Alberta's Bow River: Climate Change and Human Impacts

Bow Falls, Banff, Alberta. Credit: Tim Redpath, via Flickr.

The Bow River is a crucial artery through the heartland of Alberta. Flowing from headwaters in the Rocky Mountains through downtown Calgary and on to the rich agricultural lands to the southeast, the Bow provides a host of critical functions: clean drinking water, irrigation for agriculture, hydroelectric power, sanitation, recreation, tourism, hunting, fishing and habitat for wildlife. The Bow Valley is already home to 1.2 million people – a third of the province's population – and that number is expected to double in the next few decades[1].

In addition the Bow is also a microcosm of a global phenomenon. The twin pressures of human development and climate change are affecting river ecosystems worldwide. Almost any water-related issue – water scarcity, water quality, dangers of floods and droughts, ecosystem integrity – is reflected in some way along the Bow. This makes it a fascinating case study for understanding the natural systems that support and nurture us, but more importantly, a critical test of our ability to live within the limits imposed by those systems.

Natural features

Melt water from glaciers accounts for less than three per cent of the Bow's total flow. The vast majority of the water – around 80 per cent – comes from the snow that collects in the mountains and on the prairies over the winter[2]. When the weather becomes warm enough to melt that snow, typically in June, the river's average flow at Calgary is about 300 cubic metres per second, fast enough to drain an Olympic-sized swimming pool in less than nine seconds.[3]

Water from spring and summer snowmelt also recharges natural holding tanks like the groundwater aquifers and wetlands that line the banks of the Bow and its numerous tributaries. These natural holding tanks are the major source of the river's water during the following dry months. The total annual precipitation at Calgary is 450 to 550 millimetres per year, an estimated five to 50 millimetres of which (between one and 10 per cent) goes to recharge the wetlands and aquifers in the Prairie portion of the basin[4]. By December, the flow of the Bow river is less than a fifth of that in summer and almost entirely sustained by groundwater. This extreme variation sets the stage for everything else that happens on the river, from floods to water shortages.

Groundwater, wetlands and sloughs also play an important role in controlling the water chemistry in the Bow ecosystem. In the foothills, wetlands are lined with deep layers of decayed vegetation known as peat and are strongly interconnected to the groundwater system. Nutrients from the soil and peat support forests and other vegetation. Wetlands on the prairie, known as sloughs, tend to be more isolated from each other, but they still act as filters, helping remove excess nutrients and other dissolved chemicals. However, they cannot fulfill this role if they overflow their banks during periods of extreme wet, or if they are drained by humans to make room for development.

Rafting is a popular activity in the Bow River, even within the city limits of Calgary. Credit: Mike Murray, Bow River Basin Council.

Weather, climate and climate change

Alberta and the Prairie provinces have one of the most variable climates in North America. Both floods and droughts are frequent, but they should not be thought of as opposites. Floods are short-term events that cause massive river flow, whereas droughts are chronic, long-term deficiencies in water supply, and can be difficult to identify until after they're over. The Prairies have experienced a number of multi-year droughts, most recently from 1999-2005. Floods hit southern Alberta in 2013, 2005, 1997 and 1995. While the 2013 flood was larger than any since 1932, there is evidence that more severe floods have occurred in the past [5]. The relative lack of severe floods from 1932 to 2005 may seem significant in human terms, but the extremely variable local climate makes it hard to say if the frequency or severity of floods is increasing or decreasing.

Climatic cycles – some on the order of decades, some even longer – affect the relative dryness or wetness of the region. One example is the Pacific Decadal Oscillation (PDO) which is comparable to the El Niño/La Niña cycle, but it fluctuates over a longer time scale (decades versus years) and operates in the north Pacific, rather than the south. In the 'positive' phase of PDO, ocean temperatures in the west-central North Pacific become cool while those off the British Columbia coast become warm. This tends to lead to warmer, drier weather in Western Canada, particularly in the winter, which reduces winter snow accumulation and consequently, the amount of water flowing into the river. The 'negative' phase tends to have cooler, wetter weather, and may increase the probability of floods [6]. Scientists believe we are now in a 'negative' phase, which could last another 10 to 20 years. There are other, longer-term cycles that are still not well understood by climate scientists.

