Making the Connection

Water and Land in Alberta

Water Matters

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Making the Connection: Water and Land in Alberta

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Crowsnest Pass South. This panorama looks south over the Rocky Mountains along the Alberta - British Columbia border.
Credit: Dr. William Bowen - California Geographical Survey - http://geogdata.csun.edu

Executive Summary

Although there is a growing awareness of the value of watersheds and their role in providing a clean supply of water, these values are often not integrated into land-use planning processes. According to the International Union for the Conservation of Nature, the value of watersheds to provide ecological goods and services such as water filtration and supply is still ignored in the context of decision making. While the ecosystem provides an economic value, it is "poorly understood and rarely articulated." Consequently, these ecosystems become more degraded over time, losing their long-term value in the process.

As a first step, decision makers who approve various land-use decisions must deepen their understanding of the value of ecological goods and services in the context of land use impacts on water. *Making the Connection: Water and Land in Alberta* comprehensively details the special role of watershed features, such as forests, riparian areas, and wetlands, in an effort to further that understanding.

With a better awareness of the value of watersheds, decision makers will understand how land use impacts water quality and quantity. In Alberta, this is especially important as roads, seismic lines, agricultural fields, industrial plants, and urban development criss-cross and sprawl across the provincial landscape. While these activities provide considerable wealth to Albertans, these land uses collectively threaten watersheds.

Once the critical relationship between land use and the value of watersheds to provide ecological goods and services is better understood, those making land-use decisions can embrace comprehensive solutions. A comprehensive approach is the only one that will maintain the ecological goods and services we need. In part, this means measuring the cumulative impact of land uses across watersheds, identifying objectives to protect ecosystem goods and services, and implementing management strategies that set thresholds for land use. *Making the Connection* highlights three case studies to demonstrate how these approaches are being used in Alberta.

The approaches suggested in *Making the Connection* are far-reaching, designed to transform how decision makers, citizens, corporations, and others approach land-use decisions. These proposed approaches require decision makers at all levels to make clear tradeoffs. For communities to access clean supplies of water means society must incorporate the true value of ecological goods and services into decision making. This requires all players—including business and government —to pursue land development in a new and holistic approach.

Comprehensive change to how we make these decisions is critical to ensuring the benefits of clean, abundant water for all Albertans and the ecosystems on which they depend for many years to come.

1 Introduction

In May 2000, heavy rain washed cattle manure into a groundwater well that supplied drinking water to the town of Walkerton, Ontario. The manure contained a virulent strain of *E. coli*. Seven people died and more than 2,300 people grew seriously ill. Some still suffer long-term illness. The total cost borne by the Town of Walkerton and the Ontario government was over $64.5 million.[1] The Walkerton Inquiry galvanized governments, not only in Ontario but also across Canada, to explicitly prevent contamination as a key part of the process to protect drinking water.

The Walkerton Inquiry found that there was a failure of an entire regulatory framework and oversight system responsible for protecting water sources; poor communication among decision makers including the provincial government, the municipal water system managers, and the region's water treatment laboratory; and a failure to address threats to the quality of drinking water.[2] But the relationship between land use and water quality was a central theme in the aftermath of the tragedy. A key finding of the inquiry was the need for better mechanisms to ensure protection of source waters, which meant greater focus on land use.[3]

Walkerton offered a stark example of how land use can impact water quality, and it raised a question with all Canadians: How could a more sustainable approach to land use protect water sources? To protect water sources effectively, we first need to understand their value. Section 2 of this report describes the value of our watersheds, including the forests, wetlands, riparian areas, and groundwater recharge zones.

Intensive land use—a growing concern in Alberta—has raised the question of impacts to water sources. Significant land-use growth for all major sectors including timber harvesting, natural resource extraction, road networks, grazing and cropland, and urban development has recently prompted a provincial strategy on land-use planning. With an average two percent annual rise in population for the last 100 years, three million residents now live across Alberta's landscape. By 2026, Alberta's population is projected to be five million.[4] Growth in land use has already, and will continue to have, consequences for water sources. Section 4 describes how land use is expected to grow significantly in virtually every sector and how these multiple land uses compound impacts to water.

