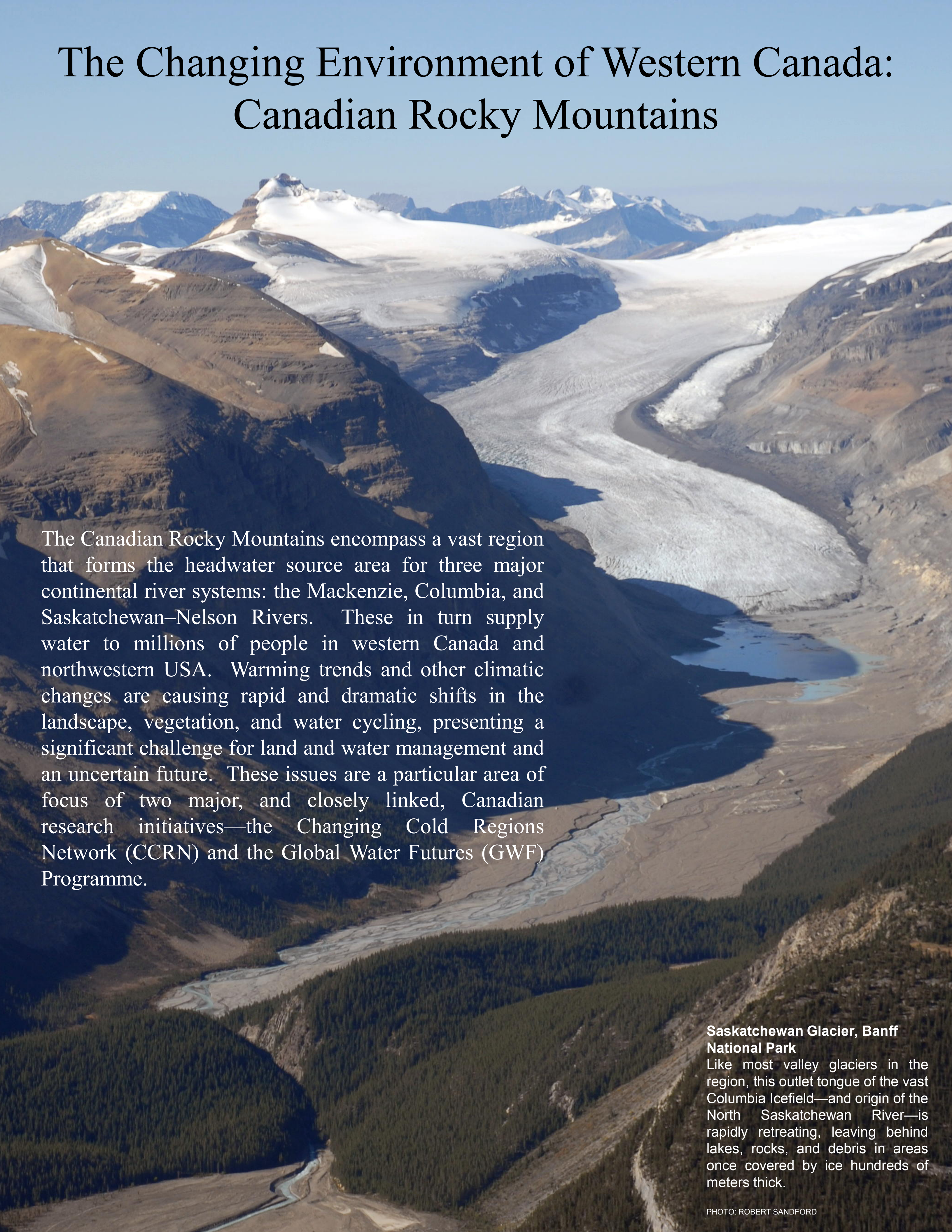
The Changing Environment of Western Canada: Canadian Rocky Mountains



The Canadian Rocky Mountains encompass a vast region that forms the headwater source area for three major continental river systems: the Mackenzie, Columbia, and Saskatchewan–Nelson Rivers. These in turn supply water to millions of people in western Canada and northwestern USA. Warming trends and other climatic changes are causing rapid and dramatic shifts in the landscape, vegetation, and water cycling, presenting a significant challenge for land and water management and an uncertain future. These issues are a particular area of focus of two major, and closely linked, Canadian research initiatives—the Changing Cold Regions Network (CCRN) and the Global Water Futures (GWF) Programme.

