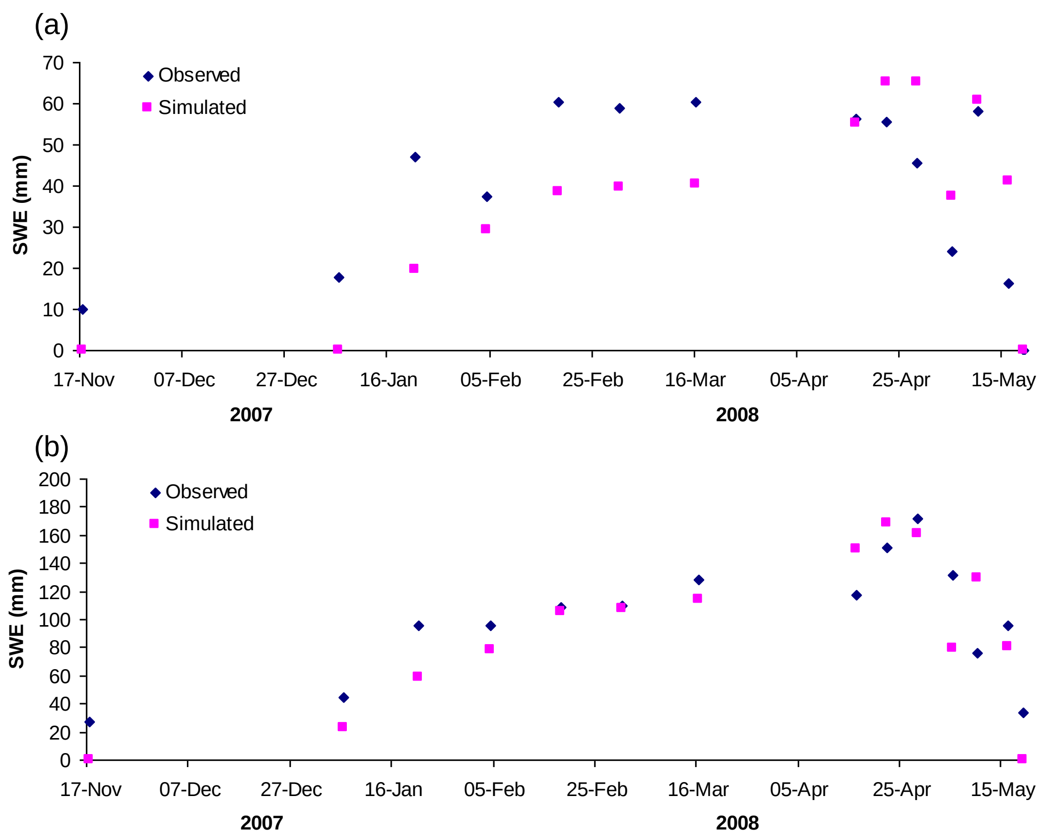


Figure 9. Comparisons of the observed and simulated snow accumulation (SWE) during 2007-08 at the Marmot Creek Research Basin. (a) Upper Forest and (b) Upper Clearing.

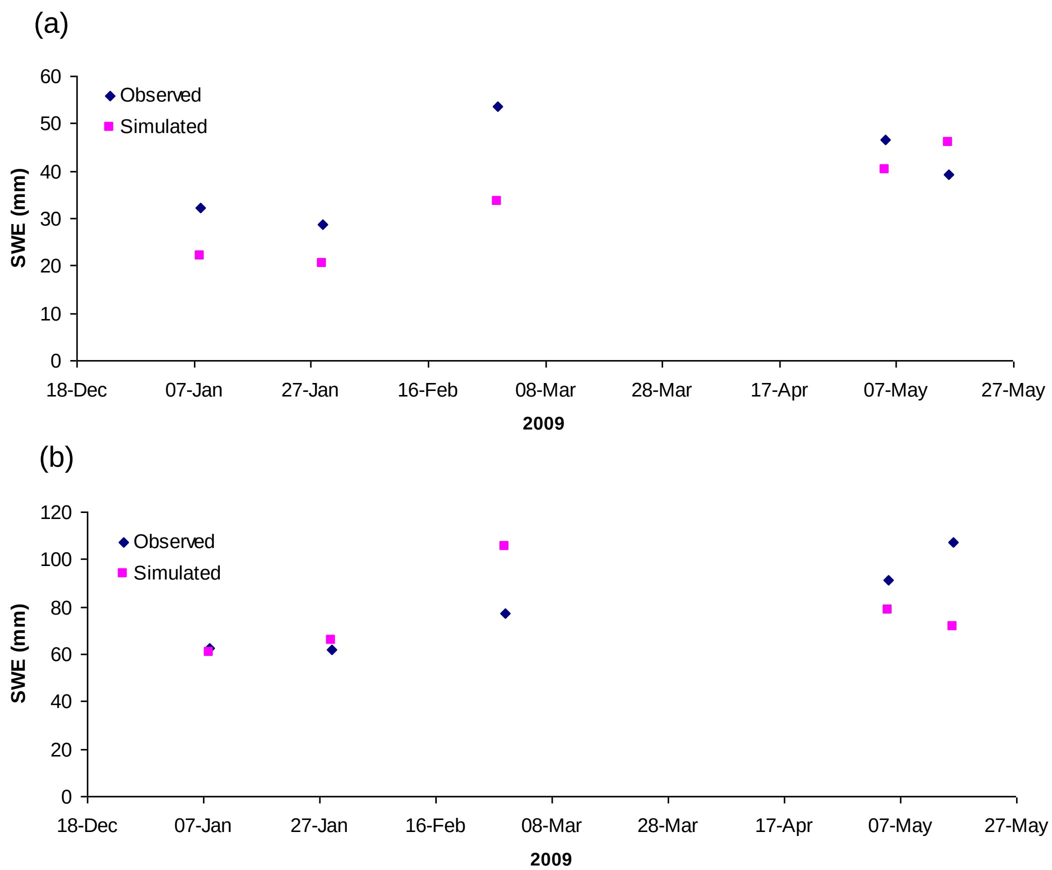


Figure 10. Comparisons of the observed and simulated snow accumulation (SWE) during 2008-09 at the Marmot Creek Research Basin. (a) Upper Forest and (b) Upper Clearing.

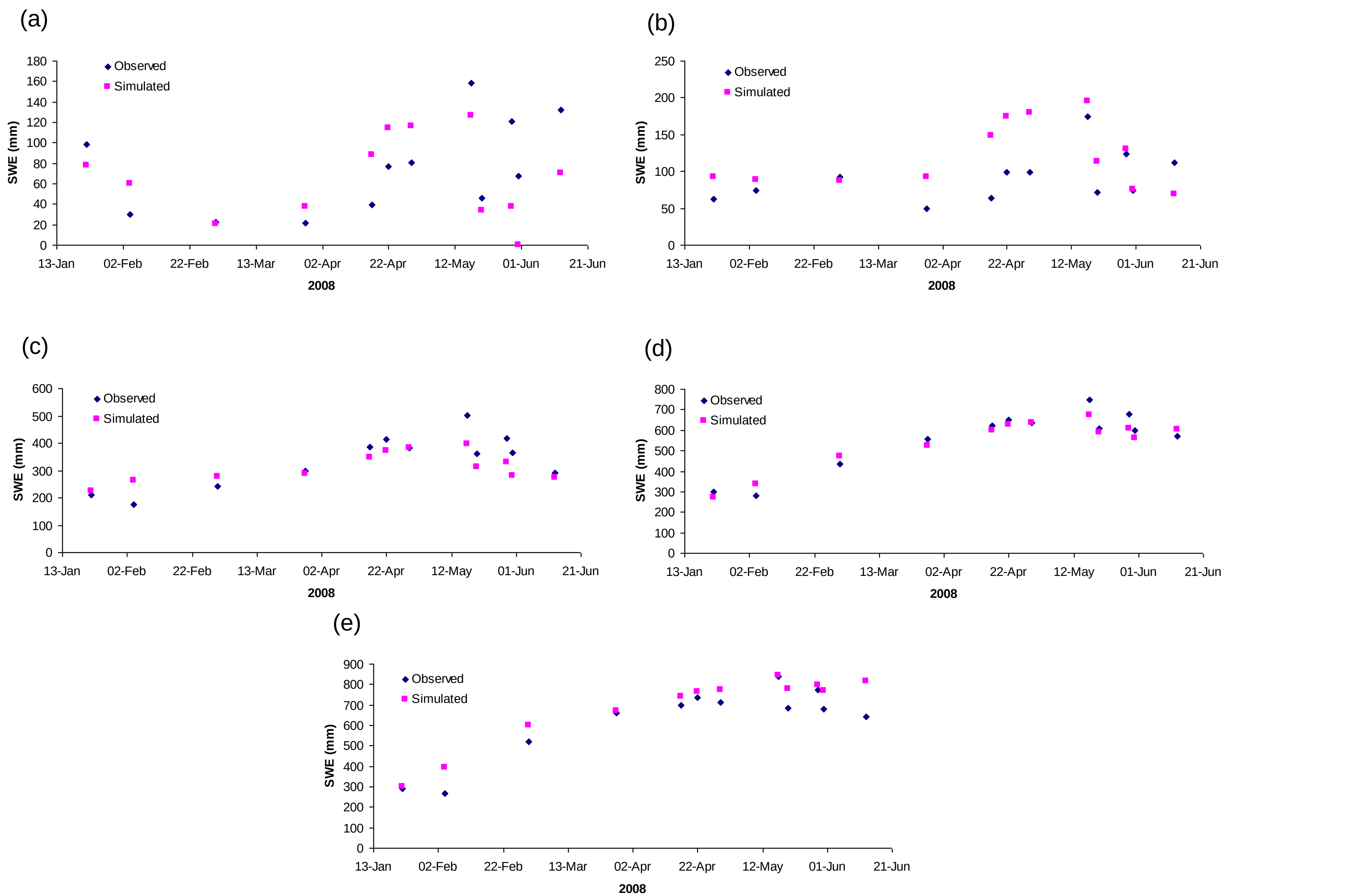


Figure 11. Comparisons of the observed and simulated snow accumulation (SWE) during 2007-08 at the Fisera Ridge, Marmot Creek Research Basin. (a) North-facing slope, (b) Ridge top, (c) Top south-facing slope, (d) Bottom south-facing slope, and (e) Larch forest.

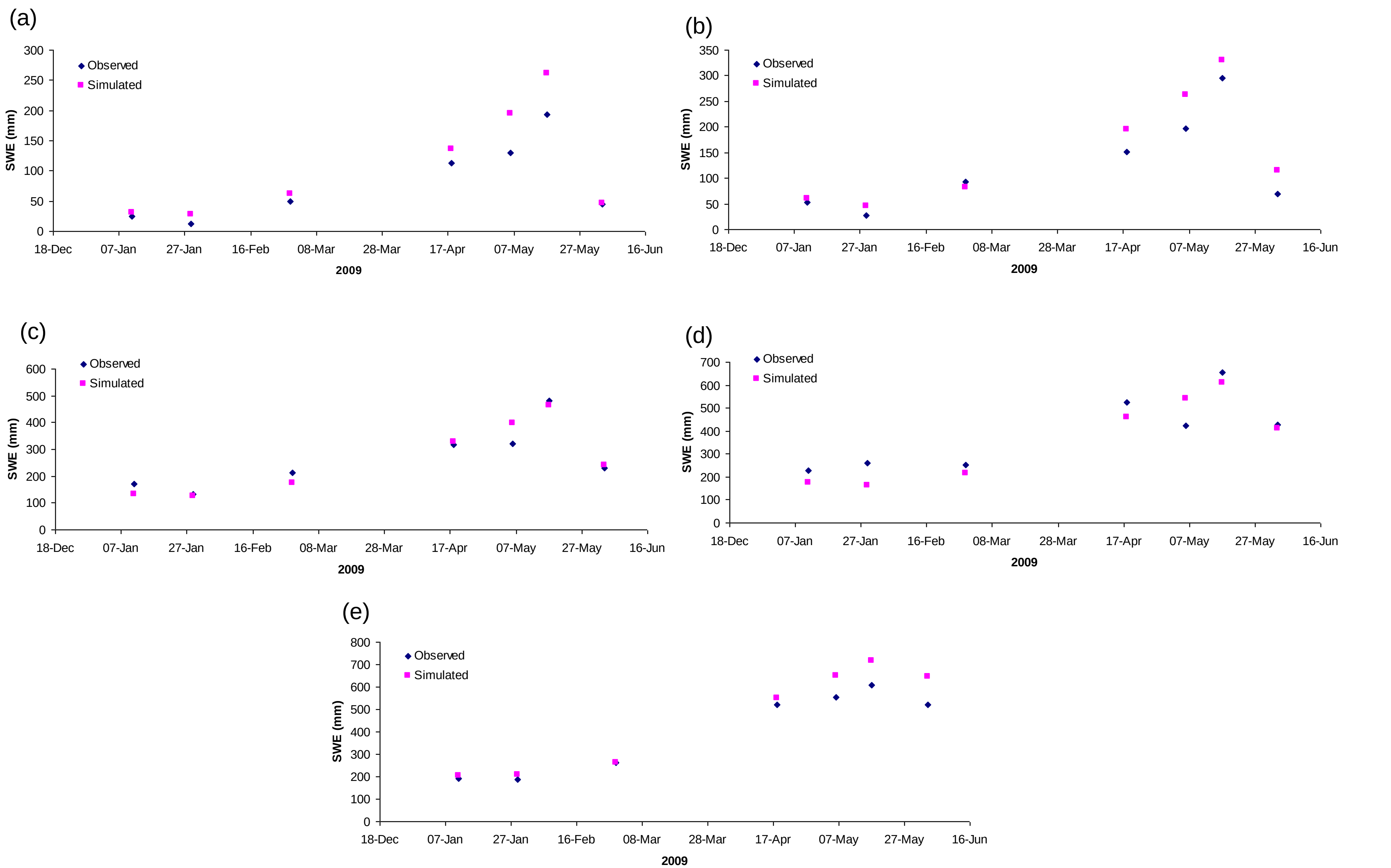


Figure 12. Comparisons of the observed and simulated snow accumulation (SWE) during 2008-09 at the Fisera Ridge, Marmot Creek Research Basin. (a) North-facing slope, (b) Ridge top, (c) Top south-facing slope, (d) Bottom south-facing slope, and (e) Larch forest.

5.2 Streamflow Tests

Streamflow simulations were conducted continuously over the period 2005 to 2009 for which meteorological measurements were available to drive the model. Modelled discharge was evaluated with respect to Water Survey of Canada discharge measurements which are available over the spring, summer and fall periods of 2006 to 2009. Observed and simulated discharges are shown in Fig. 13 for each year and show that the model can generally simulate the hydrograph shape as characterised by low flows in winter and early spring followed by spring peaks due to snowmelt and spring rainfall and a long summer recession where discharge is unresponsive to further inputs of rainfall or snowmelt. The model bias is shown in Table 4 and suggests annual errors of less than 15% with estimates in some years better than 3% in error. Discharge volumes on a monthly basis are shown in Fig. 14 and show that the seasonal progression of runoff is well represented by the model. Bias in individual months has a larger range than found annually, from less than 1% error to 59% errors in summer months (Table 4). However during the peak snowmelt flow month of June the maximum error was 25% with most errors less than 6%. Overall, these tests are considered successful in that the model developed using CRHM can represent the volume, timing, duration and seasonality of streamflow response to precipitation inputs and snowmelt. Considered with the successful simulations of SWE and the strong physical basis of the model this means that the model is simulating streamflow forming processes correctly and has potential to be used to analyze management scenarios.

Table 4. Evaluation of simulated basin streamflow discharge with model bias (MB).

	May	June	July	August	September	Overall
2006	-0.25	-0.04	-0.18	-0.24	-0.39	-0.15
2007	0.22	-0.02	-0.59	-0.15	-0.32	-0.07
2008	0.73	-0.06	-0.52	-0.42	-0.42	-0.03
2009	1.68	-0.25	-0.06	0.004	-0.82	0.02

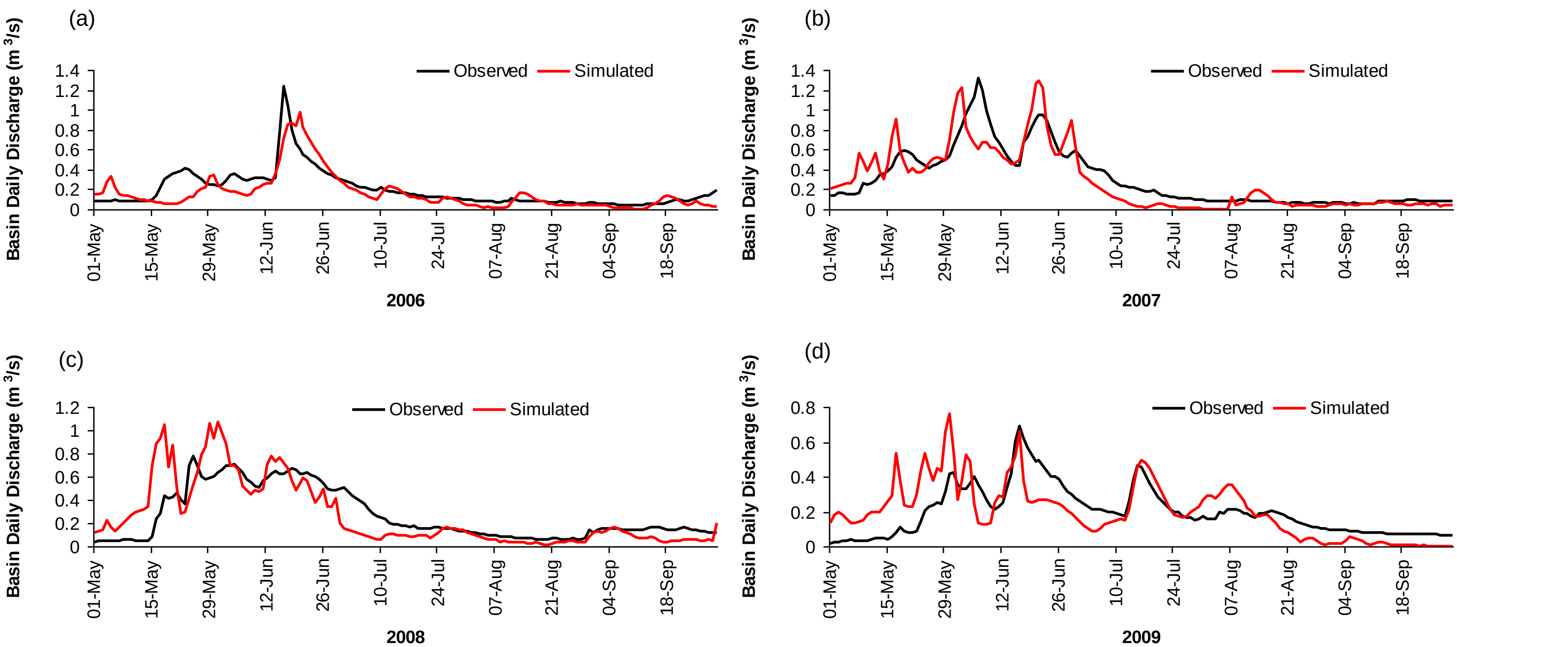


Figure 13. Comparisons of the observed and simulated daily mean discharge at the Marmot Creek. (a) 2006, (b) 2007, (c) 2008, and (d) 2009.

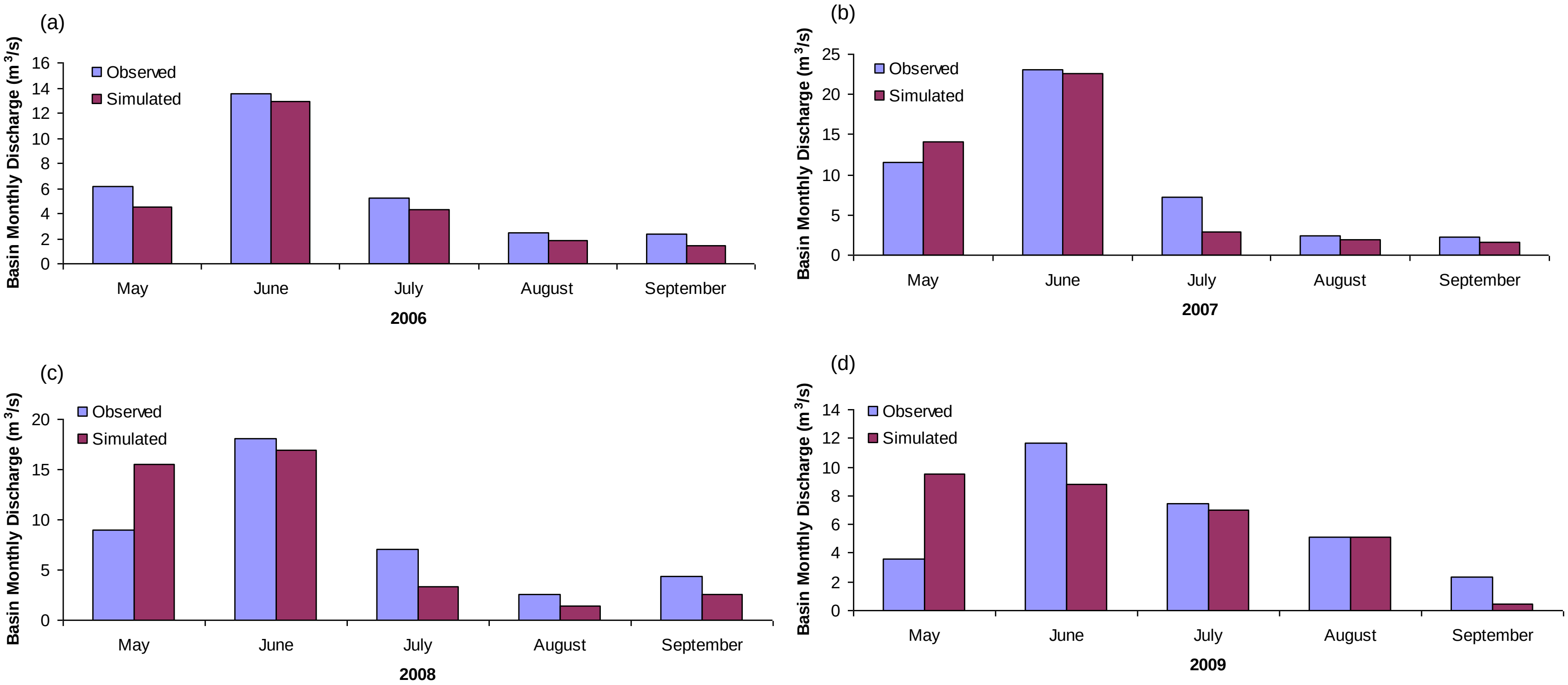


Figure 14. Comparisons of the observed and simulated monthly mean discharge at the Marmot Creek. (a) 2006, (b) 2007, (c) 2008, and (d) 2009.

6 Forest Disturbance Scenarios

6.1 Scenario Description

Nine types of forest disturbance scenarios were developed for this study. The scenarios are essentially virtual forest covers that range from the current forest cover to varying level of forest disturbances resulted from Mountain Pine Beetle (MPB) infestation, selective logging or burns from major forest fires. In total, there are 41 scenarios that are summarized in Table 5.

In both scenarios 2 to 6 and scenarios 7 to 11, the lodgepole pine forest canopy was reduced progressively from 20% to 100% by Mountain Pine Beetle; the reduction covers approximately from 3% to 15% of total basin area. A new HRU – "MPB Disturbance" was incorporated into the scenario simulation. Elevation, aspect, and slope for the MPB Disturbance HRU were estimated from the area-weight average values of elevation, aspect, and slope from the infested lodgepole pine. As the area of the MPB Disturbance HRU increased progressively with the reduction of lodgepole pine forest, LAI and canopy snow interception load capacity for the MPB Disturbance HRU gradually decreased to minimum values. The infested lodgepole pine trunks remained in the scenarios 2 to 6, with the original vegetation height, but the respective values of LAI and canopy snow interception load capacity were reduced to 1 and 3 kg m^{-2}. The beetle infested lodgepole pine was salvage logged in the scenarios 7 to 11, with the MPB Disturbance HRU being given values of 0.1 and 0 kg m^{-2} for the respective values of LAI and canopy snow interception load capacity. Evapotranspiration was suppressed from the infested lodgepole pine in all disturbed scenarios (2 to 6 and 7 to 11).

In scenarios 12 to 16 and scenarios 17 to 21, the forest area (all species) was modified progressively from 20% to 100% by fire, the modification corresponding to from 12% to 60% of total basin area. A new HRU – Fire Disturbance was added to the scenario simulation to account for formerly forested area. Elevation, aspect, and slope for the Fire Disturbance HRU were estimated from the area-weighted average values of elevation, aspect, and slope from the burned forest. The burned forest trunks were permitted to remain in the scenarios 12 to 16 with the original vegetation height, and values of LAI and canopy snow interception load capacity of 0.25 and 1 kg m^{-2} respectively. The burned forest was completely removed in the scenarios 17 to 21, with the Fire Disturbance HRU having 0.1 and 0 kg m^{-2} respectively for the values of LAI and canopy snow interception load capacity. There was no evapotranspiration permitted from the burned forests in scenarios 12 to 16 and scenarios 17 to 21.

In scenarios 22 to 26 and scenarios 32 to 36, forest on the south-facing slope was logged progressively from 20% to 100% of forested slope area; this modification covered approximately from 7% to 36% of total basin area. 1.5 m high stumps and residual roughness were kept in the scenarios 32 to 36, whereas the forest was clear-cut to bare ground in the scenarios 22 to 26. A new HRU – "South-facing Clearings" was added to the scenario simulation. In scenarios 27 to 31 and scenarios 37 to 41, forest on the north-facing slope was cut progressively from 20% to 100% of forested slope area, which corresponds to from 4% to 22% modification of the total basin area. A new HRU – "North-facing Clearings" was incorporated into the scenario simulation. 1.5 m high stump and residual roughness were retained after the logging in the scenarios 27 to 31, while it was clear-cut forest in the scenarios 37 to 41.

The parameters in each of those 41 scenarios are listed in the tables and can be found in the Appendix 1. Simulations were made of the impact of the forest disturbance scenarios on the basin snow accumulation, basin snowmelt, and basin streamflow discharge and groundwater flow at the MCRB. The Marmot Creek Basin model setup described in the modelling section was used and simulations were made for four seasons: 2005-06, 2006-07, 2007-08, and 2008-09.

Description of forest disturbance scenarios at the Marmot Creek Research Basin.

Scenario	Scenario Description	Basin Area Changed (%)
1	Current forest cover	0
2	Pine beetle reduction by 20% with infested trunk retained	3
3	Pine beetle reduction by 40% with infested trunk retained	6
4	Pine beetle reduction by 60% with infested trunk retained	9
5	Pine beetle reduction by 80% with infested trunk retained	12
6	Pine beetle reduction by 100% with infested trunk retained	15
7	Pine beetle reduction by 20% plus salvage logging	3
8	Pine beetle reduction by 40% plus salvage logging	6
9	Pine beetle reduction by 60% plus salvage logging	9
10	Pine beetle reduction by 80% plus salvage logging	12
11	Pine beetle reduction by 100% plus salvage logging	15
12	Fire reduction by 20% with trunk retained	12
13	Fire reduction by 40% with trunk retained	24
14	Fire reduction by 60% with trunk retained	36
15	Fire reduction by 80% with trunk retained	48
16	Fire reduction by 100% with trunk retained	59
17	Fire reduction by 20% with trunk removed	12
18	Fire reduction by 40% with trunk removed	24
19	Fire reduction by 60% with trunk removed	36
20	Fire reduction by 80% with trunk removed	48
21	Fire reduction by 100% with trunk removed	59
22	Reduction of forest by 20% on south facing slope	7
23	Reduction of forest by 40% on south facing slope	14
24	Reduction of forest by 60% on south facing slope	21
25	Reduction of forest by 80% on south facing slope	29
26	Reduction of forest by 100% on south facing slope	36
27	Reduction of forest by 20% on north facing slope	4
28	Reduction of forest by 40% on north facing slope	9
29	Reduction of forest by 60% on north facing slope	13
30	Reduction of forest by 80% on north facing slope	18
31	Reduction of forest by 100% on north facing slope	22
32	Reduction of forest by 20% on south facing slope with 1.5 m stump retained	7
33	Reduction of forest by 40% on south facing slope with 1.5 m stump retained	14
34	Reduction of forest by 60% on south facing slope with 1.5 m stump retained	21
35	Reduction of forest by 80% on south facing slope with 1.5 m stump retained	29
36	Reduction of forest by 100% on south facing slope with 1.5 m stump retained	36
37	Reduction of forest by 20% on north facing slope with 1.5 m stump remained	4
38	Reduction of forest by 40% on north facing slope with 1.5 m stump retained	9
39	Reduction of forest by 60% on north facing slope with 1.5 m stump retained	13
40	Reduction of forest by 80% on north facing slope with 1.5 m stump retained	18
41	Reduction of forest by 100% on north facing slope with 1.5 m stump retained	22

6.2 Scenario Results

With 41 scenarios run over four years of simulation there is a great challenge in presenting the results in a concise manner. The attached appendix contains detailed runs with SWE, snowmelt, streamflow and groundwater recharge changes associated with forest land cover manipulation.

6.2.1 Basin Snow Accumulation

The detailed results of various scenarios for the snow accumulation regime are shown in Appendix 2 for the four years of simulation. There are eight figures in each simulation season and four seasons: 2005-06, 2006-07, 2007-08, and 2008-09 are included. The figures show seasonal basin snow accumulation evolution in each scenario.

The effect of forest reduction invariably increases SWE amount and sometimes duration over Marmot Creek. However the impact of pine beetle infestation itself was quite small, with an increase if forest salvaging occurred afterwards. The small effect of pine beetle on basin scale snow accumulation is due to the low elevations of most pine forests and the associated small snow accumulations in these forests compared to the high elevations of the basin where most snow accumulation occurs. The impact of complete forest removal due to burning or selected removal on north or south facing slopes was much more effective in increasing SWE than pine beetle. In every case, complete forest disturbance due to salvage logging increased the impact on SWE compared to simple clearing or burning. In general the impact of forest manipulations on snow accumulation were most evident in the driest winters, when sublimation and melt differences due to canopy were large compared with the seasonal snow accumulation and seasonal melt energetics. This is instructive as it suggests that forest manipulations will be most effective in managing snowmelt droughts rather than snowmelt flooding.

6.2.2 Basin Snowmelt

Snowmelt sensitivity to forest manipulation is a primary focus of this report and the results reported in Appendix 2 can be summarised by examining the sensitivity of cumulative basin snowmelt to various levels and type of forest disturbance. This is shown in Fig. 15, showing the % change in snowmelt to forest disturbance. It should be noted that a 50% increase in snowmelt corresponds to about a 170 mm increase in snowmelt. The sensitivities are shown as the four-season averaged changes in the cumulative basin snowmelt against the % change of the total basin area. The results suggest that pine beetle infestation with dead trunk retention (no salvage logging) is the least effective means to increase snowmelt, due to the small area and the low elevations affected and the modest modification to canopy properties. A 15% change in basin area results from complete pine mortality due to beetle and only results in a 5% increase in snowmelt. With salvage logging the increase in snowmelt due to pine beetle doubles to 10%. By comparison, similar areal removal of forest canopy at higher elevations due to forest clearing or burns with salvage logging can almost double the effect on basin snowmelt. The most effective forest removal technique for snowmelt enhancement is forest removal due to clearing or fire with salvage logging. For canopy removed from

60% of the basin area, a 45% increase in snow accumulation can result and even a small area of the basin with canopy removal (5%) can result in a 10% increase in snowmelt. There is a slightly increased snowmelt quantity with retention of stumps (to trap blowing snow), but little effect on quantity due to slope and aspect. Burning with burned trunk retention has a relatively smaller effect on snowmelt increase, similar to that of pine beetle impacts.

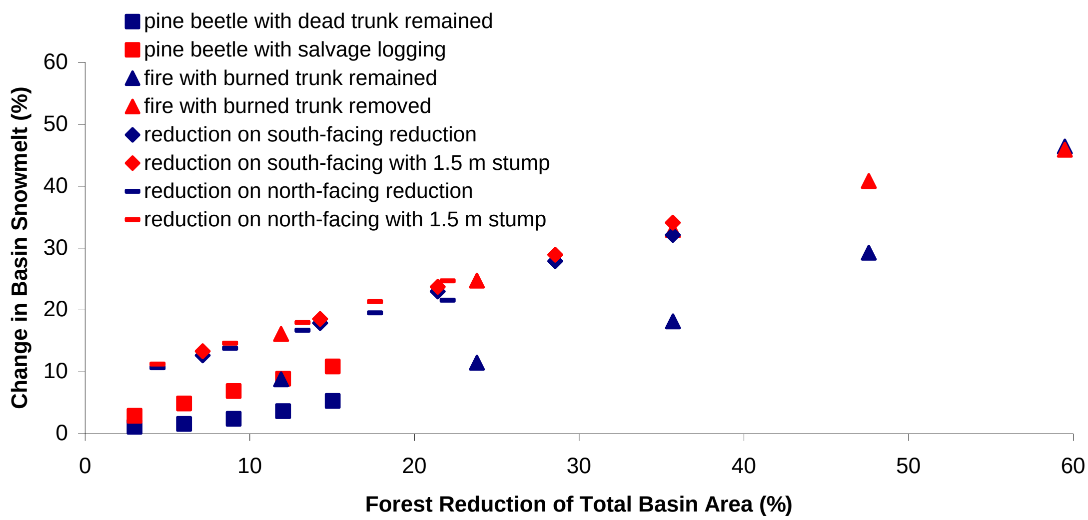


Figure 15. Change in basin snowmelt (%) as a function of forest cover reduction (expressed as % of basin area) for various forest treatments

6.2.3 Basin Streamflow and Groundwater Flow

Detailed changes to streamflow hydrographs and groundwater flow are shown in Appendices 3 and 4 for the 41 scenarios over 4 simulation years. The results are summarised in Figure 16, 17 and 18. Figure 16 shows the spring and summer seasonal (1 April to 30 September) streamflow as a % change compared to reduction in forest as a % of basin area under various forest treatments, averaged over the four years. Of immediate interest is the very small effect of pine beetle on streamflow; pine beetle killed forests with dead trunks standing can cover up to 15% of basin area but only increase streamflow by less than 2%. With salvage logging this increases slightly to just over 2%. By contrasts, forest disturbances from fire, salvage logging and clearing ranging from 5% to 35% of basin area increase streamflow by from 3% to 5%. Clearing only on south facing slopes seems slightly less effective than the other treatments. The most effective method to increase streamflow was fire with retention of burned trunks which for complete burning of the basin (60% of basin area with forest removed) resulted in an 8% increase in streamflow. Interestingly only a 5% increase in streamflow was modelled for burning with salvage logging, due to increased blowing snow sublimation and summer evaporation resulting from the reduced sheltering effect of standing deadwood on the forest floor. Similarly, clearings with retention of stumps had slightly higher streamflow than those without stumps. Very little streamflow difference due to clearing on north or south facing slopes was found despite the dramatic differences in snowmelt energetics between these slopes. Whilst the energetics affect timing, the volume of runoff is relatively similar between north and south aspects.

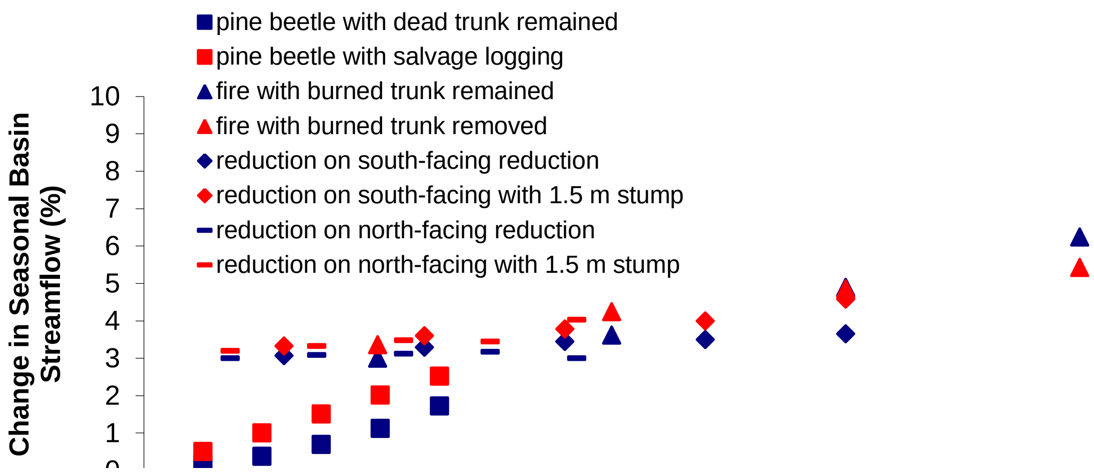


Figure 16. Change in 1 April to 30 Sept streamflow with change in forest cover, expressed as a percentage of basin area, for various forest treatments.

Peak streamflow occurred in May and June and showed little difference in timing with forest cover change; however, the peak discharge rates changed substantially. Figure 17 shows the percentage change in peak basin streamflow discharge (daily discharge) with the change in forest cover expressed as a percentage of basin area, averaged over the four years. Again, the pine beetle impacts are small, with a less than 4% increase in peak discharge from a 15% affected area and only a slight increase due to salvage logging of the pine beetle. This is due to the low elevations and level slopes of the lodgepole pine forests and hence their relatively small control on peak discharge from the basin. In contrast, even a 5% clearing of the basin forests resulted in a 7% to 8% increase in peak streamflow and further increases in forest disturbance to 60% of the basin resulted in up to a 23% increase in peak streamflow. Clearing on south facing slopes increased peak streamflow somewhat more than north facing or general clearing. Retention of burned trunks somewhat reduced the peak streamflow increase for moderate forest area disturbance but had the opposite effect with complete forest removal, possibly due to the synchronization of melt timing under a fairly uniform dead canopy when this exceeded 50% of the basin area.

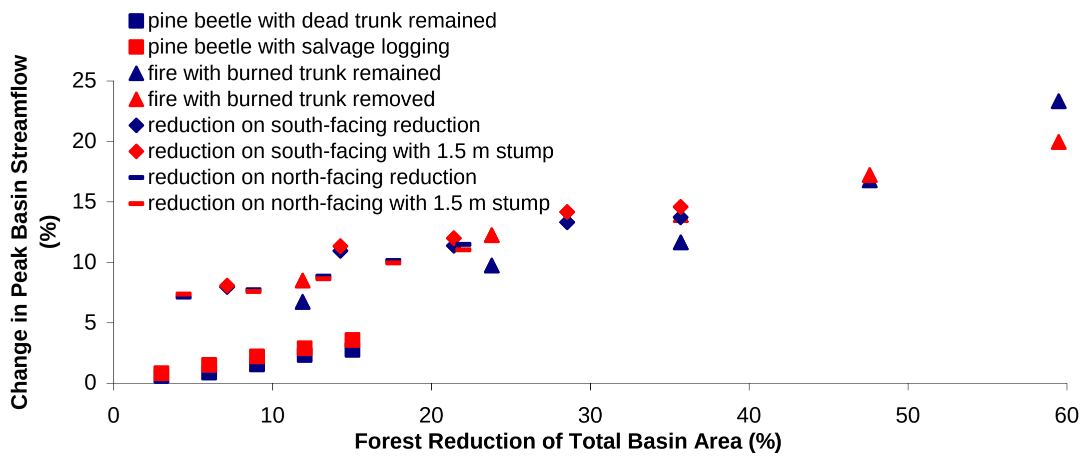


Figure 17. Change in peak daily basin streamflow discharge with change in forest cover, expressed as a percentage of basin area, for various forest treatments.