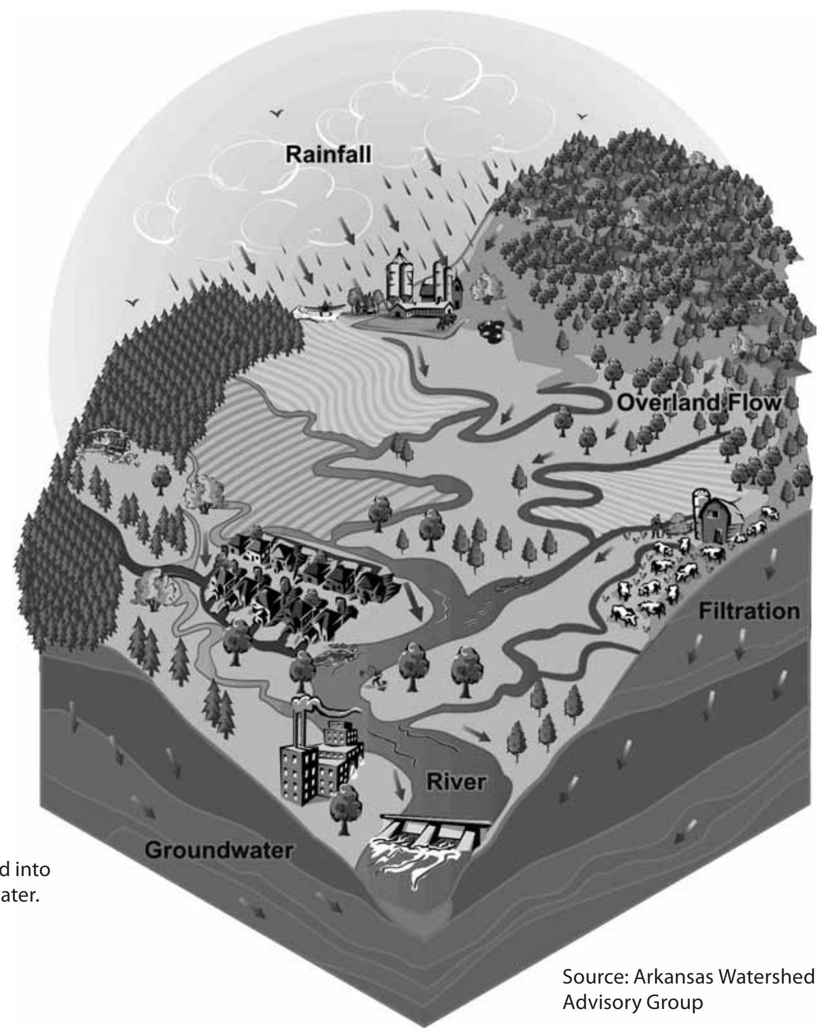
The central theme of this report, however, suggests that the value of watersheds be specifically considered and incorporated into the land-use planning process whether at the local, regional, or provincial level. Section 5 evaluates the value of ecosystem goods and services offered by Alberta's watershed.

Section 5 also identifies specific strategies that integrate consideration of the ecological value offered by these goods and services and act as an incentive to limit the cumulative land impacts that threaten that value. To illustrate our point, we present three case studies in Section 6 illustrating how the cumulative impacts from land use affect water sources and how these impacts might be assessed and addressed.

"One essential condition for success will be the ability of planners and investors to factor in environmental concerns, particularly the links between natural ecosystems, water demand, and supply. Despite the importance of healthy ecosystems for secure water supplies and the importance of secure water supplies for healthy ecosystems, recognition of the relationship between ecosystem status and water infrastructure has long been missing from water rhetoric and practice."

International Union for the Conservation of Nature

Watersheds are areas of land that catch precipitation and drain surface water to a common destination, such as a wetland, stream, river, or lake.



Rainwater falling on land can flow over land and into rivers but also can filtrate into land as groundwater.

Source: Arkansas Watershed Advisory Group

2 The Value of Watersheds

A growing awareness of the value provided by Alberta's watersheds acts as a necessary first step for incorporating their true value into land-use decision making.

Photo: Water Matters

Watersheds function to move nutrients through ecosystems, regulate and cycle water, absorb heat, and transfer energy. These "goods and services" from the ecosystem produce clean water, timber, and recreational opportunities.[5] Specific watershed features, such as forests, riparian areas, or wetlands, are very significant for maintaining water quality as an ecosystem service and water supply as an ecosystem good. Alberta's Eastern Slopes of the Rocky Mountains, for example, are mainly covered by forest and are the source of water for a number of downstream needs including agricultural, municipal, and aquatic ecosystem needs.

These watershed functions can be formally recognized. As Voora and Venema state in their ecosystem service study of the Lake Winnipeg watershed, "ecosystem service losses or gains provide an economic rationale for the preservation and restoration of environmental assets" as well as allow for more objective analysis of trade-offs in land-use decision making. Quantifying the value of ecosystem goods and services, while not able to fully account for the intrinsic and cultural value of the ecosystem, provides a means to communicate the importance of ecosystems to human well being.[6]

The ecological goods and services offered by key landscape features, such as forests, wetlands, riparian areas, and groundwater recharge zones, are addressed in turn below. Following each section is a discussion of monetary values that have actually been assigned to these features where they are available.

A note on avoided costs

The assignment of a value for certain ecological goods and services is not the same as calculating avoided costs that are often valued on a case-by-case basis. For example, compromised water quality upstream of a community can translate to increased costs to a downstream water user. A water supplier may face increased costs for testing, treating, or building new infrastructure to remove an increased number of pollutants in the water supply.[7] A downstream irrigator will only have access to lower quality water for irrigating crops, including food crops that can become contaminated by pathogens or heavy metals, and problems from water with high salinity.