Saskatchewan Glacier, Banff National Park
Like most valley glaciers in the region, this outlet tongue of the vast Columbia Icefield—and origin of the North Saskatchewan River—is rapidly retreating, leaving behind lakes, rocks, and debris in areas once covered by ice hundreds of meters thick.

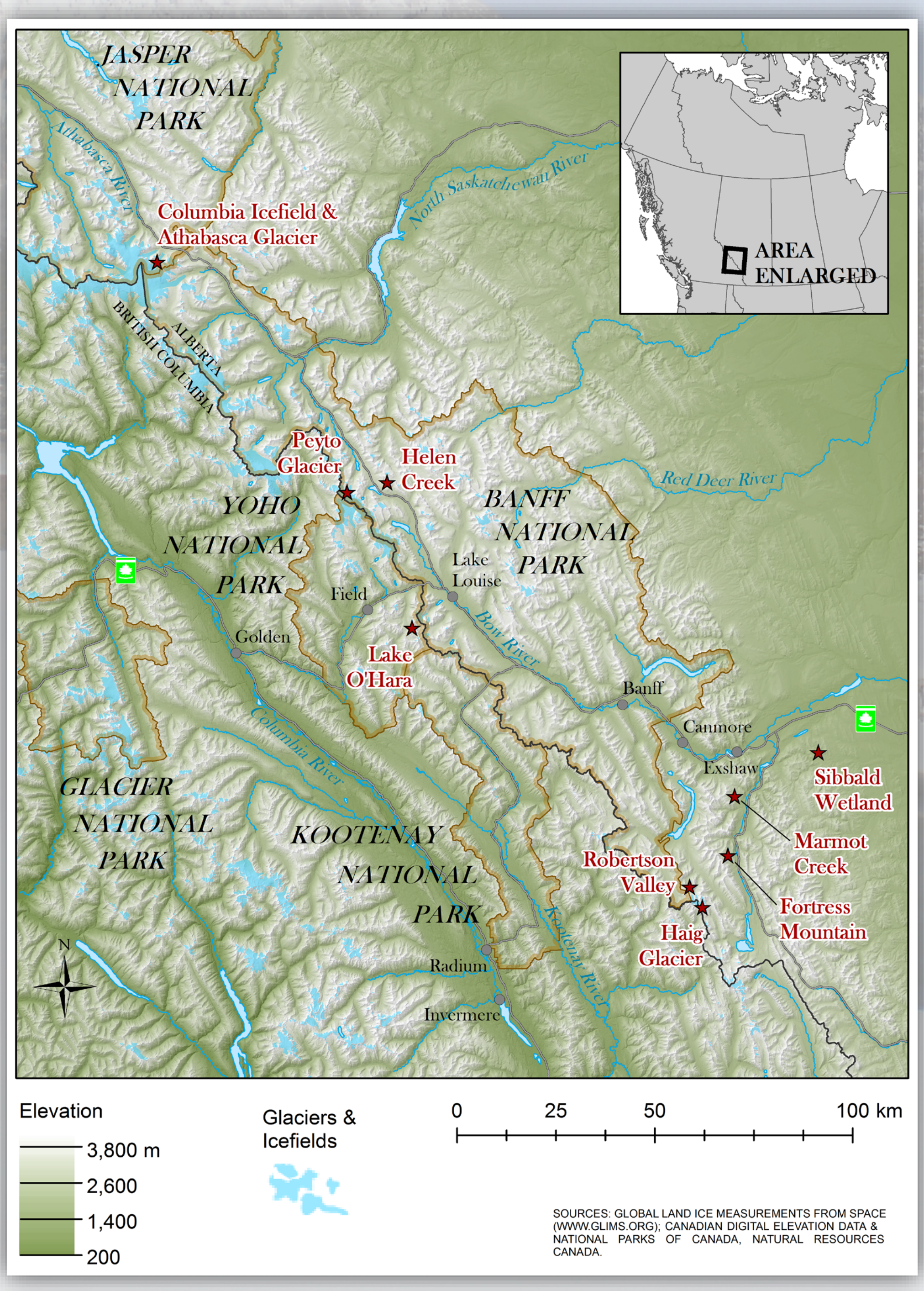
PHOTO: ROBERT SANDFORD

Field-Based Research in the Southern and Central Rockies

A key part of CCRN and GWF research in the Rocky Mountains involves field research and direct observations of the changing climate, landscape, and water cycling at a number of intensively studied and highly instrumented research watersheds. These observatories provide excellent opportunities to monitor and understand Earth system processes and their interactions and changes over time, as well as to develop and test computer simulation models for examining aspects of the systems in more detail and to better predict future change. Some of the sites have a long history of research—going as far back as the 1960s in some instances—allowing for the detection of long-term trends. Other sites have been established as research focal points more recently, by the University of Calgary and by the University of Saskatchewan as part of the Centre for Hydrology's Canadian Rockies Hydrological Observatory, but are already shedding new and valuable insights on how these systems function and respond to climate variation.

LAKE O'HARA, YOHO NATIONAL PARK, BC.

Located on the western side of the continental divide in Yoho National Park, the Lake O'Hara watershed represents a high alpine environment comprised of sub-alpine coniferous forest, alpine meadow, exposed bedrock, talus slopes, glacial moraine material, and a very small amount of glacier ice cover. Research efforts here include studies on snow hydrology, alpine groundwater hydrology, stream–groundwater interaction, alpine permafrost, and glacier mass and energy balance.