Marmot Creek streamflow does not increase dramatically with forest removal, despite the substantial increase in snow accumulation and snowmelt quantities with forest clearing. This result is consistent with that found by analysing changes in streamflow due to forest clearing experiments conducted by Golding and Swanson in the 1970s and 1980s which showed little change in streamflow timing or quantities despite various forest thinning amounts over the years (Philip Harder, unpublished B.Sc. thesis, University of Saskatchewan). It is suggested that the lack of streamflow response in this basin with forest clearing is due to the desynchronization of snowmelt caused by an increase in the heterogeneity of forest cover and snowmelt rates. Ellis (2011) has shown that forest clearing on north facing slopes at Marmot Creek will decrease melt rates while that on south facing slopes will increase melt rates. When all slopes are forest covered there are very similar melt rates, but when cleared the melt timing is spread over several more weeks and hence there is greater tendency for infiltration and percolation to groundwater and less tendency for meltwater to form runoff and streamflow.

To test this idea, annual deep groundwater recharge was examined. This is recharge to groundwater that will not contribute to streamflow at the Marmot Creek WSC stream gauge but will contribute to the regional water balance and presumably contribute to baseflow of the Kananaskis River. Groundwater recharge quantities were large, ranging from 1,020 to 1,500 dam^3 over each year, compared to annual streamflow of 3,500 to 5,600 dam^3 over each year. They primarily occur in summer and fall, when deep percolation to groundwater is possible via ice-free vertical macropores and bedrock fractures and so there is little near-surface water remaining to form sub-surface or surface runoff and hence streamflow response. As shown in Fig. 18, an increase in groundwater recharge was modelled for all forest cover reductions. For pine beetle this remained small, less than 2% with the higher values associated with larger areas affected and salvage logging. The dry lower part of the basin covered with pine is not only a poor area for generating streamflow but is ineffective in groundwater recharge as well. Up to

7% increase in groundwater recharge was simulated when forest removal was up to 50% of basin area, the most effective treatment varying with the percentage of forest removal. For smaller removals clearing on north facing slopes with stump retention was most effective, whereas for large removals, clearing due to fire with salvage logging was most effective. As forest removal exceeded 50% further increases in groundwater recharge did not occur. The cause of this remains unclear.

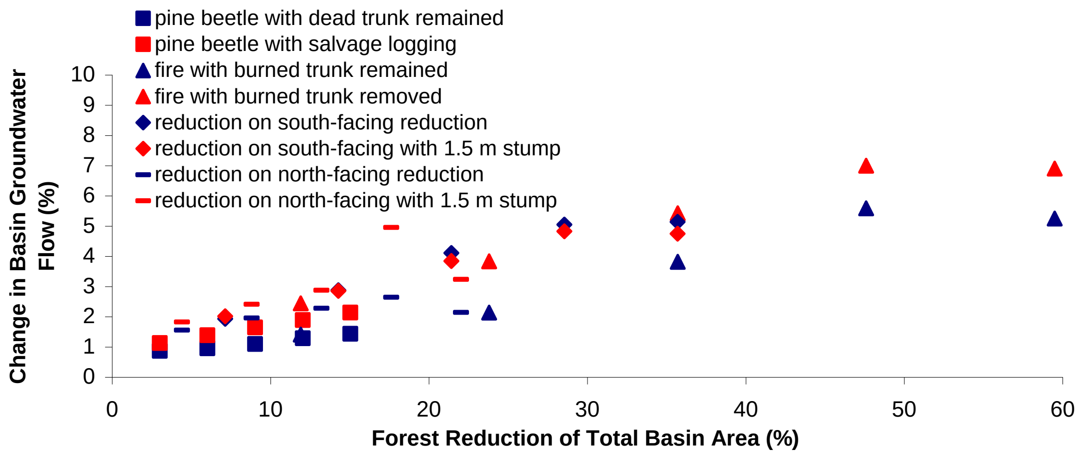


Figure 18. Change in basin groundwater flow with change in forest cover, expressed as a percentage of basin area, for various forest treatments.

7 Conclusions

Marmot Creek Research Basin was the subject of intense studies of snowmelt, water balance and streamflow generation in order to generate a five year database of precipitation inputs, snowpack dynamics and streamflow that could be used in hydrological model testing. A physically based hydrological model of the basin was constructed using the Cold Regions Hydrological Model and tested over four years of simulation. The model was found to accurately simulate snowpacks in forested and cleared landscapes and the timing and quantity of streamflow over the basin. The model was manipulated to simulate the impacts of forest disturbance on basin snow dynamics, snowmelt, streamflow and groundwater recharge. A total of 40 forest disturbance scenarios were compared to the current land use over the four simulation years. Disturbance scenarios ranged from the impact of pine beetle kill of lodgepole pine to clearing of north or south facing slopes, forest fire and salvage logging impacts.

Pine beetle impacts were small in all cases with increases in snowmelt of less than 10% and of streamflow and groundwater recharge of less than 2%. This is due to only 15% of the basin area being covered with lodgepole pine and this pine being at lower elevations which received much lower snowfall and rainfall than did higher elevations and so generated much less streamflow and groundwater recharge. Forest disturbance due to fire and clearing affected much large areas of the basin and higher elevations and were generally more than twice as effective in increasing snowmelt or streamflow. For complete forest cover removal with salvage logging a 45% increase in snowmelt was simulated, however this only translated into a 5% in spring and summer streamflow and a 7% increase in groundwater recharge. Forest fire with retention of standing burned trunks was the most effect forest cover treatment for increasing streamflow (up to 8%), as this treatment minimized sublimation of winter snow, infiltration rates and summer evaporation rates. Peak daily streamflow discharges responded more strongly to forest cover decrease than did seasonal streamflow with increases of over 20% in peak streamflow with removal of forest cover. This high sensitivity of peak flows to forest cover removal is due to the dramatic increase in melt rates upon canopy removal from level and south facing slopes. Overall however, it is suggested that the dysynchronization of snowmelt timing with forest cover removal resulted in an ineffective translation of changes in snowmelt quantity to streamflow. This resulted in a complementary increase in groundwater recharge as well as streamflow as forest cover was reduced. Presumably, a basin with differing soil characteristics, groundwater regime or topographic orientation would provide a differing hydrological response to forest cover change and the sensitivity of these changes to basin characterisation needs further examination.

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Appendices

Appendix 1 HRU Parameters for the Forest Disturbance Scenarios

Note: The following tables list the parameters that are changed in the each scenario, with italic number indicating the changed values to the current HRU and bold number for the new disturbance HRU. Note that Canopy Clearing has Boolean value: 0 for forest canopy cover and 1 for clearing; cov_type is for evaporation: 0 for no evaporation, 1 for evaporation from recharge layer only, and 2 for evaporation from entire soil column; groundcover is Ayers infiltration: 1 for bare soil and 6 for forested; inhibit_bs has Boolean value: 0 for allowing blowing snow and 1 for inhibit blowing snow; distrib is distribution parameter for blowing between HRUs.

Table A1. HRU parameters in the forest disturbance scenario 1: current forest cover.

HRU	Area (km^2)	Mean Elevation (m)	Mean Aspect (°)	Mean Slope (°)	LAI	Canopy Snow Interception Load Capacity (kg/m2)	Canopy Clearing	Vegetation Height (m)	cov_type	groundcover	inhibit_bs	distrib	Routing Length (m)
Cabin Creek Sub-basin													
South-facing Alpine Rock	0.23	2387	122	36	0.1	0	1	0.14	2	1	0	1	575
North-facing Alpine Rock	0.17	2379	69	37	0.1	0	1	0.14	2	1	0	5	484
North-facing Alpine Larch/Spruce	0.02	2222	60	35	1.1	6.6	0	3	2	6	0	5	136
South-facing Alpine Larch/Spruce	0.02	2194	115	32	1.1	6.6	0	3	2	6	0	5	130
North-facing Spruce/Fir/Lodgepole Pine	0.35	2046	62	24	2.2	8.8	0	10	2	6	1	0	742
South-facing Spruce/Fir/Lodgepole Pine	0.93	1972	151	18	2.2	8.8	0	10	2	6	1	0	1338
Level Spruce/Fir/Lodgepole Pine	0.05	1931	0	4	2.2	8.8	0	10	2	6	1	0	225
Forest Clearings	0.40	1927	140	11	1.1	3.3	1	3	2	6	0	0	805
Level Lodgepole Pine	0.05	1882	0	3	2.2	6.6	0	10	2	6	1	0	243
South-facing Lodgepole Pine	0.07	1798	204	18	2.2	6.6	0	10	2	6	1	0	290
North-facing Lodgepole Pine	0.01	1780	76	25	2.2	6.6	0	10	2	6	1	0	84
Valley Bottom	0.04	1951	135	18	2.2	6.6	0	10	2	6	1	0	2337
Middle Creek Sub-basin													
North-facing Alpine Rock	0.52	2462	82	31	0.1	0	1	0.14	2	1	0	1	944
South-facing Alpine Rock	1.37	2422	148	30	0.1	0	1	0.14	2	1	0	5	1689
South-facing Alpine Larch/Spruce	0.26	2246	138	20	1.1	6.6	0	3	2	6	0	5	618
North-facing Alpine Larch/Spruce	0.08	2211	46	18	1.1	6.6	0	3	2	6	0	5	302
North-facing Spruce/Fir/Lodgepole Pine	0.16	1995	76	21	2.2	8.8	0	10	2	6	1	0	461
South-facing Spruce/Fir/Lodgepole Pine	0.52	1953	134	22	2.2	8.8	0	10	2	6	1	0	947
Valley Bottom	0.03	2057	115	16	2.2	6.6	0	10	2	6	1	0	2907
Twin Creek Sub-basin													
North-facing Alpine Rock	0.79	2386	67	28	0.1	0	1	0.14	2	1	0	1	1217
South-facing Alpine Rock	0.15	2380	106	22	0.1	0	1	0.14	2	1	0	5	457
South-facing Alpine Larch/Spruce	0.28	2228	116	23	1.1	6.6	0	3	2	6	0	5	649
North-facing Alpine Larch/Spruce	0.28	2182	37	22	1.1	6.6	0	3	2	6	0	5	654
North-facing Spruce/Fir/Lodgepole Pine	0.64	1966	34	17	2.2	8.8	0	10	2	6	1	0	1071
South-facing Spruce/Fir/Lodgepole Pine	0.60	2014	113	21	2.2	8.8	0	10	2	6	1	0	1028
Valley Bottom	0.04	1988	119	16	2.2	6.6	0	10	2	6	1	0	2443
Marmot Confluence Sub-basin													
Forest Clearings	0.01	1903	55	11	1.1	3.3	1	3	2	6	0	1	90
North-facing Lodgepole Pine/Aspen	0.38	1786	54	13	2.2	8.8	0	10	2	6	1	0	785
South-facing Lodgepole Pine/Aspen	0.24	1725	159	13	2.2	8.8	0	10	2	6	1	0	592
Level Lodgepole Pine/Aspen	0.04	1688	0	4	2.2	8.8	0	10	2	6	1	0	210
South-facing Lodgepole Pine	0.44	1752	172	17	2.2	6.6	0	10	2	6	1	0	853
Level Lodgepole Pine	0.02	1724	0	4	2.2	6.6	0	10	2	6	1	0	150
North-facing Lodgepole Pine	0.15	1687	71	14	2.2	6.6	0	10	2	6	1	0	449
Valley Bottom	0.02	1664	163	8	2.2	6.6	0	10	2	6	1	0	1998

Table A2. HRU parameters in the forest disturbance scenario 2: pine beetle reduction by 20% with infested trunk remained.

HRU	Area (km^2)	Mean Elevation (m)	Mean Aspect (°)	Mean Slope (°)	LAI	Canopy Snow Interception Load Capacity (kg/m2)	Canopy Clearing	Vegetation Height (m)	cov_type	groundcover	inhibit_bs	distrib	Routing Length (m)
						Cabin Creek Sub-basin							
South-facing Alpine Rock	0.23	2387	122	36	0.1	0	1	0.14	2	1	0	1	575
North-facing Alpine Rock	0.17	2379	69	37	0.1	0	1	0.14	2	1	0	5	485
North-facing Alpine Larch/Spruce	0.02	2222	60	35	1.1	6.6	0	3	2	6	0	5	137
South-facing Alpine Larch/Spruce	0.02	2194	115	32	1.1	6.6	0	3	2	6	0	5	130
North-facing Spruce/Fir/Lodgepole Pine	0.35	2046	62	24	2.2	8.8	0	10	2	6	1	0	742
South-facing Spruce/Fir/Lodgepole Pine	0.93	1972	151	18	2.2	8.8	0	10	2	6	1	0	1339
Level Spruce/Fir/Lodgepole Pine	0.05	1931	0	4	2.2	8.8	0	10	2	6	1	0	225
Forest Clearings	0.40	1927	140	11	1.1	3.3	1	3	2	6	0	0	806
Level Lodgepole Pine	*0.0434*	1882	0	3	2.2	6.6	0	10	2	6	1	0	*213*
South-facing Lodgepole Pine	*0.0581*	1798	204	18	2.2	6.6	0	10	2	6	1	0	*254*
North-facing Lodgepole Pine	*0.0074*	1780	76	25	2.2	6.6	0	10	2	6	1	0	*74*
Valley Bottom	0.04	1951	135	18	2.2	6.6	0	10	2	6	1	0	2337
MPB Disturbance	**0.0272**	**1830**	**114**	**13**	**1.96**	**5.88**	**0**	**10**	**0**	**6**	**0**	**1**	**161**
						Middle Creek Sub-basin							
North-facing Alpine Rock	0.52	2462	82	31	0.1	0	1	0.14	2	1	0	1	944
South-facing Alpine Rock	1.37	2422	148	30	0.1	0	1	0.14	2	1	0	5	1689
South-facing Alpine Larch/Spruce	0.26	2246	138	20	1.1	6.6	0	3	2	6	0	5	618
North-facing Alpine Larch/Spruce	0.08	2211	46	18	1.1	6.6	0	3	2	6	0	5	302
North-facing Spruce/Fir/Lodgepole Pine	0.16	1995	76	21	2.2	8.8	0	10	2	6	1	0	461
South-facing Spruce/Fir/Lodgepole Pine	0.52	1953	134	22	2.2	8.8	0	10	2	6	1	0	947
Valley Bottom	0.03	2057	115	16	2.2	6.6	0	10	2	6	1	0	2907
						Twin Creek Sub-basin							
North-facing Alpine Rock	0.79	2386	67	28	0.1	0	1	0.14	2	1	0	1	1217
South-facing Alpine Rock	0.15	2380	106	22	0.1	0	1	0.14	2	1	0	5	457
South-facing Alpine Larch/Spruce	0.28	2228	116	23	1.1	6.6	0	3	2	6	0	5	649
North-facing Alpine Larch/Spruce	0.28	2182	37	22	1.1	6.6	0	3	2	6	0	5	654
North-facing Spruce/Fir/Lodgepole Pine	0.64	1966	34	17	2.2	8.8	0	10	2	6	1	0	1071
South-facing Spruce/Fir/Lodgepole Pine	0.60	2014	113	21	2.2	8.8	0	10	2	6	1	0	1028
Valley Bottom	0.04	1988	119	16	2.2	6.6	0	10	2	6	1	0	2443
						Marmot Confluence Sub-basin							
Forest Clearings	0.01	1903	55	11	1.1	3.3	1	3	2	6	0	1	90
North-facing Lodgepole Pine/Aspen	*0.3055*	1786	54	13	2.2	8.8	0	10	2	6	1	0	*687*
South-facing Lodgepole Pine/Aspen	*0.1911*	1725	159	13	2.2	8.8	0	10	2	6	1	0	*519*
Level Lodgepole Pine/Aspen	*0.0339*	1688	0	4	2.2	8.8	0	10	2	6	1	0	*184*
South-facing Lodgepole Pine	*0.3504*	1752	172	17	2.2	6.6	0	10	2	6	1	0	*746*
Level Lodgepole Pine	*0.0194*	1724	0	4	2.2	6.6	0	10	2	6	1	0	*131*
North-facing Lodgepole Pine	*0.1205*	1687	71	14	2.2	6.6	0	10	2	6	1	0	*393*
Valley Bottom	0.02	1664	163	8	2.2	6.6	0	10	2	6	1	0	1998
MPB Disturbance	**0.2552**	**1747**	**113**	**14**	**1.96**	**5.88**	**0**	**10**	**0**	**6**	**0**	**1**	**617**

Table A3. HRU parameters in the forest disturbance scenario 3: pine beetle reduction by 40% with infested trunk remained.

HRU	Area (km^2)	Mean Elevation (m)	Mean Aspect (˚)	Mean Slope (˚)	LAI	Canopy Snow Interception Load Capacity (kg/m2)	Canopy Clearing	Vegetation Height (m)	cov_type	groundcover	inhibit_bs	distrib	Routing Length (m)
Cabin Creek Sub-basin													
South-facing Alpine Rock	0.23	2387	122	36	0.1	0	1	0.14	2	1	0	1	575
North-facing Alpine Rock	0.17	2379	69	37	0.1	0	1	0.14	2	1	0	5	485
North-facing Alpine Larch/Spruce	0.02	2222	60	35	1.1	6.6	0	3	2	6	0	5	137
South-facing Alpine Larch/Spruce	0.02	2194	115	32	1.1	6.6	0	3	2	6	0	5	130
North-facing Spruce/Fir/Lodgepole Pine	0.35	2046	62	24	2.2	8.8	0	10	2	6	1	0	742
South-facing Spruce/Fir/Lodgepole Pine	0.93	1972	151	18	2.2	8.8	0	10	2	6	1	0	1339
Level Spruce/Fir/Lodgepole Pine	0.05	1931	0	4	2.2	8.8	0	10	2	6	1	0	225
Forest Clearings	0.40	1927	140	11	1.1	3.3	1	3	2	6	0	0	806
Level Lodgepole Pine	*0.0325*	1882	0	3	2.2	6.6	0	10	2	6	1	0	*179*
South-facing Lodgepole Pine	*0.0436*	1798	204	18	2.2	6.6	0	10	2	6	1	0	*214*
North-facing Lodgepole Pine	*0.0055*	1780	76	25	2.2	6.6	0	10	2	6	1	0	*62*
Valley Bottom	0.04	1951	135	18	2.2	6.6	0	10	2	6	1	0	2337
MPB Disturbance	**0.0544**	**1830**	**114**	**13**	**1.72**	**5.16**	**0**	**10**	**0**	**6**	**0**	**1**	**244**
Middle Creek Sub-basin													
North-facing Alpine Rock	0.52	2462	82	31	0.1	0	1	0.14	2	1	0	1	944
South-facing Alpine Rock	1.37	2422	148	30	0.1	0	1	0.14	2	1	0	5	1689
South-facing Alpine Larch/Spruce	0.26	2246	138	20	1.1	6.6	0	3	2	6	0	5	618
North-facing Alpine Larch/Spruce	0.08	2211	46	18	1.1	6.6	0	3	2	6	0	5	302
North-facing Spruce/Fir/Lodgepole Pine	0.16	1995	76	21	2.2	8.8	0	10	2	6	1	0	461
South-facing Spruce/Fir/Lodgepole Pine	0.52	1953	134	22	2.2	8.8	0	10	2	6	1	0	947
Valley Bottom	0.03	2057	115	16	2.2	6.6	0	10	2	6	1	0	2907
Twin Creek Sub-basin													
North-facing Alpine Rock	0.79	2386	67	28	0.1	0	1	0.14	2	1	0	1	1217
South-facing Alpine Rock	0.15	2380	106	22	0.1	0	1	0.14	2	1	0	5	457
South-facing Alpine Larch/Spruce	0.28	2228	116	23	1.1	6.6	0	3	2	6	0	5	649
North-facing Alpine Larch/Spruce	0.28	2182	37	22	1.1	6.6	0	3	2	6	0	5	654
North-facing Spruce/Fir/Lodgepole Pine	0.64	1966	34	17	2.2	8.8	0	10	2	6	1	0	1071
South-facing Spruce/Fir/Lodgepole Pine	0.60	2014	113	21	2.2	8.8	0	10	2	6	1	0	1028
Valley Bottom	0.04	1988	119	16	2.2	6.6	0	10	2	6	1	0	2443
Marmot Confluence Sub-basin													
Forest Clearings	0.01	1903	55	11	1.1	3.3	1	3	2	6	0	1	90
North-facing Lodgepole Pine/Aspen	*0.2291*	1786	54	13	2.2	8.8	0	10	2	6	1	0	*578*
South-facing Lodgepole Pine/Aspen	*0.1433*	1725	159	13	2.2	8.8	0	10	2	6	1	0	*436*
Level Lodgepole Pine/Aspen	*0.0254*	1688	0	4	2.2	8.8	0	10	2	6	1	0	*155*
South-facing Lodgepole Pine	*0.2628*	1752	172	17	2.2	6.6	0	10	2	6	1	0	*628*
Level Lodgepole Pine	*0.0145*	1724	0	4	2.2	6.6	0	10	2	6	1	0	*110*
North-facing Lodgepole Pine	*0.0904*	1687	71	14	2.2	6.6	0	10	2	6	1	0	*331*
Valley Bottom	0.02	1664	163	8	2.2	6.6	0	10	2	6	1	0	1998
MPB Disturbance	**0.5104**	**1747**	**113**	**14**	**1.72**	**5.16**	**0**	**10**	**0**	**6**	**0**	**1**	**935**

Table A4. HRU parameters in the forest disturbance scenario 4: pine beetle reduction by 60% with infested trunk remained.

HRU	Area (km^2)	Mean Elevation (m)	Mean Aspect (˚)	Mean Slope (˚)	LAI	Canopy Snow Interception Load Capacity (kg/m2)	Canopy Clearing	Vegetation Height (m)	cov_type	groundcover	inhibit_bs	distrib	Routing Length (m)
Cabin Creek Sub-basin													
South-facing Alpine Rock	0.23	2387	122	36	0.1	0	1	0.14	2	1	0	1	575
North-facing Alpine Rock	0.17	2379	69	37	0.1	0	1	0.14	2	1	0	5	485
North-facing Alpine Larch/Spruce	0.02	2222	60	35	1.1	6.6	0	3	2	6	0	5	137
South-facing Alpine Larch/Spruce	0.02	2194	115	32	1.1	6.6	0	3	2	6	0	5	130
North-facing Spruce/Fir/Lodgepole Pine	0.35	2046	62	24	2.2	8.8	0	10	2	6	1	0	742
South-facing Spruce/Fir/Lodgepole Pine	0.93	1972	151	18	2.2	8.8	0	10	2	6	1	0	1339
Level Spruce/Fir/Lodgepole Pine	0.05	1931	0	4	2.2	8.8	0	10	2	6	1	0	225
Forest Clearings	0.40	1927	140	11	1.1	3.3	1	3	2	6	0	0	806
Level Lodgepole Pine	*0.0217*	1882	0	3	2.2	6.6	0	10	2	6	1	0	*141*
South-facing Lodgepole Pine	*0.0291*	1798	204	18	2.2	6.6	0	10	2	6	1	0	*168*
North-facing Lodgepole Pine	*0.0037*	1780	76	25	2.2	6.6	0	10	2	6	1	0	*49*
Valley Bottom	0.04	1951	135	18	2.2	6.6	0	10	2	6	1	0	2337
MPB Disturbance	**0.0817**	**1830**	**114**	**13**	**1.48**	**4.44**	**0**	**10**	**0**	**6**	**0**	**1**	**311**
Middle Creek Sub-basin													
North-facing Alpine Rock	0.52	2462	82	31	0.1	0	1	0.14	2	1	0	1	944
South-facing Alpine Rock	1.37	2422	148	30	0.1	0	1	0.14	2	1	0	5	1689
South-facing Alpine Larch/Spruce	0.26	2246	138	20	1.1	6.6	0	3	2	6	0	5	618
North-facing Alpine Larch/Spruce	0.08	2211	46	18	1.1	6.6	0	3	2	6	0	5	302
North-facing Spruce/Fir/Lodgepole Pine	0.16	1995	76	21	2.2	8.8	0	10	2	6	1	0	461
South-facing Spruce/Fir/Lodgepole Pine	0.52	1953	134	22	2.2	8.8	0	10	2	6	1	0	947
Valley Bottom	0.03	2057	115	16	2.2	6.6	0	10	2	6	1	0	2907
Twin Creek Sub-basin													
North-facing Alpine Rock	0.79	2386	67	28	0.1	0	1	0.14	2	1	0	1	1217
South-facing Alpine Rock	0.15	2380	106	22	0.1	0	1	0.14	2	1	0	5	457
South-facing Alpine Larch/Spruce	0.28	2228	116	23	1.1	6.6	0	3	2	6	0	5	649
North-facing Alpine Larch/Spruce	0.28	2182	37	22	1.1	6.6	0	3	2	6	0	5	654
North-facing Spruce/Fir/Lodgepole Pine	0.64	1966	34	17	2.2	8.8	0	10	2	6	1	0	1071
South-facing Spruce/Fir/Lodgepole Pine	0.60	2014	113	21	2.2	8.8	0	10	2	6	1	0	1028
Valley Bottom	0.04	1988	119	16	2.2	6.6	0	10	2	6	1	0	2443
Marmot Confluence Sub-basin													
Forest Clearings	0.01	1903	55	11	1.1	3.3	1	3	2	6	0	1	90
North-facing Lodgepole Pine/Aspen	*0.1528*	1786	54	13	2.2	8.8	0	10	2	6	1	0	*453*
South-facing Lodgepole Pine/Aspen	*0.0955*	1725	159	13	2.2	8.8	0	10	2	6	1	0	*342*
Level Lodgepole Pine/Aspen	*0.0169*	1688	0	4	2.2	8.8	0	10	2	6	1	0	*121*
South-facing Lodgepole Pine	*0.1752*	1752	172	17	2.2	6.6	0	10	2	6	1	0	*492*
Level Lodgepole Pine	*0.0097*	1724	0	4	2.2	6.6	0	10	2	6	1	0	*87*
North-facing Lodgepole Pine	*0.0603*	1687	71	14	2.2	6.6	0	10	2	6	1	0	*260*
Valley Bottom	0.02	1664	163	8	2.2	6.6	0	10	2	6	1	0	1998
MPB Disturbance	**0.7656**	**1747**	**113**	**14**	**1.48**	**4.44**	**0**	**10**	**0**	**6**	**0**	**1**	**1193**

Table A5. HRU parameters in the forest disturbance scenario 5: pine beetle reduction by 80% with infested trunk remained.

HRU	Area (km^2)	Mean Elevation (m)	Mean Aspect (˚)	Mean Slope (˚)	LAI	Canopy Snow Interception Load Capacity (kg/m2)	Canopy Clearing	Vegetation Height (m)	cov_type	groundcover	inhibit_bs	distrib	Routing Length (m)
Cabin Creek Sub-basin													
South-facing Alpine Rock	0.23	2387	122	36	0.1	0	1	0.14	2	1	0	1	575
North-facing Alpine Rock	0.17	2379	69	37	0.1	0	1	0.14	2	1	0	5	485
North-facing Alpine Larch/Spruce	0.02	2222	60	35	1.1	6.6	0	3	2	6	0	5	137
South-facing Alpine Larch/Spruce	0.02	2194	115	32	1.1	6.6	0	3	2	6	0	5	130
North-facing Spruce/Fir/Lodgepole Pine	0.35	2046	62	24	2.2	8.8	0	10	2	6	1	0	742
South-facing Spruce/Fir/Lodgepole Pine	0.93	1972	151	18	2.2	8.8	0	10	2	6	1	0	1339
Level Spruce/Fir/Lodgepole Pine	0.05	1931	0	4	2.2	8.8	0	10	2	6	1	0	225
Forest Clearings	0.40	1927	140	11	1.1	3.3	1	3	2	6	0	0	806
Level Lodgepole Pine	*0.0108*	1882	0	3	2.2	6.6	0	10	2	6	1	0	*93*
South-facing Lodgepole Pine	*0.0145*	1798	204	18	2.2	6.6	0	10	2	6	1	0	*111*
North-facing Lodgepole Pine	*0.0018*	1780	76	25	2.2	6.6	0	10	2	6	1	0	*32*
Valley Bottom	0.04	1951	135	18	2.2	6.6	0	10	2	6	1	0	2337
MPB Disturbance	**0.1089**	**1830**	**114**	**13**	**1.24**	**3.72**	**0**	**10**	**0**	**6**	**0**	**1**	**370**
Middle Creek Sub-basin													
North-facing Alpine Rock	0.52	2462	82	31	0.1	0	1	0.14	2	1	0	1	944
South-facing Alpine Rock	1.37	2422	148	30	0.1	0	1	0.14	2	1	0	5	1689
South-facing Alpine Larch/Spruce	0.26	2246	138	20	1.1	6.6	0	3	2	6	0	5	618
North-facing Alpine Larch/Spruce	0.08	2211	46	18	1.1	6.6	0	3	2	6	0	5	302
North-facing Spruce/Fir/Lodgepole Pine	0.16	1995	76	21	2.2	8.8	0	10	2	6	1	0	461
South-facing Spruce/Fir/Lodgepole Pine	0.52	1953	134	22	2.2	8.8	0	10	2	6	1	0	947
Valley Bottom	0.03	2057	115	16	2.2	6.6	0	10	2	6	1	0	2907
Twin Creek Sub-basin													
North-facing Alpine Rock	0.79	2386	67	28	0.1	0	1	0.14	2	1	0	1	1217
South-facing Alpine Rock	0.15	2380	106	22	0.1	0	1	0.14	2	1	0	5	457
South-facing Alpine Larch/Spruce	0.28	2228	116	23	1.1	6.6	0	3	2	6	0	5	649
North-facing Alpine Larch/Spruce	0.28	2182	37	22	1.1	6.6	0	3	2	6	0	5	654
North-facing Spruce/Fir/Lodgepole Pine	0.64	1966	34	17	2.2	8.8	0	10	2	6	1	0	1071
South-facing Spruce/Fir/Lodgepole Pine	0.60	2014	113	21	2.2	8.8	0	10	2	6	1	0	1028
Valley Bottom	0.04	1988	119	16	2.2	6.6	0	10	2	6	1	0	2443
Marmot Confluence Sub-basin													
Forest Clearings	0.01	1903	55	11	1.1	3.3	1	3	2	6	0	1	90
North-facing Lodgepole Pine/Aspen	*0.0764*	1786	54	13	2.2	8.8	0	10	2	6	1	0	*299*
South-facing Lodgepole Pine/Aspen	*0.0478*	1725	159	13	2.2	8.8	0	10	2	6	1	0	*226*
Level Lodgepole Pine/Aspen	*0.0085*	1688	0	4	2.2	8.8	0	10	2	6	1	0	*80*
South-facing Lodgepole Pine	*0.0876*	1752	172	17	2.2	6.6	0	10	2	6	1	0	*325*
Level Lodgepole Pine	*0.0048*	1724	0	4	2.2	6.6	0	10	2	6	1	0	*57*
North-facing Lodgepole Pine	*0.0301*	1687	71	14	2.2	6.6	0	10	2	6	1	0	*171*
Valley Bottom	0.02	1664	163	8	2.2	6.6	0	10	2	6	1	0	1998
MPB Disturbance	**1.0208**	**1747**	**113**	**14**	**1.24**	**3.72**	**0**	**10**	**0**	**6**	**0**	**1**	**1417**

Table A6. HRU parameters in the forest disturbance scenario 6: pine beetle reduction by 100% with infested trunk remained.

HRU	Area (km^2)	Mean Elevation (m)	Mean Aspect (˚)	Mean Slope (˚)	LAI	Canopy Snow Interception Load Capacity (kg/m2)	Canopy Clearing	Vegetation Height (m)	cov_type	groundcover	inhibit_bs	distrib	Routing Length (m)
						Cabin Creek Sub-basin							
South-facing Alpine Rock	0.23	2387	122	36	0.1	0	1	0.14	2	1	0	1	575
North-facing Alpine Rock	0.17	2379	69	37	0.1	0	1	0.14	2	1	0	5	485
North-facing Alpine Larch/Spruce	0.02	2222	60	35	1.1	6.6	0	3	2	6	0	5	137
South-facing Alpine Larch/Spruce	0.02	2194	115	32	1.1	6.6	0	3	2	6	0	5	130
North-facing Spruce/Fir/Lodgepole Pine	0.35	2046	62	24	2.2	8.8	0	10	2	6	1	0	742
South-facing Spruce/Fir/Lodgepole Pine	0.93	1972	151	18	2.2	8.8	0	10	2	6	1	0	1339
Level Spruce/Fir/Lodgepole Pine	0.05	1931	0	4	2.2	8.8	0	10	2	6	1	0	225
Forest Clearings	0.40	1927	140	11	1.1	3.3	1	3	2	6	0	0	806
Level Lodgepole Pine	*1E-06*	1882	0	3	2.2	6.6	0	10	2	6	1	0	*0.35*
South-facing Lodgepole Pine	*1E-06*	1798	204	18	2.2	6.6	0	10	2	6	1	0	*0.35*
North-facing Lodgepole Pine	*1E-06*	1780	76	25	2.2	6.6	0	10	2	6	1	0	*0.35*
Valley Bottom	0.04	1951	135	18	2.2	6.6	0	10	2	6	1	0	2337
MPB Disturbance	**0.1361**	**1830**	**114**	**13**	**1**	**3**	**0**	**10**	**0**	**6**	**0**	**1**	**423**
						Middle Creek Sub-basin							
North-facing Alpine Rock	0.52	2462	82	31	0.1	0	1	0.14	2	1	0	1	944
South-facing Alpine Rock	1.37	2422	148	30	0.1	0	1	0.14	2	1	0	5	1689
South-facing Alpine Larch/Spruce	0.26	2246	138	20	1.1	6.6	0	3	2	6	0	5	618
North-facing Alpine Larch/Spruce	0.08	2211	46	18	1.1	6.6	0	3	2	6	0	5	302
North-facing Spruce/Fir/Lodgepole Pine	0.16	1995	76	21	2.2	8.8	0	10	2	6	1	0	461
South-facing Spruce/Fir/Lodgepole Pine	0.52	1953	134	22	2.2	8.8	0	10	2	6	1	0	947
Valley Bottom	0.03	2057	115	16	2.2	6.6	0	10	2	6	1	0	2907
						Twin Creek Sub-basin							
North-facing Alpine Rock	0.79	2386	67	28	0.1	0	1	0.14	2	1	0	1	1217
South-facing Alpine Rock	0.15	2380	106	22	0.1	0	1	0.14	2	1	0	5	457
South-facing Alpine Larch/Spruce	0.28	2228	116	23	1.1	6.6	0	3	2	6	0	5	649
North-facing Alpine Larch/Spruce	0.28	2182	37	22	1.1	6.6	0	3	2	6	0	5	654
North-facing Spruce/Fir/Lodgepole Pine	0.64	1966	34	17	2.2	8.8	0	10	2	6	1	0	1071
South-facing Spruce/Fir/Lodgepole Pine	0.60	2014	113	21	2.2	8.8	0	10	2	6	1	0	1028
Valley Bottom	0.04	1988	119	16	2.2	6.6	0	10	2	6	1	0	2443
						Marmot Confluence Sub-basin							
Forest Clearings	0.01	1903	55	11	1.1	3.3	1	3	2	6	0	1	90
North-facing Lodgepole Pine/Aspen	*1E-06*	1786	54	13	2.2	8.8	0	10	2	6	1	0	*0.35*
South-facing Lodgepole Pine/Aspen	*1E-06*	1725	159	13	2.2	8.8	0	10	2	6	1	0	*0.35*
Level Lodgepole Pine/Aspen	*1E-06*	1688	0	4	2.2	8.8	0	10	2	6	1	0	*0.35*
South-facing Lodgepole Pine	*1E-06*	1752	172	17	2.2	6.6	0	10	2	6	1	0	*0.35*
Level Lodgepole Pine	*1E-06*	1724	0	4	2.2	6.6	0	10	2	6	1	0	*0.35*
North-facing Lodgepole Pine	*1E-06*	1687	71	14	2.2	6.6	0	10	2	6	1	0	*0.35*
Valley Bottom	0.02	1664	163	8	2.2	6.6	0	10	2	6	1	0	1998
MPB Disturbance	**1.2760**	**1747**	**113**	**14**	**1**	**3**	**0**	**10**	**0**	**6**	**0**	**1**	**1620**

Table A7. HRU parameters in the forest disturbance scenario 7: pine beetle reduction by 20% plus salvage logging.