The protection of a watershed can also save significant money. For example, New York City in 1997 invested over one billion dollars to protect the 32,000-hectare Catskills-Delaware watershed. This ensures that New Yorkers have safe, clean drinking water sources while saving the City over $6 billion for two new water filtration plants.[8]

ECOSYSTEM GOODS AND SERVICES

Ecosystems provide "goods" and perform "services" that directly or indirectly contribute to human well being and the economy. Goods include water, fish, and timber. Services include water filtration and flood regulation. These goods and services hold different types of values: direct use value for drinking water and fish for example, indirect use values for recreation and flood protection for example, and non-use values for protecting the availability of goods and services for future generations.[9]

A 1997 study by Department of Agricultural Economics at Texas A&M University found that land uses in upper watersheds can increase the cost to treat drinking water. Water suppliers that dealt with chemical contaminants in their water supply paid $25 more per million gallons of water to treat water than suppliers who did not have chemical contaminants to remove. The study also found that treatment costs rose one percent for every four percent increase in raw water turbidity, which is caused by sediment, algae, and other microorganisms, often caused by upstream land-use activities such as development, intensive farming, mining, and forestry.[10]

2.1 Value of forests

Forest ecosystems play a special role in water management and the role varies depending on where the forest is located—whether in mountainous headwater areas, on hill slopes, or along riparian areas.[11] Forests regulate quantity, quality, and timing of water availability by cycling water from precipitation through soil and eventually delivering it as stream flow as well as cycling it back to the atmosphere.[12]

Forests cover almost 60 percent of Alberta and are located along the western edge of the province in the Eastern Slopes and foothills of the Rocky Mountains, and in the northern boreal forest.[13] In general, mountains, such as the Rocky Mountains and foothills, receive the largest proportion of the earth's precipitation and provide from 60 to 80 percent of the world's freshwater sources.[14]

> "Of all the outputs of forests, water may be the most important." *U.S. National Research Council*

In general, more natural vegetation cover in a watershed including forests translates into higher water quality, a more natural flow regime, and healthier aquatic ecosystems.[15] Forests help filter out sediment and other potentially harmful pollutants.[16] Sediment in water bodies provides nutrients downstream but too much compromises water quality for drinking, irrigation, and other uses.

Forests encourage infiltration of water into soils and regulate stream flows. This infiltration process of moving water into the ground stores water and reduces flooding and contributes to base flows in streams during drier times of the year.[17] As a result, forests slow and regulate stream flow from precipitation. This regulation reduces the chances of flooding during high precipitation events and consequent risks to human infrastructure and damage to streambeds.

Forests also stabilize soil. Tree roots anchor soil masses and reduce erosion of soils into waterways.[18] Forest stands along waterways also stabilize stream and riverbanks as well as shade and keep water cool for fish and aquatic species. These riparian areas contribute leaves and woody debris to streams, which are important for invertebrates and provide habitat for fish.

ALBERTA'S WATER SOURCE

In Alberta, the Eastern Slopes and foothills of the Rocky Mountains are covered primarily by forest and cover approximately 90,000 square kilometres of Alberta's landscape. They are the headwaters of the Athabasca River and the Saskatchewan River systems. The North Saskatchewan River, for example, receives approximately 86 percent of its average annual flow from the Eastern Slopes and foothills region of its watershed.[19] The Bow River receives over 73 percent of its average annual flow from the Eastern Slopes and foothills. The Red Deer River, whose portion of mountainous upper watershed is relatively small, receives approximately 65 percent from the mountainous and foothills area.[20] [21]

Photo: Steven Cretney

> “Forests are still visualized by many as behaving like a sponge, whose roots “suck up” water in times of excess (a storm event) and then release it gradually during the post-storm or post-monsoon season to augment dry-season flow. Unfortunately, tree roots are more like a pump than a sponge. Cutting the forest therefore usually increases the dry-season flow, but it also somewhat increases flood flows.”
>
> *World Bank/ WWF Alliance for Forest Conservation and Sustainable Use*

2.1.1 Economic value of ecosystem goods and services from forests

Because a forested watershed acts as a source of relatively clean water capturing, storing, and filtering water through the soil and wetlands, an economic value could be afforded to downstream water users including municipalities, agriculture, electricity generation, and recreation.