COLUMBIA ICEFIELD & ATHABASCA GLACIER, BANFF/JASPER NATIONAL PARKS, AB.

Forming the hydrological apex of North America with rivers draining into Hudson Bay and the Arctic and Pacific Oceans, the Columbia Icefield is the largest glacial mass in the Rockies. Research here has focused on measuring ice flow through the glacier system, examination of snow accumulation patterns and its transformation into glacial ice, and characterization of local scale meteorological conditions and cold drainage winds as they influence snow and ice melt.

MARMOT CREEK, KANANASKIS, AB.

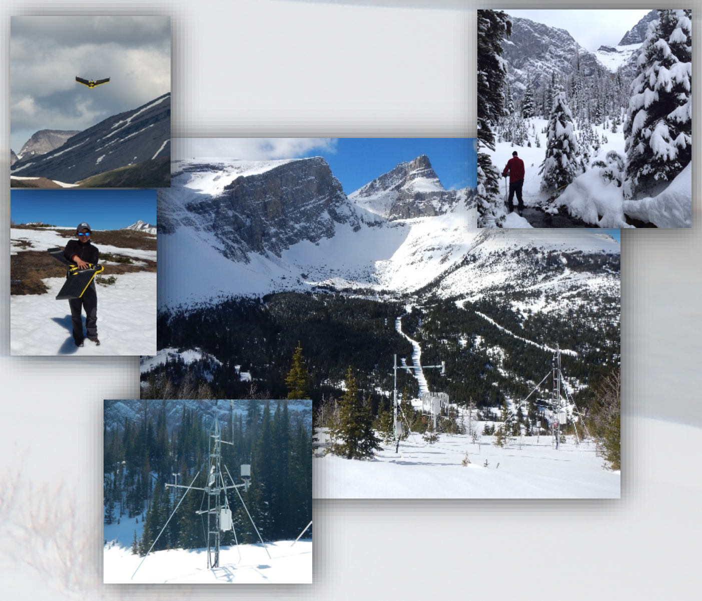
The Marmot Creek watershed is situated in the relatively drier Front Ranges and is mostly covered by montane and subalpine forest cover, and at higher elevations, alpine tundra, talus slopes, and exposed rock. Research here focusses on forest and alpine snow processes, groundwater and surface hydrology, and long-term hydro-climatic change—the site has observations going back to 1962 and stations at elevations from 1450 to 2500 m, covering variety of surface cover types and slope orientations.

PEYTO GLACIER, BANFF NATIONAL PARK, AB.

Peyto Glacier flows off of the Wapta Icefield, which is among the larger glacial masses in the Rockies and straddles the continental divide. The glacier serves as a long-term benchmark site for mass balance (annual balance of snow accumulation vs. snow and ice melt), with observations dating back to 1965. Recent scientific activities include studies of the glacier's surface meteorology and computer model development and testing to simulate mass balance and meltwater runoff from this and other glaciers in the Rockies.