HRU	Area (km^2)	Mean Elevation (m)	Mean Aspect (˚)	Mean Slope (˚)	LAI	Canopy Snow Interception Load Capacity (kg/m2)	Canopy Clearing	Vegetation Height (m)	cov_type	groundcover	inhibit_bs	distrib	Routing Length (m)
Cabin Creek Sub-basin													
South-facing Alpine Rock	0.23	2387	122	36	0.1	0	1	0.14	2	1	0	1	575
North-facing Alpine Rock	0.17	2379	69	37	0.1	0	1	0.14	2	1	0	5	485
North-facing Alpine Larch/Spruce	0.02	2222	60	35	1.1	6.6	0	3	2	6	0	5	137
South-facing Alpine Larch/Spruce	0.02	2194	115	32	1.1	6.6	0	3	2	6	0	5	130
North-facing Spruce/Fir/Lodgepole Pine	0.35	2046	62	24	2.2	8.8	0	10	2	6	1	0	742
South-facing Spruce/Fir/Lodgepole Pine	0.93	1972	151	18	2.2	8.8	0	10	2	6	1	0	1339
Level Spruce/Fir/Lodgepole Pine	0.05	1931	0	4	2.2	8.8	0	10	2	6	1	0	225
Forest Clearings	0.40	1927	140	11	1.1	3.3	1	3	2	6	0	0	806
Level Lodgepole Pine	*0.0434*	1882	0	3	2.2	6.6	0	10	2	6	1	0	*213*
South-facing Lodgepole Pine	*0.0581*	1798	204	18	2.2	6.6	0	10	2	6	1	0	*254*
North-facing Lodgepole Pine	*0.0074*	1780	76	25	2.2	6.6	0	10	2	6	1	0	*74*
Valley Bottom	0.04	1951	135	18	2.2	6.6	0	10	2	6	1	0	2337
MPB Disturbance	**0.0272**	**1830**	**114**	**13**	**0.1**	**0**	**1**	**0.1**	**0**	**1**	**0**	**1**	**161**
Middle Creek Sub-basin													
North-facing Alpine Rock	0.52	2462	82	31	0.1	0	1	0.14	2	1	0	1	944
South-facing Alpine Rock	1.37	2422	148	30	0.1	0	1	0.14	2	1	0	5	1689
South-facing Alpine Larch/Spruce	0.26	2246	138	20	1.1	6.6	0	3	2	6	0	5	618
North-facing Alpine Larch/Spruce	0.08	2211	46	18	1.1	6.6	0	3	2	6	0	5	302
North-facing Spruce/Fir/Lodgepole Pine	0.16	1995	76	21	2.2	8.8	0	10	2	6	1	0	461
South-facing Spruce/Fir/Lodgepole Pine	0.52	1953	134	22	2.2	8.8	0	10	2	6	1	0	947
Valley Bottom	0.03	2057	115	16	2.2	6.6	0	10	2	6	1	0	2907
Twin Creek Sub-basin													
North-facing Alpine Rock	0.79	2386	67	28	0.1	0	1	0.14	2	1	0	1	1217
South-facing Alpine Rock	0.15	2380	106	22	0.1	0	1	0.14	2	1	0	5	457
South-facing Alpine Larch/Spruce	0.28	2228	116	23	1.1	6.6	0	3	2	6	0	5	649
North-facing Alpine Larch/Spruce	0.28	2182	37	22	1.1	6.6	0	3	2	6	0	5	654
North-facing Spruce/Fir/Lodgepole Pine	0.64	1966	34	17	2.2	8.8	0	10	2	6	1	0	1071
South-facing Spruce/Fir/Lodgepole Pine	0.60	2014	113	21	2.2	8.8	0	10	2	6	1	0	1028
Valley Bottom	0.04	1988	119	16	2.2	6.6	0	10	2	6	1	0	2443
Marmot Confluence Sub-basin													
Forest Clearings	0.01	1903	55	11	1.1	3.3	1	3	2	6	0	1	90
North-facing Lodgepole Pine/Aspen	*0.3055*	1786	54	13	2.2	8.8	0	10	2	6	1	0	*687*
South-facing Lodgepole Pine/Aspen	*0.1911*	1725	159	13	2.2	8.8	0	10	2	6	1	0	*519*
Level Lodgepole Pine/Aspen	*0.0339*	1688	0	4	2.2	8.8	0	10	2	6	1	0	*184*
South-facing Lodgepole Pine	*0.3504*	1752	172	17	2.2	6.6	0	10	2	6	1	0	*746*
Level Lodgepole Pine	*0.0194*	1724	0	4	2.2	6.6	0	10	2	6	1	0	*131*
North-facing Lodgepole Pine	*0.1205*	1687	71	14	2.2	6.6	0	10	2	6	1	0	*393*
Valley Bottom	0.02	1664	163	8	2.2	6.6	0	10	2	6	1	0	1998
MPB Disturbance	**0.2552**	**1747**	**113**	**14**	**0.1**	**0**	**1**	**0.1**	**0**	**1**	**0**	**1**	**617**

Table A8. HRU parameters in the forest disturbance scenario 8: pine beetle reduction by 40% plus salvage logging.

HRU	Area (km^2)	Mean Elevation (m)	Mean Aspect (°)	Mean Slope (°)	LAI	Canopy Snow Interception Load Capacity (kg/m2)	Canopy Clearing	Vegetation Height (m)	cov_type	groundcover	inhibit_bs	distrib	Routing Length (m)
Cabin Creek Sub-basin													
South-facing Alpine Rock	0.23	2387	122	36	0.1	0	1	0.14	2	1	0	1	575
North-facing Alpine Rock	0.17	2379	69	37	0.1	0	1	0.14	2	1	0	5	485
North-facing Alpine Larch/Spruce	0.02	2222	60	35	1.1	6.6	0	3	2	6	0	5	137
South-facing Alpine Larch/Spruce	0.02	2194	115	32	1.1	6.6	0	3	2	6	0	5	130
North-facing Spruce/Fir/Lodgepole Pine	0.35	2046	62	24	2.2	8.8	0	10	2	6	1	0	742
South-facing Spruce/Fir/Lodgepole Pine	0.93	1972	151	18	2.2	8.8	0	10	2	6	1	0	1339
Level Spruce/Fir/Lodgepole Pine	0.05	1931	0	4	2.2	8.8	0	10	2	6	1	0	225
Forest Clearings	0.40	1927	140	11	1.1	3.3	1	3	2	6	0	0	806
Level Lodgepole Pine	*0.0325*	1882	0	3	2.2	6.6	0	10	2	6	1	0	*179*
South-facing Lodgepole Pine	*0.0436*	1798	204	18	2.2	6.6	0	10	2	6	1	0	*214*
North-facing Lodgepole Pine	*0.0055*	1780	76	25	2.2	6.6	0	10	2	6	1	0	*62*
Valley Bottom	0.04	1951	135	18	2.2	6.6	0	10	2	6	1	0	2337
MPB Disturbance	**0.0544**	**1830**	**114**	**13**	**0.1**	**0**	**1**	**0.1**	**0**	**1**	**0**	**1**	**244**
Middle Creek Sub-basin													
North-facing Alpine Rock	0.52	2462	82	31	0.1	0	1	0.14	2	1	0	1	944
South-facing Alpine Rock	1.37	2422	148	30	0.1	0	1	0.14	2	1	0	5	1689
South-facing Alpine Larch/Spruce	0.26	2246	138	20	1.1	6.6	0	3	2	6	0	5	618
North-facing Alpine Larch/Spruce	0.08	2211	46	18	1.1	6.6	0	3	2	6	0	5	302
North-facing Spruce/Fir/Lodgepole Pine	0.16	1995	76	21	2.2	8.8	0	10	2	6	1	0	461
South-facing Spruce/Fir/Lodgepole Pine	0.52	1953	134	22	2.2	8.8	0	10	2	6	1	0	947
Valley Bottom	0.03	2057	115	16	2.2	6.6	0	10	2	6	1	0	2907
Twin Creek Sub-basin													
North-facing Alpine Rock	0.79	2386	67	28	0.1	0	1	0.14	2	1	0	1	1217
South-facing Alpine Rock	0.15	2380	106	22	0.1	0	1	0.14	2	1	0	5	457
South-facing Alpine Larch/Spruce	0.28	2228	116	23	1.1	6.6	0	3	2	6	0	5	649
North-facing Alpine Larch/Spruce	0.28	2182	37	22	1.1	6.6	0	3	2	6	0	5	654
North-facing Spruce/Fir/Lodgepole Pine	0.64	1966	34	17	2.2	8.8	0	10	2	6	1	0	1071
South-facing Spruce/Fir/Lodgepole Pine	0.60	2014	113	21	2.2	8.8	0	10	2	6	1	0	1028
Valley Bottom	0.04	1988	119	16	2.2	6.6	0	10	2	6	1	0	2443
Marmot Confluence Sub-basin													
Forest Clearings	0.01	1903	55	11	1.1	3.3	1	3	2	6	0	1	90
North-facing Lodgepole Pine/Aspen	*0.2291*	1786	54	13	2.2	8.8	0	10	2	6	1	0	*578*
South-facing Lodgepole Pine/Aspen	*0.1433*	1725	159	13	2.2	8.8	0	10	2	6	1	0	*436*
Level Lodgepole Pine/Aspen	*0.0254*	1688	0	4	2.2	8.8	0	10	2	6	1	0	*155*
South-facing Lodgepole Pine	*0.2628*	1752	172	17	2.2	6.6	0	10	2	6	1	0	*628*
Level Lodgepole Pine	*0.0145*	1724	0	4	2.2	6.6	0	10	2	6	1	0	*110*
North-facing Lodgepole Pine	*0.0904*	1687	71	14	2.2	6.6	0	10	2	6	1	0	*331*
Valley Bottom	0.02	1664	163	8	2.2	6.6	0	10	2	6	1	0	1998
MPB Disturbance	**0.5104**	**1747**	**113**	**14**	**0.1**	**0**	**1**	**0.1**	**0**	**1**	**0**	**1**	**935**

Table A9. HRU parameters in the forest disturbance scenario 9: pine beetle reduction by 60% plus salvage logging.

HRU	Area (km^2)	Mean Elevation (m)	Mean Aspect (˚)	Mean Slope (˚)	LAI	Canopy Snow Interception Load Capacity (kg/m2)	Canopy Clearing	Vegetation Height (m)	cov_type	groundcover	inhibit_bs	distrib	Routing Length (m)
Cabin Creek Sub-basin													
South-facing Alpine Rock	0.23	2387	122	36	0.1	0	1	0.14	2	1	0	1	575
North-facing Alpine Rock	0.17	2379	69	37	0.1	0	1	0.14	2	1	0	5	485
North-facing Alpine Larch/Spruce	0.02	2222	60	35	1.1	6.6	0	3	2	6	0	5	137
South-facing Alpine Larch/Spruce	0.02	2194	115	32	1.1	6.6	0	3	2	6	0	5	130
North-facing Spruce/Fir/Lodgepole Pine	0.35	2046	62	24	2.2	8.8	0	10	2	6	1	0	742
South-facing Spruce/Fir/Lodgepole Pine	0.93	1972	151	18	2.2	8.8	0	10	2	6	1	0	1339
Level Spruce/Fir/Lodgepole Pine	0.05	1931	0	4	2.2	8.8	0	10	2	6	1	0	225
Forest Clearings	0.40	1927	140	11	1.1	3.3	1	3	2	6	0	0	806
Level Lodgepole Pine	*0.0217*	1882	0	3	2.2	6.6	0	10	2	6	1	0	*141*
South-facing Lodgepole Pine	*0.0291*	1798	204	18	2.2	6.6	0	10	2	6	1	0	*168*
North-facing Lodgepole Pine	*0.0037*	1780	76	25	2.2	6.6	0	10	2	6	1	0	*49*
Valley Bottom	0.04	1951	135	18	2.2	6.6	0	10	2	6	1	0	2337
MPB Disturbance	**0.0817**	**1830**	**114**	**13**	**0.1**	**0**	**1**	**0.1**	**0**	**1**	**0**	**1**	**311**
Middle Creek Sub-basin													
North-facing Alpine Rock	0.52	2462	82	31	0.1	0	1	0.14	2	1	0	1	944
South-facing Alpine Rock	1.37	2422	148	30	0.1	0	1	0.14	2	1	0	5	1689
South-facing Alpine Larch/Spruce	0.26	2246	138	20	1.1	6.6	0	3	2	6	0	5	618
North-facing Alpine Larch/Spruce	0.08	2211	46	18	1.1	6.6	0	3	2	6	0	5	302
North-facing Spruce/Fir/Lodgepole Pine	0.16	1995	76	21	2.2	8.8	0	10	2	6	1	0	461
South-facing Spruce/Fir/Lodgepole Pine	0.52	1953	134	22	2.2	8.8	0	10	2	6	1	0	947
Valley Bottom	0.03	2057	115	16	2.2	6.6	0	10	2	6	1	0	2907
Twin Creek Sub-basin													
North-facing Alpine Rock	0.79	2386	67	28	0.1	0	1	0.14	2	1	0	1	1217
South-facing Alpine Rock	0.15	2380	106	22	0.1	0	1	0.14	2	1	0	5	457
South-facing Alpine Larch/Spruce	0.28	2228	116	23	1.1	6.6	0	3	2	6	0	5	649
North-facing Alpine Larch/Spruce	0.28	2182	37	22	1.1	6.6	0	3	2	6	0	5	654
North-facing Spruce/Fir/Lodgepole Pine	0.64	1966	34	17	2.2	8.8	0	10	2	6	1	0	1071
South-facing Spruce/Fir/Lodgepole Pine	0.60	2014	113	21	2.2	8.8	0	10	2	6	1	0	1028
Valley Bottom	0.04	1988	119	16	2.2	6.6	0	10	2	6	1	0	2443
Marmot Confluence Sub-basin													
Forest Clearings	0.01	1903	55	11	1.1	3.3	1	3	2	6	0	1	90
North-facing Lodgepole Pine/Aspen	*0.1528*	1786	54	13	2.2	8.8	0	10	2	6	1	0	*453*
South-facing Lodgepole Pine/Aspen	*0.0955*	1725	159	13	2.2	8.8	0	10	2	6	1	0	*342*
Level Lodgepole Pine/Aspen	*0.0169*	1688	0	4	2.2	8.8	0	10	2	6	1	0	*121*
South-facing Lodgepole Pine	*0.1752*	1752	172	17	2.2	6.6	0	10	2	6	1	0	*492*
Level Lodgepole Pine	*0.0097*	1724	0	4	2.2	6.6	0	10	2	6	1	0	*87*
North-facing Lodgepole Pine	*0.0603*	1687	71	14	2.2	6.6	0	10	2	6	1	0	*260*
Valley Bottom	0.02	1664	163	8	2.2	6.6	0	10	2	6	1	0	1998
MPB Disturbance	**0.7656**	**1747**	**113**	**14**	**0.1**	**0**	**1**	**0.1**	**0**	**1**	**0**	**1**	**1193**

Table A10. HRU parameters in the forest disturbance scenario 10: pine beetle reduction by 80% plus salvage logging.

HRU	Area (km^2)	Mean Elevation (m)	Mean Aspect (˚)	Mean Slope (˚)	LAI	Canopy Snow Interception Load Capacity (kg/m2)	Canopy Clearing	Vegetation Height (m)	cov_type	groundcover	inhibit_bs	distrib	Routing Length (m)
Cabin Creek Sub-basin													
South-facing Alpine Rock	0.23	2387	122	36	0.1	0	1	0.14	2	1	0	1	575
North-facing Alpine Rock	0.17	2379	69	37	0.1	0	1	0.14	2	1	0	5	485
North-facing Alpine Larch/Spruce	0.02	2222	60	35	1.1	6.6	0	3	2	6	0	5	137
South-facing Alpine Larch/Spruce	0.02	2194	115	32	1.1	6.6	0	3	2	6	0	5	130
North-facing Spruce/Fir/Lodgepole Pine	0.35	2046	62	24	2.2	8.8	0	10	2	6	1	0	742
South-facing Spruce/Fir/Lodgepole Pine	0.93	1972	151	18	2.2	8.8	0	10	2	6	1	0	1339
Level Spruce/Fir/Lodgepole Pine	0.05	1931	0	4	2.2	8.8	0	10	2	6	1	0	225
Forest Clearings	0.40	1927	140	11	1.1	3.3	1	3	2	6	0	0	806
Level Lodgepole Pine	*0.0108*	1882	0	3	2.2	6.6	0	10	2	6	1	0	*93*
South-facing Lodgepole Pine	*0.0145*	1798	204	18	2.2	6.6	0	10	2	6	1	0	*111*
North-facing Lodgepole Pine	*0.0018*	1780	76	25	2.2	6.6	0	10	2	6	1	0	*32*
Valley Bottom	0.04	1951	135	18	2.2	6.6	0	10	2	6	1	0	2337
MPB Disturbance	**0.1089**	**1830**	**114**	**13**	**0.1**	**0**	**1**	**0.1**	**0**	**1**	**0**	**1**	**370**
Middle Creek Sub-basin													
North-facing Alpine Rock	0.52	2462	82	31	0.1	0	1	0.14	2	1	0	1	944
South-facing Alpine Rock	1.37	2422	148	30	0.1	0	1	0.14	2	1	0	5	1689
South-facing Alpine Larch/Spruce	0.26	2246	138	20	1.1	6.6	0	3	2	6	0	5	618
North-facing Alpine Larch/Spruce	0.08	2211	46	18	1.1	6.6	0	3	2	6	0	5	302
North-facing Spruce/Fir/Lodgepole Pine	0.16	1995	76	21	2.2	8.8	0	10	2	6	1	0	461
South-facing Spruce/Fir/Lodgepole Pine	0.52	1953	134	22	2.2	8.8	0	10	2	6	1	0	947
Valley Bottom	0.03	2057	115	16	2.2	6.6	0	10	2	6	1	0	2907
Twin Creek Sub-basin													
North-facing Alpine Rock	0.79	2386	67	28	0.1	0	1	0.14	2	1	0	1	1217
South-facing Alpine Rock	0.15	2380	106	22	0.1	0	1	0.14	2	1	0	5	457
South-facing Alpine Larch/Spruce	0.28	2228	116	23	1.1	6.6	0	3	2	6	0	5	649
North-facing Alpine Larch/Spruce	0.28	2182	37	22	1.1	6.6	0	3	2	6	0	5	654
North-facing Spruce/Fir/Lodgepole Pine	0.64	1966	34	17	2.2	8.8	0	10	2	6	1	0	1071
South-facing Spruce/Fir/Lodgepole Pine	0.60	2014	113	21	2.2	8.8	0	10	2	6	1	0	1028
Valley Bottom	0.04	1988	119	16	2.2	6.6	0	10	2	6	1	0	2443
Marmot Confluence Sub-basin													
Forest Clearings	0.01	1903	55	11	1.1	3.3	1	3	2	6	0	1	90
North-facing Lodgepole Pine/Aspen	*0.0764*	1786	54	13	2.2	8.8	0	10	2	6	1	0	*299*
South-facing Lodgepole Pine/Aspen	*0.0478*	1725	159	13	2.2	8.8	0	10	2	6	1	0	*226*
Level Lodgepole Pine/Aspen	*0.0085*	1688	0	4	2.2	8.8	0	10	2	6	1	0	*80*
South-facing Lodgepole Pine	*0.0876*	1752	172	17	2.2	6.6	0	10	2	6	1	0	*325*
Level Lodgepole Pine	*0.0048*	1724	0	4	2.2	6.6	0	10	2	6	1	0	*57*
North-facing Lodgepole Pine	*0.0301*	1687	71	14	2.2	6.6	0	10	2	6	1	0	*171*
Valley Bottom	0.02	1664	163	8	2.2	6.6	0	10	2	6	1	0	1998
MPB Disturbance	**1.0208**	**1747**	**113**	**14**	**0.1**	**0**	**1**	**0.1**	**0**	**1**	**0**	**1**	**1417**

Table A11. HRU parameters in the forest disturbance scenario 11: pine beetle reduction by 100% plus salvage logging.

HRU	Area (km^2)	Mean Elevation (m)	Mean Aspect (˚)	Mean Slope (˚)	LAI	Canopy Snow Interception Load Capacity (kg/m2)	Canopy Clearing	Vegetation Height (m)	cov_type	groundcover	inhibit_bs	distrib	Routing Length (m)
						Cabin Creek Sub-basin							
South-facing Alpine Rock	0.23	2387	122	36	0.1	0	1	0.14	2	1	0	1	575
North-facing Alpine Rock	0.17	2379	69	37	0.1	0	1	0.14	2	1	0	5	485
North-facing Alpine Larch/Spruce	0.02	2222	60	35	1.1	6.6	0	3	2	6	0	5	137
South-facing Alpine Larch/Spruce	0.02	2194	115	32	1.1	6.6	0	3	2	6	0	5	130
North-facing Spruce/Fir/Lodgepole Pine	0.35	2046	62	24	2.2	8.8	0	10	2	6	1	0	742
South-facing Spruce/Fir/Lodgepole Pine	0.93	1972	151	18	2.2	8.8	0	10	2	6	1	0	1339
Level Spruce/Fir/Lodgepole Pine	0.05	1931	0	4	2.2	8.8	0	10	2	6	1	0	225
Forest Clearings	0.40	1927	140	11	1.1	3.3	1	3	2	6	0	0	806
Level Lodgepole Pine	*1E-06*	1882	0	3	2.2	6.6	0	10	2	6	1	0	*0.35*
South-facing Lodgepole Pine	*1E-06*	1798	204	18	2.2	6.6	0	10	2	6	1	0	*0.35*
North-facing Lodgepole Pine	*1E-06*	1780	76	25	2.2	6.6	0	10	2	6	1	0	*0.35*
Valley Bottom	0.04	1951	135	18	2.2	6.6	0	10	2	6	1	0	2337
MPB Disturbance	**0.1361**	**1830**	**114**	**13**	**0.1**	**0**	**1**	**0.1**	**0**	**1**	**0**	**1**	**423**
						Middle Creek Sub-basin							
North-facing Alpine Rock	0.52	2462	82	31	0.1	0	1	0.14	2	1	0	1	944
South-facing Alpine Rock	1.37	2422	148	30	0.1	0	1	0.14	2	1	0	5	1689
South-facing Alpine Larch/Spruce	0.26	2246	138	20	1.1	6.6	0	3	2	6	0	5	618
North-facing Alpine Larch/Spruce	0.08	2211	46	18	1.1	6.6	0	3	2	6	0	5	302
North-facing Spruce/Fir/Lodgepole Pine	0.16	1995	76	21	2.2	8.8	0	10	2	6	1	0	461
South-facing Spruce/Fir/Lodgepole Pine	0.52	1953	134	22	2.2	8.8	0	10	2	6	1	0	947
Valley Bottom	0.03	2057	115	16	2.2	6.6	0	10	2	6	1	0	2907
						Twin Creek Sub-basin							
North-facing Alpine Rock	0.79	2386	67	28	0.1	0	1	0.14	2	1	0	1	1217
South-facing Alpine Rock	0.15	2380	106	22	0.1	0	1	0.14	2	1	0	5	457
South-facing Alpine Larch/Spruce	0.28	2228	116	23	1.1	6.6	0	3	2	6	0	5	649
North-facing Alpine Larch/Spruce	0.28	2182	37	22	1.1	6.6	0	3	2	6	0	5	654
North-facing Spruce/Fir/Lodgepole Pine	0.64	1966	34	17	2.2	8.8	0	10	2	6	1	0	1071
South-facing Spruce/Fir/Lodgepole Pine	0.60	2014	113	21	2.2	8.8	0	10	2	6	1	0	1028
Valley Bottom	0.04	1988	119	16	2.2	6.6	0	10	2	6	1	0	2443
						Marmot Confluence Sub-basin							
Forest Clearings	0.01	1903	55	11	1.1	3.3	1	3	2	6	0	1	90
North-facing Lodgepole Pine/Aspen	*1E-06*	1786	54	13	2.2	8.8	0	10	2	6	1	0	*0.35*
South-facing Lodgepole Pine/Aspen	*1E-06*	1725	159	13	2.2	8.8	0	10	2	6	1	0	*0.35*
Level Lodgepole Pine/Aspen	*1E-06*	1688	0	4	2.2	8.8	0	10	2	6	1	0	*0.35*
South-facing Lodgepole Pine	*1E-06*	1752	172	17	2.2	6.6	0	10	2	6	1	0	*0.35*
Level Lodgepole Pine	*1E-06*	1724	0	4	2.2	6.6	0	10	2	6	1	0	*0.35*
North-facing Lodgepole Pine	*1E-06*	1687	71	14	2.2	6.6	0	10	2	6	1	0	*0.35*
Valley Bottom	0.02	1664	163	8	2.2	6.6	0	10	2	6	1	0	1998
MPB Disturbance	**1.2760**	**1747**	**113**	**14**	**0.1**	**0**	**1**	**0.1**	**0**	**1**	**0**	**1**	**1620**

Table A12. HRU parameters in the forest disturbance scenario 12: fire reduction by 20% with trunk remained.

HRU	Area (km^2)	Mean Elevation (m)	Mean Aspect (˚)	Mean Slope (˚)	LAI	Canopy Snow Interception Load Capacity (kg/m2)	Canopy Clearing	Vegetation Height (m)	cov_type	groundcover	inhibit_bs	distrib	Routing Length (m)
						Cabin Creek Sub-basin							
South-facing Alpine Rock	0.23	2387	122	36	0.1	0	1	0.14	2	1	0	1	575
North-facing Alpine Rock	0.17	2379	69	37	0.1	0	1	0.14	2	1	0	5	485
North-facing Alpine Larch/Spruce	*0.0166*	2222	60	35	1.1	6.6	0	3	2	6	0	5	*120*
South-facing Alpine Larch/Spruce	*0.0153*	2194	115	32	1.1	6.6	0	3	2	6	0	5	*114*
North-facing Spruce/Fir/Lodgepole Pine	*0.2778*	2046	62	24	2.2	8.8	0	10	2	6	1	0	*649*
South-facing Spruce/Fir/Lodgepole Pine	*0.7426*	1972	151	18	2.2	8.8	0	10	2	6	1	0	*1171*
Level Spruce/Fir/Lodgepole Pine	*0.0380*	1931	0	4	2.2	8.8	0	10	2	6	1	0	*197*
Forest Clearings	0.40	1927	140	11	1.1	3.3	1	3	2	6	0	0	806
Level Lodgepole Pine	*0.0434*	1882	0	3	2.2	6.6	0	10	2	6	1	0	*213*
South-facing Lodgepole Pine	*0.0581*	1798	204	18	2.2	6.6	0	10	2	6	1	0	*254*
North-facing Lodgepole Pine	*0.0074*	1780	76	25	2.2	6.6	0	10	2	6	1	0	*74*
Valley Bottom	0.04	1951	135	18	2.2	6.6	0	10	2	6	1	0	2337
Fire Disturbance	**0.2998**	**1981**	**121**	**19**	**1.81**	**7**	**0**	**10**	**0**	**6**	**1**	**1**	**680**
						Middle Creek Sub-basin							
North-facing Alpine Rock	0.52	2462	82	31	0.1	0	1	0.14	2	1	0	1	944
South-facing Alpine Rock	1.37	2422	148	30	0.1	0	1	0.14	2	1	0	5	1689
South-facing Alpine Larch/Spruce	*0.2047*	2246	138	20	1.1	6.6	0	3	2	6	0	5	*541*
North-facing Alpine Larch/Spruce	*0.0623*	2211	46	18	1.1	6.6	0	3	2	6	0	5	*265*
North-facing Spruce/Fir/Lodgepole Pine	*0.1261*	1995	76	21	2.2	8.8	0	10	2	6	1	0	*404*
South-facing Spruce/Fir/Lodgepole Pine	*0.4173*	1953	134	22	2.2	8.8	0	10	2	6	1	0	*829*
Valley Bottom	0.03	2057	115	16	2.2	6.6	0	10	2	6	1	0	2907
Fire Disturbance	**0.2026**	**2053**	**119**	**21**	**1.49**	**6.68**	**0**	**10**	**0**	**6**	**1**	**1**	**537**
						Twin Creek Sub-basin							
North-facing Alpine Rock	0.79	2386	67	28	0.1	0	1	0.14	2	1	0	1	1217
South-facing Alpine Rock	0.15	2380	106	22	0.1	0	1	0.14	2	1	0	5	457
South-facing Alpine Larch/Spruce	*0.2226*	2228	116	23	1.1	6.6	0	3	2	6	0	5	*568*
North-facing Alpine Larch/Spruce	*0.2253*	2182	37	22	1.1	6.6	0	3	2	6	0	5	*573*
North-facing Spruce/Fir/Lodgepole Pine	*0.5121*	1966	34	17	2.2	8.8	0	10	2	6	1	0	*937*
South-facing Spruce/Fir/Lodgepole Pine	*0.4785*	2014	113	21	2.2	8.8	0	10	2	6	1	0	*900*
Valley Bottom	0.04	1988	119	16	2.2	6.6	0	10	2	6	1	0	2443
Fire Disturbance	**0.3596**	**2056**	**74**	**20**	**1.57**	**6.68**	**0**	**10**	**0**	**6**	**1**	**1**	**758**
						Marmot Confluence Sub-basin							
Forest Clearings	0.01	1903	55	11	1.1	3.3	1	3	2	6	0	1	90
North-facing Lodgepole Pine/Aspen	*0.3055*	1786	54	13	2.2	8.8	0	10	2	6	1	0	*687*
South-facing Lodgepole Pine/Aspen	*0.1911*	1725	159	13	2.2	8.8	0	10	2	6	1	0	*519*
Level Lodgepole Pine/Aspen	*0.0339*	1688	0	4	2.2	8.8	0	10	2	6	1	0	*184*
South-facing Lodgepole Pine	*0.3504*	1752	172	17	2.2	6.6	0	10	2	6	1	0	*746*
Level Lodgepole Pine	*0.0194*	1724	0	4	2.2	6.6	0	10	2	6	1	0	*131*
North-facing Lodgepole Pine	*0.1205*	1687	71	14	2.2	6.6	0	10	2	6	1	0	*393*
Valley Bottom	0.02	1664	163	8	2.2	6.6	0	10	2	6	1	0	1998
Fire Disturbance	**0.2552**	**1747**	**113**	**14**	**1.81**	**6.36**	**0**	**10**	**0**	**6**	**1**	**1**	**617**

Table A13. HRU parameters in the forest disturbance scenario 13: fire reduction by 40% with trunk remained.

HRU	Area (km^2)	Mean Elevation (m)	Mean Aspect (˚)	Mean Slope (˚)	LAI	Canopy Snow Interception Load Capacity (kg/m2)	Canopy Clearing	Vegetation Height (m)	cov_type	groundcover	inhibit_bs	distrib	Routing Length (m)
Cabin Creek Sub-basin													
South-facing Alpine Rock	0.23	2387	122	36	0.1	0	1	0.14	2	1	0	1	575
North-facing Alpine Rock	0.17	2379	69	37	0.1	0	1	0.14	2	1	0	5	485
North-facing Alpine Larch/Spruce	*0.0125*	2222	60	35	1.1	6.6	0	3	2	6	0	5	*101*
South-facing Alpine Larch/Spruce	*0.0115*	2194	115	32	1.1	6.6	0	3	2	6	0	5	*96*
North-facing Spruce/Fir/Lodgepole Pine	*0.2083*	2046	62	24	2.2	8.8	0	10	2	6	1	0	*546*
South-facing Spruce/Fir/Lodgepole Pine	*0.5570*	1972	151	18	2.2	8.8	0	10	2	6	1	0	*985*
Level Spruce/Fir/Lodgepole Pine	*0.0285*	1931	0	4	2.2	8.8	0	10	2	6	1	0	*166*
Forest Clearings	0.40	1927	140	11	1.1	3.3	1	3	2	6	0	0	806
Level Lodgepole Pine	*0.0325*	1882	0	3	2.2	6.6	0	10	2	6	1	0	*179*
South-facing Lodgepole Pine	*0.0436*	1798	204	18	2.2	6.6	0	10	2	6	1	0	*214*
North-facing Lodgepole Pine	*0.0055*	1780	76	25	2.2	6.6	0	10	2	6	1	0	*62*
Valley Bottom	0.04	1951	135	18	2.2	6.6	0	10	2	6	1	0	2337
Fire Disturbance	**0.5996**	**1981**	**121**	**19**	**1.42**	**5.5**	**0**	**10**	**0**	**6**	**1**	**1**	**1030**
Middle Creek Sub-basin													
North-facing Alpine Rock	0.52	2462	82	31	0.1	0	1	0.14	2	1	0	1	944
South-facing Alpine Rock	1.37	2422	148	30	0.1	0	1	0.14	2	1	0	5	1689
South-facing Alpine Larch/Spruce	*0.1536*	2246	138	20	1.1	6.6	0	3	2	6	0	5	*455*
North-facing Alpine Larch/Spruce	*0.0467*	2211	46	18	1.1	6.6	0	3	2	6	0	5	*223*
North-facing Spruce/Fir/Lodgepole Pine	*0.0945*	1995	76	21	2.2	8.8	0	10	2	6	1	0	*340*
South-facing Spruce/Fir/Lodgepole Pine	*0.3130*	1953	134	22	2.2	8.8	0	10	2	6	1	0	*697*
Valley Bottom	0.03	2057	115	16	2.2	6.6	0	10	2	6	1	0	2907
Fire Disturbance	**0.4052**	**2053**	**119**	**21**	**1.18**	**5.26**	**0**	**10**	**0**	**6**	**1**	**1**	**814**
Twin Creek Sub-basin													
North-facing Alpine Rock	0.79	2386	67	28	0.1	0	1	0.14	2	1	0	1	1217
South-facing Alpine Rock	0.15	2380	106	22	0.1	0	1	0.14	2	1	0	5	457
South-facing Alpine Larch/Spruce	*0.1670*	2228	116	23	1.1	6.6	0	3	2	6	0	5	*478*
North-facing Alpine Larch/Spruce	*0.1690*	2182	37	22	1.1	6.6	0	3	2	6	0	5	*482*
North-facing Spruce/Fir/Lodgepole Pine	*0.3841*	1966	34	17	2.2	8.8	0	10	2	6	1	0	*788*
South-facing Spruce/Fir/Lodgepole Pine	*0.3589*	2014	113	21	2.2	8.8	0	10	2	6	1	0	*757*
Valley Bottom	0.04	1988	119	16	2.2	6.6	0	10	2	6	1	0	2443
Fire Disturbance	**0.7193**	**2056**	**74**	**20**	**1.24**	**5.26**	**0**	**10**	**0**	**6**	**1**	**1**	**1149**
Marmot Confluence Sub-basin													
Forest Clearings	0.01	1903	55	11	1.1	3.3	1	3	2	6	0	1	90
North-facing Lodgepole Pine/Aspen	*0.2291*	1786	54	13	2.2	8.8	0	10	2	6	1	0	*578*
South-facing Lodgepole Pine/Aspen	*0.1433*	1725	159	13	2.2	8.8	0	10	2	6	1	0	*436*
Level Lodgepole Pine/Aspen	*0.0254*	1688	0	4	2.2	8.8	0	10	2	6	1	0	*155*
South-facing Lodgepole Pine	*0.2628*	1752	172	17	2.2	6.6	0	10	2	6	1	0	*628*
Level Lodgepole Pine	*0.0145*	1724	0	4	2.2	6.6	0	10	2	6	1	0	*110*
North-facing Lodgepole Pine	*0.0904*	1687	71	14	2.2	6.6	0	10	2	6	1	0	*331*
Valley Bottom	0.02	1664	163	8	2.2	6.6	0	10	2	6	1	0	1998
Fire Disturbance	**0.5104**	**1747**	**113**	**14**	**1.42**	**5.02**	**0**	**10**	**0**	**6**	**1**	**1**	**935**

Table A14. HRU parameters in the forest disturbance scenario 14: fire reduction by 60% with trunk remained.

HRU	Area (km^2)	Mean Elevation (m)	Mean Aspect (˚)	Mean Slope (˚)	LAI	Canopy Snow Interception Load Capacity (kg/m2)	Canopy Clearing	Vegetation Height (m)	cov_type	groundcover	inhibit_bs	distrib	Routing Length (m)
Cabin Creek Sub-basin													
South-facing Alpine Rock	0.23	2387	122	36	0.1	0	1	0.14	2	1	0	1	575
North-facing Alpine Rock	0.17	2379	69	37	0.1	0	1	0.14	2	1	0	5	485
North-facing Alpine Larch/Spruce	*0.0083*	2222	60	35	1.1	6.6	0	3	2	6	0	5	*79*
South-facing Alpine Larch/Spruce	*0.0076*	2194	115	32	1.1	6.6	0	3	2	6	0	5	*75*
North-facing Spruce/Fir/Lodgepole Pine	*0.1389*	2046	62	24	2.2	8.8	0	10	2	6	1	0	*428*
South-facing Spruce/Fir/Lodgepole Pine	*0.3713*	1972	151	18	2.2	8.8	0	10	2	6	1	0	*773*
Level Spruce/Fir/Lodgepole Pine	*0.0190*	1931	0	4	2.2	8.8	0	10	2	6	1	0	*130*
Forest Clearings	0.40	1927	140	11	1.1	3.3	1	3	2	6	0	0	806
Level Lodgepole Pine	*0.0217*	1882	0	3	2.2	6.6	0	10	2	6	1	0	*141*
South-facing Lodgepole Pine	*0.0291*	1798	204	18	2.2	6.6	0	10	2	6	1	0	*168*
North-facing Lodgepole Pine	*0.0037*	1780	76	25	2.2	6.6	0	10	2	6	1	0	*49*
Valley Bottom	0.04	1951	135	18	2.2	6.6	0	10	2	6	1	0	2337
Fire Disturbance	**0.8994**	**1981**	**121**	**19**	**1.03**	**4**	**0**	**10**	**0**	**6**	**1**	**1**	**1314**
Middle Creek Sub-basin													
North-facing Alpine Rock	0.52	2462	82	31	0.1	0	1	0.14	2	1	0	1	944
South-facing Alpine Rock	1.37	2422	148	30	0.1	0	1	0.14	2	1	0	5	1689
South-facing Alpine Larch/Spruce	*0.1024*	2246	138	20	1.1	6.6	0	3	2	6	0	5	*357*
North-facing Alpine Larch/Spruce	*0.0312*	2211	46	18	1.1	6.6	0	3	2	6	0	5	*175*
North-facing Spruce/Fir/Lodgepole Pine	*0.0630*	1995	76	21	2.2	8.8	0	10	2	6	1	0	*267*
South-facing Spruce/Fir/Lodgepole Pine	*0.2087*	1953	134	22	2.2	8.8	0	10	2	6	1	0	*547*
Valley Bottom	0.03	2057	115	16	2.2	6.6	0	10	2	6	1	0	2907
Fire Disturbance	**0.6078**	**2053**	**119**	**21**	**0.87**	**3.84**	**0**	**10**	**0**	**6**	**1**	**1**	**1038**
Twin Creek Sub-basin													
North-facing Alpine Rock	0.79	2386	67	28	0.1	0	1	0.14	2	1	0	1	1217
South-facing Alpine Rock	0.15	2380	106	22	0.1	0	1	0.14	2	1	0	5	457
South-facing Alpine Larch/Spruce	*0.1113*	2228	116	23	1.1	6.6	0	3	2	6	0	5	*375*
North-facing Alpine Larch/Spruce	*0.1127*	2182	37	22	1.1	6.6	0	3	2	6	0	5	*378*
North-facing Spruce/Fir/Lodgepole Pine	*0.2561*	1966	34	17	2.2	8.8	0	10	2	6	1	0	*618*
South-facing Spruce/Fir/Lodgepole Pine	*0.2392*	2014	113	21	2.2	8.8	0	10	2	6	1	0	*594*
Valley Bottom	0.04	1988	119	16	2.2	6.6	0	10	2	6	1	0	2443
Fire Disturbance	**1.0789**	**2056**	**74**	**20**	**0.91**	**3.84**	**0**	**10**	**0**	**6**	**1**	**1**	**1465**
Marmot Confluence Sub-basin													
Forest Clearings	0.01	1903	55	11	1.1	3.3	1	3	2	6	0	1	90
North-facing Lodgepole Pine/Aspen	*0.1528*	1786	54	13	2.2	8.8	0	10	2	6	1	0	*453*
South-facing Lodgepole Pine/Aspen	*0.0955*	1725	159	13	2.2	8.8	0	10	2	6	1	0	*342*
Level Lodgepole Pine/Aspen	*0.0169*	1688	0	4	2.2	8.8	0	10	2	6	1	0	*121*
South-facing Lodgepole Pine	*0.1752*	1752	172	17	2.2	6.6	0	10	2	6	1	0	*492*
Level Lodgepole Pine	*0.0097*	1724	0	4	2.2	6.6	0	10	2	6	1	0	*87*
North-facing Lodgepole Pine	*0.0603*	1687	71	14	2.2	6.6	0	10	2	6	1	0	*260*
Valley Bottom	0.02	1664	163	8	2.2	6.6	0	10	2	6	1	0	1998
Fire Disturbance	**0.7656**	**1747**	**113**	**14**	**1.03**	**3.68**	**0**	**10**	**0**	**6**	**1**	**1**	**1193**

Table A15. HRU parameters in the forest disturbance scenario 15: fire reduction by 80% with trunk remained.