The economic value of watershed services from Canada’s boreal forests for municipal water use was estimated to be $18 million in 2002, according to one study.[22] This study also estimated the overall market and non-market value of the multitude of goods and services that the boreal forest provided in 2002. Market value of the boreal forest—including mining, oil and gas products, timber, and hydroelectric power—was estimated to have a total value of $62.0 billion but a net value of $50.9 billion because of resource extraction costs, such as air pollution, carbon emissions, and government subsidies to industry. Meanwhile the report estimated non-market services—including water filtration, flood control, nature-related activities, and subsistence value for Aboriginal peoples—at $703 billion, 13.8 times the value of net market value.[23]

A study of southern Manitoba (part of the Lake Winnipeg watershed) estimated the value of water supply services from forest cover to be $0.11 per hectare per year. But forests offer more than just water supply services. If all the ecosystem services offered by forests in southern Manitoba are considered, including climate regulation, pest control by birds, habitat, food production, and recreation, the value climbs to as much as $677.54 per hectare annually.[24]

In many cases, forests reduce the need for drinking water treatment.[25] One analysis of the importance of forests around the Greater Toronto Area (GTA) calculated that it would cost $27 million per year to replace the natural services of runoff control if 10 percent of the current forest cover was lost to urban land use.[26] The same report calculated that if they translated the value of water filtration by this forested area and wetlands around GTA (276,608 hectares), using the value of $474 per hectare per year, the annual value of this water filtration service would be $131 million. The study attributed $86.5 million per year to forest cover in this Greenbelt area and $44.6 million to wetland cover.[27]

> "A study of 27 water suppliers in the United States found that for every 10 percent loss in forest cover, there is a 20 percent increase in water treatment costs, and approximately 50 percent of the variation in treatment costs can be explained by the amount of forest cover in the source water area."
>
> *David Suzuki Foundation and Friends of the Greenbelt Foundation*

Forested watersheds in the United States provide water to approximately 60 million people served by 3,400 public water systems, according to the U.S. Environmental Protection Agency (EPA).[28] A study of 27 water suppliers in the United States in 2002 found that the cost of treating drinking water varies depending on the percentage of forest cover in the source water area. The study found that for every 10 percent loss in forest cover, there is a 20 percent increase in water treatment costs, and approximately 50 percent of the variation in treatment costs can be explained by the amount of forest cover in the source water area.[29]

2.2 Value of wetlands

Wetlands are an integral component of watersheds not only storing, purifying, and supplying freshwater but also storing carbon and supporting plants and wildlife.[30] Because wetlands have the capacity to absorb and retain high water flows, wetlands slow the release of floodwaters and prevent flooding.[31]

Photo: Lorne Fitch

Wetlands act as a pollution filter in watersheds, removing and storing sediment, nutrients such as phosphorus and nitrogen, and other chemicals such as pesticides.[32] Wetlands can filter out from 80 to 770 kilograms of phosphorus per hectare per year and from 350 to 32,000 kilograms of nitrogen per hectare per year.[33]

Wetlands also contribute to groundwater storage and supply by allowing surface water to slowly seep into the ground. Near springs, groundwater also flows into wetlands, particularly during drier times of the year; these wetlands serve as crucial waterfowl habitat and sustain aquatic life during these dry periods.[34] In agricultural areas, wetlands can also be an important source of water for livestock.[35]

2.2.1 Economic value of ecosystem goods and services from wetlands

Wetlands offer significant value for the ecosystem services they provide. Wetlands in Canada's boreal ecosystem, largely made up of forest cover and peatland wetlands, offer significant water supply and quality services. Peatland services include the regulation of water flows, purification of water, and sequestration of carbon.[36] On a per hectare basis, the value of wetlands in Canada's boreal wetlands for water filtering and flood control has been estimated as $925.45 per hectare.[37] Altogether, ecosystem services offered by Canada's boreal wetlands for flood control, water filtering, and biodiversity are valued at $110.7 billion (2002 dollars) annually.[38]

Ontario's Greenbelt watersheds are primary sources of water for Lake Ontario, which is the source of drinking water for millions of people in Canada and the United States.[39] It is estimated that wetlands are valued at $379 million annually for flood control alone.[40] Overall, it is estimated that wetlands provide $1.3 billion per year for water regulation, water filtration, flood control, waste treatment, recreation, and habitat.[41]

In the southern Lake Winnipeg watersheds that are similar to southern Alberta geography, wetlands were valued at providing $939 to $1567.47 per hectare annually of ecosystem services, contributing $21 to $35 million annually for 223,547 hectares.[42]

ABOUT ALBERTA'S WETLANDS

In Alberta there are five types of wetlands: bogs and fens—both of which are peatland wetlands in central and northern Alberta—and marshes, ponds, and swamps—which are non-peatland wetlands in central and southern Alberta.[43] Classification is based on the types of animal and plant communities that each supports and on the amount of water saturation and permanence. Approximately 90 percent of Alberta's wetlands are peatlands located in the boreal region, while about nine percent of wetlands are non-peatland wetlands located in Alberta's settled (white) area, primarily in southern Alberta.[44]