FORTRESS MOUNTAIN, KANANASKIS, AB.

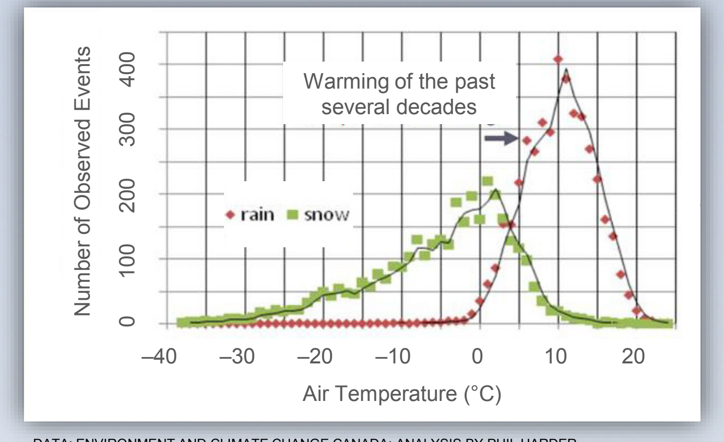
The Fortress Mountain research site, located in the Kananaskis Valley, was established as a research site in 2012. The area receives more abundant snowfall than Marmot Creek and other areas further east in Front Ranges. Research efforts are directed at studies of blowing snow transport, redistribution, and melt, as well as groundwater hydrology. The site has also served as a testbed for new instrumentation and snow measurement techniques, such as airborne drones equipped with a variety of imaging sensors.



What Changes are Occurring and What Does the Future Hold?

Air temperatures in the region have increased by as much as two degrees Celsius since the 1960s, with even greater warming in the winter and spring months. This in turn has led to an ongoing tendency towards more rainfall in place of snow in many parts of the Rockies, especially during the spring and fall seasons and at lower elevations. In association with long-term climatic changes, there have been extreme weather events in recent years, including flooding and drought (explored in more detail next), with major societal impacts. Projections of future climate show confidence in continued warming throughout this century, and while there is more uncertainty on how precipitation might change on average, it is quite likely the area will see increased variability and extremes in the amount, type, and intensity of precipitation. These changes are tied to a vastly and rapidly changing landscape, ecosystem, and water cycle.

Rainfall vs. Snowfall, Kananaskis Valley

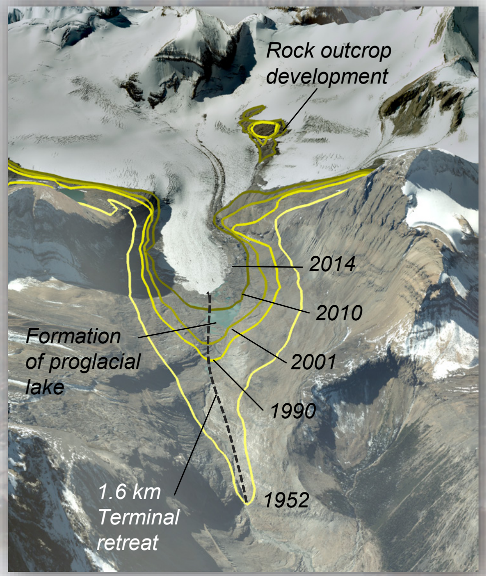


DATA: ENVIRONMENT AND CLIMATE CHANGE CANADA; ANALYSIS BY PHIL HARDER.

DECLINING SNOWPACKS

At low elevations, maximum winter snow water equivalent—the depth of water from completely melting the snow—has decreased considerably in recent decades and spring melt has occurred earlier. The winter snowpack at mid- and high elevations is becoming increasingly sensitive as early spring and even winter temperatures approach 0°C for extended periods of time. This is apparent in the graph to the left from observations in the Kananaskis Valley: where a large proportion of precipitation falls at temperatures near 0°C, even very slight warming shifts the balance between rain and snow dramatically.

Peyto Glacier, Banff National Park



IMAGERY: BANFF NATIONAL PARK AERIAL PHOTOGRAHY (2014); HISTORIC GLACIER EXTENTS FROM ALBERTA GOVERNMENT AERIAL PHOTOGRAHY, NASA LANDSAT 5 & 7, and SPOT 5 IMAGERY.