Super-imposed on all this are the effects of climate change. While annual average temperatures across southern Canada have increased between 0.5 and 1.5 C over the past century,[7] some local effects are even stronger. Weather stations in the foothills of the Rocky Mountains show evidence of milder winters: during October to March, daily average temperatures have increased by about 2 degrees C and daily minimum temperatures by 3 to 4 degrees C since 1962 [8]. Although these same stations show no trend in total precipitation, the warmer winter temperatures mean lower snow accumulation. They also mean earlier springs, and when plants soak up moisture from soil and transpire it into the air, less water is available to get into the river. The result is lower summer flows, raising issues of water scarcity. Marmot Creek, a well-studied tributary of the Kananaskis River, which in turn flows into the Bow, has lost a quarter of its flow over the last 50 years [8]; the average flow of the Bow River at Banff has decreased by about 12 per cent over the last century[9].

It's important to note that while the effects of climate change are important, the reduction in flows is small compared to the amount that is taken out of the river by humans, whether for drinking water in cities and towns or to irrigate crops. On average, humans withdraw about 22 per cent of the Bow River's water; in a dry year it can be even more[10].

Impacts of human development

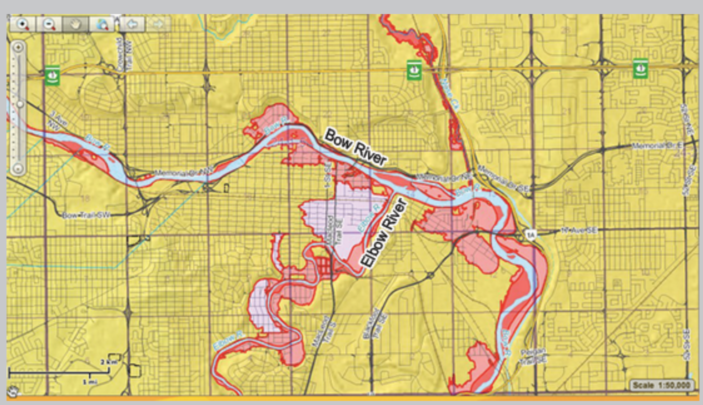
With access to easy water for drinking and

The Flood

The 2013 Alberta floods were caused by a low-pressure system carrying warm, moist air from the Gulf of Mexico, which developed over Montana and started to move north toward the foothills in late June. Blocked to the west by the Rocky Mountains, and to the north by an Arctic high-pressure system, the storm dumped more than 200 millimetres of rain – about half the average annual total for the area – in only two days. The rain alone would have caused a flood, but the warm humid air and rain falling on snow also melted the mountain snowpacks, and the still-frozen ground was unable to absorb any of the extra water. Apart from its localized nature and the fact that it remained stationary for so long (features still being studied by meteorologists) this weather system was not very different from other well-documented storms that have occurred in the area[11].

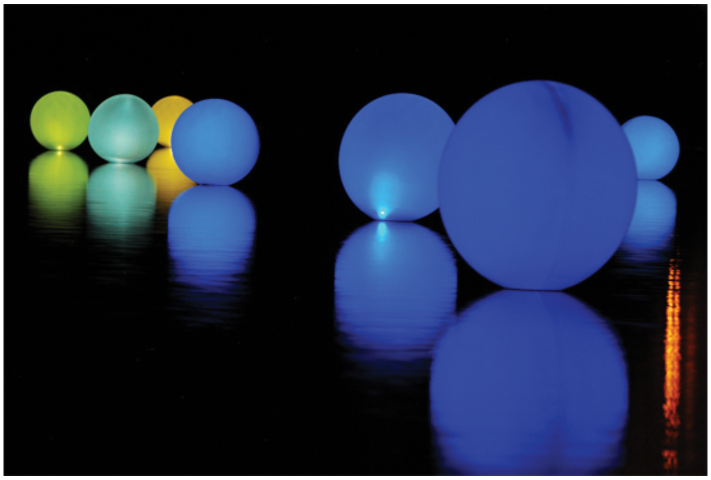
Starting in the 1970s, the Alberta government embarked on an extensive program of mapping flood hazard areas along the Bow; these maps are available online. They are based on the height of the land surrounding the river and the maximum river flow determined by scientists to have a one per cent chance of being equaled or exceeded in any year; this is often called the "100-year flood" but in fact a flood of any magnitude can occur at any time. Engineering reports[12] show that the estimated peak flow for a "100-year flood" is higher than the maximum observed in June 2013, in other words, it was likely only a 50- to 70-year flood.

In Calgary and other communities, many homes and businesses were located within the flood hazard areas that had been mapped out decades before. Total damage was estimated at $3 billion to 5 billion. Preventing development in flood plains would significantly reduce damage from future floods.