HRU	Area (km^2)	Mean Elevation (m)	Mean Aspect (˚)	Mean Slope (˚)	LAI	Canopy Snow Interception Load Capacity (kg/m2)	Canopy Clearing	Vegetation Height (m)	cov_type	groundcover	inhibit_bs	distrib	Routing Length (m)
Cabin Creek Sub-basin													
South-facing Alpine Rock	0.23	2387	122	36	0.1	0	1	0.14	2	1	0	1	575
North-facing Alpine Rock	0.17	2379	69	37	0.1	0	1	0.14	2	1	0	5	485
North-facing Alpine Larch/Spruce	*0.0042*	2222	60	35	1.1	6.6	0	3	2	6	0	5	*52*
South-facing Alpine Larch/Spruce	*0.0038*	2194	115	32	1.1	6.6	0	3	2	6	0	5	*50*
North-facing Spruce/Fir/Lodgepole Pine	*0.0694*	2046	62	24	2.2	8.8	0	10	2	6	1	0	*283*
South-facing Spruce/Fir/Lodgepole Pine	*0.1857*	1972	151	18	2.2	8.8	0	10	2	6	1	0	*510*
Level Spruce/Fir/Lodgepole Pine	*0.0095*	1931	0	4	2.2	8.8	0	10	2	6	1	0	*86*
Forest Clearings	0.40	1927	140	11	1.1	3.3	1	3	2	6	0	0	806
Level Lodgepole Pine	*0.0108*	1882	0	3	2.2	6.6	0	10	2	6	1	0	*93*
South-facing Lodgepole Pine	*0.0145*	1798	204	18	2.2	6.6	0	10	2	6	1	0	*111*
North-facing Lodgepole Pine	*0.0018*	1780	76	25	2.2	6.6	0	10	2	6	1	0	*32*
Valley Bottom	0.04	1951	135	18	2.2	6.6	0	10	2	6	1	0	2337
Fire Disturbance	**1.1992**	**1981**	**121**	**19**	**0.64**	**2.5**	**0**	**10**	**0**	**6**	**1**	**1**	**1561**
Middle Creek Sub-basin													
North-facing Alpine Rock	0.52	2462	82	31	0.1	0	1	0.14	2	1	0	1	944
South-facing Alpine Rock	1.37	2422	148	30	0.1	0	1	0.14	2	1	0	5	1689
South-facing Alpine Larch/Spruce	*0.0512*	2246	138	20	1.1	6.6	0	3	2	6	0	5	*235*
North-facing Alpine Larch/Spruce	*0.0156*	2211	46	18	1.1	6.6	0	3	2	6	0	5	*115*
North-facing Spruce/Fir/Lodgepole Pine	*0.0315*	1995	76	21	2.2	8.8	0	10	2	6	1	0	*176*
South-facing Spruce/Fir/Lodgepole Pine	*0.1043*	1953	134	22	2.2	8.8	0	10	2	6	1	0	*361*
Valley Bottom	0.03	2057	115	16	2.2	6.6	0	10	2	6	1	0	2907
Fire Disturbance	**0.8104**	**2053**	**119**	**21**	**0.56**	**2.42**	**0**	**10**	**0**	**6**	**1**	**1**	**1234**
Twin Creek Sub-basin													
North-facing Alpine Rock	0.79	2386	67	28	0.1	0	1	0.14	2	1	0	1	1217
South-facing Alpine Rock	0.15	2380	106	22	0.1	0	1	0.14	2	1	0	5	457
South-facing Alpine Larch/Spruce	*0.0557*	2228	116	23	1.1	6.6	0	3	2	6	0	5	*247*
North-facing Alpine Larch/Spruce	*0.0563*	2182	37	22	1.1	6.6	0	3	2	6	0	5	*249*
North-facing Spruce/Fir/Lodgepole Pine	*0.1280*	1966	34	17	2.2	8.8	0	10	2	6	1	0	*408*
South-facing Spruce/Fir/Lodgepole Pine	*0.1196*	2014	113	21	2.2	8.8	0	10	2	6	1	0	*392*
Valley Bottom	0.04	1988	119	16	2.2	6.6	0	10	2	6	1	0	2443
Fire Disturbance	**1.4386**	**2056**	**74**	**20**	**0.58**	**2.42**	**0**	**10**	**0**	**6**	**1**	**1**	**1741**
Marmot Confluence Sub-basin													
Forest Clearings	0.01	1903	55	11	1.1	3.3	1	3	2	6	0	1	90
North-facing Lodgepole Pine/Aspen	*0.0764*	1786	54	13	2.2	8.8	0	10	2	6	1	0	*299*
South-facing Lodgepole Pine/Aspen	*0.0478*	1725	159	13	2.2	8.8	0	10	2	6	1	0	*226*
Level Lodgepole Pine/Aspen	*0.0085*	1688	0	4	2.2	8.8	0	10	2	6	1	0	*80*
South-facing Lodgepole Pine	*0.0876*	1752	172	17	2.2	6.6	0	10	2	6	1	0	*325*
Level Lodgepole Pine	*0.0048*	1724	0	4	2.2	6.6	0	10	2	6	1	0	*57*
North-facing Lodgepole Pine	*0.0301*	1687	71	14	2.2	6.6	0	10	2	6	1	0	*171*
Valley Bottom	0.02	1664	163	8	2.2	6.6	0	10	2	6	1	0	1998
Fire Disturbance	**1.0208**	**1747**	**113**	**14**	**0.64**	**2.34**	**0**	**10**	**0**	**6**	**1**	**1**	**1417**

Table A16. HRU parameters in the forest disturbance scenario 16: fire reduction by 100% with trunk remained.

HRU	Area (km^2)	Mean Elevation (m)	Mean Aspect (˚)	Mean Slope (˚)	LAI	Canopy Snow Interception Load Capacity (kg/m2)	Canopy Clearing	Vegetation Height (m)	cov_type	groundcover	inhibit_bs	distrib	Routing Length (m)
Cabin Creek Sub-basin													
South-facing Alpine Rock	0.23	2387	122	36	0.1	0	1	0.14	2	1	0	1	575
North-facing Alpine Rock	0.17	2379	69	37	0.1	0	1	0.14	2	1	0	5	485
North-facing Alpine Larch/Spruce	*1E-06*	2222	60	35	1.1	6.6	0	3	2	6	0	5	*0.35*
South-facing Alpine Larch/Spruce	*1E-06*	2194	115	32	1.1	6.6	0	3	2	6	0	5	*0.35*
North-facing Spruce/Fir/Lodgepole Pine	*1E-06*	2046	62	24	2.2	8.8	0	10	2	6	1	0	*0.35*
South-facing Spruce/Fir/Lodgepole Pine	*1E-06*	1972	151	18	2.2	8.8	0	10	2	6	1	0	*0.35*
Level Spruce/Fir/Lodgepole Pine	*1E-06*	1931	0	4	2.2	8.8	0	10	2	6	1	0	*0.35*
Forest Clearings	0.40	1927	140	11	1.1	3.3	1	3	2	6	0	0	806
Level Lodgepole Pine	*1E-06*	1882	0	3	2.2	6.6	0	10	2	6	1	0	*0.35*
South-facing Lodgepole Pine	*1E-06*	1798	204	18	2.2	6.6	0	10	2	6	1	0	*0.35*
North-facing Lodgepole Pine	*1E-06*	1780	76	25	2.2	6.6	0	10	2	6	1	0	*0.35*
Valley Bottom	0.04	1951	135	18	2.2	6.6	0	10	2	6	1	0	2337
Fire Disturbance	**1.4990**	**1981**	**121**	**19**	**0.25**	**1**	**0**	**10**	**0**	**6**	**1**	**1**	**1785**
Middle Creek Sub-basin													
North-facing Alpine Rock	0.52	2462	82	31	0.1	0	1	0.14	2	1	0	1	944
South-facing Alpine Rock	1.37	2422	148	30	0.1	0	1	0.14	2	1	0	5	1689
South-facing Alpine Larch/Spruce	*1E-06*	2246	138	20	1.1	6.6	0	3	2	6	0	5	*0.35*
North-facing Alpine Larch/Spruce	*1E-06*	2211	46	18	1.1	6.6	0	3	2	6	0	5	*0.35*
North-facing Spruce/Fir/Lodgepole Pine	*1E-06*	1995	76	21	2.2	8.8	0	10	2	6	1	0	*0.35*
South-facing Spruce/Fir/Lodgepole Pine	*1E-06*	1953	134	22	2.2	8.8	0	10	2	6	1	0	*0.35*
Valley Bottom	0.03	2057	115	16	2.2	6.6	0	10	2	6	1	0	2907
Fire Disturbance	**1.0131**	**2053**	**119**	**21**	**0.25**	**1**	**0**	**10**	**0**	**6**	**1**	**1**	**1411**
Twin Creek Sub-basin													
North-facing Alpine Rock	0.79	2386	67	28	0.1	0	1	0.14	2	1	0	1	1217
South-facing Alpine Rock	0.15	2380	106	22	0.1	0	1	0.14	2	1	0	5	457
South-facing Alpine Larch/Spruce	*1E-06*	2228	116	23	1.1	6.6	0	3	2	6	0	5	*0.35*
North-facing Alpine Larch/Spruce	*1E-06*	2182	37	22	1.1	6.6	0	3	2	6	0	5	*0.35*
North-facing Spruce/Fir/Lodgepole Pine	*1E-06*	1966	34	17	2.2	8.8	0	10	2	6	1	0	*0.35*
South-facing Spruce/Fir/Lodgepole Pine	*1E-06*	2014	113	21	2.2	8.8	0	10	2	6	1	0	*0.35*
Valley Bottom	0.04	1988	119	16	2.2	6.6	0	10	2	6	1	0	2443
Fire Disturbance	**1.7982**	**2056**	**74**	**20**	**0.25**	**1**	**0**	**10**	**0**	**6**	**1**	**1**	**1991**
Marmot Confluence Sub-basin													
Forest Clearings	0.01	1903	55	11	1.1	3.3	1	3	2	6	0	1	90
North-facing Lodgepole Pine/Aspen	*1E-06*	1786	54	13	2.2	8.8	0	10	2	6	1	0	*0.35*
South-facing Lodgepole Pine/Aspen	*1E-06*	1725	159	13	2.2	8.8	0	10	2	6	1	0	*0.35*
Level Lodgepole Pine/Aspen	*1E-06*	1688	0	4	2.2	8.8	0	10	2	6	1	0	*0.35*
South-facing Lodgepole Pine	*1E-06*	1752	172	17	2.2	6.6	0	10	2	6	1	0	*0.35*
Level Lodgepole Pine	*1E-06*	1724	0	4	2.2	6.6	0	10	2	6	1	0	*0.35*
North-facing Lodgepole Pine	*1E-06*	1687	71	14	2.2	6.6	0	10	2	6	1	0	*0.35*
Valley Bottom	0.02	1664	163	8	2.2	6.6	0	10	2	6	1	0	1998
Fire Disturbance	**1.2760**	**1747**	**113**	**14**	**0.25**	**1**	**0**	**10**	**0**	**6**	**1**	**1**	**1620**

Table A17. HRU parameters in the forest disturbance scenario 17: fire reduction by 20% with trunk removed.

HRU	Area (km^2)	Mean Elevation (m)	Mean Aspect (˚)	Mean Slope (˚)	LAI	Canopy Snow Interception Load Capacity (kg/m2)	Canopy Clearing	Vegetation Height (m)	cov_type	groundcover	inhibit_bs	distrib	Routing Length (m)
Cabin Creek Sub-basin													
South-facing Alpine Rock	0.23	2387	122	36	0.1	0	1	0.14	2	1	0	1	575
North-facing Alpine Rock	0.17	2379	69	37	0.1	0	1	0.14	2	1	0	5	485
North-facing Alpine Larch/Spruce	*0.0166*	2222	60	35	1.1	6.6	0	3	2	6	0	5	*120*
South-facing Alpine Larch/Spruce	*0.0153*	2194	115	32	1.1	6.6	0	3	2	6	0	5	*114*
North-facing Spruce/Fir/Lodgepole Pine	*0.2778*	2046	62	24	2.2	8.8	0	10	2	6	1	0	*649*
South-facing Spruce/Fir/Lodgepole Pine	*0.7426*	1972	151	18	2.2	8.8	0	10	2	6	1	0	*1171*
Level Spruce/Fir/Lodgepole Pine	*0.0380*	1931	0	4	2.2	8.8	0	10	2	6	1	0	*197*
Forest Clearings	0.40	1927	140	11	1.1	3.3	1	3	2	6	0	0	806
Level Lodgepole Pine	*0.0434*	1882	0	3	2.2	6.6	0	10	2	6	1	0	*213*
South-facing Lodgepole Pine	*0.0581*	1798	204	18	2.2	6.6	0	10	2	6	1	0	*254*
North-facing Lodgepole Pine	*0.0074*	1780	76	25	2.2	6.6	0	10	2	6	1	0	*74*
Valley Bottom	0.04	1951	135	18	2.2	6.6	0	10	2	6	1	0	2337
Fire Disturbance	**0.2998**	**1981**	**121**	**19**	**0.1**	**0**	**1**	**0.1**	**0**	**1**	**0**	**1**	**680**
Middle Creek Sub-basin													
North-facing Alpine Rock	0.52	2462	82	31	0.1	0	1	0.14	2	1	0	1	944
South-facing Alpine Rock	1.37	2422	148	30	0.1	0	1	0.14	2	1	0	5	1689
South-facing Alpine Larch/Spruce	*0.2047*	2246	138	20	1.1	6.6	0	3	2	6	0	5	*541*
North-facing Alpine Larch/Spruce	*0.0623*	2211	46	18	1.1	6.6	0	3	2	6	0	5	*265*
North-facing Spruce/Fir/Lodgepole Pine	*0.1261*	1995	76	21	2.2	8.8	0	10	2	6	1	0	*404*
South-facing Spruce/Fir/Lodgepole Pine	*0.4173*	1953	134	22	2.2	8.8	0	10	2	6	1	0	*829*
Valley Bottom	0.03	2057	115	16	2.2	6.6	0	10	2	6	1	0	2907
Fire Disturbance	**0.2026**	**2053**	**119**	**21**	**0.1**	**0**	**1**	**0.1**	**0**	**1**	**0**	**1**	**537**
Twin Creek Sub-basin													
North-facing Alpine Rock	0.79	2386	67	28	0.1	0	1	0.14	2	1	0	1	1217
South-facing Alpine Rock	0.15	2380	106	22	0.1	0	1	0.14	2	1	0	5	457
South-facing Alpine Larch/Spruce	*0.2226*	2228	116	23	1.1	6.6	0	3	2	6	0	5	*568*
North-facing Alpine Larch/Spruce	*0.2253*	2182	37	22	1.1	6.6	0	3	2	6	0	5	*573*
North-facing Spruce/Fir/Lodgepole Pine	*0.5121*	1966	34	17	2.2	8.8	0	10	2	6	1	0	*937*
South-facing Spruce/Fir/Lodgepole Pine	*0.4785*	2014	113	21	2.2	8.8	0	10	2	6	1	0	*900*
Valley Bottom	0.04	1988	119	16	2.2	6.6	0	10	2	6	1	0	2443
Fire Disturbance	**0.3596**	**2056**	**74**	**20**	**0.1**	**0**	**1**	**0.1**	**0**	**1**	**0**	**1**	**758**
Marmot Confluence Sub-basin													
Forest Clearings	0.01	1903	55	11	1.1	3.3	1	3	2	6	0	1	90
North-facing Lodgepole Pine/Aspen	*0.3055*	1786	54	13	2.2	8.8	0	10	2	6	1	0	*687*
South-facing Lodgepole Pine/Aspen	*0.1911*	1725	159	13	2.2	8.8	0	10	2	6	1	0	*519*
Level Lodgepole Pine/Aspen	*0.0339*	1688	0	4	2.2	8.8	0	10	2	6	1	0	*184*
South-facing Lodgepole Pine	*0.3504*	1752	172	17	2.2	6.6	0	10	2	6	1	0	*746*
Level Lodgepole Pine	*0.0194*	1724	0	4	2.2	6.6	0	10	2	6	1	0	*131*
North-facing Lodgepole Pine	*0.1205*	1687	71	14	2.2	6.6	0	10	2	6	1	0	*393*
Valley Bottom	0.02	1664	163	8	2.2	6.6	0	10	2	6	1	0	1998
Fire Disturbance	**0.2552**	**1747**	**113**	**14**	**0.1**	**0**	**1**	**0.1**	**0**	**1**	**0**	**1**	**617**

Table A18. HRU parameters in the forest disturbance scenario 18: fire reduction by 40% with trunk removed.

HRU	Area (km^2)	Mean Elevation (m)	Mean Aspect (˚)	Mean Slope (˚)	LAI	Canopy Snow Interception Load Capacity (kg/m2)	Canopy Clearing	Vegetation Height (m)	cov_type	groundcover	inhibit_bs	distrib	Routing Length (m)
						Cabin Creek Sub-basin							
South-facing Alpine Rock	0.23	2387	122	36	0.1	0	1	0.14	2	1	0	1	575
North-facing Alpine Rock	0.17	2379	69	37	0.1	0	1	0.14	2	1	0	5	485
North-facing Alpine Larch/Spruce	*0.0125*	2222	60	35	1.1	6.6	0	3	2	6	0	5	*101*
South-facing Alpine Larch/Spruce	*0.0115*	2194	115	32	1.1	6.6	0	3	2	6	0	5	*96*
North-facing Spruce/Fir/Lodgepole Pine	*0.2083*	2046	62	24	2.2	8.8	0	10	2	6	1	0	*546*
South-facing Spruce/Fir/Lodgepole Pine	*0.5570*	1972	151	18	2.2	8.8	0	10	2	6	1	0	*985*
Level Spruce/Fir/Lodgepole Pine	*0.0285*	1931	0	4	2.2	8.8	0	10	2	6	1	0	*166*
Forest Clearings	0.40	1927	140	11	1.1	3.3	1	3	2	6	0	0	806
Level Lodgepole Pine	*0.0325*	1882	0	3	2.2	6.6	0	10	2	6	1	0	*179*
South-facing Lodgepole Pine	*0.0436*	1798	204	18	2.2	6.6	0	10	2	6	1	0	*214*
North-facing Lodgepole Pine	*0.0055*	1780	76	25	2.2	6.6	0	10	2	6	1	0	*62*
Valley Bottom	0.04	1951	135	18	2.2	6.6	0	10	2	6	1	0	2337
Fire Disturbance	**0.5996**	**1981**	**121**	**19**	**0.1**	**0**	**1**	**0.1**	**0**	**1**	**0**	**1**	**1030**
						Middle Creek Sub-basin							
North-facing Alpine Rock	0.52	2462	82	31	0.1	0	1	0.14	2	1	0	1	944
South-facing Alpine Rock	1.37	2422	148	30	0.1	0	1	0.14	2	1	0	5	1689
South-facing Alpine Larch/Spruce	*0.1536*	2246	138	20	1.1	6.6	0	3	2	6	0	5	*455*
North-facing Alpine Larch/Spruce	*0.0467*	2211	46	18	1.1	6.6	0	3	2	6	0	5	*223*
North-facing Spruce/Fir/Lodgepole Pine	*0.0945*	1995	76	21	2.2	8.8	0	10	2	6	1	0	*340*
South-facing Spruce/Fir/Lodgepole Pine	*0.3130*	1953	134	22	2.2	8.8	0	10	2	6	1	0	*697*
Valley Bottom	0.03	2057	115	16	2.2	6.6	0	10	2	6	1	0	2907
Fire Disturbance	**0.4052**	**2053**	**119**	**21**	**0.1**	**0**	**1**	**0.1**	**0**	**1**	**0**	**1**	**814**
						Twin Creek Sub-basin							
North-facing Alpine Rock	0.79	2386	67	28	0.1	0	1	0.14	2	1	0	1	1217
South-facing Alpine Rock	0.15	2380	106	22	0.1	0	1	0.14	2	1	0	5	457
South-facing Alpine Larch/Spruce	*0.1670*	2228	116	23	1.1	6.6	0	3	2	6	0	5	*478*
North-facing Alpine Larch/Spruce	*0.1690*	2182	37	22	1.1	6.6	0	3	2	6	0	5	*482*
North-facing Spruce/Fir/Lodgepole Pine	*0.3841*	1966	34	17	2.2	8.8	0	10	2	6	1	0	*788*
South-facing Spruce/Fir/Lodgepole Pine	*0.3589*	2014	113	21	2.2	8.8	0	10	2	6	1	0	*757*
Valley Bottom	0.04	1988	119	16	2.2	6.6	0	10	2	6	1	0	2443
Fire Disturbance	**0.7193**	**2056**	**74**	**20**	**0.1**	**0**	**1**	**0.1**	**0**	**1**	**0**	**1**	**1149**
						Marmot Confluence Sub-basin							
Forest Clearings	0.01	1903	55	11	1.1	3.3	1	3	2	6	0	1	90
North-facing Lodgepole Pine/Aspen	*0.2291*	1786	54	13	2.2	8.8	0	10	2	6	1	0	*578*
South-facing Lodgepole Pine/Aspen	*0.1433*	1725	159	13	2.2	8.8	0	10	2	6	1	0	*436*
Level Lodgepole Pine/Aspen	*0.0254*	1688	0	4	2.2	8.8	0	10	2	6	1	0	*155*
South-facing Lodgepole Pine	*0.2628*	1752	172	17	2.2	6.6	0	10	2	6	1	0	*628*
Level Lodgepole Pine	*0.0145*	1724	0	4	2.2	6.6	0	10	2	6	1	0	*110*
North-facing Lodgepole Pine	*0.0904*	1687	71	14	2.2	6.6	0	10	2	6	1	0	*331*
Valley Bottom	0.02	1664	163	8	2.2	6.6	0	10	2	6	1	0	1998
Fire Disturbance	**0.5104**	**1747**	**113**	**14**	**0.1**	**0**	**1**	**0.1**	**0**	**1**	**0**	**1**	**935**

Table A19. HRU parameters in the forest disturbance scenario 19: fire reduction by 60% with trunk removed.

HRU	Area (km^2)	Mean Elevation (m)	Mean Aspect (˚)	Mean Slope (˚)	LAI	Canopy Snow Interception Load Capacity (kg/m2)	Canopy Clearing	Vegetation Height (m)	cov_type	groundcover	inhibit_bs	distrib	Routing Length (m)
Cabin Creek Sub-basin													
South-facing Alpine Rock	0.23	2387	122	36	0.1	0	1	0.14	2	1	0	1	575
North-facing Alpine Rock	0.17	2379	69	37	0.1	0	1	0.14	2	1	0	5	485
North-facing Alpine Larch/Spruce	*0.0083*	2222	60	35	1.1	6.6	0	3	2	6	0	5	*79*
South-facing Alpine Larch/Spruce	*0.0076*	2194	115	32	1.1	6.6	0	3	2	6	0	5	*75*
North-facing Spruce/Fir/Lodgepole Pine	*0.1389*	2046	62	24	2.2	8.8	0	10	2	6	1	0	*428*
South-facing Spruce/Fir/Lodgepole Pine	*0.3713*	1972	151	18	2.2	8.8	0	10	2	6	1	0	*773*
Level Spruce/Fir/Lodgepole Pine	*0.0190*	1931	0	4	2.2	8.8	0	10	2	6	1	0	*130*
Forest Clearings	0.40	1927	140	11	1.1	3.3	1	3	2	6	0	0	806
Level Lodgepole Pine	*0.0217*	1882	0	3	2.2	6.6	0	10	2	6	1	0	*141*
South-facing Lodgepole Pine	*0.0291*	1798	204	18	2.2	6.6	0	10	2	6	1	0	*168*
North-facing Lodgepole Pine	*0.0037*	1780	76	25	2.2	6.6	0	10	2	6	1	0	*49*
Valley Bottom	0.04	1951	135	18	2.2	6.6	0	10	2	6	1	0	2337
Fire Disturbance	**0.8994**	**1981**	**121**	**19**	**0.1**	**0**	**1**	**0.1**	**0**	**1**	**0**	**1**	**1314**
Middle Creek Sub-basin													
North-facing Alpine Rock	0.52	2462	82	31	0.1	0	1	0.14	2	1	0	1	944
South-facing Alpine Rock	1.37	2422	148	30	0.1	0	1	0.14	2	1	0	5	1689
South-facing Alpine Larch/Spruce	*0.1024*	2246	138	20	1.1	6.6	0	3	2	6	0	5	*357*
North-facing Alpine Larch/Spruce	*0.0312*	2211	46	18	1.1	6.6	0	3	2	6	0	5	*175*
North-facing Spruce/Fir/Lodgepole Pine	*0.0630*	1995	76	21	2.2	8.8	0	10	2	6	1	0	*267*
South-facing Spruce/Fir/Lodgepole Pine	*0.2087*	1953	134	22	2.2	8.8	0	10	2	6	1	0	*547*
Valley Bottom	0.03	2057	115	16	2.2	6.6	0	10	2	6	1	0	2907
Fire Disturbance	**0.6078**	**2053**	**119**	**21**	**0.1**	**0**	**1**	**0.1**	**0**	**1**	**0**	**1**	**1038**
Twin Creek Sub-basin													
North-facing Alpine Rock	0.79	2386	67	28	0.1	0	1	0.14	2	1	0	1	1217
South-facing Alpine Rock	0.15	2380	106	22	0.1	0	1	0.14	2	1	0	5	457
South-facing Alpine Larch/Spruce	*0.1113*	2228	116	23	1.1	6.6	0	3	2	6	0	5	*375*
North-facing Alpine Larch/Spruce	*0.1127*	2182	37	22	1.1	6.6	0	3	2	6	0	5	*378*
North-facing Spruce/Fir/Lodgepole Pine	*0.2561*	1966	34	17	2.2	8.8	0	10	2	6	1	0	*618*
South-facing Spruce/Fir/Lodgepole Pine	*0.2392*	2014	113	21	2.2	8.8	0	10	2	6	1	0	*594*
Valley Bottom	0.04	1988	119	16	2.2	6.6	0	10	2	6	1	0	2443
Fire Disturbance	**1.0789**	**2056**	**74**	**20**	**0.1**	**0**	**1**	**0.1**	**0**	**1**	**0**	**1**	**1465**
Marmot Confluence Sub-basin													
Forest Clearings	0.01	1903	55	11	1.1	3.3	1	3	2	6	0	1	90
North-facing Lodgepole Pine/Aspen	*0.1528*	1786	54	13	2.2	8.8	0	10	2	6	1	0	*453*
South-facing Lodgepole Pine/Aspen	*0.0955*	1725	159	13	2.2	8.8	0	10	2	6	1	0	*342*
Level Lodgepole Pine/Aspen	*0.0169*	1688	0	4	2.2	8.8	0	10	2	6	1	0	*121*
South-facing Lodgepole Pine	*0.1752*	1752	172	17	2.2	6.6	0	10	2	6	1	0	*492*
Level Lodgepole Pine	*0.0097*	1724	0	4	2.2	6.6	0	10	2	6	1	0	*87*
North-facing Lodgepole Pine	*0.0603*	1687	71	14	2.2	6.6	0	10	2	6	1	0	*260*
Valley Bottom	0.02	1664	163	8	2.2	6.6	0	10	2	6	1	0	1998
Fire Disturbance	**0.7656**	**1747**	**113**	**14**	**0.1**	**0**	**1**	**0.1**	**0**	**1**	**0**	**1**	**1193**

Table A20. HRU parameters in the forest disturbance scenario 20: fire reduction by 80% with trunk removed.

HRU	Area (km^2)	Mean Elevation (m)	Mean Aspect (˚)	Mean Slope (˚)	LAI	Canopy Snow Interception Load Capacity (kg/m2)	Canopy Clearing	Vegetation Height (m)	cov_type	groundcover	inhibit_bs	distrib	Routing Length (m)
						Cabin Creek Sub-basin							
South-facing Alpine Rock	0.23	2387	122	36	0.1	0	1	0.14	2	1	0	1	575
North-facing Alpine Rock	0.17	2379	69	37	0.1	0	1	0.14	2	1	0	5	485
North-facing Alpine Larch/Spruce	*0.0042*	2222	60	35	1.1	6.6	0	3	2	6	0	5	*52*
South-facing Alpine Larch/Spruce	*0.0038*	2194	115	32	1.1	6.6	0	3	2	6	0	5	*50*
North-facing Spruce/Fir/Lodgepole Pine	*0.0694*	2046	62	24	2.2	8.8	0	10	2	6	1	0	*283*
South-facing Spruce/Fir/Lodgepole Pine	*0.1857*	1972	151	18	2.2	8.8	0	10	2	6	1	0	*510*
Level Spruce/Fir/Lodgepole Pine	*0.0095*	1931	0	4	2.2	8.8	0	10	2	6	1	0	*86*
Forest Clearings	0.40	1927	140	11	1.1	3.3	1	3	2	6	0	0	806
Level Lodgepole Pine	*0.0108*	1882	0	3	2.2	6.6	0	10	2	6	1	0	*93*
South-facing Lodgepole Pine	*0.0145*	1798	204	18	2.2	6.6	0	10	2	6	1	0	*111*
North-facing Lodgepole Pine	*0.0018*	1780	76	25	2.2	6.6	0	10	2	6	1	0	*32*
Valley Bottom	0.04	1951	135	18	2.2	6.6	0	10	2	6	1	0	2337
Fire Disturbance	**1.1992**	**1981**	**121**	**19**	**0.1**	**0**	**1**	**0.1**	**0**	**1**	**0**	**1**	**1561**
						Middle Creek Sub-basin							
North-facing Alpine Rock	0.52	2462	82	31	0.1	0	1	0.14	2	1	0	1	944
South-facing Alpine Rock	1.37	2422	148	30	0.1	0	1	0.14	2	1	0	5	1689
South-facing Alpine Larch/Spruce	*0.0512*	2246	138	20	1.1	6.6	0	3	2	6	0	5	*235*
North-facing Alpine Larch/Spruce	*0.0156*	2211	46	18	1.1	6.6	0	3	2	6	0	5	*115*
North-facing Spruce/Fir/Lodgepole Pine	*0.0315*	1995	76	21	2.2	8.8	0	10	2	6	1	0	*176*
South-facing Spruce/Fir/Lodgepole Pine	*0.1043*	1953	134	22	2.2	8.8	0	10	2	6	1	0	*361*
Valley Bottom	0.03	2057	115	16	2.2	6.6	0	10	2	6	1	0	2907
Fire Disturbance	**0.8104**	**2053**	**119**	**21**	**0.1**	**0**	**1**	**0.1**	**0**	**1**	**0**	**1**	**1234**
						Twin Creek Sub-basin							
North-facing Alpine Rock	0.79	2386	67	28	0.1	0	1	0.14	2	1	0	1	1217
South-facing Alpine Rock	0.15	2380	106	22	0.1	0	1	0.14	2	1	0	5	457
South-facing Alpine Larch/Spruce	*0.0557*	2228	116	23	1.1	6.6	0	3	2	6	0	5	*247*
North-facing Alpine Larch/Spruce	*0.0563*	2182	37	22	1.1	6.6	0	3	2	6	0	5	*249*
North-facing Spruce/Fir/Lodgepole Pine	*0.1280*	1966	34	17	2.2	8.8	0	10	2	6	1	0	*408*
South-facing Spruce/Fir/Lodgepole Pine	*0.1196*	2014	113	21	2.2	8.8	0	10	2	6	1	0	*392*
Valley Bottom	0.04	1988	119	16	2.2	6.6	0	10	2	6	1	0	2443
Fire Disturbance	**1.4386**	**2056**	**74**	**20**	**0.1**	**0**	**1**	**0.1**	**0**	**1**	**0**	**1**	**1741**
						Marmot Confluence Sub-basin							
Forest Clearings	0.01	1903	55	11	1.1	3.3	1	3	2	6	0	1	90
North-facing Lodgepole Pine/Aspen	*0.0764*	1786	54	13	2.2	8.8	0	10	2	6	1	0	*299*
South-facing Lodgepole Pine/Aspen	*0.0478*	1725	159	13	2.2	8.8	0	10	2	6	1	0	*226*
Level Lodgepole Pine/Aspen	*0.0085*	1688	0	4	2.2	8.8	0	10	2	6	1	0	*80*
South-facing Lodgepole Pine	*0.0876*	1752	172	17	2.2	6.6	0	10	2	6	1	0	*325*
Level Lodgepole Pine	*0.0048*	1724	0	4	2.2	6.6	0	10	2	6	1	0	*57*
North-facing Lodgepole Pine	*0.0301*	1687	71	14	2.2	6.6	0	10	2	6	1	0	*171*
Valley Bottom	0.02	1664	163	8	2.2	6.6	0	10	2	6	1	0	1998
Fire Disturbance	**1.0208**	**1747**	**113**	**14**	**0.1**	**0**	**1**	**0.1**	**0**	**1**	**0**	**1**	**1417**

Table A21. HRU parameters in the forest disturbance scenario 21: fire reduction by 100% with trunk removed.

HRU	Area (km^2)	Mean Elevation (m)	Mean Aspect (˚)	Mean Slope (˚)	LAI	Canopy Snow Interception Load Capacity (kg/m2)	Canopy Clearing	Vegetation Height (m)	cov_type	groundcover	inhibit_bs	distrib	Routing Length (m)
Cabin Creek Sub-basin													
South-facing Alpine Rock	0.23	2387	122	36	0.1	0	1	0.14	2	1	0	1	575
North-facing Alpine Rock	0.17	2379	69	37	0.1	0	1	0.14	2	1	0	5	485
North-facing Alpine Larch/Spruce	*1E-06*	2222	60	35	1.1	6.6	0	3	2	6	0	5	*0.35*
South-facing Alpine Larch/Spruce	*1E-06*	2194	115	32	1.1	6.6	0	3	2	6	0	5	*0.35*
North-facing Spruce/Fir/Lodgepole Pine	*1E-06*	2046	62	24	2.2	8.8	0	10	2	6	1	0	*0.35*
South-facing Spruce/Fir/Lodgepole Pine	*1E-06*	1972	151	18	2.2	8.8	0	10	2	6	1	0	*0.35*
Level Spruce/Fir/Lodgepole Pine	*1E-06*	1931	0	4	2.2	8.8	0	10	2	6	1	0	*0.35*
Forest Clearings	0.40	1927	140	11	1.1	3.3	1	3	2	6	0	0	806
Level Lodgepole Pine	*1E-06*	1882	0	3	2.2	6.6	0	10	2	6	1	0	*0.35*
South-facing Lodgepole Pine	*1E-06*	1798	204	18	2.2	6.6	0	10	2	6	1	0	*0.35*
North-facing Lodgepole Pine	*1E-06*	1780	76	25	2.2	6.6	0	10	2	6	1	0	*0.35*
Valley Bottom	0.04	1951	135	18	2.2	6.6	0	10	2	6	1	0	2337
Fire Disturbance	**1.4990**	**1981**	**121**	**19**	**0.1**	**0**	**1**	**0.1**	**0**	**1**	**0**	**1**	**1785**
Middle Creek Sub-basin													
North-facing Alpine Rock	0.52	2462	82	31	0.1	0	1	0.14	2	1	0	1	944
South-facing Alpine Rock	1.37	2422	148	30	0.1	0	1	0.14	2	1	0	5	1689
South-facing Alpine Larch/Spruce	*1E-06*	2246	138	20	1.1	6.6	0	3	2	6	0	5	*0.35*
North-facing Alpine Larch/Spruce	*1E-06*	2211	46	18	1.1	6.6	0	3	2	6	0	5	*0.35*
North-facing Spruce/Fir/Lodgepole Pine	*1E-06*	1995	76	21	2.2	8.8	0	10	2	6	1	0	*0.35*
South-facing Spruce/Fir/Lodgepole Pine	*1E-06*	1953	134	22	2.2	8.8	0	10	2	6	1	0	*0.35*
Valley Bottom	0.03	2057	115	16	2.2	6.6	0	10	2	6	1	0	2907
Fire Disturbance	**1.0131**	**2053**	**119**	**21**	**0.1**	**0**	**1**	**0.1**	**0**	**1**	**0**	**1**	**1411**
Twin Creek Sub-basin													
North-facing Alpine Rock	0.79	2386	67	28	0.1	0	1	0.14	2	1	0	1	1217
South-facing Alpine Rock	0.15	2380	106	22	0.1	0	1	0.14	2	1	0	5	457
South-facing Alpine Larch/Spruce	*1E-06*	2228	116	23	1.1	6.6	0	3	2	6	0	5	*0.35*
North-facing Alpine Larch/Spruce	*1E-06*	2182	37	22	1.1	6.6	0	3	2	6	0	5	*0.35*
North-facing Spruce/Fir/Lodgepole Pine	*1E-06*	1966	34	17	2.2	8.8	0	10	2	6	1	0	*0.35*
South-facing Spruce/Fir/Lodgepole Pine	*1E-06*	2014	113	21	2.2	8.8	0	10	2	6	1	0	*0.35*
Valley Bottom	0.04	1988	119	16	2.2	6.6	0	10	2	6	1	0	2443
Fire Disturbance	**1.7982**	**2056**	**74**	**20**	**0.1**	**0**	**1**	**0.1**	**0**	**1**	**0**	**1**	**1991**
Marmot Confluence Sub-basin													
Forest Clearings	0.01	1903	55	11	1.1	3.3	1	3	2	6	0	1	90
North-facing Lodgepole Pine/Aspen	*1E-06*	1786	54	13	2.2	8.8	0	10	2	6	1	0	*0.35*
South-facing Lodgepole Pine/Aspen	*1E-06*	1725	159	13	2.2	8.8	0	10	2	6	1	0	*0.35*
Level Lodgepole Pine/Aspen	*1E-06*	1688	0	4	2.2	8.8	0	10	2	6	1	0	*0.35*
South-facing Lodgepole Pine	*1E-06*	1752	172	17	2.2	6.6	0	10	2	6	1	0	*0.35*
Level Lodgepole Pine	*1E-06*	1724	0	4	2.2	6.6	0	10	2	6	1	0	*0.35*
North-facing Lodgepole Pine	*1E-06*	1687	71	14	2.2	6.6	0	10	2	6	1	0	*0.35*
Valley Bottom	0.02	1664	163	8	2.2	6.6	0	10	2	6	1	0	1998
Fire Disturbance	**1.2760**	**1747**	**113**	**14**	**0.1**	**0**	**1**	**0.1**	**0**	**1**	**0**	**1**	**1620**

Table A22. HRU parameters in the forest disturbance scenario 22: reduction of forest by 20% on south facing slope.