RETREATING GLACIERS

Glaciers and icefields in the Rockies have been losing ice mass and retreating in extent, and this appears to have recently accelerated. Observations at the Peyto Glacier (left) provide a clear example of the changes that are unfolding. Research suggests that within the next few decades or less, many of the region's low elevation and valley bottom glaciers will have mostly vanished. By the end of the 21st century even the highest elevation glaciers and upland icefields will have either disappeared or disintegrated considerably.

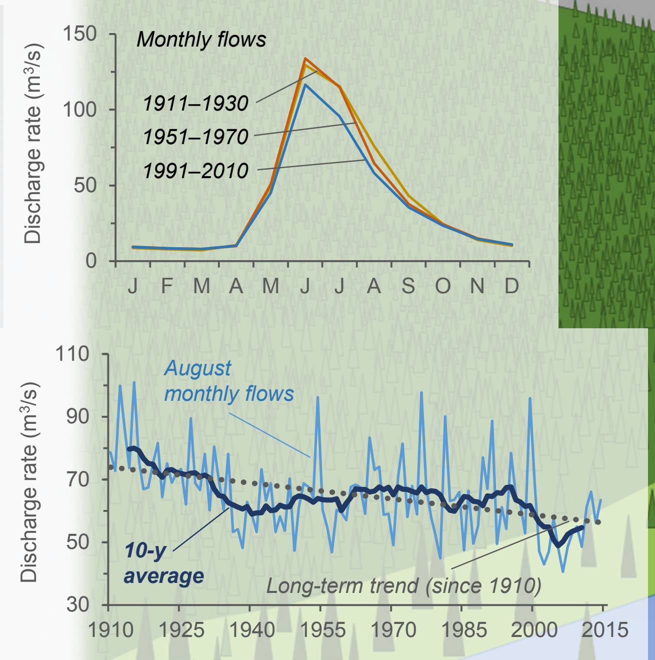
Bow River Valley, Banff National Park

PHOTOS: MOUNTAIN LEGACY PROJECT; UNIVERSITY OF VICTORIA

ALTERED WATER CYCLING

Climate warming and other changes have led to earlier rising and peak flows in spring, and decreasing flows in summer and fall in many rivers, including the Bow River as shown in the graphs at right. In future, the earlier melt of seasonal snow will likely mean slower average melt rates under conditions of less intense solar radiation and cooler temperatures, which will act to reduce peak river flow volumes. And with ongoing glacier decline and the occurrence of extensive melting conditions over vast areas of upland icefields, a temporary period of enhanced late-season flow may occur.

Bow River at the Town of Banff



SOURCE: GOVERNMENT OF CANADA, HISTORICAL HYDROMETRIC DATA (HTTP://WATEROFFICE.EC.GC.CA)

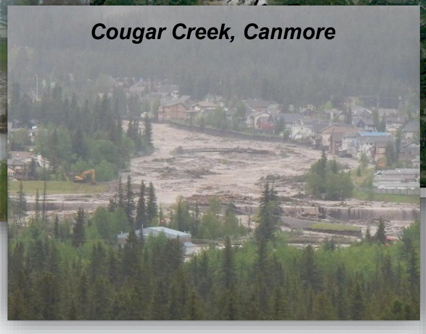
INCREASING WILDFIRE AND TREELINE ADVANCE

With a warming climate and drier conditions, the intensity and extent of wildfires is expected to increase significantly, bringing about a shift in valley bottom ecosystems from forests to grasslands. Historically, areas such as the Bow Valley (above) were sparsely vegetated as a result of fire, but fire suppression efforts, in part, had allowed forest growth. Disease and pests such as the Mountain Pine Beetle also represent a potential threat to forest ecosystems under a warmer climate. At high elevations, treeline forest cover and shrubs are advancing and infilling in many areas, which has an important influence on snow, soils, and microclimate conditions.

Varying Extremes: Devastating Floods to Record Dry Conditions

In late June 2013, intense rain fell for several days over a large area of the southern Rockies and Foothills, causing widespread flooding and severe damage to communities, transportation infrastructure, and the City of Calgary, as well as several deaths. Only two years later the region experienced some of the driest spring and summer conditions in its history, with record breaking warmth, early melt of snowpacks and creeks running dry, glaciers experiencing record ice loss, and extreme low river flows out of the mountains. The question remains as to whether such extremes may become more frequent and whether their magnitude and impacts could be worse in future. The answer is very likely yes in both cases.