This map produced by Alberta Environment (www.envinfo.gov.ab.ca/FloodHazard/) shows the location of floodways (dark red) and flood fringes (light red) in downtown Calgary.

transportation, not to mention rich soils fertilized by periodic floods, river valleys are always attractive for human settlement. But a large and growing population is affecting the river's health on a variety of fronts:



The colours of these illuminated balloons, which floated down the Bow River during a 2010 festival, reflect data from reports on water quality; blue represents excess nutrients like nitrogen and phosophorus, while turquoise indicates pesticides. Credit: Kim Faires, via Flickr. More information is available from the creators: www.riveroflight.org and www.creatmosphere.com.

Water scarcity

Besides providing drinking water for major communities like Canmore, Cochrane and Calgary, the Bow supports farmers who grow spring wheat, durum wheat, canola, barley, and alfalfa as well as those rearing cattle and other livestock. In all, the region produces roughly $2 billion worth of agricultural products each year, more than 17 per cent of Alberta's total. Unfortunately, much of the water used to grow these crops is transpired through their leaves into the atmosphere and can be lost to the watershed. That which does get returned can be contaminated with fertilizers, pesticides, or animal waste.

Until 2006, the provincial government issued permits, called allocations, to withdraw water from the Bow River for municipal, agricultural or other use. The current total that can be withdrawn under the allocation system is about 2.8 billion cubic metres per year, nearly 60 per cent of the total flow of the river, although not all permit holders withdraw their maximum entitlement. Of the water withdrawn 71 per cent is used for agriculture, while 18 per cent is for municipal drinking water[13].

In 2006, responding to concerns over water scarcity, Alberta Environment placed a moratorium on new allocations and imposed conditions on the transfer of existing allocations, e.g., holding back 10 per cent of each transferred allocation to encourage conservation [14]. A more comprehensive water allocation management system is under review [15][16]. The population of the Bow River basin is expected to double within the next few decades [17], further increasing pressure on this limited resource.

Dams and water management

The Bow River already has 13 dams that control the levels of eight reservoirs. All of these dams are relatively small, and all were built for the purpose of generating hydroelectric power, rather than conserving water supply in times of drought. The 2013 flood event showed that the system of dams is too small to absorb storm surges; furthermore, if reservoir levels are kept high in order to see the human population through a drought, there is less reserve capacity to absorb the waters from any potential flood.

Maintaining the integrity of wetlands can help buffer the effects of small increases in flow, but as with human dams, these natural systems are too small to protect against all major floods.

Nutrient loading and chemical pollutants

Nutrients like nitrogen and phosphorus are important for plant growth, but if they reach the river at high concentrations, they can cause explosive growth of

Beaver wetlands in the Kananaskis

Beaver-felled tree. Credit: Gary Scott, via stock.xchng.

All wetlands buffer river flow by holding water during wet periods and releasing it during dry ones. In the Kananaskis, beaver dams enhance this effect by holding even more water than the wetlands could do on their own. Although they can be – and in 2013, were – destroyed by flood waters, beaver ponds nonetheless remain an important part of the ecosystem, and provide habitat for other animals.

Scientists have used aerial photography to document the extent of beaver within the Kananaskis. In provincial parks, national parks or improvement districts (inhabited areas within parks) the proportion of wetlands with beaver dams was about 60 per cent. However, this drops to 40 per cent on First Nations territory, and 20 per cent in municipal districts [18]. Given the influence beaver have on stream flows and groundwater interfaces, the loss of beaver dams could reduce the resiliency of rivers like the Bow [19].

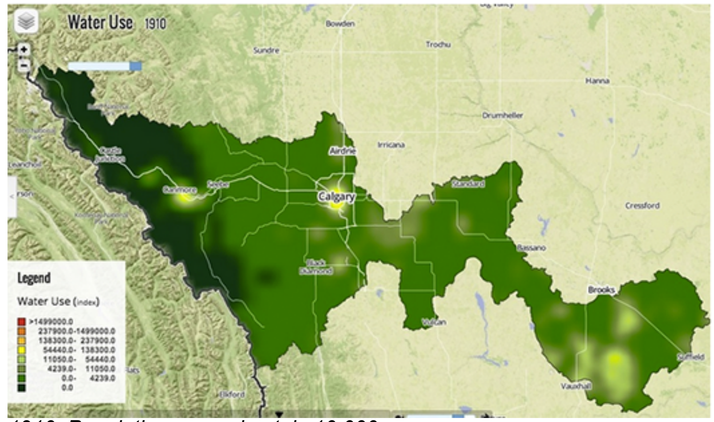
algae. This algal bloom uses up all the dissolved oxygen, leading to ‘dead zones’ that kill fish and other aquatic life, a phenomenon known as eutrophication. As well, some algal species also produce their own natural toxins which make the water unsafe for drinking.