In 1996, wetlands covered about 117,400 square kilometres or 18 percent of Alberta.[45] The extent of non-peatland wetlands in central and southern Alberta would be much higher today if over 60 percent of wetlands in Alberta's settled area had not been drained for or degraded by agricultural and land development.[46] The original area of non-peatland wetlands was estimated to be 35,500 square kilometres.[47] An estimated 21,900 square kilometres of non-peatland wetland had been lost by 2003.[48] Loss of wetlands during drought periods in the 1970s and early 1980s caused waterfowl populations to decline by one third by the mid 1980s.[49] The area remaining of non-peatland wetland in 1996 was about 13,500 square kilometres.[50]

While peatlands make up 90 percent of Alberta's wetlands, the extent of loss is unknown. However, large-scale industrial development of oil sands in northeastern Alberta is likely to contribute to major wetland loss in the immediate region. A recent analysis of the oil sands region estimated that the total footprint of oil sands operations including tailings ponds, pits, facilities, and infrastructure to be 65,040 hectares as of spring 2008. The estimated wetland loss in this area was 24,416 hectares or 38 percent of the total footprint.[51]

2.3 Value of riparian areas

Riparian areas, the so-called "green zone" of land alongside water bodies, play a critical role in the protection of water quality and quantity. Riparian areas are an essential landscape feature that form the transition zone between water bodies—streams, rivers, lakes, wetlands—and upland areas. At the watershed scale, riparian areas also include floodplains and alluvial aquifers.[52]

Riparian areas are natural filters that reduce sediment, nutrients, harmful bacteria, and other contaminants from washing from the land into water bodies, particularly during storm events.[53] As a pollution filter, riparian areas can reduce the concentration of nitrogen in runoff and floodwater by up to 90 percent and reduce the concentration of phosphorous by 50 percent.[54] Riparian areas may be one of the most important landscape features to protect drinking water supply especially if non-forest land-uses are occurring beyond the riparian zone that also contribute sediment, fertilizers, and other contaminants.[55]

VALUE OF THE SMALL STREAMS

Protecting small streams and riparian zones can have a significant impact on ensuring water quality and quantity in larger rivers. Small streams are essential to moving nutrients, fluids, and wastes among watershed components. According to one report, small streams—the small headwater and tributary streams—comprise up to 85 percent of the total stream length and therefore collect and drain most of the watershed of surface runoff.[59] As a result, these small streams strongly influence the volume, timing, and quality of overall stream flow in a watershed. Yet they are often ignored in land-use planning processes.[60]

Riparian areas unify soils, vegetation, and connect surface water and groundwater. Because water from streams and rivers can percolate into groundwater along riverbanks, these areas play a big role in replenishing groundwater and in reducing floods by absorbing floodwaters during high flows and releasing them slowly during drier times of year.[56]

Riparian zones are important for ecosystem health.[57] As the transition zone between water and land that has higher soil moisture levels, plant communities are unique to these areas with higher biodiversity than upland areas. Although riparian areas make up only approximately two percent of the land base, one study estimates that at least 80 percent of all fish and wildlife species in southern Alberta meet some or all of their lifecycle requirements in riparian areas.[58]

Plant leaves and other plant litter in riparian zones provide nutrients for the aquatic food chain. Riparian trees and shrubs drop woody debris into the water that provides critical habitat for benthic invertebrates and fish. Overhanging vegetation also provides shade, regulating water temperature, which is particularly important on hot summer days.[61] Roots of riparian plants help prevent erosion of the shoreline by dissipating the water's energy from high flows or wave action.[62]

Healthy functioning riparian zones require 1) sufficient water flows for riparian vegetation that vary through the seasons for survival and regeneration of plant species; 2) healthy, forested riparian zones that are at least 20 to 30 metres in width, and wider if the land slopes steeply;[63] and 3) a diversity of plant species, including woody plant species, and time to ensure when older plants die off, younger plants are there to fill their space.[64]

2.3.1 Economic value of ecosystem goods and services from riparian areas

The benefits of riparian areas are well recognized, but the economic valuation of riparian areas is not as advanced as that of forests and wetlands. Some studies suggest that riparian areas are increasingly being recognized as having economic value.