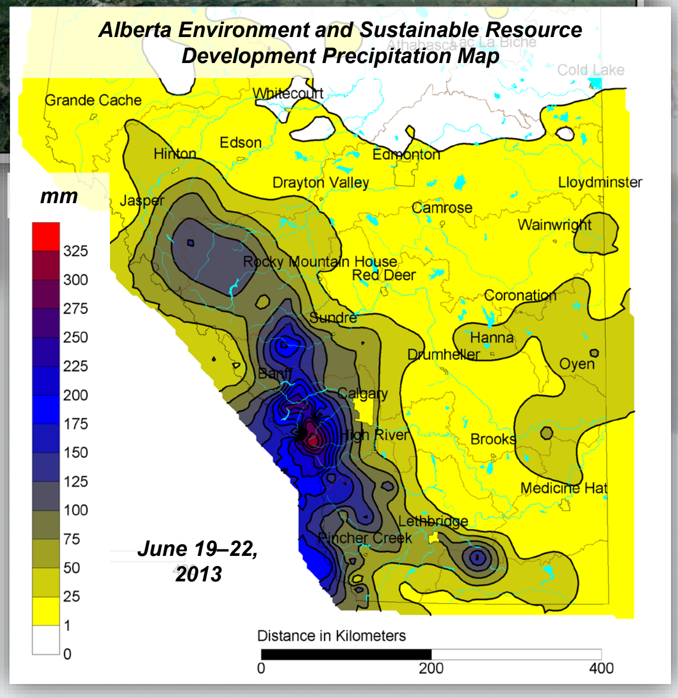
2013 Floods



PHOTOS: JOHN POMEROY

1. Overnight June 19–20, 2013: Rain & Floods Begin
Torrential rains begin to fall over the east slopes of the Rockies and foothills, and creeks swell to raging torrents. Many residents of towns such as Canmore and Exshaw are forced to flee in the night with no warning. Over the next 24 hours, road and rail line washouts cut off transportation throughout the region, while the spillways of many reservoirs are opened as an emergency measure.

EXTREME PRECIPITATION
Moisture transport was mostly from the Eastern Plains with the system stalling over the region for days. This type of event is not unusual in spring, but in this case rainfall intensity was similar to that of a tropical storm. Remaining high elevation snow-packs were quickly melted by warm rain, further adding to the flow of creeks.



HTTP://ENVIRONMENT.ALBERTA.CA/FORECASTING/DATA/PRECIPMAPS/EVENT_JUN19_22.PDF

PHOTO: TODD KOROL, REUTERS

2. June 20, 2013: State of Emergency
With rising floodwaters out of the mountains, many communities east of the Rockies declare a state of emergency and evacuations begin. High River was particularly hard hit by flooding with much of the town under several meters of water.

3. June 21, 2013: Mass Evacuations in Calgary
About 75,000 people are forced to flee their homes due to flooding along the Elbow River. Much of the downtown core is flooded, including the Saddledome and Stampede grounds. Soldiers are deployed to the flood zone to assist.