HRU	Area (km^2)	Mean Elevation (m)	Mean Aspect (˚)	Mean Slope (˚)	LAI	Canopy Snow Interception Load Capacity (kg/m2)	Canopy Clearing	Vegetation Height (m)	cov_type	groundcover	inhibit_bs	distrib	Routing Length (m)
						Cabin Creek Sub-basin							
South-facing Alpine Rock	0.23	2387	122	36	0.1	0	1	0.14	2	1	0	1	575
North-facing Alpine Rock	0.17	2379	69	37	0.1	0	1	0.14	2	1	0	5	485
North-facing Alpine Larch/Spruce	0.02	2222	60	35	1.1	6.6	0	3	2	6	0	5	137
South-facing Alpine Larch/Spruce	*0.0153*	2194	115	32	1.1	6.6	0	3	2	6	0	5	*114*
North-facing Spruce/Fir/Lodgepole Pine	0.35	2046	62	24	2.2	8.8	0	10	2	6	1	0	742
South-facing Spruce/Fir/Lodgepole Pine	*0.7426*	1972	151	18	2.2	8.8	0	10	2	6	1	0	*1171*
Level Spruce/Fir/Lodgepole Pine	0.05	1931	0	4	2.2	8.8	0	10	2	6	1	0	225
Forest Clearings	0.40	1927	140	11	1.1	3.3	1	3	2	6	0	0	806
Level Lodgepole Pine	0.05	1882	0	3	2.2	6.6	0	10	2	6	1	0	244
South-facing Lodgepole Pine	*0.0581*	1798	204	18	2.2	6.6	0	10	2	6	1	0	*254*
North-facing Lodgepole Pine	0.01	1780	76	25	2.2	6.6	0	10	2	6	1	0	84
Valley Bottom	0.04	1951	135	18	2.2	6.6	0	10	2	6	1	0	2337
South-facing Clearings	**0.2040**	**1964**	**154**	**18**	**0.1**	**0**	**1**	**0.1**	**2**	**1**	**0**	**1**	**539**
						Middle Creek Sub-basin							
North-facing Alpine Rock	0.52	2462	82	31	0.1	0	1	0.14	2	1	0	1	944
South-facing Alpine Rock	1.37	2422	148	30	0.1	0	1	0.14	2	1	0	5	1689
South-facing Alpine Larch/Spruce	*0.2047*	2246	138	20	1.1	6.6	0	3	2	6	0	5	*541*
North-facing Alpine Larch/Spruce	0.08	2211	46	18	1.1	6.6	0	3	2	6	0	5	303
North-facing Spruce/Fir/Lodgepole Pine	0.16	1995	76	21	2.2	8.8	0	10	2	6	1	0	462
South-facing Spruce/Fir/Lodgepole Pine	*0.4173*	1953	134	22	2.2	8.8	0	10	2	6	1	0	*829*
Valley Bottom	0.03	2057	115	16	2.2	6.6	0	10	2	6	1	0	2907
South-facing Clearings	**0.1555**	**2049**	**135**	**21**	**0.1**	**0**	**1**	**0.1**	**2**	**1**	**0**	**1**	**458**
						Twin Creek Sub-basin							
North-facing Alpine Rock	0.79	2386	67	28	0.1	0	1	0.14	2	1	0	1	1218
South-facing Alpine Rock	0.15	2380	106	22	0.1	0	1	0.14	2	1	0	5	457
South-facing Alpine Larch/Spruce	*0.2226*	2228	116	23	1.1	6.6	0	3	2	6	0	5	*568*
North-facing Alpine Larch/Spruce	0.28	2182	37	22	1.1	6.6	0	3	2	6	0	5	655
North-facing Spruce/Fir/Lodgepole Pine	0.64	1966	34	17	2.2	8.8	0	10	2	6	1	0	1071
South-facing Spruce/Fir/Lodgepole Pine	*0.4785*	2014	113	21	2.2	8.8	0	10	2	6	1	0	*900*
Valley Bottom	0.04	1988	119	16	2.2	6.6	0	10	2	6	1	0	2443
South-facing Clearings	**0.1753**	**2082**	**114**	**22**	**0.1**	**0**	**1**	**0.1**	**2**	**1**	**0**	**1**	**492**
						Marmot Confluence Sub-basin							
Forest Clearings	0.01	1903	55	11	1.1	3.3	1	3	2	6	0	1	90
North-facing Lodgepole Pine/Aspen	0.38	1786	54	13	2.2	8.8	0	10	2	6	1	0	786
South-facing Lodgepole Pine/Aspen	*0.1911*	1725	159	13	2.2	8.8	0	10	2	6	1	0	*519*
Level Lodgepole Pine/Aspen	0.04	1688	0	4	2.2	8.8	0	10	2	6	1	0	210
South-facing Lodgepole Pine	*0.3504*	1752	172	17	2.2	6.6	0	10	2	6	1	0	*746*
Level Lodgepole Pine	0.02	1724	0	4	2.2	6.6	0	10	2	6	1	0	150
North-facing Lodgepole Pine	0.15	1687	71	14	2.2	6.6	0	10	2	6	1	0	450
Valley Bottom	0.02	1664	163	8	2.2	6.6	0	10	2	6	1	0	1998
South-facing Clearings	**0.1354**	**1742**	**167**	**15**	**0.1**	**0**	**1**	**0.1**	**2**	**1**	**0**	**1**	**422**

Table A23. HRU parameters in the forest disturbance scenario 23: reduction of forest by 40% on south facing slope.

HRU	Area (km^2)	Mean Elevation (m)	Mean Aspect (°)	Mean Slope (°)	LAI	Canopy Snow Interception Load Capacity (kg/m2)	Canopy Clearing	Vegetation Height (m)	cov_type	groundcover	inhibit_bs	distrib	Routing Length (m)
Cabin Creek Sub-basin													
South-facing Alpine Rock	0.23	2387	122	36	0.1	0	1	0.14	2	1	0	1	575
North-facing Alpine Rock	0.17	2379	69	37	0.1	0	1	0.14	2	1	0	5	485
North-facing Alpine Larch/Spruce	0.02	2222	60	35	1.1	6.6	0	3	2	6	0	5	137
South-facing Alpine Larch/Spruce	*0.0115*	2194	115	32	1.1	6.6	0	3	2	6	0	5	*96*
North-facing Spruce/Fir/Lodgepole Pine	0.35	2046	62	24	2.2	8.8	0	10	2	6	1	0	742
South-facing Spruce/Fir/Lodgepole Pine	*0.5570*	1972	151	18	2.2	8.8	0	10	2	6	1	0	*985*
Level Spruce/Fir/Lodgepole Pine	0.05	1931	0	4	2.2	8.8	0	10	2	6	1	0	225
Forest Clearings	0.40	1927	140	11	1.1	3.3	1	3	2	6	0	0	806
Level Lodgepole Pine	0.05	1882	0	3	2.2	6.6	0	10	2	6	1	0	244
South-facing Lodgepole Pine	*0.0436*	1798	204	18	2.2	6.6	0	10	2	6	1	0	*214*
North-facing Lodgepole Pine	0.01	1780	76	25	2.2	6.6	0	10	2	6	1	0	84
Valley Bottom	0.04	1951	135	18	2.2	6.6	0	10	2	6	1	0	2337
South-facing Clearings	**0.4080**	**1964**	**154**	**18**	**0.1**	**0**	**1**	**0.1**	**2**	**1**	**0**	**1**	**818**
Middle Creek Sub-basin													
North-facing Alpine Rock	0.52	2462	82	31	0.1	0	1	0.14	2	1	0	1	944
South-facing Alpine Rock	1.37	2422	148	30	0.1	0	1	0.14	2	1	0	5	1689
South-facing Alpine Larch/Spruce	*0.1536*	2246	138	20	1.1	6.6	0	3	2	6	0	5	*455*
North-facing Alpine Larch/Spruce	0.08	2211	46	18	1.1	6.6	0	3	2	6	0	5	303
North-facing Spruce/Fir/Lodgepole Pine	0.16	1995	76	21	2.2	8.8	0	10	2	6	1	0	462
South-facing Spruce/Fir/Lodgepole Pine	*0.3130*	1953	134	22	2.2	8.8	0	10	2	6	1	0	*697*
Valley Bottom	0.03	2057	115	16	2.2	6.6	0	10	2	6	1	0	2907
South-facing Clearings	**0.3110**	**2049**	**135**	**21**	**0.1**	**0**	**1**	**0.1**	**2**	**1**	**0**	**1**	**695**
Twin Creek Sub-basin													
North-facing Alpine Rock	0.79	2386	67	28	0.1	0	1	0.14	2	1	0	1	1218
South-facing Alpine Rock	0.15	2380	106	22	0.1	0	1	0.14	2	1	0	5	457
South-facing Alpine Larch/Spruce	*0.1670*	2228	116	23	1.1	6.6	0	3	2	6	0	5	*478*
North-facing Alpine Larch/Spruce	0.28	2182	37	22	1.1	6.6	0	3	2	6	0	5	655
North-facing Spruce/Fir/Lodgepole Pine	0.64	1966	34	17	2.2	8.8	0	10	2	6	1	0	1071
South-facing Spruce/Fir/Lodgepole Pine	*0.3589*	2014	113	21	2.2	8.8	0	10	2	6	1	0	*757*
Valley Bottom	0.04	1988	119	16	2.2	6.6	0	10	2	6	1	0	2443
South-facing Clearings	**0.3506**	**2082**	**114**	**22**	**0.1**	**0**	**1**	**0.1**	**2**	**1**	**0**	**1**	**746**
Marmot Confluence Sub-basin													
Forest Clearings	0.01	1903	55	11	1.1	3.3	1	3	2	6	0	1	90
North-facing Lodgepole Pine/Aspen	0.38	1786	54	13	2.2	8.8	0	10	2	6	1	0	786
South-facing Lodgepole Pine/Aspen	*0.1433*	1725	159	13	2.2	8.8	0	10	2	6	1	0	*436*
Level Lodgepole Pine/Aspen	0.04	1688	0	4	2.2	8.8	0	10	2	6	1	0	210
South-facing Lodgepole Pine	*0.2628*	1752	172	17	2.2	6.6	0	10	2	6	1	0	*628*
Level Lodgepole Pine	0.02	1724	0	4	2.2	6.6	0	10	2	6	1	0	150
North-facing Lodgepole Pine	0.15	1687	71	14	2.2	6.6	0	10	2	6	1	0	450
Valley Bottom	0.02	1664	163	8	2.2	6.6	0	10	2	6	1	0	1998
South-facing Clearings	**0.2707**	**1742**	**167**	**15**	**0.1**	**0**	**1**	**0.1**	**2**	**1**	**0**	**1**	**639**

Table A24. HRU parameters in the forest disturbance scenario 24: reduction of forest by 60% on south facing slope.

HRU	Area (km^2)	Mean Elevation (m)	Mean Aspect (˚)	Mean Slope (˚)	LAI	Canopy Snow Interception Load Capacity (kg/m2)	Canopy Clearing	Vegetation Height (m)	cov_type	groundcover	inhibit_bs	distrib	Routing Length (m)
Cabin Creek Sub-basin													
South-facing Alpine Rock	0.23	2387	122	36	0.1	0	1	0.14	2	1	0	1	575
North-facing Alpine Rock	0.17	2379	69	37	0.1	0	1	0.14	2	1	0	5	485
North-facing Alpine Larch/Spruce	0.02	2222	60	35	1.1	6.6	0	3	2	6	0	5	137
South-facing Alpine Larch/Spruce	*0.0076*	2194	115	32	1.1	6.6	0	3	2	6	0	5	*75*
North-facing Spruce/Fir/Lodgepole Pine	0.35	2046	62	24	2.2	8.8	0	10	2	6	1	0	742
South-facing Spruce/Fir/Lodgepole Pine	*0.3713*	1972	151	18	2.2	8.8	0	10	2	6	1	0	*773*
Level Spruce/Fir/Lodgepole Pine	0.05	1931	0	4	2.2	8.8	0	10	2	6	1	0	225
Forest Clearings	0.40	1927	140	11	1.1	3.3	1	3	2	6	0	0	806
Level Lodgepole Pine	0.05	1882	0	3	2.2	6.6	0	10	2	6	1	0	244
South-facing Lodgepole Pine	*0.0291*	1798	204	18	2.2	6.6	0	10	2	6	1	0	*168*
North-facing Lodgepole Pine	0.01	1780	76	25	2.2	6.6	0	10	2	6	1	0	84
Valley Bottom	0.04	1951	135	18	2.2	6.6	0	10	2	6	1	0	2337
South-facing Clearings	**0.6120**	**1964**	**154**	**18**	**0.1**	**0**	**1**	**0.1**	**2**	**1**	**0**	**1**	**1043**
Middle Creek Sub-basin													
North-facing Alpine Rock	0.52	2462	82	31	0.1	0	1	0.14	2	1	0	1	944
South-facing Alpine Rock	1.37	2422	148	30	0.1	0	1	0.14	2	1	0	5	1689
South-facing Alpine Larch/Spruce	*0.1024*	2246	138	20	1.1	6.6	0	3	2	6	0	5	*357*
North-facing Alpine Larch/Spruce	0.08	2211	46	18	1.1	6.6	0	3	2	6	0	5	303
North-facing Spruce/Fir/Lodgepole Pine	0.16	1995	76	21	2.2	8.8	0	10	2	6	1	0	462
South-facing Spruce/Fir/Lodgepole Pine	*0.2087*	1953	134	22	2.2	8.8	0	10	2	6	1	0	*547*
Valley Bottom	0.03	2057	115	16	2.2	6.6	0	10	2	6	1	0	2907
South-facing Clearings	**0.4666**	**2049**	**135**	**21**	**0.1**	**0**	**1**	**0.1**	**2**	**1**	**0**	**1**	**886**
Twin Creek Sub-basin													
North-facing Alpine Rock	0.79	2386	67	28	0.1	0	1	0.14	2	1	0	1	1218
South-facing Alpine Rock	0.15	2380	106	22	0.1	0	1	0.14	2	1	0	5	457
South-facing Alpine Larch/Spruce	*0.1113*	2228	116	23	1.1	6.6	0	3	2	6	0	5	*375*
North-facing Alpine Larch/Spruce	0.28	2182	37	22	1.1	6.6	0	3	2	6	0	5	655
North-facing Spruce/Fir/Lodgepole Pine	0.64	1966	34	17	2.2	8.8	0	10	2	6	1	0	1071
South-facing Spruce/Fir/Lodgepole Pine	*0.2392*	2014	113	21	2.2	8.8	0	10	2	6	1	0	*594*
Valley Bottom	0.04	1988	119	16	2.2	6.6	0	10	2	6	1	0	2443
South-facing Clearings	**0.5258**	**2082**	**114**	**22**	**0.1**	**0**	**1**	**0.1**	**2**	**1**	**0**	**1**	**952**
Marmot Confluence Sub-basin													
Forest Clearings	0.01	1903	55	11	1.1	3.3	1	3	2	6	0	1	90
North-facing Lodgepole Pine/Aspen	0.38	1786	54	13	2.2	8.8	0	10	2	6	1	0	786
South-facing Lodgepole Pine/Aspen	*0.0955*	1725	159	13	2.2	8.8	0	10	2	6	1	0	*342*
Level Lodgepole Pine/Aspen	0.04	1688	0	4	2.2	8.8	0	10	2	6	1	0	210
South-facing Lodgepole Pine	*0.1752*	1752	172	17	2.2	6.6	0	10	2	6	1	0	*492*
Level Lodgepole Pine	0.02	1724	0	4	2.2	6.6	0	10	2	6	1	0	150
North-facing Lodgepole Pine	0.15	1687	71	14	2.2	6.6	0	10	2	6	1	0	450
Valley Bottom	0.02	1664	163	8	2.2	6.6	0	10	2	6	1	0	1998
South-facing Clearings	**0.4061**	**1742**	**167**	**15**	**0.1**	**0**	**1**	**0.1**	**2**	**1**	**0**	**1**	**815**

Table A25. HRU parameters in the forest disturbance scenario 25: reduction of forest by 80% on south facing slope.

HRU	Area (km^2)	Mean Elevation (m)	Mean Aspect (˚)	Mean Slope (˚)	LAI	Canopy Snow Interception Load Capacity (kg/m2)	Canopy Clearing	Vegetation Height (m)	cov_type	groundcover	inhibit_bs	distrib	Routing Length (m)
						Cabin Creek Sub-basin							
South-facing Alpine Rock	0.23	2387	122	36	0.1	0	1	0.14	2	1	0	1	575
North-facing Alpine Rock	0.17	2379	69	37	0.1	0	1	0.14	2	1	0	5	485
North-facing Alpine Larch/Spruce	0.02	2222	60	35	1.1	6.6	0	3	2	6	0	5	137
South-facing Alpine Larch/Spruce	*0.0038*	2194	115	32	1.1	6.6	0	3	2	6	0	5	*50*
North-facing Spruce/Fir/Lodgepole Pine	0.35	2046	62	24	2.2	8.8	0	10	2	6	1	0	742
South-facing Spruce/Fir/Lodgepole Pine	*0.1857*	1972	151	18	2.2	8.8	0	10	2	6	1	0	*510*
Level Spruce/Fir/Lodgepole Pine	0.05	1931	0	4	2.2	8.8	0	10	2	6	1	0	225
Forest Clearings	0.40	1927	140	11	1.1	3.3	1	3	2	6	0	0	806
Level Lodgepole Pine	0.05	1882	0	3	2.2	6.6	0	10	2	6	1	0	244
South-facing Lodgepole Pine	*0.0145*	1798	204	18	2.2	6.6	0	10	2	6	1	0	*111*
North-facing Lodgepole Pine	0.01	1780	76	25	2.2	6.6	0	10	2	6	1	0	84
Valley Bottom	0.04	1951	135	18	2.2	6.6	0	10	2	6	1	0	2337
South-facing Clearings	**0.8160**	**1964**	**154**	**18**	**0.1**	**0**	**1**	**0.1**	**2**	**1**	**0**	**1**	**1239**
						Middle Creek Sub-basin							
North-facing Alpine Rock	0.52	2462	82	31	0.1	0	1	0.14	2	1	0	1	944
South-facing Alpine Rock	1.37	2422	148	30	0.1	0	1	0.14	2	1	0	5	1689
South-facing Alpine Larch/Spruce	*0.0512*	2246	138	20	1.1	6.6	0	3	2	6	0	5	*235*
North-facing Alpine Larch/Spruce	0.08	2211	46	18	1.1	6.6	0	3	2	6	0	5	303
North-facing Spruce/Fir/Lodgepole Pine	0.16	1995	76	21	2.2	8.8	0	10	2	6	1	0	462
South-facing Spruce/Fir/Lodgepole Pine	*0.1043*	1953	134	22	2.2	8.8	0	10	2	6	1	0	*361*
Valley Bottom	0.03	2057	115	16	2.2	6.6	0	10	2	6	1	0	2907
South-facing Clearings	**0.6221**	**2049**	**135**	**21**	**0.1**	**0**	**1**	**0.1**	**2**	**1**	**0**	**1**	**1053**
						Twin Creek Sub-basin							
North-facing Alpine Rock	0.79	2386	67	28	0.1	0	1	0.14	2	1	0	1	1218
South-facing Alpine Rock	0.15	2380	106	22	0.1	0	1	0.14	2	1	0	5	457
South-facing Alpine Larch/Spruce	*0.0557*	2228	116	23	1.1	6.6	0	3	2	6	0	5	*247*
North-facing Alpine Larch/Spruce	0.28	2182	37	22	1.1	6.6	0	3	2	6	0	5	655
North-facing Spruce/Fir/Lodgepole Pine	0.64	1966	34	17	2.2	8.8	0	10	2	6	1	0	1071
South-facing Spruce/Fir/Lodgepole Pine	*0.1196*	2014	113	21	2.2	8.8	0	10	2	6	1	0	*392*
Valley Bottom	0.04	1988	119	16	2.2	6.6	0	10	2	6	1	0	2443
South-facing Clearings	**0.7011**	**2082**	**114**	**22**	**0.1**	**0**	**1**	**0.1**	**2**	**1**	**0**	**1**	**1131**
						Marmot Confluence Sub-basin							
Forest Clearings	0.01	1903	55	11	1.1	3.3	1	3	2	6	0	1	90
North-facing Lodgepole Pine/Aspen	0.38	1786	54	13	2.2	8.8	0	10	2	6	1	0	786
South-facing Lodgepole Pine/Aspen	*0.0478*	1725	159	13	2.2	8.8	0	10	2	6	1	0	*226*
Level Lodgepole Pine/Aspen	0.04	1688	0	4	2.2	8.8	0	10	2	6	1	0	210
South-facing Lodgepole Pine	*0.0876*	1752	172	17	2.2	6.6	0	10	2	6	1	0	*325*
Level Lodgepole Pine	0.02	1724	0	4	2.2	6.6	0	10	2	6	1	0	150
North-facing Lodgepole Pine	0.15	1687	71	14	2.2	6.6	0	10	2	6	1	0	450
Valley Bottom	0.02	1664	163	8	2.2	6.6	0	10	2	6	1	0	1998
South-facing Clearings	**0.5415**	**1742**	**167**	**15**	**0.1**	**0**	**1**	**0.1**	**2**	**1**	**0**	**1**	**969**

Table A26. HRU parameters in the forest disturbance scenario 26: reduction of forest by 100% on south facing slope.

HRU	Area (km^2)	Mean Elevation (m)	Mean Aspect (˚)	Mean Slope (˚)	LAI	Canopy Snow Interception Load Capacity (kg/m2)	Canopy Clearing	Vegetation Height (m)	cov_type	groundcover	inhibit_bs	distrib	Routing Length (m)
Cabin Creek Sub-basin													
South-facing Alpine Rock	0.23	2387	122	36	0.1	0	1	0.14	2	1	0	1	575
North-facing Alpine Rock	0.17	2379	69	37	0.1	0	1	0.14	2	1	0	5	485
North-facing Alpine Larch/Spruce	0.02	2222	60	35	1.1	6.6	0	3	2	6	0	5	137
South-facing Alpine Larch/Spruce	*1E-06*	2194	115	32	1.1	6.6	0	3	2	6	0	5	*0.35*
North-facing Spruce/Fir/Lodgepole Pine	0.35	2046	62	24	2.2	8.8	0	10	2	6	1	0	742
South-facing Spruce/Fir/Lodgepole Pine	*1E-06*	1972	151	18	2.2	8.8	0	10	2	6	1	0	*0.35*
Level Spruce/Fir/Lodgepole Pine	0.05	1931	0	4	2.2	8.8	0	10	2	6	1	0	225
Forest Clearings	0.40	1927	140	11	1.1	3.3	1	3	2	6	0	0	806
Level Lodgepole Pine	0.05	1882	0	3	2.2	6.6	0	10	2	6	1	0	244
South-facing Lodgepole Pine	*1E-06*	1798	204	18	2.2	6.6	0	10	2	6	1	0	*0.35*
North-facing Lodgepole Pine	0.01	1780	76	25	2.2	6.6	0	10	2	6	1	0	84
Valley Bottom	0.04	1951	135	18	2.2	6.6	0	10	2	6	1	0	2337
South-facing Clearings	**1.0200**	**1964**	**154**	**18**	**0.1**	**0**	**1**	**0.1**	**2**	**1**	**0**	**1**	**1417**
Middle Creek Sub-basin													
North-facing Alpine Rock	0.52	2462	82	31	0.1	0	1	0.14	2	1	0	1	944
South-facing Alpine Rock	1.37	2422	148	30	0.1	0	1	0.14	2	1	0	5	1689
South-facing Alpine Larch/Spruce	*1E-06*	2246	138	20	1.1	6.6	0	3	2	6	0	5	*0.35*
North-facing Alpine Larch/Spruce	0.08	2211	46	18	1.1	6.6	0	3	2	6	0	5	303
North-facing Spruce/Fir/Lodgepole Pine	0.16	1995	76	21	2.2	8.8	0	10	2	6	1	0	462
South-facing Spruce/Fir/Lodgepole Pine	*1E-06*	1953	134	22	2.2	8.8	0	10	2	6	1	0	*0.35*
Valley Bottom	0.03	2057	115	16	2.2	6.6	0	10	2	6	1	0	2907
South-facing Clearings	**0.7776**	**2049**	**135**	**21**	**0.1**	**0**	**1**	**0.1**	**2**	**1**	**0**	**1**	**1204**
Twin Creek Sub-basin													
North-facing Alpine Rock	0.79	2386	67	28	0.1	0	1	0.14	2	1	0	1	1218
South-facing Alpine Rock	0.15	2380	106	22	0.1	0	1	0.14	2	1	0	5	457
South-facing Alpine Larch/Spruce	*1E-06*	2228	116	23	1.1	6.6	0	3	2	6	0	5	*0.35*
North-facing Alpine Larch/Spruce	0.28	2182	37	22	1.1	6.6	0	3	2	6	0	5	655
North-facing Spruce/Fir/Lodgepole Pine	0.64	1966	34	17	2.2	8.8	0	10	2	6	1	0	1071
South-facing Spruce/Fir/Lodgepole Pine	*1E-06*	2014	113	21	2.2	8.8	0	10	2	6	1	0	*0.35*
Valley Bottom	0.04	1988	119	16	2.2	6.6	0	10	2	6	1	0	2443
South-facing Clearings	**0.8764**	**2082**	**114**	**22**	**0.1**	**0**	**1**	**0.1**	**2**	**1**	**0**	**1**	**1293**
Marmot Confluence Sub-basin													
Forest Clearings	0.01	1903	55	11	1.1	3.3	1	3	2	6	0	1	90
North-facing Lodgepole Pine/Aspen	0.38	1786	54	13	2.2	8.8	0	10	2	6	1	0	786
South-facing Lodgepole Pine/Aspen	*1E-06*	1725	159	13	2.2	8.8	0	10	2	6	1	0	*0.35*
Level Lodgepole Pine/Aspen	0.04	1688	0	4	2.2	8.8	0	10	2	6	1	0	210
South-facing Lodgepole Pine	*1E-06*	1752	172	17	2.2	6.6	0	10	2	6	1	0	*0.35*
Level Lodgepole Pine	0.02	1724	0	4	2.2	6.6	0	10	2	6	1	0	150
North-facing Lodgepole Pine	0.15	1687	71	14	2.2	6.6	0	10	2	6	1	0	450
Valley Bottom	0.02	1664	163	8	2.2	6.6	0	10	2	6	1	0	1998
South-facing Clearings	**0.6769**	**1742**	**167**	**15**	**0.1**	**0**	**1**	**0.1**	**2**	**1**	**0**	**1**	**1108**

Table A27. HRU parameters in the forest disturbance scenario 27: reduction of forest by 20% on north facing slope.

HRU	Area (km^2)	Mean Elevation (m)	Mean Aspect (˚)	Mean Slope (˚)	LAI	Canopy Snow Interception Load Capacity (kg/m2)	Canopy Clearing	Vegetation Height (m)	cov_type	groundcover	inhibit_bs	distrib	Routing Length (m)
						Cabin Creek Sub-basin							
South-facing Alpine Rock	0.23	2387	122	36	0.1	0	1	0.14	2	1	0	1	575
North-facing Alpine Rock	0.17	2379	69	37	0.1	0	1	0.14	2	1	0	5	485
North-facing Alpine Larch/Spruce	*0.0166*	2222	60	35	1.1	6.6	0	3	2	6	0	5	*120*
South-facing Alpine Larch/Spruce	0.02	2194	115	32	1.1	6.6	0	3	2	6	0	5	130
North-facing Spruce/Fir/Lodgepole Pine	*0.2778*	2046	62	24	2.2	8.8	0	10	2	6	1	0	*649*
South-facing Spruce/Fir/Lodgepole Pine	0.93	1972	151	18	2.2	8.8	0	10	2	6	1	0	1339
Level Spruce/Fir/Lodgepole Pine	0.05	1931	0	4	2.2	8.8	0	10	2	6	1	0	225
Forest Clearings	0.40	1927	140	11	1.1	3.3	1	3	2	6	0	0	806
Level Lodgepole Pine	0.05	1882	0	3	2.2	6.6	0	10	2	6	1	0	244
South-facing Lodgepole Pine	0.07	1798	204	18	2.2	6.6	0	10	2	6	1	0	290
North-facing Lodgepole Pine	*0.0074*	1780	76	25	2.2	6.6	0	10	2	6	1	0	*74*
Valley Bottom	0.04	1951	135	18	2.2	6.6	0	10	2	6	1	0	2337
North-facing Clearings	**0.0754**	**1964**	**154**	**18**	**0.1**	**0**	**1**	**0.1**	**2**	**1**	**0**	**1**	**297**
						Middle Creek Sub-basin							
North-facing Alpine Rock	0.52	2462	82	31	0.1	0	1	0.14	2	1	0	1	944
South-facing Alpine Rock	1.37	2422	148	30	0.1	0	1	0.14	2	1	0	5	1689
South-facing Alpine Larch/Spruce	0.26	2246	138	20	1.1	6.6	0	3	2	6	0	5	618
North-facing Alpine Larch/Spruce	*0.0623*	2211	46	18	1.1	6.6	0	3	2	6	0	5	*265*
North-facing Spruce/Fir/Lodgepole Pine	*0.1261*	1995	76	21	2.2	8.8	0	10	2	6	1	0	*404*
South-facing Spruce/Fir/Lodgepole Pine	0.52	1953	134	22	2.2	8.8	0	10	2	6	1	0	947
Valley Bottom	0.03	2057	115	16	2.2	6.6	0	10	2	6	1	0	2907
North-facing Clearings	**0.0471**	**2049**	**135**	**21**	**0.1**	**0**	**1**	**0.1**	**2**	**1**	**0**	**1**	**224**
						Twin Creek Sub-basin							
North-facing Alpine Rock	0.79	2386	67	28	0.1	0	1	0.14	2	1	0	1	1218
South-facing Alpine Rock	0.15	2380	106	22	0.1	0	1	0.14	2	1	0	5	457
South-facing Alpine Larch/Spruce	0.28	2228	116	23	1.1	6.6	0	3	2	6	0	5	650
North-facing Alpine Larch/Spruce	*0.2253*	2182	37	22	1.1	6.6	0	3	2	6	0	5	*573*
North-facing Spruce/Fir/Lodgepole Pine	*0.5121*	1966	34	17	2.2	8.8	0	10	2	6	1	0	*937*
South-facing Spruce/Fir/Lodgepole Pine	0.60	2014	113	21	2.2	8.8	0	10	2	6	1	0	1028
Valley Bottom	0.04	1988	119	16	2.2	6.6	0	10	2	6	1	0	2443
North-facing Clearings	**0.1844**	**2082**	**114**	**22**	**0.1**	**0**	**1**	**0.1**	**2**	**1**	**0**	**1**	**508**
						Marmot Confluence Sub-basin							
Forest Clearings	0.01	1903	55	11	1.1	3.3	1	3	2	6	0	1	90
North-facing Lodgepole Pine/Aspen	*0.3055*	1786	54	13	2.2	8.8	0	10	2	6	1	0	*687*
South-facing Lodgepole Pine/Aspen	0.24	1725	159	13	2.2	8.8	0	10	2	6	1	0	593
Level Lodgepole Pine/Aspen	0.04	1688	0	4	2.2	8.8	0	10	2	6	1	0	210
South-facing Lodgepole Pine	0.44	1752	172	17	2.2	6.6	0	10	2	6	1	0	853
Level Lodgepole Pine	0.02	1724	0	4	2.2	6.6	0	10	2	6	1	0	150
North-facing Lodgepole Pine	*0.1205*	1687	71	14	2.2	6.6	0	10	2	6	1	0	*393*
Valley Bottom	0.02	1664	163	8	2.2	6.6	0	10	2	6	1	0	1998
North-facing Clearings	**0.1065**	**1742**	**167**	**15**	**0.1**	**0**	**1**	**0.1**	**2**	**1**	**0**	**1**	**365**

Table A28. HRU parameters in the forest disturbance scenario 28: reduction of forest by 40% on north facing slope.

HRU	Area (km^2)	Mean Elevation (m)	Mean Aspect (˚)	Mean Slope (˚)	LAI	Canopy Snow Interception Load Capacity (kg/m2)	Canopy Clearing	Vegetation Height (m)	cov_type	groundcover	inhibit_bs	distrib	Routing Length (m)
Cabin Creek Sub-basin													
South-facing Alpine Rock	0.23	2387	122	36	0.1	0	1	0.14	2	1	0	1	575
North-facing Alpine Rock	0.17	2379	69	37	0.1	0	1	0.14	2	1	0	5	485
North-facing Alpine Larch/Spruce	*0.0125*	2222	60	35	1.1	6.6	0	3	2	6	0	5	*101*
South-facing Alpine Larch/Spruce	0.02	2194	115	32	1.1	6.6	0	3	2	6	0	5	130
North-facing Spruce/Fir/Lodgepole Pine	*0.2083*	2046	62	24	2.2	8.8	0	10	2	6	1	0	*546*
South-facing Spruce/Fir/Lodgepole Pine	0.93	1972	151	18	2.2	8.8	0	10	2	6	1	0	1339
Level Spruce/Fir/Lodgepole Pine	0.05	1931	0	4	2.2	8.8	0	10	2	6	1	0	225
Forest Clearings	0.40	1927	140	11	1.1	3.3	1	3	2	6	0	0	806
Level Lodgepole Pine	0.05	1882	0	3	2.2	6.6	0	10	2	6	1	0	244
South-facing Lodgepole Pine	0.07	1798	204	18	2.2	6.6	0	10	2	6	1	0	290
North-facing Lodgepole Pine	*0.0055*	1780	76	25	2.2	6.6	0	10	2	6	1	0	*62*
Valley Bottom	0.04	1951	135	18	2.2	6.6	0	10	2	6	1	0	2337
North-facing Clearings	**0.1509**	**1964**	**154**	**18**	**0.1**	**0**	**1**	**0.1**	**2**	**1**	**0**	**1**	**450**
Middle Creek Sub-basin													
North-facing Alpine Rock	0.52	2462	82	31	0.1	0	1	0.14	2	1	0	1	944
South-facing Alpine Rock	1.37	2422	148	30	0.1	0	1	0.14	2	1	0	5	1689
South-facing Alpine Larch/Spruce	0.26	2246	138	20	1.1	6.6	0	3	2	6	0	5	618
North-facing Alpine Larch/Spruce	*0.0467*	2211	46	18	1.1	6.6	0	3	2	6	0	5	*223*
North-facing Spruce/Fir/Lodgepole Pine	*0.0945*	1995	76	21	2.2	8.8	0	10	2	6	1	0	*340*
South-facing Spruce/Fir/Lodgepole Pine	0.52	1953	134	22	2.2	8.8	0	10	2	6	1	0	947
Valley Bottom	0.03	2057	115	16	2.2	6.6	0	10	2	6	1	0	2907
North-facing Clearings	**0.0942**	**2049**	**135**	**21**	**0.1**	**0**	**1**	**0.1**	**2**	**1**	**0**	**1**	**339**
Twin Creek Sub-basin													
North-facing Alpine Rock	0.79	2386	67	28	0.1	0	1	0.14	2	1	0	1	1218
South-facing Alpine Rock	0.15	2380	106	22	0.1	0	1	0.14	2	1	0	5	457
South-facing Alpine Larch/Spruce	0.28	2228	116	23	1.1	6.6	0	3	2	6	0	5	650
North-facing Alpine Larch/Spruce	*0.1690*	2182	37	22	1.1	6.6	0	3	2	6	0	5	*482*
North-facing Spruce/Fir/Lodgepole Pine	*0.3841*	1966	34	17	2.2	8.8	0	10	2	6	1	0	*788*
South-facing Spruce/Fir/Lodgepole Pine	0.60	2014	113	21	2.2	8.8	0	10	2	6	1	0	1028
Valley Bottom	0.04	1988	119	16	2.2	6.6	0	10	2	6	1	0	2443
North-facing Clearings	**0.3687**	**2082**	**114**	**22**	**0.1**	**0**	**1**	**0.1**	**2**	**1**	**0**	**1**	**769**
Marmot Confluence Sub-basin													
Forest Clearings	0.01	1903	55	11	1.1	3.3	1	3	2	6	0	1	90
North-facing Lodgepole Pine/Aspen	*0.2291*	1786	54	13	2.2	8.8	0	10	2	6	1	0	*578*
South-facing Lodgepole Pine/Aspen	0.24	1725	159	13	2.2	8.8	0	10	2	6	1	0	593
Level Lodgepole Pine/Aspen	0.04	1688	0	4	2.2	8.8	0	10	2	6	1	0	210
South-facing Lodgepole Pine	0.44	1752	172	17	2.2	6.6	0	10	2	6	1	0	853
Level Lodgepole Pine	0.02	1724	0	4	2.2	6.6	0	10	2	6	1	0	150
North-facing Lodgepole Pine	*0.0904*	1687	71	14	2.2	6.6	0	10	2	6	1	0	*331*
Valley Bottom	0.02	1664	163	8	2.2	6.6	0	10	2	6	1	0	1998
North-facing Clearings	**0.2130**	**1742**	**167**	**15**	**0.1**	**0**	**1**	**0.1**	**2**	**1**	**0**	**1**	**554**

Table A29. HRU parameters in the forest disturbance scenario 29: reduction of forest by 60% on north facing slope.

HRU	Area (km^2)	Mean Elevation (m)	Mean Aspect (˚)	Mean Slope (˚)	LAI	Canopy Snow Interception Load Capacity (kg/m2)	Canopy Clearing	Vegetation Height (m)	cov_type	groundcover	inhibit_bs	distrib	Routing Length (m)
Cabin Creek Sub-basin													
South-facing Alpine Rock	0.23	2387	122	36	0.1	0	1	0.14	2	1	0	1	575
North-facing Alpine Rock	0.17	2379	69	37	0.1	0	1	0.14	2	1	0	5	485
North-facing Alpine Larch/Spruce	*0.0083*	2222	60	35	1.1	6.6	0	3	2	6	0	5	*79*
South-facing Alpine Larch/Spruce	0.02	2194	115	32	1.1	6.6	0	3	2	6	0	5	130
North-facing Spruce/Fir/Lodgepole Pine	*0.1389*	2046	62	24	2.2	8.8	0	10	2	6	1	0	*428*
South-facing Spruce/Fir/Lodgepole Pine	0.93	1972	151	18	2.2	8.8	0	10	2	6	1	0	1339
Level Spruce/Fir/Lodgepole Pine	0.05	1931	0	4	2.2	8.8	0	10	2	6	1	0	225
Forest Clearings	0.40	1927	140	11	1.1	3.3	1	3	2	6	0	0	806
Level Lodgepole Pine	0.05	1882	0	3	2.2	6.6	0	10	2	6	1	0	244
South-facing Lodgepole Pine	0.07	1798	204	18	2.2	6.6	0	10	2	6	1	0	290
North-facing Lodgepole Pine	*0.0037*	1780	76	25	2.2	6.6	0	10	2	6	1	0	*49*
Valley Bottom	0.04	1951	135	18	2.2	6.6	0	10	2	6	1	0	2337
North-facing Clearings	**0.2263**	**1964**	**154**	**18**	**0.1**	**0**	**1**	**0.1**	**2**	**1**	**0**	**1**	**574**
Middle Creek Sub-basin													
North-facing Alpine Rock	0.52	2462	82	31	0.1	0	1	0.14	2	1	0	1	944
South-facing Alpine Rock	1.37	2422	148	30	0.1	0	1	0.14	2	1	0	5	1689
South-facing Alpine Larch/Spruce	0.26	2246	138	20	1.1	6.6	0	3	2	6	0	5	618
North-facing Alpine Larch/Spruce	*0.0312*	2211	46	18	1.1	6.6	0	3	2	6	0	5	*175*
North-facing Spruce/Fir/Lodgepole Pine	*0.0630*	1995	76	21	2.2	8.8	0	10	2	6	1	0	*267*
South-facing Spruce/Fir/Lodgepole Pine	0.52	1953	134	22	2.2	8.8	0	10	2	6	1	0	947
Valley Bottom	0.03	2057	115	16	2.2	6.6	0	10	2	6	1	0	2907
North-facing Clearings	**0.1413**	**2049**	**135**	**21**	**0.1**	**0**	**1**	**0.1**	**2**	**1**	**0**	**1**	**433**
Twin Creek Sub-basin													
North-facing Alpine Rock	0.79	2386	67	28	0.1	0	1	0.14	2	1	0	1	1218
South-facing Alpine Rock	0.15	2380	106	22	0.1	0	1	0.14	2	1	0	5	457
South-facing Alpine Larch/Spruce	0.28	2228	116	23	1.1	6.6	0	3	2	6	0	5	650
North-facing Alpine Larch/Spruce	*0.1127*	2182	37	22	1.1	6.6	0	3	2	6	0	5	*378*
North-facing Spruce/Fir/Lodgepole Pine	*0.2561*	1966	34	17	2.2	8.8	0	10	2	6	1	0	*618*
South-facing Spruce/Fir/Lodgepole Pine	0.60	2014	113	21	2.2	8.8	0	10	2	6	1	0	1028
Valley Bottom	0.04	1988	119	16	2.2	6.6	0	10	2	6	1	0	2443
North-facing Clearings	**0.5531**	**2082**	**114**	**22**	**0.1**	**0**	**1**	**0.1**	**2**	**1**	**0**	**1**	**981**
Marmot Confluence Sub-basin													
Forest Clearings	0.01	1903	55	11	1.1	3.3	1	3	2	6	0	1	90
North-facing Lodgepole Pine/Aspen	*0.1528*	1786	54	13	2.2	8.8	0	10	2	6	1	0	*453*
South-facing Lodgepole Pine/Aspen	0.24	1725	159	13	2.2	8.8	0	10	2	6	1	0	593
Level Lodgepole Pine/Aspen	0.04	1688	0	4	2.2	8.8	0	10	2	6	1	0	210
South-facing Lodgepole Pine	0.44	1752	172	17	2.2	6.6	0	10	2	6	1	0	853
Level Lodgepole Pine	0.02	1724	0	4	2.2	6.6	0	10	2	6	1	0	150
North-facing Lodgepole Pine	*0.0603*	1687	71	14	2.2	6.6	0	10	2	6	1	0	*260*
Valley Bottom	0.02	1664	163	8	2.2	6.6	0	10	2	6	1	0	1998
North-facing Clearings	**0.3195**	**1742**	**167**	**15**	**0.1**	**0**	**1**	**0.1**	**2**	**1**	**0**	**1**	**706**

Table A30. HRU parameters in the forest disturbance scenario 30: reduction of forest by 80% on north facing slope.