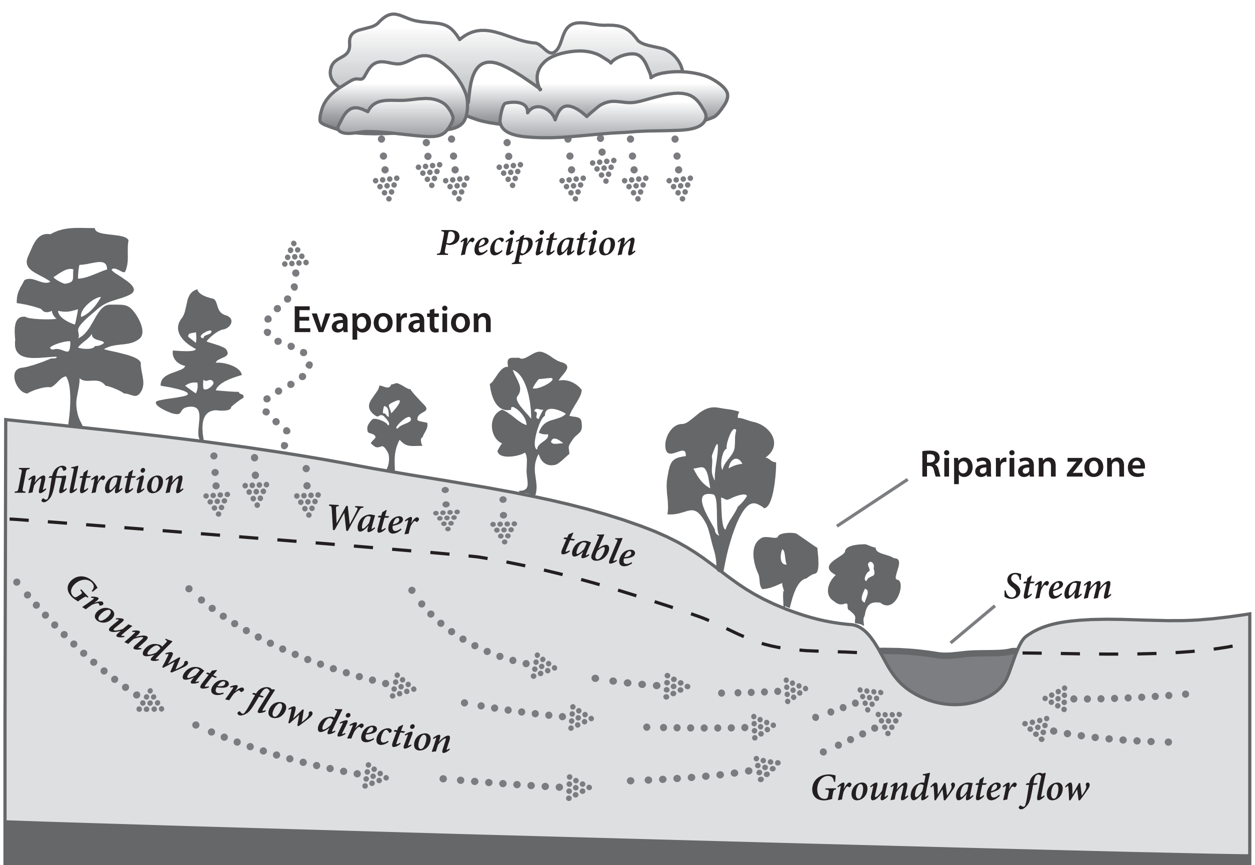
One study in Fairfax County, Virginia suggests that the presence of forested riparian buffers reduced costs of runoff following storms by $57 million.[65] A number of governments in Canada pay private landowners to maintain riparian areas from development, from $10 per acre per year by the Manitoba Riparian Tax Credit program to $150 per acre per year by both the City of Ottawa and the Municipality of Waterloo incentive programs.[66]

Photo: Lorne Fitch

2.4 Value of groundwater recharge zones

Groundwater recharge zones are critical for replenishing groundwater supplies. These recharge zones include riparian areas, wetlands, and areas of land that are more porous and let more water seep into the ground than other areas. Therefore, protection of recharge zones from detrimental land use is an important way to protect groundwater supplies.

Of all the freshwater in the world, nearly 70 percent is estimated to be stored in polar ice and glaciers, while most of the remainder is stored underground as groundwater. At any point in time, approximately 30 percent of all freshwater is underground as groundwater; surface water makes up less than 0.3 percent of all freshwater.[67] Groundwater is thus an important source of water in many parts of the world. [68] Although in 2005 only about three percent of total licensed water use in Alberta was for groundwater, it is used for some industrial and agricultural operations, as well as many municipalities.[69] Communities such as Canmore and Okotoks obtain a portion of their drinking water demand from groundwater (including groundwater that is connected to surface water). Approximately 12 percent of Albertans (440,000 people), including 90 percent of rural Albertans, rely on unlicensed use of groundwater as their private source of water.[70]



Water seeping into the land (infiltration) becomes groundwater that can also flow into surface water including streams, rivers, and lakes. Land that is considered "impervious" such as roads and parking lots cannot allow for this infiltration to occur to replenish groundwater.

Groundwater not only supplies immediate needs but is also a crucial long-term reservoir that supplies rivers and streams in times of low precipitation and needs to be regularly replenished to maintain flows.