PHOTO: JOHNATHAN HAYWARD, THE CANADIAN PRESS

2015 Dry Conditions

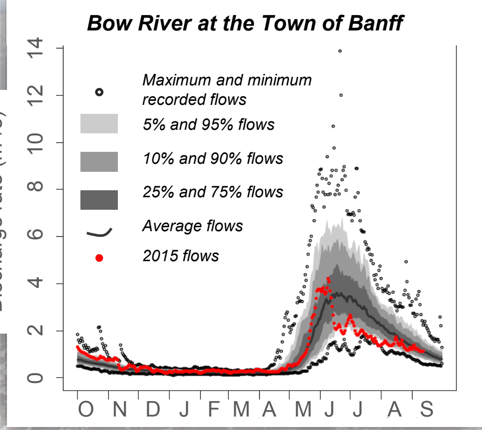


PHOTO: CHRIS DEBEER

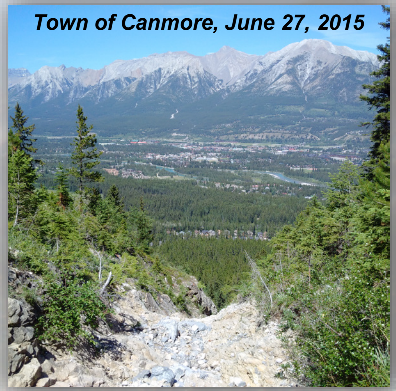
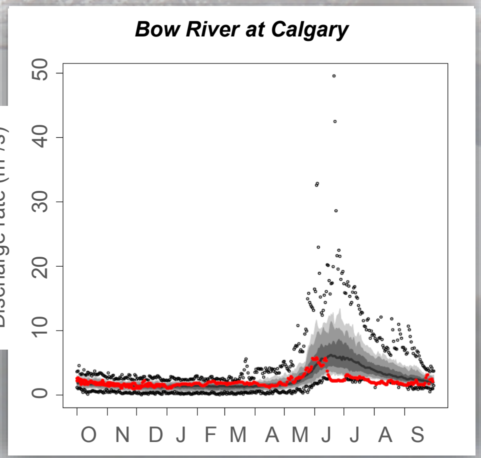
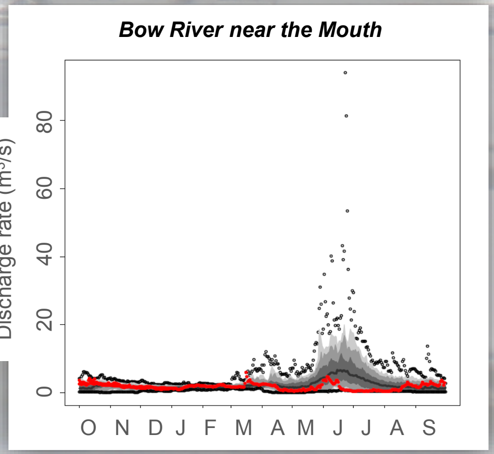


PHOTO: JOHN POMEROY





SOURCE: GOVERNMENT OF CANADA, HISTORICAL HYDROMETRIC DATA (HTTP://WATEROFFICE.EC.GC.CA); ANALYSIS BY PAUL WHITFIELD.

RECORD LOW FLOWS
With an early spring melt and very warm conditions, rising flows were early while glacier melt sustained flows in the high elevation areas. However, further downstream, river discharge rates were progressively lower and in places such as Calgary and beyond, after municipal and irrigation withdrawals, these were at a record or near-record low. It is clear that during such dry years, glaciers and groundwater alone cannot sustain summer river flows in southern Alberta.

RECORD GLACIER LOSS AND DEPLETED SNOW
Unusually warm and dry conditions in 2015 led to reduced snowpack depth and volume and early melt, while glaciers in the region showed record ice loss through the summer. Mountains such as those near Canmore (above) normally hold snow at high elevation well into July or later, but this had entirely vanished much earlier in 2015. As a result, soil moisture and groundwater levels were the lowest on record and creeks ran dry by mid-summer, as was observed at the Marmot Creek Research Basin.

The CCRN and GWF research programs aim to advance Canada's resiliency to events such as flooding and drought by improving the understanding and prediction of climate and landcover change and thier associated effects. Computer models and forecasting tools will be developed to deliver a new capacity for providing disaster warning to governments, communities and the public, including Canada's first national flood forecasting and seasonal flow forecasting system, new drought warning capability, and water quality models and monitoring that warn of hazards to health and drinking water supply. New models will allow communities and industries to manage future water-related risks by providing tools and resources needed to plan sustainable infrastructure. Mountain research and modelling for GWF will be headquartered in the GWF Coldwater Laboratory located in Canmore, Alberta and close to field sites.

For more information, visit **ccrnetwork.ca** or **globalwaterfutures.ca**.

Fortress Mountain Research Site
This meteorological station, along with over 35 other high elevation snow and weather stations, is a part of CCRN's and GWF's observational network in the Rockies, and contributes to improving the ability to predict changes in water yield from the Saskatchewan, Mackenzie, and Columbia River Basins.

PHOTO: JOHN POMEROY

CCRN Changing Cold Regions Network · UNIVERSITY OF CALGARY · Natural Resources Canada / Ressources naturelles Canada · Canada · NSERC CRSNG

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