HRU	Area (km^2)	Mean Elevation (m)	Mean Aspect (˚)	Mean Slope (˚)	LAI	Canopy Snow Interception Load Capacity (kg/m2)	Canopy Clearing	Vegetation Height (m)	cov_type	groundcover	inhibit_bs	distrib	Routing Length (m)
						Cabin Creek Sub-basin							
South-facing Alpine Rock	0.23	2387	122	36	0.1	0	1	0.14	2	1	0	1	575
North-facing Alpine Rock	0.17	2379	69	37	0.1	0	1	0.14	2	1	0	5	485
North-facing Alpine Larch/Spruce	*0.0042*	2222	60	35	1.1	6.6	0	3	2	6	0	5	*52*
South-facing Alpine Larch/Spruce	0.02	2194	115	32	1.1	6.6	0	3	2	6	0	5	130
North-facing Spruce/Fir/Lodgepole Pine	*0.0694*	2046	62	24	2.2	8.8	0	10	2	6	1	0	*283*
South-facing Spruce/Fir/Lodgepole Pine	0.93	1972	151	18	2.2	8.8	0	10	2	6	1	0	1339
Level Spruce/Fir/Lodgepole Pine	0.05	1931	0	4	2.2	8.8	0	10	2	6	1	0	225
Forest Clearings	0.40	1927	140	11	1.1	3.3	1	3	2	6	0	0	806
Level Lodgepole Pine	0.05	1882	0	3	2.2	6.6	0	10	2	6	1	0	244
South-facing Lodgepole Pine	0.07	1798	204	18	2.2	6.6	0	10	2	6	1	0	290
North-facing Lodgepole Pine	*0.0018*	1780	76	25	2.2	6.6	0	10	2	6	1	0	*32*
Valley Bottom	0.04	1951	135	18	2.2	6.6	0	10	2	6	1	0	2337
North-facing Clearings	**0.3018**	**1964**	**154**	**18**	**0.1**	**0**	**1**	**0.1**	**2**	**1**	**0**	**1**	**682**
						Middle Creek Sub-basin							
North-facing Alpine Rock	0.52	2462	82	31	0.1	0	1	0.14	2	1	0	1	944
South-facing Alpine Rock	1.37	2422	148	30	0.1	0	1	0.14	2	1	0	5	1689
South-facing Alpine Larch/Spruce	0.26	2246	138	20	1.1	6.6	0	3	2	6	0	5	618
North-facing Alpine Larch/Spruce	*0.0156*	2211	46	18	1.1	6.6	0	3	2	6	0	5	*115*
North-facing Spruce/Fir/Lodgepole Pine	*0.0315*	1995	76	21	2.2	8.8	0	10	2	6	1	0	*176*
South-facing Spruce/Fir/Lodgepole Pine	0.52	1953	134	22	2.2	8.8	0	10	2	6	1	0	947
Valley Bottom	0.03	2057	115	16	2.2	6.6	0	10	2	6	1	0	2907
North-facing Clearings	**0.1884**	**2049**	**135**	**21**	**0.1**	**0**	**1**	**0.1**	**2**	**1**	**0**	**1**	**514**
						Twin Creek Sub-basin							
North-facing Alpine Rock	0.79	2386	67	28	0.1	0	1	0.14	2	1	0	1	1218
South-facing Alpine Rock	0.15	2380	106	22	0.1	0	1	0.14	2	1	0	5	457
South-facing Alpine Larch/Spruce	0.28	2228	116	23	1.1	6.6	0	3	2	6	0	5	650
North-facing Alpine Larch/Spruce	*0.0563*	2182	37	22	1.1	6.6	0	3	2	6	0	5	*249*
North-facing Spruce/Fir/Lodgepole Pine	*0.1280*	1966	34	17	2.2	8.8	0	10	2	6	1	0	*408*
South-facing Spruce/Fir/Lodgepole Pine	0.60	2014	113	21	2.2	8.8	0	10	2	6	1	0	1028
Valley Bottom	0.04	1988	119	16	2.2	6.6	0	10	2	6	1	0	2443
North-facing Clearings	**0.7375**	**2082**	**114**	**22**	**0.1**	**0**	**1**	**0.1**	**2**	**1**	**0**	**1**	**1166**
						Marmot Confluence Sub-basin							
Forest Clearings	0.01	1903	55	11	1.1	3.3	1	3	2	6	0	1	90
North-facing Lodgepole Pine/Aspen	*0.0764*	1786	54	13	2.2	8.8	0	10	2	6	1	0	*299*
South-facing Lodgepole Pine/Aspen	0.24	1725	159	13	2.2	8.8	0	10	2	6	1	0	593
Level Lodgepole Pine/Aspen	0.04	1688	0	4	2.2	8.8	0	10	2	6	1	0	210
South-facing Lodgepole Pine	0.44	1752	172	17	2.2	6.6	0	10	2	6	1	0	853
Level Lodgepole Pine	0.02	1724	0	4	2.2	6.6	0	10	2	6	1	0	150
North-facing Lodgepole Pine	*0.0301*	1687	71	14	2.2	6.6	0	10	2	6	1	0	*171*
Valley Bottom	0.02	1664	163	8	2.2	6.6	0	10	2	6	1	0	1998
North-facing Clearings	**0.4260**	**1742**	**167**	**15**	**0.1**	**0**	**1**	**0.1**	**2**	**1**	**0**	**1**	**839**

Table A31. HRU parameters in the forest disturbance scenario 31: reduction of forest by 100% on north facing slope.

HRU	Area (km^2)	Mean Elevation (m)	Mean Aspect (˚)	Mean Slope (˚)	LAI	Canopy Snow Interception Load Capacity (kg/m2)	Canopy Clearing	Vegetation Height (m)	cov_type	groundcover	inhibit_bs	distrib	Routing Length (m)
						Cabin Creek Sub-basin							
South-facing Alpine Rock	0.23	2387	122	36	0.1	0	1	0.14	2	1	0	1	575
North-facing Alpine Rock	0.17	2379	69	37	0.1	0	1	0.14	2	1	0	5	485
North-facing Alpine Larch/Spruce	*1E-06*	2222	60	35	1.1	6.6	0	3	2	6	0	5	*0.35*
South-facing Alpine Larch/Spruce	0.02	2194	115	32	1.1	6.6	0	3	2	6	0	5	130
North-facing Spruce/Fir/Lodgepole Pine	*1E-06*	2046	62	24	2.2	8.8	0	10	2	6	1	0	*0.35*
South-facing Spruce/Fir/Lodgepole Pine	0.93	1972	151	18	2.2	8.8	0	10	2	6	1	0	1339
Level Spruce/Fir/Lodgepole Pine	0.05	1931	0	4	2.2	8.8	0	10	2	6	1	0	225
Forest Clearings	0.40	1927	140	11	1.1	3.3	1	3	2	6	0	0	806
Level Lodgepole Pine	0.05	1882	0	3	2.2	6.6	0	10	2	6	1	0	244
South-facing Lodgepole Pine	0.07	1798	204	18	2.2	6.6	0	10	2	6	1	0	290
North-facing Lodgepole Pine	*1E-06*	1780	76	25	2.2	6.6	0	10	2	6	1	0	*0.35*
Valley Bottom	0.04	1951	135	18	2.2	6.6	0	10	2	6	1	0	2337
North-facing Clearings	**0.3772**	**1964**	**154**	**18**	**0.1**	**0**	**1**	**0.1**	**2**	**1**	**0**	**1**	**780**
						Middle Creek Sub-basin							
North-facing Alpine Rock	0.52	2462	82	31	0.1	0	1	0.14	2	1	0	1	944
South-facing Alpine Rock	1.37	2422	148	30	0.1	0	1	0.14	2	1	0	5	1689
South-facing Alpine Larch/Spruce	0.26	2246	138	20	1.1	6.6	0	3	2	6	0	5	618
North-facing Alpine Larch/Spruce	*1E-06*	2211	46	18	1.1	6.6	0	3	2	6	0	5	*0.35*
North-facing Spruce/Fir/Lodgepole Pine	*1E-06*	1995	76	21	2.2	8.8	0	10	2	6	1	0	*0.35*
South-facing Spruce/Fir/Lodgepole Pine	0.52	1953	134	22	2.2	8.8	0	10	2	6	1	0	947
Valley Bottom	0.03	2057	115	16	2.2	6.6	0	10	2	6	1	0	2907
North-facing Clearings	**0.2355**	**2049**	**135**	**21**	**0.1**	**0**	**1**	**0.1**	**2**	**1**	**0**	**1**	**588**
						Twin Creek Sub-basin							
North-facing Alpine Rock	0.79	2386	67	28	0.1	0	1	0.14	2	1	0	1	1218
South-facing Alpine Rock	0.15	2380	106	22	0.1	0	1	0.14	2	1	0	5	457
South-facing Alpine Larch/Spruce	0.28	2228	116	23	1.1	6.6	0	3	2	6	0	5	650
North-facing Alpine Larch/Spruce	*1E-06*	2182	37	22	1.1	6.6	0	3	2	6	0	5	*0.35*
North-facing Spruce/Fir/Lodgepole Pine	*1E-06*	1966	34	17	2.2	8.8	0	10	2	6	1	0	*0.35*
South-facing Spruce/Fir/Lodgepole Pine	0.60	2014	113	21	2.2	8.8	0	10	2	6	1	0	1028
Valley Bottom	0.04	1988	119	16	2.2	6.6	0	10	2	6	1	0	2443
North-facing Clearings	**0.9218**	**2082**	**114**	**22**	**0.1**	**0**	**1**	**0.1**	**2**	**1**	**0**	**1**	**1333**
						Marmot Confluence Sub-basin							
Forest Clearings	0.01	1903	55	11	1.1	3.3	1	3	2	6	0	1	90
North-facing Lodgepole Pine/Aspen	*1E-06*	1786	54	13	2.2	8.8	0	10	2	6	1	0	*0.35*
South-facing Lodgepole Pine/Aspen	0.24	1725	159	13	2.2	8.8	0	10	2	6	1	0	593
Level Lodgepole Pine/Aspen	0.04	1688	0	4	2.2	8.8	0	10	2	6	1	0	210
South-facing Lodgepole Pine	0.44	1752	172	17	2.2	6.6	0	10	2	6	1	0	853
Level Lodgepole Pine	0.02	1724	0	4	2.2	6.6	0	10	2	6	1	0	150
North-facing Lodgepole Pine	*1E-06*	1687	71	14	2.2	6.6	0	10	2	6	1	0	*0.35*
Valley Bottom	0.02	1664	163	8	2.2	6.6	0	10	2	6	1	0	1998
North-facing Clearings	**0.5325**	**1742**	**167**	**15**	**0.1**	**0**	**1**	**0.1**	**2**	**1**	**0**	**1**	**959**

Table A32. HRU parameters in the forest disturbance scenario 32: reduction of forest by 20% on south facing slope with 1.5 m stump remained.

HRU	Area (km^2)	Mean Elevation (m)	Mean Aspect (˚)	Mean Slope (˚)	LAI	Canopy Snow Interception Load Capacity (kg/m2)	Canopy Clearing	Vegetation Height (m)	cov_type	groundcover	inhibit_bs	distrib	Routing Length (m)
Cabin Creek Sub-basin													
South-facing Alpine Rock	0.23	2387	122	36	0.1	0	1	0.14	2	1	0	1	575
North-facing Alpine Rock	0.17	2379	69	37	0.1	0	1	0.14	2	1	0	5	485
North-facing Alpine Larch/Spruce	0.02	2222	60	35	1.1	6.6	0	3	2	6	0	5	137
South-facing Alpine Larch/Spruce	*0.0153*	2194	115	32	1.1	6.6	0	3	2	6	0	5	*114*
North-facing Spruce/Fir/Lodgepole Pine	0.35	2046	62	24	2.2	8.8	0	10	2	6	1	0	742
South-facing Spruce/Fir/Lodgepole Pine	*0.7426*	1972	151	18	2.2	8.8	0	10	2	6	1	0	*1171*
Level Spruce/Fir/Lodgepole Pine	0.05	1931	0	4	2.2	8.8	0	10	2	6	1	0	225
Forest Clearings	0.40	1927	140	11	1.1	3.3	1	3	2	6	0	0	806
Level Lodgepole Pine	0.05	1882	0	3	2.2	6.6	0	10	2	6	1	0	244
South-facing Lodgepole Pine	*0.0581*	1798	204	18	2.2	6.6	0	10	2	6	1	0	*254*
North-facing Lodgepole Pine	0.01	1780	76	25	2.2	6.6	0	10	2	6	1	0	84
Valley Bottom	0.04	1951	135	18	2.2	6.6	0	10	2	6	1	0	2337
South-facing Clearings	**0.2040**	**1964**	**154**	**18**	**0.1**	**0**	**1**	**1.5**	**2**	**6**	**0**	**1**	**539**
Middle Creek Sub-basin													
North-facing Alpine Rock	0.52	2462	82	31	0.1	0	1	0.14	2	1	0	1	944
South-facing Alpine Rock	1.37	2422	148	30	0.1	0	1	0.14	2	1	0	5	1689
South-facing Alpine Larch/Spruce	*0.2047*	2246	138	20	1.1	6.6	0	3	2	6	0	5	*541*
North-facing Alpine Larch/Spruce	0.08	2211	46	18	1.1	6.6	0	3	2	6	0	5	303
North-facing Spruce/Fir/Lodgepole Pine	0.16	1995	76	21	2.2	8.8	0	10	2	6	1	0	462
South-facing Spruce/Fir/Lodgepole Pine	*0.4173*	1953	134	22	2.2	8.8	0	10	2	6	1	0	*829*
Valley Bottom	0.03	2057	115	16	2.2	6.6	0	10	2	6	1	0	2907
South-facing Clearings	**0.1555**	**2049**	**135**	**21**	**0.1**	**0**	**1**	**1.5**	**2**	**6**	**0**	**1**	**458**
Twin Creek Sub-basin													
North-facing Alpine Rock	0.79	2386	67	28	0.1	0	1	0.14	2	1	0	1	1218
South-facing Alpine Rock	0.15	2380	106	22	0.1	0	1	0.14	2	1	0	5	457
South-facing Alpine Larch/Spruce	*0.2226*	2228	116	23	1.1	6.6	0	3	2	6	0	5	*568*
North-facing Alpine Larch/Spruce	0.28	2182	37	22	1.1	6.6	0	3	2	6	0	5	655
North-facing Spruce/Fir/Lodgepole Pine	0.64	1966	34	17	2.2	8.8	0	10	2	6	1	0	1071
South-facing Spruce/Fir/Lodgepole Pine	*0.4785*	2014	113	21	2.2	8.8	0	10	2	6	1	0	*900*
Valley Bottom	0.04	1988	119	16	2.2	6.6	0	10	2	6	1	0	2443
South-facing Clearings	**0.1753**	**2082**	**114**	**22**	**0.1**	**0**	**1**	**1.5**	**2**	**6**	**0**	**1**	**492**
Marmot Confluence Sub-basin													
Forest Clearings	0.01	1903	55	11	1.1	3.3	1	3	2	6	0	1	90
North-facing Lodgepole Pine/Aspen	0.38	1786	54	13	2.2	8.8	0	10	2	6	1	0	786
South-facing Lodgepole Pine/Aspen	*0.1911*	1725	159	13	2.2	8.8	0	10	2	6	1	0	*519*
Level Lodgepole Pine/Aspen	0.04	1688	0	4	2.2	8.8	0	10	2	6	1	0	210
South-facing Lodgepole Pine	*0.3504*	1752	172	17	2.2	6.6	0	10	2	6	1	0	*746*
Level Lodgepole Pine	0.02	1724	0	4	2.2	6.6	0	10	2	6	1	0	150
North-facing Lodgepole Pine	0.15	1687	71	14	2.2	6.6	0	10	2	6	1	0	450
Valley Bottom	0.02	1664	163	8	2.2	6.6	0	10	2	6	1	0	1998
South-facing Clearings	**0.1354**	**1742**	**167**	**15**	**0.1**	**0**	**1**	**1.5**	**2**	**6**	**0**	**1**	**422**

Table A33. HRU parameters in the forest disturbance scenario 33: reduction of forest by 40% on south facing slope with 1.5 m stump remained.

HRU	Area (km^2)	Mean Elevation (m)	Mean Aspect (˚)	Mean Slope (˚)	LAI	Canopy Snow Interception Load Capacity (kg/m2)	Canopy Clearing	Vegetation Height (m)	cov_type	groundcover	inhibit_bs	distrib	Routing Length (m)
Cabin Creek Sub-basin													
South-facing Alpine Rock	0.23	2387	122	36	0.1	0	1	0.14	2	1	0	1	575
North-facing Alpine Rock	0.17	2379	69	37	0.1	0	1	0.14	2	1	0	5	485
North-facing Alpine Larch/Spruce	0.02	2222	60	35	1.1	6.6	0	3	2	6	0	5	137
South-facing Alpine Larch/Spruce	*0.0115*	2194	115	32	1.1	6.6	0	3	2	6	0	5	*96*
North-facing Spruce/Fir/Lodgepole Pine	0.35	2046	62	24	2.2	8.8	0	10	2	6	1	0	742
South-facing Spruce/Fir/Lodgepole Pine	*0.5570*	1972	151	18	2.2	8.8	0	10	2	6	1	0	*985*
Level Spruce/Fir/Lodgepole Pine	0.05	1931	0	4	2.2	8.8	0	10	2	6	1	0	225
Forest Clearings	0.40	1927	140	11	1.1	3.3	1	3	2	6	0	0	806
Level Lodgepole Pine	0.05	1882	0	3	2.2	6.6	0	10	2	6	1	0	244
South-facing Lodgepole Pine	*0.0436*	1798	204	18	2.2	6.6	0	10	2	6	1	0	*214*
North-facing Lodgepole Pine	0.01	1780	76	25	2.2	6.6	0	10	2	6	1	0	84
Valley Bottom	0.04	1951	135	18	2.2	6.6	0	10	2	6	1	0	2337
South-facing Clearings	**0.4080**	**1964**	**154**	**18**	**0.1**	**0**	**1**	**1.5**	**2**	**6**	**0**	**1**	**818**
Middle Creek Sub-basin													
North-facing Alpine Rock	0.52	2462	82	31	0.1	0	1	0.14	2	1	0	1	944
South-facing Alpine Rock	1.37	2422	148	30	0.1	0	1	0.14	2	1	0	5	1689
South-facing Alpine Larch/Spruce	*0.1536*	2246	138	20	1.1	6.6	0	3	2	6	0	5	*455*
North-facing Alpine Larch/Spruce	0.08	2211	46	18	1.1	6.6	0	3	2	6	0	5	303
North-facing Spruce/Fir/Lodgepole Pine	0.16	1995	76	21	2.2	8.8	0	10	2	6	1	0	462
South-facing Spruce/Fir/Lodgepole Pine	*0.3130*	1953	134	22	2.2	8.8	0	10	2	6	1	0	*697*
Valley Bottom	0.03	2057	115	16	2.2	6.6	0	10	2	6	1	0	2907
South-facing Clearings	**0.3110**	**2049**	**135**	**21**	**0.1**	**0**	**1**	**1.5**	**2**	**6**	**0**	**1**	**695**
Twin Creek Sub-basin													
North-facing Alpine Rock	0.79	2386	67	28	0.1	0	1	0.14	2	1	0	1	1218
South-facing Alpine Rock	0.15	2380	106	22	0.1	0	1	0.14	2	1	0	5	457
South-facing Alpine Larch/Spruce	*0.1670*	2228	116	23	1.1	6.6	0	3	2	6	0	5	*478*
North-facing Alpine Larch/Spruce	0.28	2182	37	22	1.1	6.6	0	3	2	6	0	5	655
North-facing Spruce/Fir/Lodgepole Pine	0.64	1966	34	17	2.2	8.8	0	10	2	6	1	0	1071
South-facing Spruce/Fir/Lodgepole Pine	*0.3589*	2014	113	21	2.2	8.8	0	10	2	6	1	0	*757*
Valley Bottom	0.04	1988	119	16	2.2	6.6	0	10	2	6	1	0	2443
South-facing Clearings	**0.3506**	**2082**	**114**	**22**	**0.1**	**0**	**1**	**1.5**	**2**	**6**	**0**	**1**	**746**
Marmot Confluence Sub-basin													
Forest Clearings	0.01	1903	55	11	1.1	3.3	1	3	2	6	0	1	90
North-facing Lodgepole Pine/Aspen	0.38	1786	54	13	2.2	8.8	0	10	2	6	1	0	786
South-facing Lodgepole Pine/Aspen	*0.1433*	1725	159	13	2.2	8.8	0	10	2	6	1	0	*436*
Level Lodgepole Pine/Aspen	0.04	1688	0	4	2.2	8.8	0	10	2	6	1	0	210
South-facing Lodgepole Pine	*0.2628*	1752	172	17	2.2	6.6	0	10	2	6	1	0	*628*
Level Lodgepole Pine	0.02	1724	0	4	2.2	6.6	0	10	2	6	1	0	150
North-facing Lodgepole Pine	0.15	1687	71	14	2.2	6.6	0	10	2	6	1	0	450
Valley Bottom	0.02	1664	163	8	2.2	6.6	0	10	2	6	1	0	1998
South-facing Clearings	**0.2707**	**1742**	**167**	**15**	**0.1**	**0**	**1**	**1.5**	**2**	**6**	**0**	**1**	**639**

Table A34. HRU parameters in the forest disturbance scenario 34: reduction of forest by 60% on south facing slope with 1.5 m stump remained.

HRU	Area (km^2)	Mean Elevation (m)	Mean Aspect (˚)	Mean Slope (˚)	LAI	Canopy Snow Interception Load Capacity (kg/m2)	Canopy Clearing	Vegetation Height (m)	cov_type	groundcover	inhibit_bs	distrib	Routing Length (m)
						Cabin Creek Sub-basin							
South-facing Alpine Rock	0.23	2387	122	36	0.1	0	1	0.14	2	1	0	1	575
North-facing Alpine Rock	0.17	2379	69	37	0.1	0	1	0.14	2	1	0	5	485
North-facing Alpine Larch/Spruce	0.02	2222	60	35	1.1	6.6	0	3	2	6	0	5	137
South-facing Alpine Larch/Spruce	*0.0076*	2194	115	32	1.1	6.6	0	3	2	6	0	5	*75*
North-facing Spruce/Fir/Lodgepole Pine	0.35	2046	62	24	2.2	8.8	0	10	2	6	1	0	742
South-facing Spruce/Fir/Lodgepole Pine	*0.3713*	1972	151	18	2.2	8.8	0	10	2	6	1	0	*773*
Level Spruce/Fir/Lodgepole Pine	0.05	1931	0	4	2.2	8.8	0	10	2	6	1	0	225
Forest Clearings	0.40	1927	140	11	1.1	3.3	1	3	2	6	0	0	806
Level Lodgepole Pine	0.05	1882	0	3	2.2	6.6	0	10	2	6	1	0	244
South-facing Lodgepole Pine	*0.0291*	1798	204	18	2.2	6.6	0	10	2	6	1	0	*168*
North-facing Lodgepole Pine	0.01	1780	76	25	2.2	6.6	0	10	2	6	1	0	84
Valley Bottom	0.04	1951	135	18	2.2	6.6	0	10	2	6	1	0	2337
South-facing Clearings	**0.6120**	**1964**	**154**	**18**	**0.1**	**0**	**1**	**1.5**	**2**	**6**	**0**	**1**	**1043**
						Middle Creek Sub-basin							
North-facing Alpine Rock	0.52	2462	82	31	0.1	0	1	0.14	2	1	0	1	944
South-facing Alpine Rock	1.37	2422	148	30	0.1	0	1	0.14	2	1	0	5	1689
South-facing Alpine Larch/Spruce	*0.1024*	2246	138	20	1.1	6.6	0	3	2	6	0	5	*357*
North-facing Alpine Larch/Spruce	0.08	2211	46	18	1.1	6.6	0	3	2	6	0	5	303
North-facing Spruce/Fir/Lodgepole Pine	0.16	1995	76	21	2.2	8.8	0	10	2	6	1	0	462
South-facing Spruce/Fir/Lodgepole Pine	*0.2087*	1953	134	22	2.2	8.8	0	10	2	6	1	0	*547*
Valley Bottom	0.03	2057	115	16	2.2	6.6	0	10	2	6	1	0	2907
South-facing Clearings	**0.4666**	**2049**	**135**	**21**	**0.1**	**0**	**1**	**1.5**	**2**	**6**	**0**	**1**	**886**
						Twin Creek Sub-basin							
North-facing Alpine Rock	0.79	2386	67	28	0.1	0	1	0.14	2	1	0	1	1218
South-facing Alpine Rock	0.15	2380	106	22	0.1	0	1	0.14	2	1	0	5	457
South-facing Alpine Larch/Spruce	*0.1113*	2228	116	23	1.1	6.6	0	3	2	6	0	5	*375*
North-facing Alpine Larch/Spruce	0.28	2182	37	22	1.1	6.6	0	3	2	6	0	5	655
North-facing Spruce/Fir/Lodgepole Pine	0.64	1966	34	17	2.2	8.8	0	10	2	6	1	0	1071
South-facing Spruce/Fir/Lodgepole Pine	*0.2392*	2014	113	21	2.2	8.8	0	10	2	6	1	0	*594*
Valley Bottom	0.04	1988	119	16	2.2	6.6	0	10	2	6	1	0	2443
South-facing Clearings	**0.5258**	**2082**	**114**	**22**	**0.1**	**0**	**1**	**1.5**	**2**	**6**	**0**	**1**	**952**
						Marmot Confluence Sub-basin							
Forest Clearings	0.01	1903	55	11	1.1	3.3	1	3	2	6	0	1	90
North-facing Lodgepole Pine/Aspen	0.38	1786	54	13	2.2	8.8	0	10	2	6	1	0	786
South-facing Lodgepole Pine/Aspen	*0.0955*	1725	159	13	2.2	8.8	0	10	2	6	1	0	*342*
Level Lodgepole Pine/Aspen	0.04	1688	0	4	2.2	8.8	0	10	2	6	1	0	210
South-facing Lodgepole Pine	*0.1752*	1752	172	17	2.2	6.6	0	10	2	6	1	0	*492*
Level Lodgepole Pine	0.02	1724	0	4	2.2	6.6	0	10	2	6	1	0	150
North-facing Lodgepole Pine	0.15	1687	71	14	2.2	6.6	0	10	2	6	1	0	450
Valley Bottom	0.02	1664	163	8	2.2	6.6	0	10	2	6	1	0	1998
South-facing Clearings	**0.4061**	**1742**	**167**	**15**	**0.1**	**0**	**1**	**1.5**	**2**	**6**	**0**	**1**	**815**

Table A35. HRU parameters in the forest disturbance scenario 35: reduction of forest by 80% on south facing slope with 1.5 m stump remained.

HRU	Area (km^2)	Mean Elevation (m)	Mean Aspect (˚)	Mean Slope (˚)	LAI	Canopy Snow Interception Load Capacity (kg/m2)	Canopy Clearing	Vegetation Height (m)	cov_type	groundcover	inhibit_bs	distrib	Routing Length (m)
Cabin Creek Sub-basin													
South-facing Alpine Rock	0.23	2387	122	36	0.1	0	1	0.14	2	1	0	1	575
North-facing Alpine Rock	0.17	2379	69	37	0.1	0	1	0.14	2	1	0	5	485
North-facing Alpine Larch/Spruce	0.02	2222	60	35	1.1	6.6	0	3	2	6	0	5	137
South-facing Alpine Larch/Spruce	*0.0038*	2194	115	32	1.1	6.6	0	3	2	6	0	5	*50*
North-facing Spruce/Fir/Lodgepole Pine	0.35	2046	62	24	2.2	8.8	0	10	2	6	1	0	742
South-facing Spruce/Fir/Lodgepole Pine	*0.1857*	1972	151	18	2.2	8.8	0	10	2	6	1	0	*510*
Level Spruce/Fir/Lodgepole Pine	0.05	1931	0	4	2.2	8.8	0	10	2	6	1	0	225
Forest Clearings	0.40	1927	140	11	1.1	3.3	1	3	2	6	0	0	806
Level Lodgepole Pine	0.05	1882	0	3	2.2	6.6	0	10	2	6	1	0	244
South-facing Lodgepole Pine	*0.0145*	1798	204	18	2.2	6.6	0	10	2	6	1	0	*111*
North-facing Lodgepole Pine	0.01	1780	76	25	2.2	6.6	0	10	2	6	1	0	84
Valley Bottom	0.04	1951	135	18	2.2	6.6	0	10	2	6	1	0	2337
South-facing Clearings	**0.8160**	**1964**	**154**	**18**	**0.1**	**0**	**1**	**1.5**	**2**	**6**	**0**	**1**	**1239**
Middle Creek Sub-basin													
North-facing Alpine Rock	0.52	2462	82	31	0.1	0	1	0.14	2	1	0	1	944
South-facing Alpine Rock	1.37	2422	148	30	0.1	0	1	0.14	2	1	0	5	1689
South-facing Alpine Larch/Spruce	*0.0512*	2246	138	20	1.1	6.6	0	3	2	6	0	5	*235*
North-facing Alpine Larch/Spruce	0.08	2211	46	18	1.1	6.6	0	3	2	6	0	5	303
North-facing Spruce/Fir/Lodgepole Pine	0.16	1995	76	21	2.2	8.8	0	10	2	6	1	0	462
South-facing Spruce/Fir/Lodgepole Pine	*0.1043*	1953	134	22	2.2	8.8	0	10	2	6	1	0	*361*
Valley Bottom	0.03	2057	115	16	2.2	6.6	0	10	2	6	1	0	2907
South-facing Clearings	**0.6221**	**2049**	**135**	**21**	**0.1**	**0**	**1**	**1.5**	**2**	**6**	**0**	**1**	**1053**
Twin Creek Sub-basin													
North-facing Alpine Rock	0.79	2386	67	28	0.1	0	1	0.14	2	1	0	1	1218
South-facing Alpine Rock	0.15	2380	106	22	0.1	0	1	0.14	2	1	0	5	457
South-facing Alpine Larch/Spruce	*0.0557*	2228	116	23	1.1	6.6	0	3	2	6	0	5	*247*
North-facing Alpine Larch/Spruce	0.28	2182	37	22	1.1	6.6	0	3	2	6	0	5	655
North-facing Spruce/Fir/Lodgepole Pine	0.64	1966	34	17	2.2	8.8	0	10	2	6	1	0	1071
South-facing Spruce/Fir/Lodgepole Pine	*0.1196*	2014	113	21	2.2	8.8	0	10	2	6	1	0	*392*
Valley Bottom	0.04	1988	119	16	2.2	6.6	0	10	2	6	1	0	2443
South-facing Clearings	**0.7011**	**2082**	**114**	**22**	**0.1**	**0**	**1**	**1.5**	**2**	**6**	**0**	**1**	**1131**
Marmot Confluence Sub-basin													
Forest Clearings	0.01	1903	55	11	1.1	3.3	1	3	2	6	0	1	90
North-facing Lodgepole Pine/Aspen	0.38	1786	54	13	2.2	8.8	0	10	2	6	1	0	786
South-facing Lodgepole Pine/Aspen	*0.0478*	1725	159	13	2.2	8.8	0	10	2	6	1	0	*226*
Level Lodgepole Pine/Aspen	0.04	1688	0	4	2.2	8.8	0	10	2	6	1	0	210
South-facing Lodgepole Pine	*0.0876*	1752	172	17	2.2	6.6	0	10	2	6	1	0	*325*
Level Lodgepole Pine	0.02	1724	0	4	2.2	6.6	0	10	2	6	1	0	150
North-facing Lodgepole Pine	0.15	1687	71	14	2.2	6.6	0	10	2	6	1	0	450
Valley Bottom	0.02	1664	163	8	2.2	6.6	0	10	2	6	1	0	1998
South-facing Clearings	**0.5415**	**1742**	**167**	**15**	**0.1**	**0**	**1**	**1.5**	**2**	**6**	**0**	**1**	**969**

Table A36. HRU parameters in the forest disturbance scenario 36: reduction of forest by 100% on south facing slope with 1.5 m stump remained.

HRU	Area (km^2)	Mean Elevation (m)	Mean Aspect (˚)	Mean Slope (˚)	LAI	Canopy Snow Interception Load Capacity (kg/m2)	Canopy Clearing	Vegetation Height (m)	cov_type	groundcover	inhibit_bs	distrib	Routing Length (m)
						Cabin Creek Sub-basin							
South-facing Alpine Rock	0.23	2387	122	36	0.1	0	1	0.14	2	1	0	1	575
North-facing Alpine Rock	0.17	2379	69	37	0.1	0	1	0.14	2	1	0	5	485
North-facing Alpine Larch/Spruce	0.02	2222	60	35	1.1	6.6	0	3	2	6	0	5	137
South-facing Alpine Larch/Spruce	*1E-06*	2194	115	32	1.1	6.6	0	3	2	6	0	5	*0.35*
North-facing Spruce/Fir/Lodgepole Pine	0.35	2046	62	24	2.2	8.8	0	10	2	6	1	0	742
South-facing Spruce/Fir/Lodgepole Pine	*1E-06*	1972	151	18	2.2	8.8	0	10	2	6	1	0	*0.35*
Level Spruce/Fir/Lodgepole Pine	0.05	1931	0	4	2.2	8.8	0	10	2	6	1	0	225
Forest Clearings	0.40	1927	140	11	1.1	3.3	1	3	2	6	0	0	806
Level Lodgepole Pine	0.05	1882	0	3	2.2	6.6	0	10	2	6	1	0	244
South-facing Lodgepole Pine	*1E-06*	1798	204	18	2.2	6.6	0	10	2	6	1	0	*0.35*
North-facing Lodgepole Pine	0.01	1780	76	25	2.2	6.6	0	10	2	6	1	0	84
Valley Bottom	0.04	1951	135	18	2.2	6.6	0	10	2	6	1	0	2337
South-facing Clearings	**1.0200**	**1964**	**154**	**18**	**0.1**	**0**	**1**	**1.5**	**2**	**6**	**0**	**1**	**1417**
						Middle Creek Sub-basin							
North-facing Alpine Rock	0.52	2462	82	31	0.1	0	1	0.14	2	1	0	1	944
South-facing Alpine Rock	1.37	2422	148	30	0.1	0	1	0.14	2	1	0	5	1689
South-facing Alpine Larch/Spruce	*1E-06*	2246	138	20	1.1	6.6	0	3	2	6	0	5	*0.35*
North-facing Alpine Larch/Spruce	0.08	2211	46	18	1.1	6.6	0	3	2	6	0	5	303
North-facing Spruce/Fir/Lodgepole Pine	0.16	1995	76	21	2.2	8.8	0	10	2	6	1	0	462
South-facing Spruce/Fir/Lodgepole Pine	*1E-06*	1953	134	22	2.2	8.8	0	10	2	6	1	0	*0.35*
Valley Bottom	0.03	2057	115	16	2.2	6.6	0	10	2	6	1	0	2907
South-facing Clearings	**0.7776**	**2049**	**135**	**21**	**0.1**	**0**	**1**	**1.5**	**2**	**6**	**0**	**1**	**1204**
						Twin Creek Sub-basin							
North-facing Alpine Rock	0.79	2386	67	28	0.1	0	1	0.14	2	1	0	1	1218
South-facing Alpine Rock	0.15	2380	106	22	0.1	0	1	0.14	2	1	0	5	457
South-facing Alpine Larch/Spruce	*1E-06*	2228	116	23	1.1	6.6	0	3	2	6	0	5	*0.35*
North-facing Alpine Larch/Spruce	0.28	2182	37	22	1.1	6.6	0	3	2	6	0	5	655
North-facing Spruce/Fir/Lodgepole Pine	0.64	1966	34	17	2.2	8.8	0	10	2	6	1	0	1071
South-facing Spruce/Fir/Lodgepole Pine	*1E-06*	2014	113	21	2.2	8.8	0	10	2	6	1	0	*0.35*
Valley Bottom	0.04	1988	119	16	2.2	6.6	0	10	2	6	1	0	2443
South-facing Clearings	**0.8764**	**2082**	**114**	**22**	**0.1**	**0**	**1**	**1.5**	**2**	**6**	**0**	**1**	**1293**
						Marmot Confluence Sub-basin							
Forest Clearings	0.01	1903	55	11	1.1	3.3	1	3	2	6	0	1	90
North-facing Lodgepole Pine/Aspen	0.38	1786	54	13	2.2	8.8	0	10	2	6	1	0	786
South-facing Lodgepole Pine/Aspen	*1E-06*	1725	159	13	2.2	8.8	0	10	2	6	1	0	*0.35*
Level Lodgepole Pine/Aspen	0.04	1688	0	4	2.2	8.8	0	10	2	6	1	0	210
South-facing Lodgepole Pine	*1E-06*	1752	172	17	2.2	6.6	0	10	2	6	1	0	*0.35*
Level Lodgepole Pine	0.02	1724	0	4	2.2	6.6	0	10	2	6	1	0	150
North-facing Lodgepole Pine	0.15	1687	71	14	2.2	6.6	0	10	2	6	1	0	450
Valley Bottom	0.02	1664	163	8	2.2	6.6	0	10	2	6	1	0	1998
South-facing Clearings	**0.6769**	**1742**	**167**	**15**	**0.1**	**0**	**1**	**1.5**	**2**	**6**	**0**	**1**	**1108**

Table A37. HRU parameters in the forest disturbance scenario 37: reduction of forest by 20% on north facing slope with 1.5 m stump remained.