Protection of these areas is also important to prevent contamination of groundwater. The porosity of a recharge zone (see box) presents the potential for contamination of groundwater supplies. Soil will filter out contaminants (except those that are dissolved) as the water moves through the soil; the sandier the soil, however, the more porous and easily susceptible the groundwater is to contamination.[71]

GROUNDWATER AND GROUNDWATER RECHARGE

Groundwater is water that is present between soil particles and in porous rock, saturating all the ground's available space below the water table. Groundwater recharges, or moves into the ground, in either one of two ways: by precipitation infiltrating vertically through soil and porous rock until it reaches the water table or by seepage from surface water bodies.[72] Thus surface water and groundwater are closely connected and are essentially one resource.

Groundwater recharge zones are critical land areas where surface water and precipitation infiltrate to replenish groundwater. The process by which water moves into the ground is called infiltration.[73] Land areas that are more effective than others at allowing water to infiltrate are called recharge zones. Slope steepness, soil texture, structure and amount of compaction (i.e., the soil infiltration capacity), soil depth, the degree of previous saturation, and depth of groundwater determine the amount of precipitation that the ground can absorb in a single storm event.[74] Coarse, gravelly soils and shallow fractured bedrock have the highest potential infiltration rates.[75] The volume of groundwater recharge depends on the amount, distribution, and timing of precipitation.[76]

In groundwater recharge zones it is important to protect well-vegetated or natural areas because vegetation promotes the ground's absorption of precipitation, while hardened or paved ground leads to rapid runoff. Groundwater recharge zones thus reduce flooding by absorbing runoff and contribute to a more stable flow regime in rivers, helping to support natural ecosystems, as well as sustaining drinking water supplies.

AQUIFERS

An aquifer is a layer of fractured rock or unconsolidated deposit that stores and transmits water.[77] An unconfined or shallow aquifer is below ground but open to the atmosphere and surface water through openings in the soil. A confined aquifer is deeper within the ground below a confining layer, such as clay, and is less sensitive to changes in precipitation and surface water levels.[78]

Groundwater is crucial for aquatic ecosystems, especially as it contributes significant proportions of flow to streams and rivers in late summer and early fall when there is little precipitation. For example, groundwater contributed 50 percent of the flow of the Bow River in 1970 when the river had the lowest flow on record.[79] A recent study of Jumping Pound Creek, a tributary of the Bow River that flows through Cochrane, found that groundwater contributed 68 percent of stream flow. Water quality sampling in this study further showed significant interaction between groundwater and surface water.[80]

2.4.1 Economic value of ecosystem goods and services from groundwater

Because of a lack of basic groundwater data, few studies explicitly estimate the value of groundwater recharge areas.[81] However, the value of groundwater recharge can be indirectly calculated as one of the services of wetlands, forests, and riparian areas. Groundwater recharge value can also be indirectly valued according to the economic value of groundwater itself. A 1994 study found that the total annual benefit of groundwater in the Assiniboine Delta aquifer (Manitoba) for the year 1990, based on quantities used for agriculture and for other purposes (including recreation), was between $4.7 million based on an economic efficiency perspective and $43.6 million based on a regional development perspective.[82]

The economic value of groundwater and groundwater recharge areas depends on local conditions. In some cases, there is no potential to increase a recharge area, but seeking an alternative to groundwater sources for a community can be very expensive. A study in Caledon, Ontario (population 40,000), which relies on groundwater as its source of drinking water, found that the replacement cost for this water would be $33 million per year.[83] When the groundwater in the Lacombe/Ponoka area of Alberta was unable to meet the needs of the growing population, the government authorized the construction of a pipeline to transfer water from another river basin. The estimated cost of this pipeline was $36 million.[84]

3 Land Use and Its Impact on Water Sources

Land-use decisions can affect water sources, influencing both water quality and quantity. From forests to farmland to cities, land-use changes can reduce the ability of watersheds to provide a steady supply of clean water.[85] Ultimately, damage to the key landscape features discussed above, as well as overall land-use activities across an entire watershed, can compromise the water-related goods and services that watersheds naturally provide.

Type of land use	Resulting impact to water	Potential impact on water sources
Wastewater treatment plans and industrial facilities	Point source pollution —discharges from specific and discrete (point) sources	Water quality (cumulatively, multiple point sources can together degrade water quality)
Agriculture (fertilizers, pesticides, manure), urban runoff (streets, gardens, industrial sites, road salts), deforested areas. Air pollution can also be a source of non-point source pollution because contaminants in the air can be deposited on the land and water body surfaces	Pollution that collects on land and flows into surface and groundwater — called runoff or non-point source pollution	Water quality and quantity
Roads, parking lots, rooftops, and driveways	Impervious surfaces such as roads and buildings leading to the compacting of soils and the paving over of natural areas	Increases the volume of polluted runoff[86] and decreases infiltration of water into groundwater;[87] reduces groundwater supplies; higher runoff volumes and rates increase erosion of land and stream banks and potential for flooding; increases sediment and nutrient loadings.[88]
Forestry, agriculture, and urbanization	Vegetation removal	Removal of vegetation reduces the absorptive capacity of the landscape resulting in higher runoff volumes; vegetation particularly influences the patterns and rates of erosion and deposition of sediments;[89] can accentuate high flows (e.g., stormwater runoff) and low flows (i.e., less storage for drier times of the year).
Urbanization, forestry, industrial activities, agriculture	Removal, draining, or alteration of wetlands	Removes filtering capacity of the landscape; increases spring high flows; decreases baseflows that are critical at drier times of the year.
Residential/commercial development, industrial use, irrigation, agricultural	Water withdrawal	Changes from the natural flow regime.[90] (A natural flow regime is the water flow variation a river experiences throughout the year and from year to year without diversions and dams. Because animals and plants have evolved to use river flow changes as cues for specific lifecycle changes, alteration of flow regimes has a significant impact on aquatic life and riparian plants.)