Excess nutrients come primarily from agricultural runoff, but they can also come from municipal wastewater. Treatment plants designed to remove such nutrients can be overwhelmed during high flows. The outflows from such facilities can also still contain pharmaceutical compounds and other chemicals in the original wastewater that may not easily be degraded; evidence from nearby watersheds shows that these compounds could potentially damage the health of fish[20].

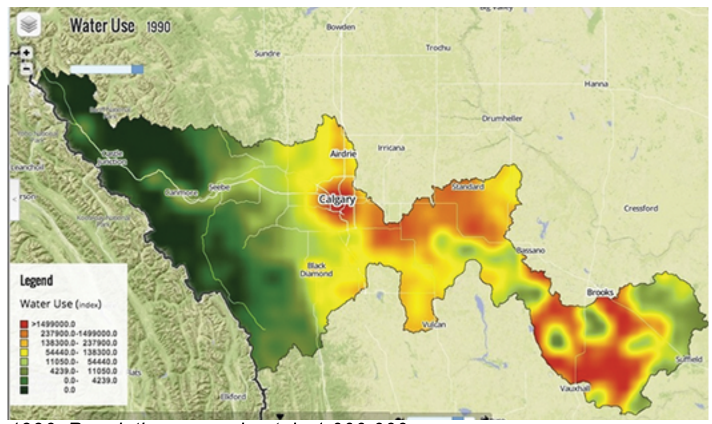
Emerging nutrient management techniques such as slow-release fertilizers and variable-rate application can reduce nutrient loads and potentially save money in the long term [21][22][23]. Natural or artificial wetlands can corral algae blooms before they reach the larger watershed. Wastewater treatment plants can be upgraded, but such upgrades have a high upfront capital cost.

Conclusion

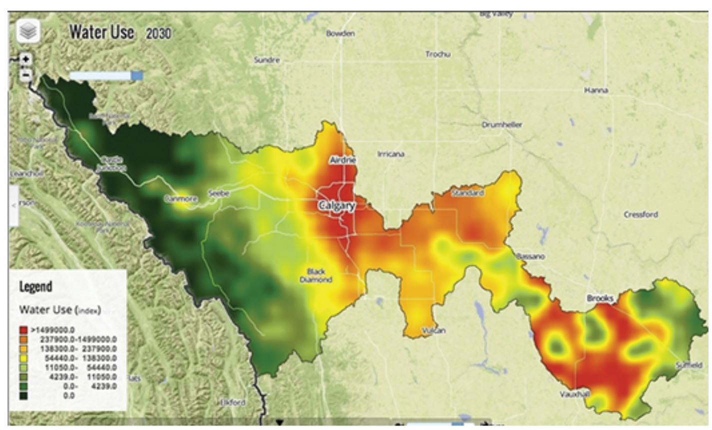
From the First Nations who once made their bows from the dogwoods and shrubs that grew along the river’s banks to today’s farmers and city-dwellers who depend on



1910: Population approximately 10,000.



1990: Population approximately 1,000,000.



2030: Population approximately 1,900,000.

The diagrams above are derived from the ALCES model [17], and show the water use across the watershed for the years 1910, 1990 and 2030. The simulation breaks the desired area into cells measuring 5 km x 5 km and colour codes those cells based on how many cubic metres of water per year are being used: dark green indicates the lowest water use; dark red indicates the highest.

it for drinking water, electric power, irrigation and sanitation, the Bow remains a crucial lifeline. Climate change and population increase are key challenges that will make it more difficult for the river to fulfill these roles in the future.

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For more information please write to us at:
info@sciencemedia.ca

Expert Reviewers:

1. Barrie Bonsal, Research Scientist, Watershed Hydrology and Ecology Research Division, Environment Canada
2. Masaki Hayashi, Professor, Department of Geoscience, University of Calgary
3. Ronald Stewart, Professor, Department of Environment and Geography, University of Manitoba
4. Brad Stelfox, Landscape Ecologist, ALCES Landscape and Land Use Ltd
5. Phillip Harder, Ph.D. Candidate, Centre for Hydrology, University of Saskatchewan

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