HRU	Area (km^2)	Mean Elevation (m)	Mean Aspect (˚)	Mean Slope (˚)	LAI	Canopy Snow Interception Load Capacity (kg/m2)	Canopy Clearing	Vegetation Height (m)	cov_type	groundcover	inhibit_bs	distrib	Routing Length (m)
Cabin Creek Sub-basin													
South-facing Alpine Rock	0.23	2387	122	36	0.1	0	1	0.14	2	1	0	1	575
North-facing Alpine Rock	0.17	2379	69	37	0.1	0	1	0.14	2	1	0	5	485
North-facing Alpine Larch/Spruce	*0.0166*	2222	60	35	1.1	6.6	0	3	2	6	0	5	*120*
South-facing Alpine Larch/Spruce	0.02	2194	115	32	1.1	6.6	0	3	2	6	0	5	130
North-facing Spruce/Fir/Lodgepole Pine	*0.2778*	2046	62	24	2.2	8.8	0	10	2	6	1	0	*649*
South-facing Spruce/Fir/Lodgepole Pine	0.93	1972	151	18	2.2	8.8	0	10	2	6	1	0	1339
Level Spruce/Fir/Lodgepole Pine	0.05	1931	0	4	2.2	8.8	0	10	2	6	1	0	225
Forest Clearings	0.40	1927	140	11	1.1	3.3	1	3	2	6	0	0	806
Level Lodgepole Pine	0.05	1882	0	3	2.2	6.6	0	10	2	6	1	0	244
South-facing Lodgepole Pine	0.07	1798	204	18	2.2	6.6	0	10	2	6	1	0	290
North-facing Lodgepole Pine	*0.0074*	1780	76	25	2.2	6.6	0	10	2	6	1	0	*74*
Valley Bottom	0.04	1951	135	18	2.2	6.6	0	10	2	6	1	0	2337
North-facing Clearings	**0.0754**	**1964**	**154**	**18**	**0.1**	**0**	**1**	**1.5**	**2**	**6**	**0**	**1**	**297**
Middle Creek Sub-basin													
North-facing Alpine Rock	0.52	2462	82	31	0.1	0	1	0.14	2	1	0	1	944
South-facing Alpine Rock	1.37	2422	148	30	0.1	0	1	0.14	2	1	0	5	1689
South-facing Alpine Larch/Spruce	0.26	2246	138	20	1.1	6.6	0	3	2	6	0	5	618
North-facing Alpine Larch/Spruce	*0.0623*	2211	46	18	1.1	6.6	0	3	2	6	0	5	*265*
North-facing Spruce/Fir/Lodgepole Pine	*0.1261*	1995	76	21	2.2	8.8	0	10	2	6	1	0	*404*
South-facing Spruce/Fir/Lodgepole Pine	0.52	1953	134	22	2.2	8.8	0	10	2	6	1	0	947
Valley Bottom	0.03	2057	115	16	2.2	6.6	0	10	2	6	1	0	2907
North-facing Clearings	**0.0471**	**2049**	**135**	**21**	**0.1**	**0**	**1**	**1.5**	**2**	**6**	**0**	**1**	**224**
Twin Creek Sub-basin													
North-facing Alpine Rock	0.79	2386	67	28	0.1	0	1	0.14	2	1	0	1	1218
South-facing Alpine Rock	0.15	2380	106	22	0.1	0	1	0.14	2	1	0	5	457
South-facing Alpine Larch/Spruce	0.28	2228	116	23	1.1	6.6	0	3	2	6	0	5	650
North-facing Alpine Larch/Spruce	*0.2253*	2182	37	22	1.1	6.6	0	3	2	6	0	5	*573*
North-facing Spruce/Fir/Lodgepole Pine	*0.5121*	1966	34	17	2.2	8.8	0	10	2	6	1	0	*937*
South-facing Spruce/Fir/Lodgepole Pine	0.60	2014	113	21	2.2	8.8	0	10	2	6	1	0	1028
Valley Bottom	0.04	1988	119	16	2.2	6.6	0	10	2	6	1	0	2443
North-facing Clearings	**0.1844**	**2082**	**114**	**22**	**0.1**	**0**	**1**	**1.5**	**2**	**6**	**0**	**1**	**508**
Marmot Confluence Sub-basin													
Forest Clearings	0.01	1903	55	11	1.1	3.3	1	3	2	6	0	1	90
North-facing Lodgepole Pine/Aspen	*0.3055*	1786	54	13	2.2	8.8	0	10	2	6	1	0	*687*
South-facing Lodgepole Pine/Aspen	0.24	1725	159	13	2.2	8.8	0	10	2	6	1	0	593
Level Lodgepole Pine/Aspen	0.04	1688	0	4	2.2	8.8	0	10	2	6	1	0	210
South-facing Lodgepole Pine	0.44	1752	172	17	2.2	6.6	0	10	2	6	1	0	853
Level Lodgepole Pine	0.02	1724	0	4	2.2	6.6	0	10	2	6	1	0	150
North-facing Lodgepole Pine	*0.1205*	1687	71	14	2.2	6.6	0	10	2	6	1	0	*393*
Valley Bottom	0.02	1664	163	8	2.2	6.6	0	10	2	6	1	0	1998
North-facing Clearings	**0.1065**	**1742**	**167**	**15**	**0.1**	**0**	**1**	**1.5**	**2**	**6**	**0**	**1**	**365**

Table A38. HRU parameters in the forest disturbance scenario 38: reduction of forest by 40% on north facing slope with 1.5 m stump remained.

HRU	Area (km^2)	Mean Elevation (m)	Mean Aspect (˚)	Mean Slope (˚)	LAI	Canopy Snow Interception Load Capacity (kg/m2)	Canopy Clearing	Vegetation Height (m)	cov_type	groundcover	inhibit_bs	distrib	Routing Length (m)
Cabin Creek Sub-basin													
South-facing Alpine Rock	0.23	2387	122	36	0.1	0	1	0.14	2	1	0	1	575
North-facing Alpine Rock	0.17	2379	69	37	0.1	0	1	0.14	2	1	0	5	485
North-facing Alpine Larch/Spruce	*0.0125*	2222	60	35	1.1	6.6	0	3	2	6	0	5	*101*
South-facing Alpine Larch/Spruce	0.02	2194	115	32	1.1	6.6	0	3	2	6	0	5	130
North-facing Spruce/Fir/Lodgepole Pine	*0.2083*	2046	62	24	2.2	8.8	0	10	2	6	1	0	*546*
South-facing Spruce/Fir/Lodgepole Pine	0.93	1972	151	18	2.2	8.8	0	10	2	6	1	0	1339
Level Spruce/Fir/Lodgepole Pine	0.05	1931	0	4	2.2	8.8	0	10	2	6	1	0	225
Forest Clearings	0.40	1927	140	11	1.1	3.3	1	3	2	6	0	0	806
Level Lodgepole Pine	0.05	1882	0	3	2.2	6.6	0	10	2	6	1	0	244
South-facing Lodgepole Pine	0.07	1798	204	18	2.2	6.6	0	10	2	6	1	0	290
North-facing Lodgepole Pine	*0.0055*	1780	76	25	2.2	6.6	0	10	2	6	1	0	*62*
Valley Bottom	0.04	1951	135	18	2.2	6.6	0	10	2	6	1	0	2337
North-facing Clearings	**0.1509**	**1964**	**154**	**18**	**0.1**	**0**	**1**	**1.5**	**2**	**6**	**0**	**1**	**450**
Middle Creek Sub-basin													
North-facing Alpine Rock	0.52	2462	82	31	0.1	0	1	0.14	2	1	0	1	944
South-facing Alpine Rock	1.37	2422	148	30	0.1	0	1	0.14	2	1	0	5	1689
South-facing Alpine Larch/Spruce	0.26	2246	138	20	1.1	6.6	0	3	2	6	0	5	618
North-facing Alpine Larch/Spruce	*0.0467*	2211	46	18	1.1	6.6	0	3	2	6	0	5	*223*
North-facing Spruce/Fir/Lodgepole Pine	*0.0945*	1995	76	21	2.2	8.8	0	10	2	6	1	0	*340*
South-facing Spruce/Fir/Lodgepole Pine	0.52	1953	134	22	2.2	8.8	0	10	2	6	1	0	947
Valley Bottom	0.03	2057	115	16	2.2	6.6	0	10	2	6	1	0	2907
North-facing Clearings	**0.0942**	**2049**	**135**	**21**	**0.1**	**0**	**1**	**1.5**	**2**	**6**	**0**	**1**	**339**
Twin Creek Sub-basin													
North-facing Alpine Rock	0.79	2386	67	28	0.1	0	1	0.14	2	1	0	1	1218
South-facing Alpine Rock	0.15	2380	106	22	0.1	0	1	0.14	2	1	0	5	457
South-facing Alpine Larch/Spruce	0.28	2228	116	23	1.1	6.6	0	3	2	6	0	5	650
North-facing Alpine Larch/Spruce	*0.1690*	2182	37	22	1.1	6.6	0	3	2	6	0	5	*482*
North-facing Spruce/Fir/Lodgepole Pine	*0.3841*	1966	34	17	2.2	8.8	0	10	2	6	1	0	*788*
South-facing Spruce/Fir/Lodgepole Pine	0.60	2014	113	21	2.2	8.8	0	10	2	6	1	0	1028
Valley Bottom	0.04	1988	119	16	2.2	6.6	0	10	2	6	1	0	2443
North-facing Clearings	**0.3687**	**2082**	**114**	**22**	**0.1**	**0**	**1**	**1.5**	**2**	**6**	**0**	**1**	**769**
Marmot Confluence Sub-basin													
Forest Clearings	0.01	1903	55	11	1.1	3.3	1	3	2	6	0	1	90
North-facing Lodgepole Pine/Aspen	*0.2291*	1786	54	13	2.2	8.8	0	10	2	6	1	0	*578*
South-facing Lodgepole Pine/Aspen	0.24	1725	159	13	2.2	8.8	0	10	2	6	1	0	593
Level Lodgepole Pine/Aspen	0.04	1688	0	4	2.2	8.8	0	10	2	6	1	0	210
South-facing Lodgepole Pine	0.44	1752	172	17	2.2	6.6	0	10	2	6	1	0	853
Level Lodgepole Pine	0.02	1724	0	4	2.2	6.6	0	10	2	6	1	0	150
North-facing Lodgepole Pine	*0.0904*	1687	71	14	2.2	6.6	0	10	2	6	1	0	*331*
Valley Bottom	0.02	1664	163	8	2.2	6.6	0	10	2	6	1	0	1998
North-facing Clearings	**0.2130**	**1742**	**167**	**15**	**0.1**	**0**	**1**	**1.5**	**2**	**6**	**0**	**1**	**554**

Table A39. HRU parameters in the forest disturbance scenario 39: reduction of forest by 60% on north facing slope with 1.5 m stump remained.

HRU	Area (km^2)	Mean Elevation (m)	Mean Aspect (˚)	Mean Slope (˚)	LAI	Canopy Snow Interception Load Capacity (kg/m2)	Canopy Clearing	Vegetation Height (m)	cov_type	groundcover	inhibit_bs	distrib	Routing Length (m)
Cabin Creek Sub-basin													
South-facing Alpine Rock	0.23	2387	122	36	0.1	0	1	0.14	2	1	0	1	575
North-facing Alpine Rock	0.17	2379	69	37	0.1	0	1	0.14	2	1	0	5	485
North-facing Alpine Larch/Spruce	*0.0083*	2222	60	35	1.1	6.6	0	3	2	6	0	5	*79*
South-facing Alpine Larch/Spruce	0.02	2194	115	32	1.1	6.6	0	3	2	6	0	5	130
North-facing Spruce/Fir/Lodgepole Pine	*0.1389*	2046	62	24	2.2	8.8	0	10	2	6	1	0	*428*
South-facing Spruce/Fir/Lodgepole Pine	0.93	1972	151	18	2.2	8.8	0	10	2	6	1	0	1339
Level Spruce/Fir/Lodgepole Pine	0.05	1931	0	4	2.2	8.8	0	10	2	6	1	0	225
Forest Clearings	0.40	1927	140	11	1.1	3.3	1	3	2	6	0	0	806
Level Lodgepole Pine	0.05	1882	0	3	2.2	6.6	0	10	2	6	1	0	244
South-facing Lodgepole Pine	0.07	1798	204	18	2.2	6.6	0	10	2	6	1	0	290
North-facing Lodgepole Pine	*0.0037*	1780	76	25	2.2	6.6	0	10	2	6	1	0	*49*
Valley Bottom	0.04	1951	135	18	2.2	6.6	0	10	2	6	1	0	2337
North-facing Clearings	**0.2263**	**1964**	**154**	**18**	**0.1**	**0**	**1**	**1.5**	**2**	**6**	**0**	**1**	**574**
Middle Creek Sub-basin													
North-facing Alpine Rock	0.52	2462	82	31	0.1	0	1	0.14	2	1	0	1	944
South-facing Alpine Rock	1.37	2422	148	30	0.1	0	1	0.14	2	1	0	5	1689
South-facing Alpine Larch/Spruce	0.26	2246	138	20	1.1	6.6	0	3	2	6	0	5	618
North-facing Alpine Larch/Spruce	*0.0312*	2211	46	18	1.1	6.6	0	3	2	6	0	5	*175*
North-facing Spruce/Fir/Lodgepole Pine	*0.0630*	1995	76	21	2.2	8.8	0	10	2	6	1	0	*267*
South-facing Spruce/Fir/Lodgepole Pine	0.52	1953	134	22	2.2	8.8	0	10	2	6	1	0	947
Valley Bottom	0.03	2057	115	16	2.2	6.6	0	10	2	6	1	0	2907
North-facing Clearings	**0.1413**	**2049**	**135**	**21**	**0.1**	**0**	**1**	**1.5**	**2**	**6**	**0**	**1**	**433**
Twin Creek Sub-basin													
North-facing Alpine Rock	0.79	2386	67	28	0.1	0	1	0.14	2	1	0	1	1218
South-facing Alpine Rock	0.15	2380	106	22	0.1	0	1	0.14	2	1	0	5	457
South-facing Alpine Larch/Spruce	0.28	2228	116	23	1.1	6.6	0	3	2	6	0	5	650
North-facing Alpine Larch/Spruce	*0.1127*	2182	37	22	1.1	6.6	0	3	2	6	0	5	*378*
North-facing Spruce/Fir/Lodgepole Pine	*0.2561*	1966	34	17	2.2	8.8	0	10	2	6	1	0	*618*
South-facing Spruce/Fir/Lodgepole Pine	0.60	2014	113	21	2.2	8.8	0	10	2	6	1	0	1028
Valley Bottom	0.04	1988	119	16	2.2	6.6	0	10	2	6	1	0	2443
North-facing Clearings	**0.5531**	**2082**	**114**	**22**	**0.1**	**0**	**1**	**1.5**	**2**	**6**	**0**	**1**	**981**
Marmot Confluence Sub-basin													
Forest Clearings	0.01	1903	55	11	1.1	3.3	1	3	2	6	0	1	90
North-facing Lodgepole Pine/Aspen	*0.1528*	1786	54	13	2.2	8.8	0	10	2	6	1	0	*453*
South-facing Lodgepole Pine/Aspen	0.24	1725	159	13	2.2	8.8	0	10	2	6	1	0	593
Level Lodgepole Pine/Aspen	0.04	1688	0	4	2.2	8.8	0	10	2	6	1	0	210
South-facing Lodgepole Pine	0.44	1752	172	17	2.2	6.6	0	10	2	6	1	0	853
Level Lodgepole Pine	0.02	1724	0	4	2.2	6.6	0	10	2	6	1	0	150
North-facing Lodgepole Pine	*0.0603*	1687	71	14	2.2	6.6	0	10	2	6	1	0	*260*
Valley Bottom	0.02	1664	163	8	2.2	6.6	0	10	2	6	1	0	1998
North-facing Clearings	**0.3195**	**1742**	**167**	**15**	**0.1**	**0**	**1**	**1.5**	**2**	**6**	**0**	**1**	**706**

Table A40. HRU parameters in the forest disturbance scenario 40: reduction of forest by 80% on north facing slope with 1.5 m stump remained.

HRU	Area (km^2)	Mean Elevation (m)	Mean Aspect (°)	Mean Slope (°)	LAI	Canopy Snow Interception Load Capacity (kg/m2)	Canopy Clearing	Vegetation Height (m)	cov_type	groundcover	inhibit_bs	distrib	Routing Length (m)
						Cabin Creek Sub-basin							
South-facing Alpine Rock	0.23	2387	122	36	0.1	0	1	0.14	2	1	0	1	575
North-facing Alpine Rock	0.17	2379	69	37	0.1	0	1	0.14	2	1	0	5	485
North-facing Alpine Larch/Spruce	*0.0042*	2222	60	35	1.1	6.6	0	3	2	6	0	5	*52*
South-facing Alpine Larch/Spruce	0.02	2194	115	32	1.1	6.6	0	3	2	6	0	5	130
North-facing Spruce/Fir/Lodgepole Pine	*0.0694*	2046	62	24	2.2	8.8	0	10	2	6	1	0	*283*
South-facing Spruce/Fir/Lodgepole Pine	0.93	1972	151	18	2.2	8.8	0	10	2	6	1	0	1339
Level Spruce/Fir/Lodgepole Pine	0.05	1931	0	4	2.2	8.8	0	10	2	6	1	0	225
Forest Clearings	0.40	1927	140	11	1.1	3.3	1	3	2	6	0	0	806
Level Lodgepole Pine	0.05	1882	0	3	2.2	6.6	0	10	2	6	1	0	244
South-facing Lodgepole Pine	0.07	1798	204	18	2.2	6.6	0	10	2	6	1	0	290
North-facing Lodgepole Pine	*0.0018*	1780	76	25	2.2	6.6	0	10	2	6	1	0	*32*
Valley Bottom	0.04	1951	135	18	2.2	6.6	0	10	2	6	1	0	2337
North-facing Clearings	**0.3018**	**1964**	**154**	**18**	**0.1**	**0**	**1**	**1.5**	**2**	**6**	**0**	**1**	**682**
						Middle Creek Sub-basin							
North-facing Alpine Rock	0.52	2462	82	31	0.1	0	1	0.14	2	1	0	1	944
South-facing Alpine Rock	1.37	2422	148	30	0.1	0	1	0.14	2	1	0	5	1689
South-facing Alpine Larch/Spruce	0.26	2246	138	20	1.1	6.6	0	3	2	6	0	5	618
North-facing Alpine Larch/Spruce	*0.0156*	2211	46	18	1.1	6.6	0	3	2	6	0	5	*115*
North-facing Spruce/Fir/Lodgepole Pine	*0.0315*	1995	76	21	2.2	8.8	0	10	2	6	1	0	*176*
South-facing Spruce/Fir/Lodgepole Pine	0.52	1953	134	22	2.2	8.8	0	10	2	6	1	0	947
Valley Bottom	0.03	2057	115	16	2.2	6.6	0	10	2	6	1	0	2907
North-facing Clearings	**0.1884**	**2049**	**135**	**21**	**0.1**	**0**	**1**	**1.5**	**2**	**6**	**0**	**1**	**514**
						Twin Creek Sub-basin							
North-facing Alpine Rock	0.79	2386	67	28	0.1	0	1	0.14	2	1	0	1	1218
South-facing Alpine Rock	0.15	2380	106	22	0.1	0	1	0.14	2	1	0	5	457
South-facing Alpine Larch/Spruce	0.28	2228	116	23	1.1	6.6	0	3	2	6	0	5	650
North-facing Alpine Larch/Spruce	*0.0563*	2182	37	22	1.1	6.6	0	3	2	6	0	5	*249*
North-facing Spruce/Fir/Lodgepole Pine	*0.1280*	1966	34	17	2.2	8.8	0	10	2	6	1	0	*408*
South-facing Spruce/Fir/Lodgepole Pine	0.60	2014	113	21	2.2	8.8	0	10	2	6	1	0	1028
Valley Bottom	0.04	1988	119	16	2.2	6.6	0	10	2	6	1	0	2443
North-facing Clearings	**0.7375**	**2082**	**114**	**22**	**0.1**	**0**	**1**	**1.5**	**2**	**6**	**0**	**1**	**1166**
						Marmot Confluence Sub-basin							
Forest Clearings	0.01	1903	55	11	1.1	3.3	1	3	2	6	0	1	90
North-facing Lodgepole Pine/Aspen	*0.0764*	1786	54	13	2.2	8.8	0	10	2	6	1	0	*299*
South-facing Lodgepole Pine/Aspen	0.24	1725	159	13	2.2	8.8	0	10	2	6	1	0	593
Level Lodgepole Pine/Aspen	0.04	1688	0	4	2.2	8.8	0	10	2	6	1	0	210
South-facing Lodgepole Pine	0.44	1752	172	17	2.2	6.6	0	10	2	6	1	0	853
Level Lodgepole Pine	0.02	1724	0	4	2.2	6.6	0	10	2	6	1	0	150
North-facing Lodgepole Pine	*0.0301*	1687	71	14	2.2	6.6	0	10	2	6	1	0	*171*
Valley Bottom	0.02	1664	163	8	2.2	6.6	0	10	2	6	1	0	1998
North-facing Clearings	**0.4260**	**1742**	**167**	**15**	**0.1**	**0**	**1**	**1.5**	**2**	**6**	**0**	**1**	**839**

Table A41. HRU parameters in the forest disturbance scenario 41: reduction of forest by 100% on north facing slope with 1.5 m stump remained.

HRU	Area (km^2)	Mean Elevation (m)	Mean Aspect (˚)	Mean Slope (˚)	LAI	Canopy Snow Interception Load Capacity (kg/m2)	Canopy Clearing	Vegetation Height (m)	cov_type	groundcover	inhibit_bs	distrib	Routing Length (m)
						Cabin Creek Sub-basin							
South-facing Alpine Rock	0.23	2387	122	36	0.1	0	1	0.14	2	1	0	1	575
North-facing Alpine Rock	0.17	2379	69	37	0.1	0	1	0.14	2	1	0	5	485
North-facing Alpine Larch/Spruce	*1E-06*	2222	60	35	1.1	6.6	0	3	2	6	0	5	*0.35*
South-facing Alpine Larch/Spruce	0.02	2194	115	32	1.1	6.6	0	3	2	6	0	5	130
North-facing Spruce/Fir/Lodgepole Pine	*1E-06*	2046	62	24	2.2	8.8	0	10	2	6	1	0	*0.35*
South-facing Spruce/Fir/Lodgepole Pine	0.93	1972	151	18	2.2	8.8	0	10	2	6	1	0	1339
Level Spruce/Fir/Lodgepole Pine	0.05	1931	0	4	2.2	8.8	0	10	2	6	1	0	225
Forest Clearings	0.40	1927	140	11	1.1	3.3	1	3	2	6	0	0	806
Level Lodgepole Pine	0.05	1882	0	3	2.2	6.6	0	10	2	6	1	0	244
South-facing Lodgepole Pine	0.07	1798	204	18	2.2	6.6	0	10	2	6	1	0	290
North-facing Lodgepole Pine	*1E-06*	1780	76	25	2.2	6.6	0	10	2	6	1	0	*0.35*
Valley Bottom	0.04	1951	135	18	2.2	6.6	0	10	2	6	1	0	2337
North-facing Clearings	**0.3772**	**1964**	**154**	**18**	**0.1**	**0**	**1**	**1.5**	**2**	**6**	**0**	**1**	**780**
						Middle Creek Sub-basin							
North-facing Alpine Rock	0.52	2462	82	31	0.1	0	1	0.14	2	1	0	1	944
South-facing Alpine Rock	1.37	2422	148	30	0.1	0	1	0.14	2	1	0	5	1689
South-facing Alpine Larch/Spruce	0.26	2246	138	20	1.1	6.6	0	3	2	6	0	5	618
North-facing Alpine Larch/Spruce	*1E-06*	2211	46	18	1.1	6.6	0	3	2	6	0	5	*0.35*
North-facing Spruce/Fir/Lodgepole Pine	*1E-06*	1995	76	21	2.2	8.8	0	10	2	6	1	0	*0.35*
South-facing Spruce/Fir/Lodgepole Pine	0.52	1953	134	22	2.2	8.8	0	10	2	6	1	0	947
Valley Bottom	0.03	2057	115	16	2.2	6.6	0	10	2	6	1	0	2907
North-facing Clearings	**0.2355**	**2049**	**135**	**21**	**0.1**	**0**	**1**	**1.5**	**2**	**6**	**0**	**1**	**588**
						Twin Creek Sub-basin							
North-facing Alpine Rock	0.79	2386	67	28	0.1	0	1	0.14	2	1	0	1	1218
South-facing Alpine Rock	0.15	2380	106	22	0.1	0	1	0.14	2	1	0	5	457
South-facing Alpine Larch/Spruce	0.28	2228	116	23	1.1	6.6	0	3	2	6	0	5	650
North-facing Alpine Larch/Spruce	*1E-06*	2182	37	22	1.1	6.6	0	3	2	6	0	5	*0.35*
North-facing Spruce/Fir/Lodgepole Pine	*1E-06*	1966	34	17	2.2	8.8	0	10	2	6	1	0	*0.35*
South-facing Spruce/Fir/Lodgepole Pine	0.60	2014	113	21	2.2	8.8	0	10	2	6	1	0	1028
Valley Bottom	0.04	1988	119	16	2.2	6.6	0	10	2	6	1	0	2443
North-facing Clearings	**0.9218**	**2082**	**114**	**22**	**0.1**	**0**	**1**	**1.5**	**2**	**6**	**0**	**1**	**1333**
						Marmot Confluence Sub-basin							
Forest Clearings	0.01	1903	55	11	1.1	3.3	1	3	2	6	0	1	90
North-facing Lodgepole Pine/Aspen	*1E-06*	1786	54	13	2.2	8.8	0	10	2	6	1	0	*0.35*
South-facing Lodgepole Pine/Aspen	0.24	1725	159	13	2.2	8.8	0	10	2	6	1	0	593
Level Lodgepole Pine/Aspen	0.04	1688	0	4	2.2	8.8	0	10	2	6	1	0	210
South-facing Lodgepole Pine	0.44	1752	172	17	2.2	6.6	0	10	2	6	1	0	853
Level Lodgepole Pine	0.02	1724	0	4	2.2	6.6	0	10	2	6	1	0	150
North-facing Lodgepole Pine	*1E-06*	1687	71	14	2.2	6.6	0	10	2	6	1	0	*0.35*
Valley Bottom	0.02	1664	163	8	2.2	6.6	0	10	2	6	1	0	1998
North-facing Clearings	**0.5325**	**1742**	**167**	**15**	**0.1**	**0**	**1**	**1.5**	**2**	**6**	**0**	**1**	**959**

Appendix 2 Snow Accumulation (mm SWE) Regime Changes with Forest Disturbance Scenario

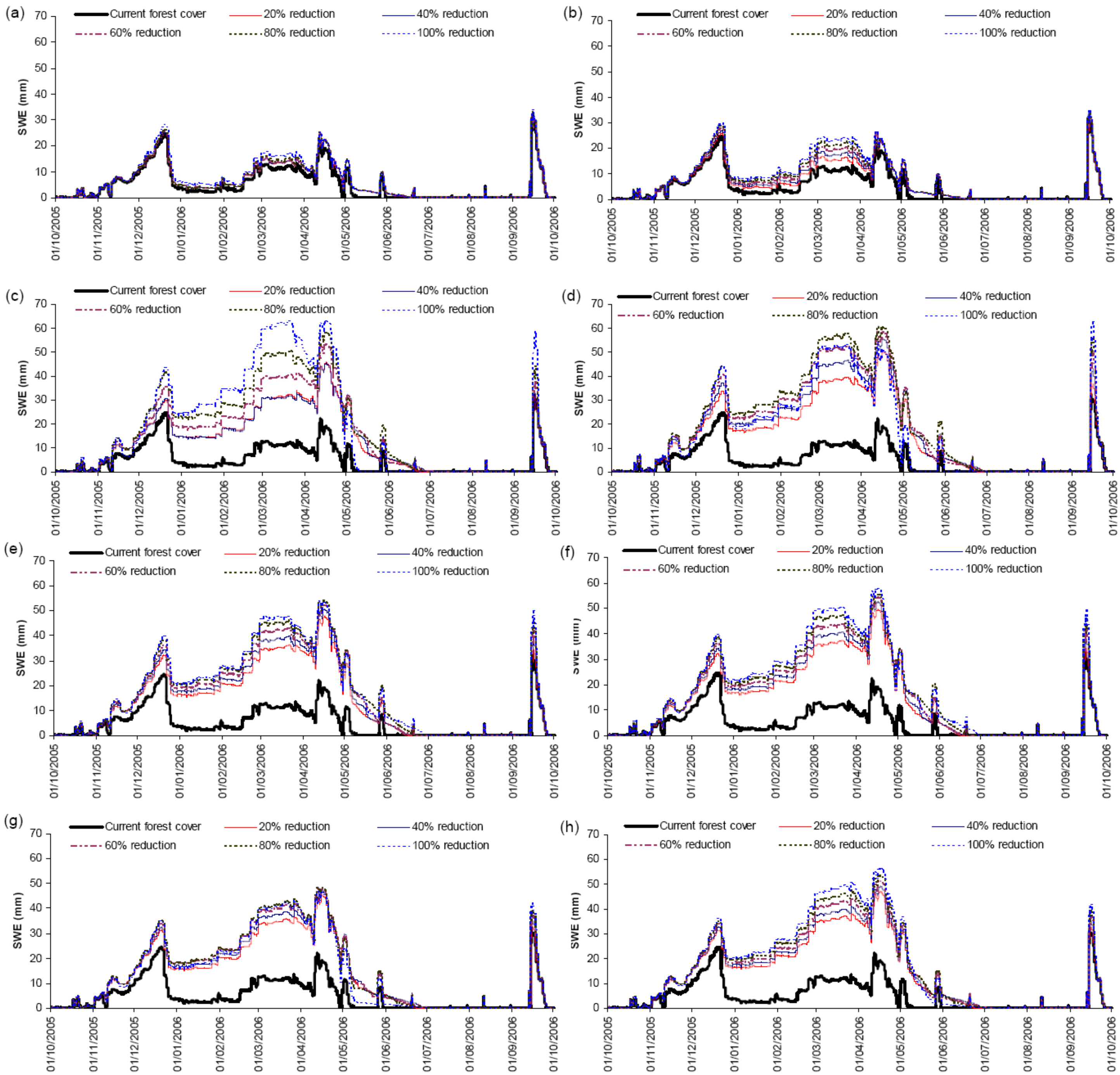

Figure A1. Sensitivity of Marmot Creek Basin snow accumulation to the forest disturbance scenarios during 1 October 2005-30 September 2006. (a) pine beetle reducing pine with infested trunk remained, (b) pine beetle reducing pine plus salvage logging, (c) fire reducing all forest with burned truck remained, (d) fire reducing all forest with burned trunk removed, (e) logging south-facing forest cover, (f) logging south-facing with 1.5 m stumps remained, (g) logging north-facing forest cover, and (h) logging north-facing with 1.5 m stumps remained.

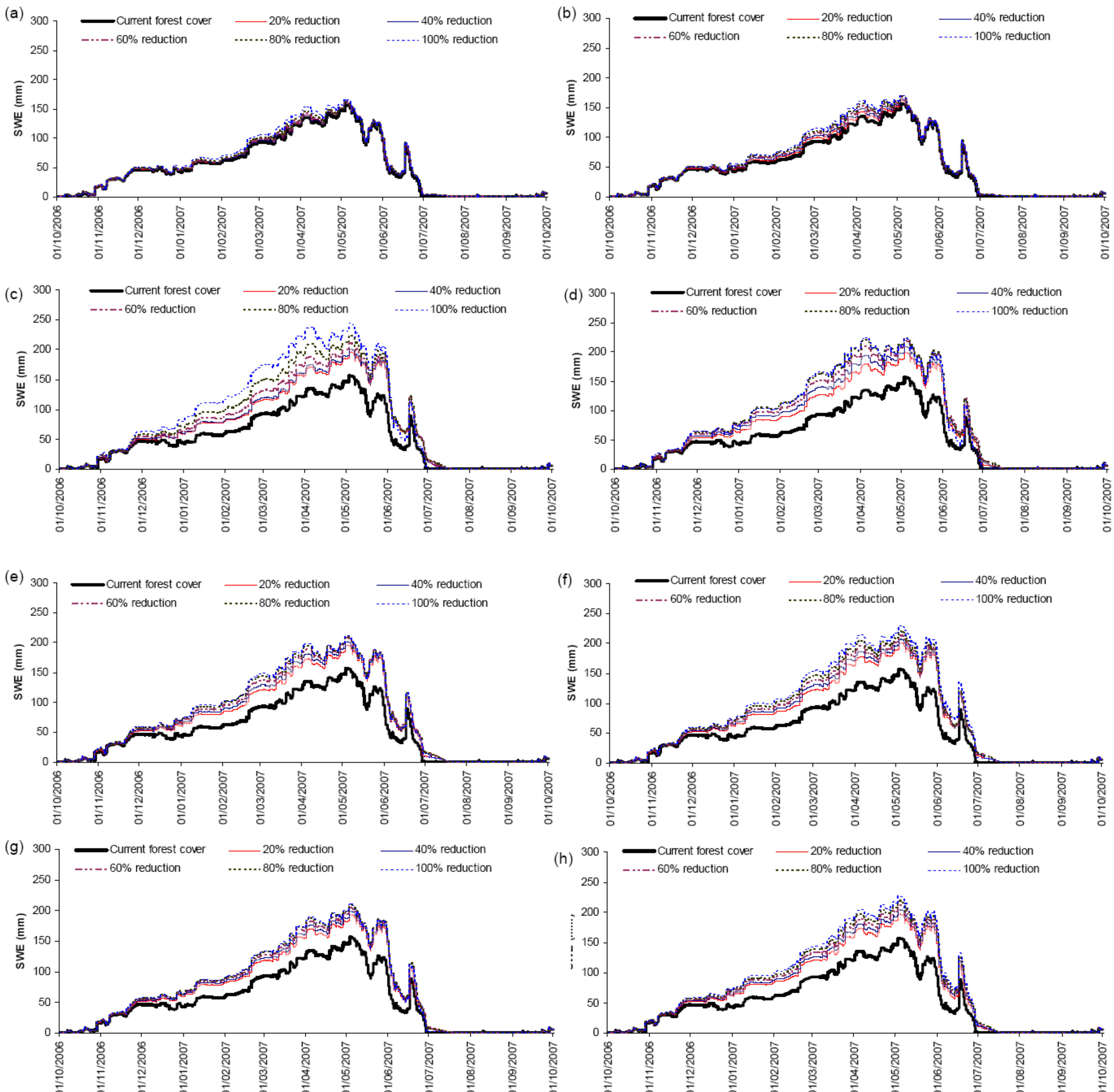

Figure A2. Sensitivity of Marmot Creek Basin snow accumulation to the forest disturbance scenarios during 1 October 2006-30 September 2007. (a) pine beetle reducing pine with infested trunk remained, (b) pine beetle reducing pine plus salvage logging, (c) fire reducing all forest with burned truck remained, (d) fire reducing all forest with burned trunk removed, (e) logging south-facing forest cover, (f) logging south-facing with 1.5 m stumps remained, (g) logging north-facing forest cover, and (h) logging north-facing with 1.5 m stumps remained.

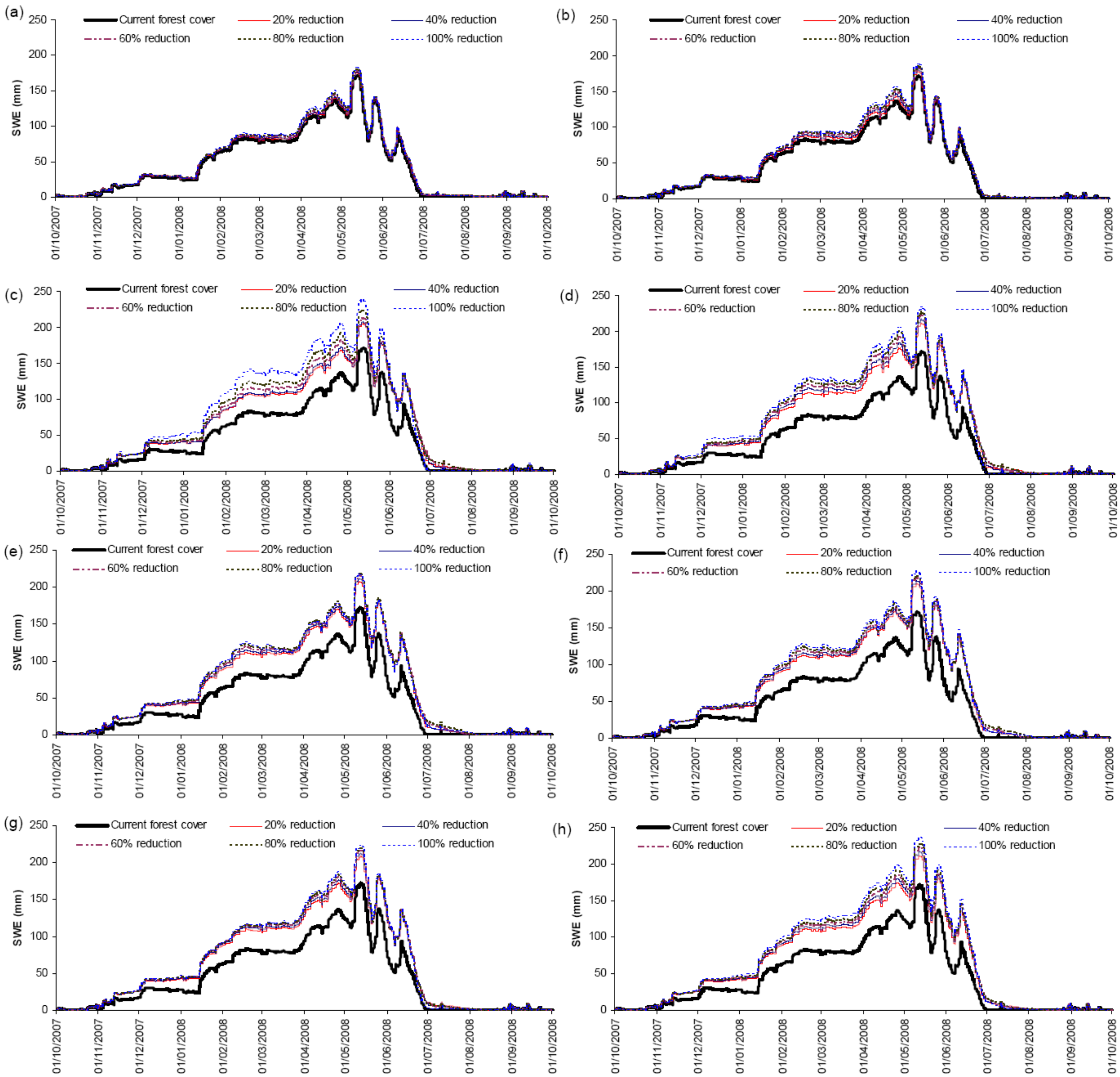

Figure A3. Sensitivity of Marmot Creek Basin snow accumulation to the forest disturbance scenarios during 1 October 2007-30 September 2008. (a) pine beetle reducing pine with infested trunk remained, (b) pine beetle reducing pine plus salvage logging, (c) fire reducing all forest with burned truck remained, (d) fire reducing all forest with burned trunk removed, (e) logging south-facing forest cover, (f) logging south-facing with 1.5 m stumps remained, (g) logging north-facing forest cover, and (h) logging north-facing with 1.5 m stumps remained.

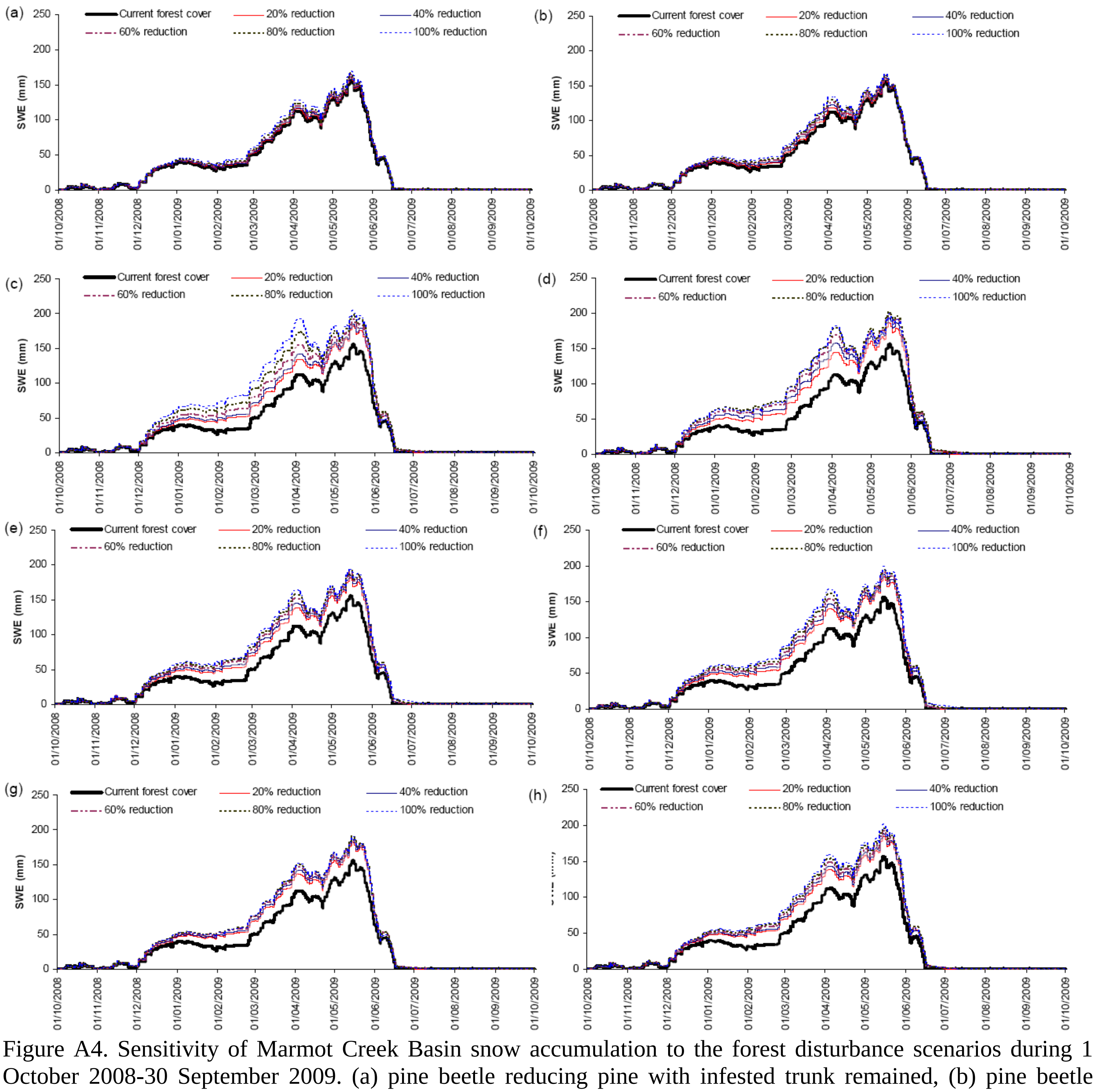

Figure A4. Sensitivity of Marmot Creek Basin snow accumulation to the forest disturbance scenarios during 1 October 2008-30 September 2009. (a) pine beetle reducing pine with infested trunk remained, (b) pine beetle reducing pine plus salvage logging, (c) fire reducing all forest with burned truck remained, (d) fire reducing all forest with burned trunk removed, (e) logging south-facing forest cover, (f) logging south-facing with 1.5 m stumps remained, (g) logging north-facing forest cover, and (h) logging north-facing with 1.5 m stumps remained.

Appendix 3 Streamflow (dam^3 per day) Regime Changes with Forest Disturbance Scenario

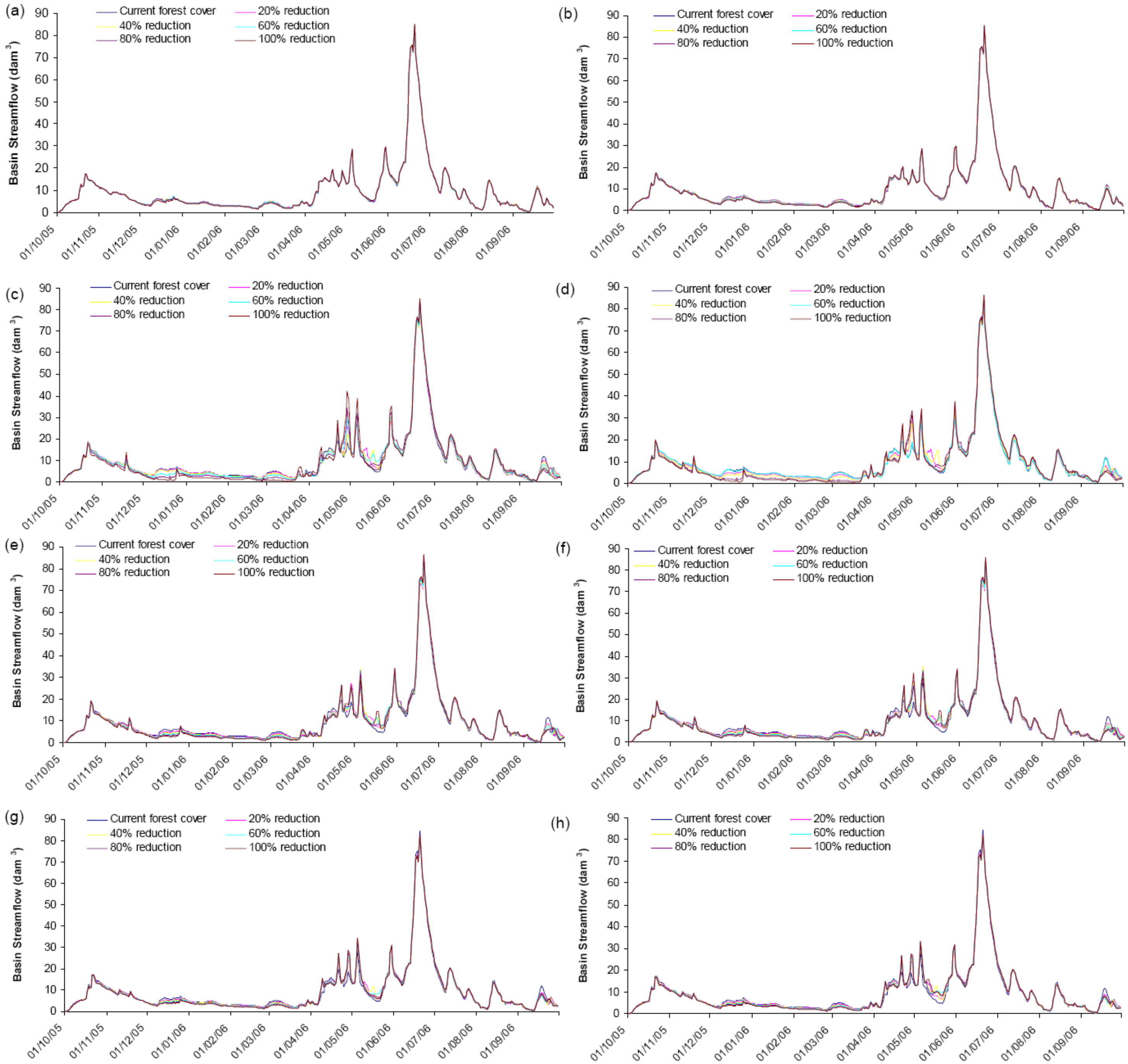

Figure A5. Sensitivity of Marmot Creek Research Basin streamflow to the forest disturbance scenarios during 1 October 2005-30 September 2006. (a) pine beetle reducing pine with infested trunk remained, (b) pine beetle reducing pine plus salvage logging, (c) fire reducing all forest with burned truck remained, (d) fire reducing all forest with burned trunk removed, (e) logging south-facing forest cover, (f) logging south-facing with 1.5 m stumps remained, (g) logging north-facing forest cover, and (h) logging north-facing with 1.5 m stumps remained.

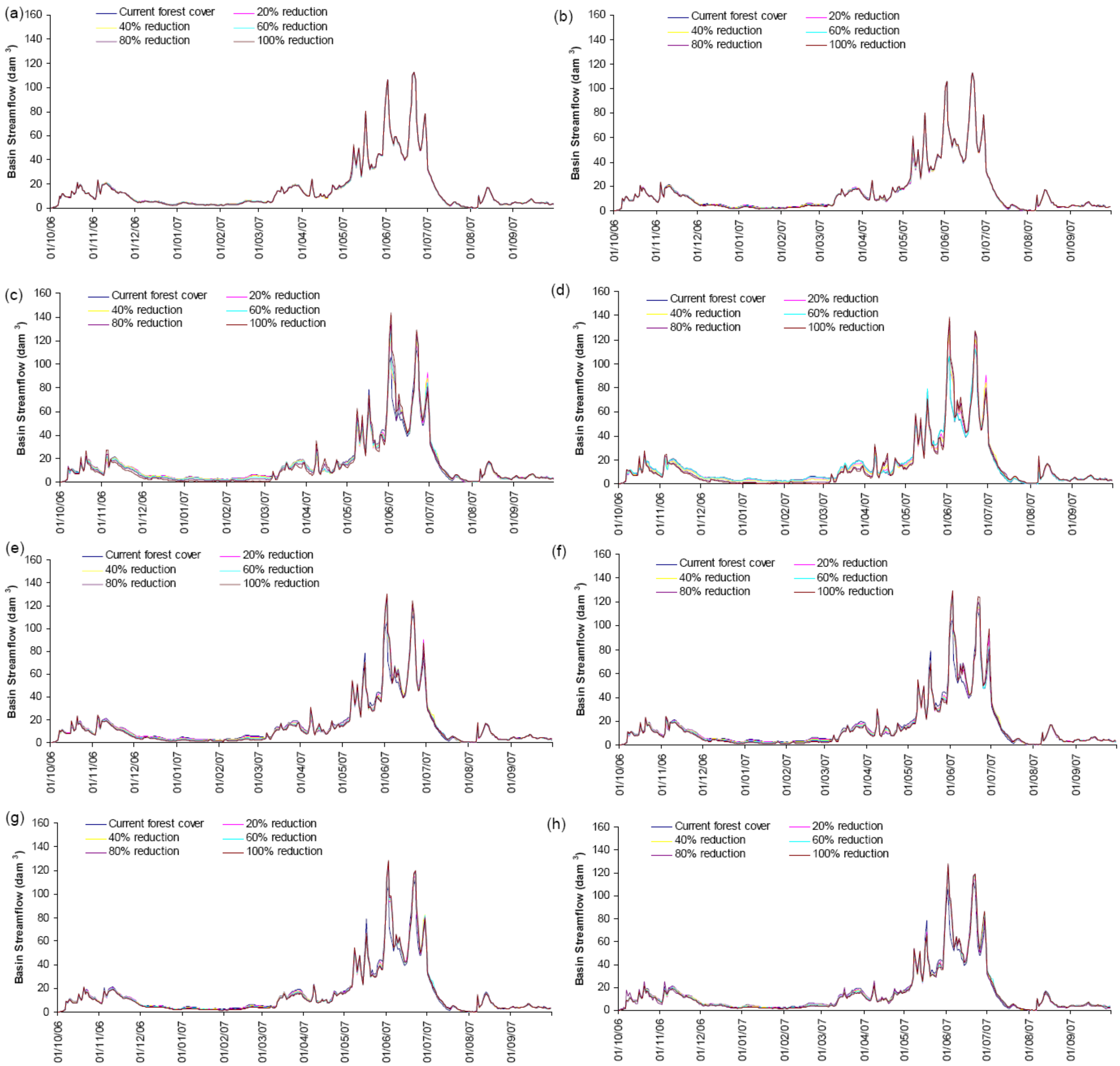

Figure A6. Sensitivity of Marmot Creek Research Basin streamflow to the forest disturbance scenarios during 1 October 2006-30 September 2007. (a) pine beetle reducing pine with infested trunk remained, (b) pine beetle reducing pine plus salvage logging, (c) fire reducing all forest with burned truck remained, (d) fire reducing all forest with burned trunk removed, (e) logging south-facing forest cover, (f) logging south-facing with 1.5 m stumps remained, (g) logging north-facing forest cover, and (h) logging north-facing with 1.5 m stumps remained.

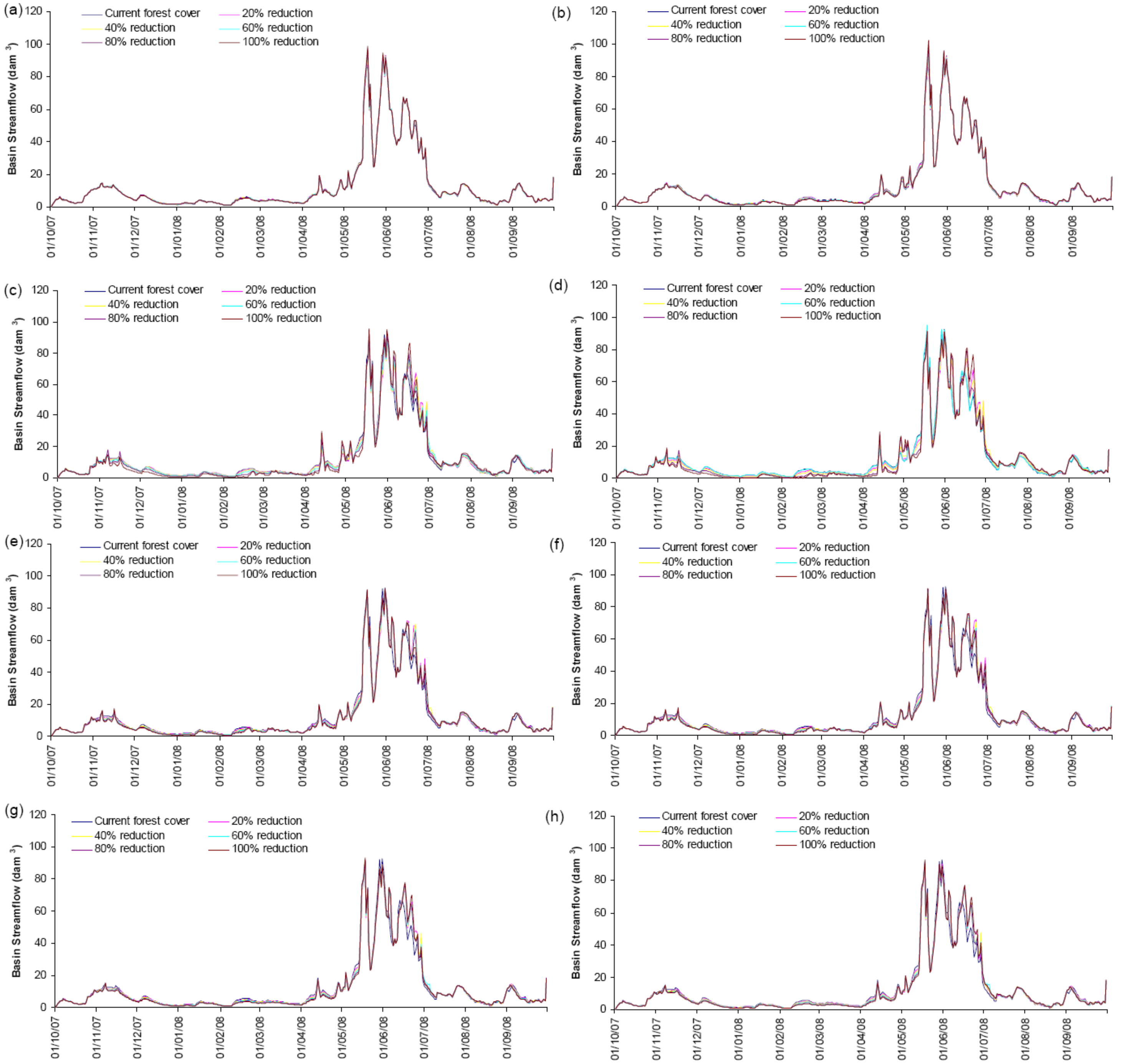

Figure A7. Sensitivity of Marmot Creek Research Basin streamflow to the forest disturbance scenarios during 1 October 2007-30 September 2008. (a) pine beetle reducing pine with infested trunk remained, (b) pine beetle reducing pine plus salvage logging, (c) fire reducing all forest with burned truck remained, (d) fire reducing all forest with burned trunk removed, (e) logging south-facing forest cover, (f) logging south-facing with 1.5 m stumps remained, (g) logging north-facing forest cover, and (h) logging north-facing with 1.5 m stumps remained.

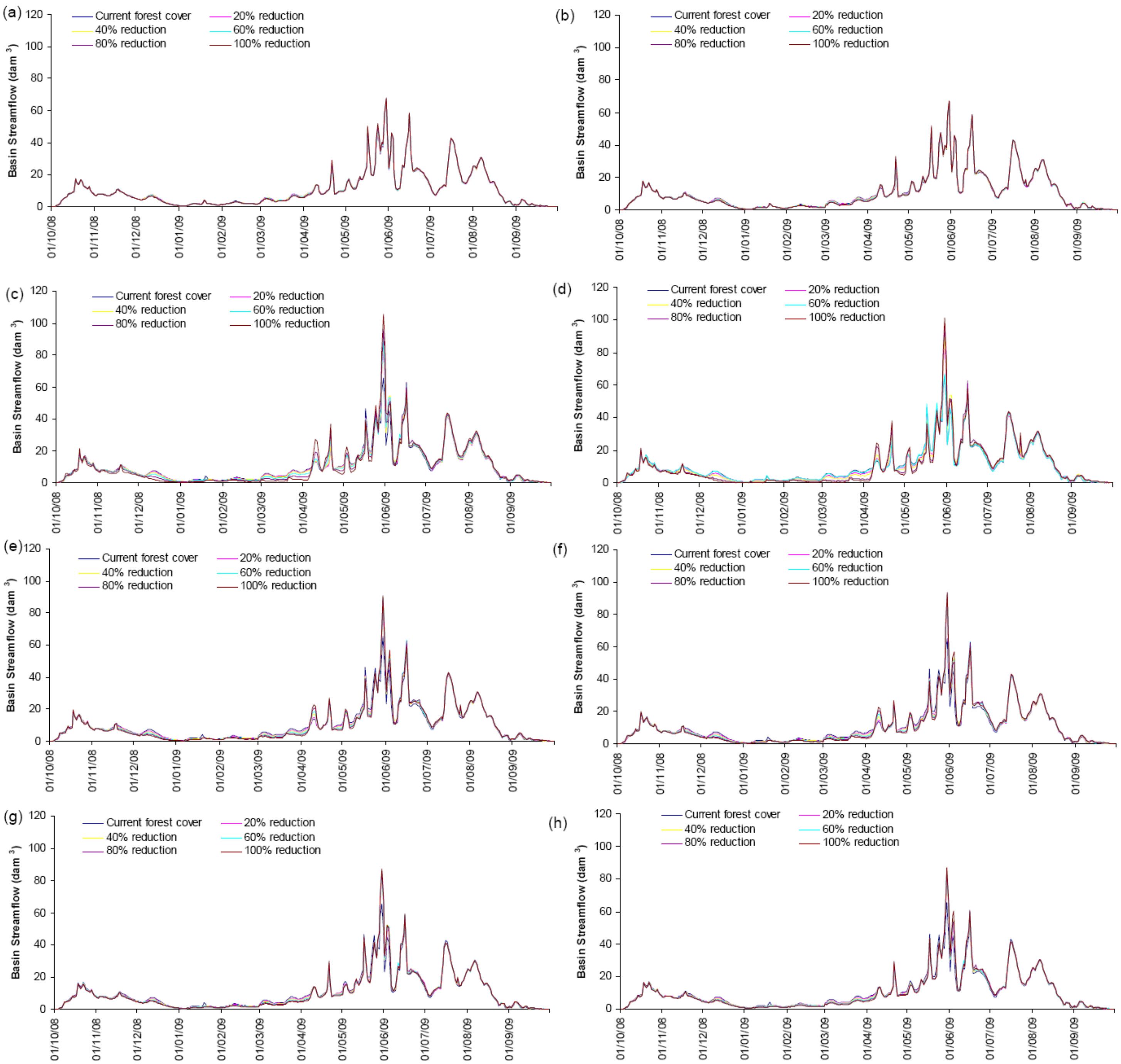

Figure A8. Sensitivity of Marmot Creek Research Basin streamflow to the forest disturbance scenarios during 1 October 2008-30 September 2009. (a) pine beetle reducing pine with infested trunk remained, (b) pine beetle reducing pine plus salvage logging, (c) fire reducing all forest with burned truck remained, (d) fire reducing all forest with burned trunk removed, (e) logging south-facing forest cover, (f) logging south-facing with 1.5 m stumps remained, (g) logging north-facing forest cover, and (h) logging north-facing with 1.5 m stumps remained.

Appendix 3 Groundwater Flow (dam^3 per day) Regime Changes with Forest Disturbance Scenario

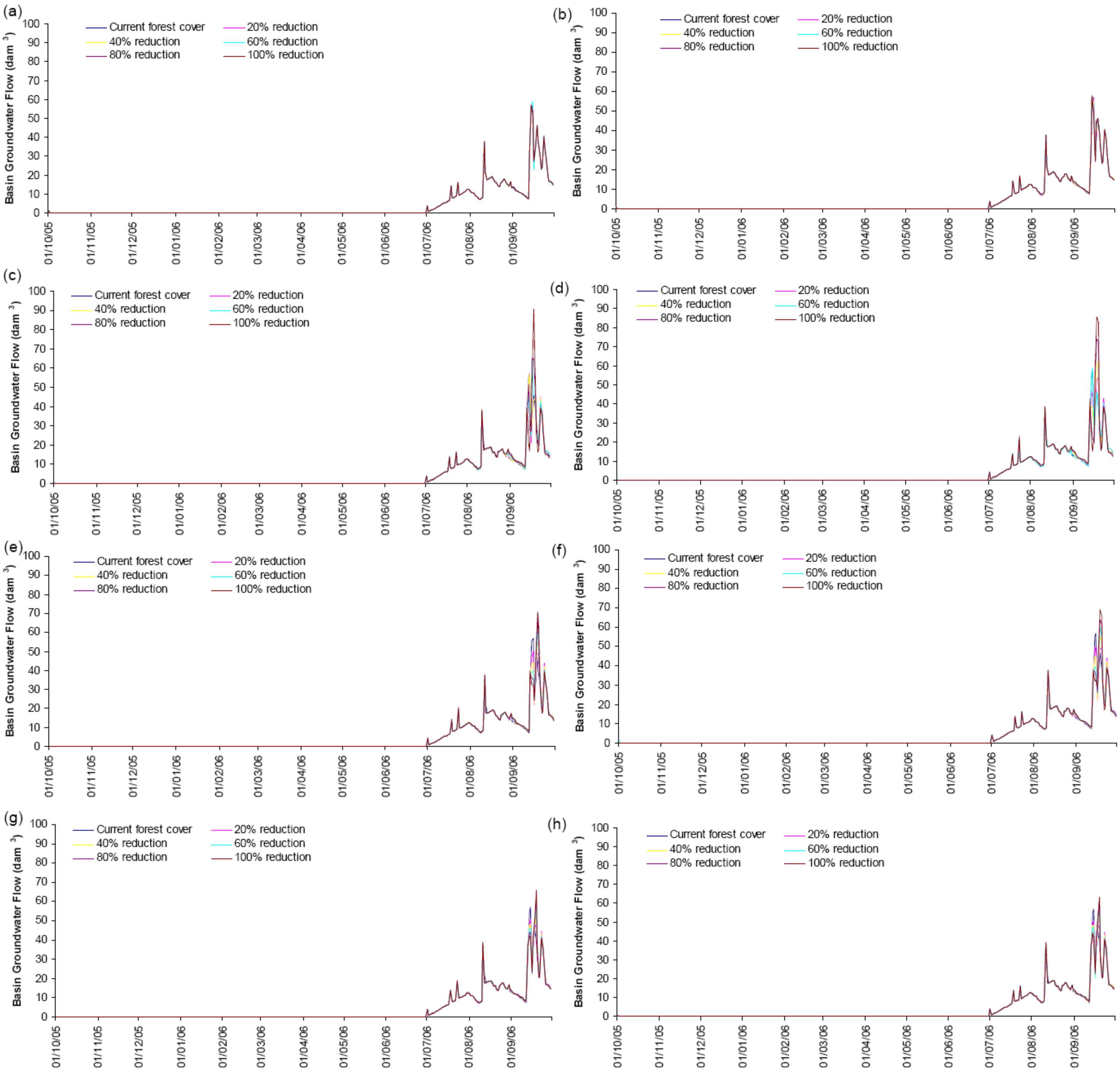

Figure A9. Sensitivity of Marmot Creek Research Basin active groundwater flow to the forest disturbance scenarios during 1 October 2005-30 September 2006. (a) pine beetle reducing pine with infested trunk remained, (b) pine beetle reducing pine plus salvage logging, (c) fire reducing all forest with burned truck remained, (d) fire reducing all forest with burned trunk removed, (e) logging south-facing forest cover, (f) logging south-facing with 1.5 m stumps remained, (g) logging north-facing forest cover, and (h) logging north-facing with 1.5 m stumps remained.

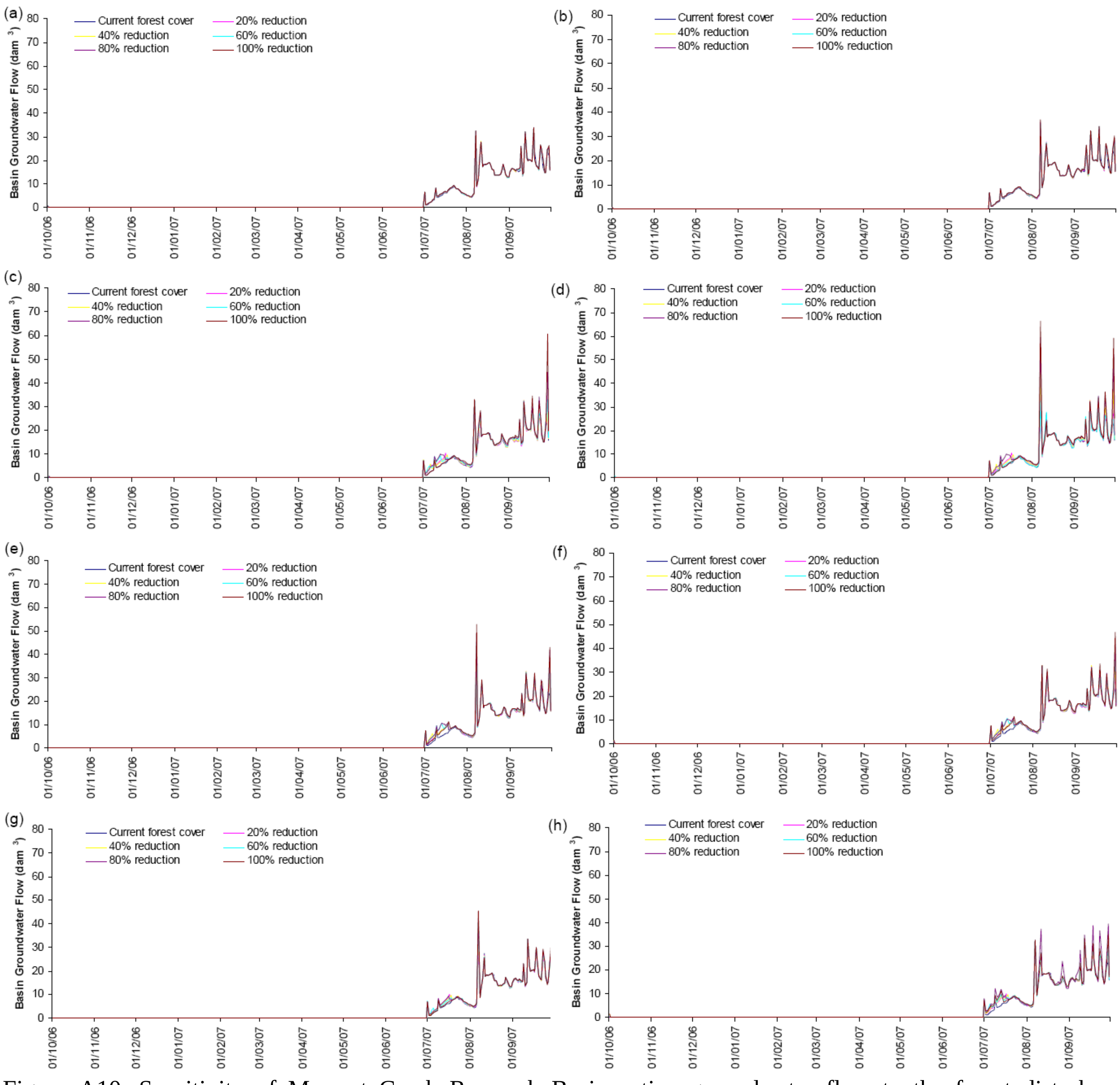

Figure A10. Sensitivity of Marmot Creek Research Basin active groundwater flow to the forest disturbance scenarios during 1 October 2006-30 September 2007. (a) pine beetle reducing pine with infested trunk remained, (b) pine beetle reducing pine plus salvage logging, (c) fire reducing all forest with burned truck remained, (d) fire reducing all forest with burned trunk removed, (e) logging south-facing forest cover, (f) logging south-facing with 1.5 m stumps remained, (g) logging north-facing forest cover, and (h) logging north-facing with 1.5 m stumps remained.

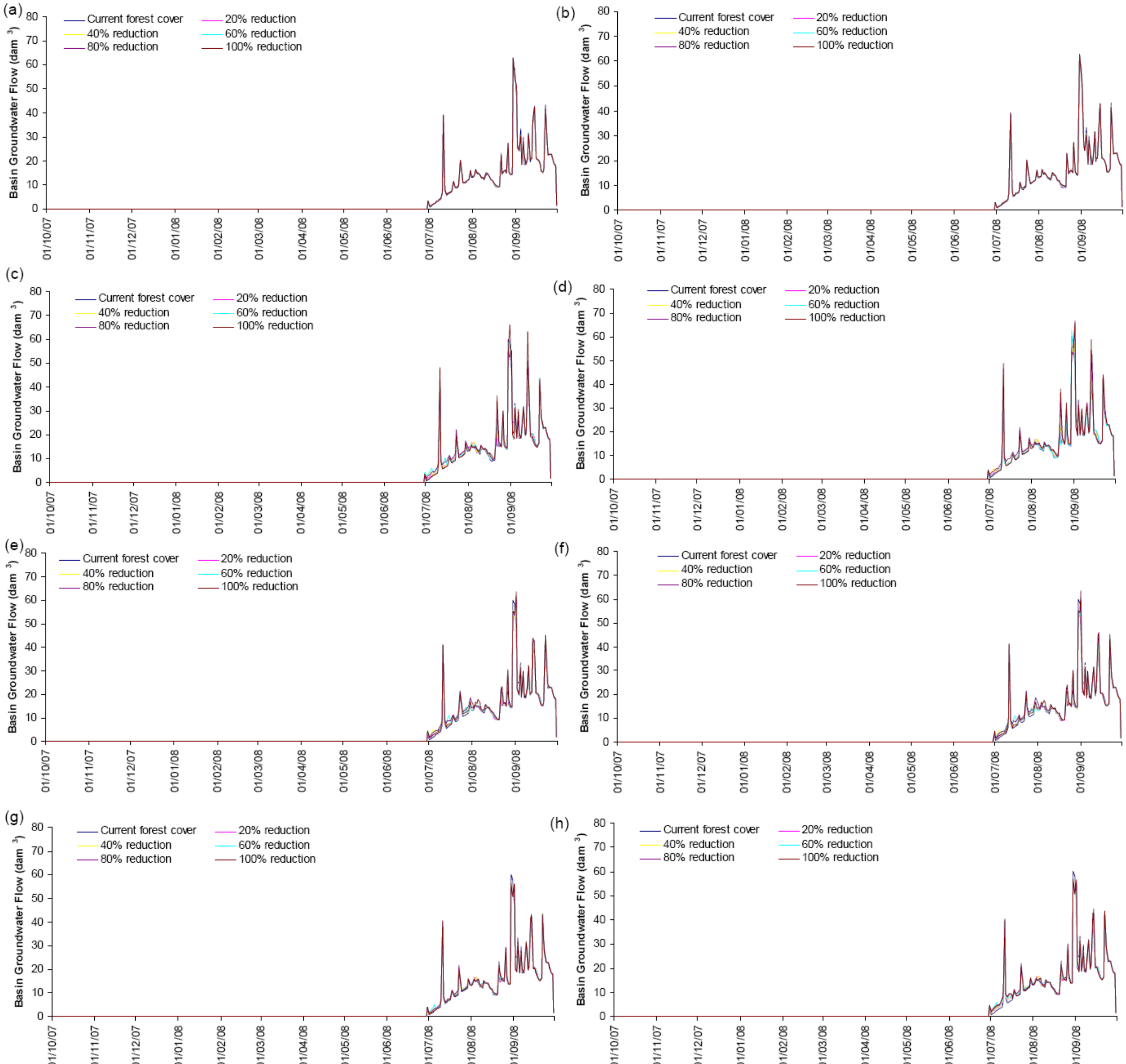

Figure A11. Sensitivity of Marmot Creek Research Basin active groundwater flow to the forest disturbance scenarios during 1 October 2007-30 September 2008. (a) pine beetle reducing pine with infested trunk remained, (b) pine beetle reducing pine plus salvage logging, (c) fire reducing all forest with burned truck remained, (d) fire reducing all forest with burned trunk removed, (e) logging south-facing forest cover, (f) logging south-facing with 1.5 m stumps remained, (g) logging north-facing forest cover, and (h) logging north-facing with 1.5 m stumps remained.

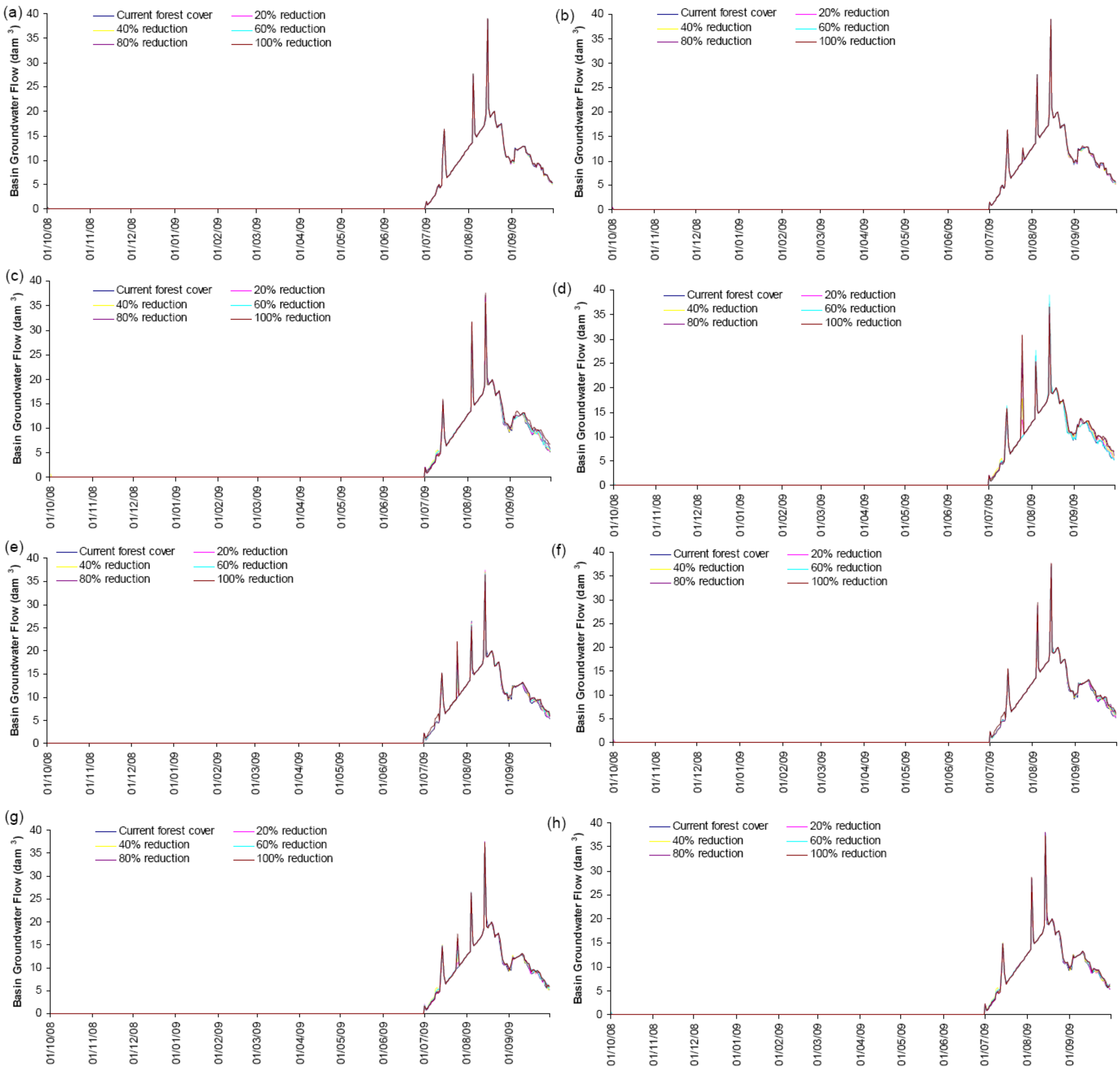

Figure A12. Sensitivity of Marmot Creek Research Basin active groundwater flow to the forest disturbance scenarios during 1 October 2008-30 September 2009. (a) pine beetle reducing pine with infested trunk remained, (b) pine beetle reducing pine plus salvage logging, (c) fire reducing all forest with burned truck remained, (d) fire reducing all forest with burned trunk removed, (e) logging south-facing forest cover, (f) logging south-facing with 1.5 m stumps remained, (g) logging north-facing forest cover, and (h) logging north-facing with 1.5 m stumps remained.