4 Cumulative Impacts of Land Use on Water Sources

Land-use activities—depending on the number, intensity, extent, duration, and type— can have a profound impact on the valuable ecological goods and services that can be offered by a watershed. The longer an ecological disturbance persists in a watershed, the more pronounced the impact is likely to be.[91] Some land uses have long lag times between the activity and the watershed's response to the activity.[92] A necessary step to developing management strategies to protect ecological goods and services is to understand how multiple types of land use can collectively impact watersheds. This section outlines a) how an individual land-use type can impact water sources; b) the presence of this land type in Alberta; and c) future projects for expansion of the land-use type based on available information. As discussed in Section 5, the identification of cumulative effects affords decision makers the opportunity to be strategic in identifying management actions.

LAND USE CAN AFFECT GROUNDWATER

Multiple land-use activities such as industrial sites and gas stations occur in groundwater recharge zones; because these areas are relatively porous, any ground contamination can be followed by groundwater contamination. Because groundwater and surface water are connected, contamination can also end up in surface water or pollution in surface water can end up in groundwater.[93] This connection between shallow unconfined aquifers and surface water means these unconfined aquifers need to be protected in a similar way to surface water sources—through protection of forests, wetlands, small streams, and high-yield recharge areas.[94]

4.1 Timber harvesting

Removal of forest cover can alter water yield, peak and low-flow patterns, and water quality including water temperature.[95] Disturbances such as clear cutting and roads in forests can cause changes in forest structure, changes to water flow pathways above and within soil, and changes in water and soil chemistry.[96] Reduced forest canopy allows more precipitation to reach the forest floor rather than being caught in the canopy and evaporating back into the atmosphere. This leads to higher frequency

Photo: Meghan Beveridge

WHY ARE UNFRAGMENTED FORESTS IMPORTANT FOR WATER SOURCES?

- They minimize non-point pollution and soil erosion
- They maintain water and air temperature for habitat protection and microclimate control
- They maintain natural hydrology of local areas
- They protect groundwater recharge areas
- They resist invasive species that can change how the forest cycles water
- They maintain overall ecosystem functioning, habitat, and biodiversity

and greater magnitude of floods, as well as an overall increase in total water yield but less surface and subsurface storage.[97] It can also exacerbate periods of low flows because water runs off the land more quickly and is not stored in the soil or in aquifers.

WILDLIFE SUFFERING FROM HUMAN LAND USE

One cumulative impact of land use across Alberta is wildlife loss. At least one quarter of Alberta's wildlife species are at risk or require special management or habitat protection to stall their long-term decline.[100] Grassland conversion to agriculture has endangered the swift fox, burrowing owl, and sage grouse. Fragmentation and disturbances in forests have negatively affected woodland caribou, grizzly bears, birds, reptiles (38 percent are at risk), and amphibians (50 percent are at risk). Native fish species such as bull trout, westslope cutthroat trout, and walleye have been put at risk through introduction of non-native fish species, dams, over fishing, and habitat loss.[101]

Most of Alberta's forested watersheds are over 50 percent developed.[98] Approximately 87 percent of Alberta's forested areas are allocated as Forest Management Units, which are areas of forest managed for timber extraction.[99] As of 1998, over twenty million hectares (equivalent to 30 percent of Alberta) have been allotted to long-term Forest Management Agreements (FMAs), which are negotiated agreements between individual companies and government to provide companies with rights to harvest and reforest trees on Crown land. Approximately 1.6 million hectares have been harvested since large-scale commercial timber harvesting began in Alberta in the 1950s.[102] At the current rate of forest allocations and if cut rates continue, approximately 10 million hectares of Alberta's forests (equivalent to 15 percent of Alberta) will be harvested by 2105.[103]

According to Global Forest Watch, 98.6 percent of the area logged in 2007 in Alberta was done by clearcutting.[104] Clearcutting can lead to excessive erosion and sedimentation in streams,[105] the severity of which depends on the size of the clearcut and the slope of the cut area. However, changes in management practices can reduce erosion and sedimentation from timber harvesting.[106]

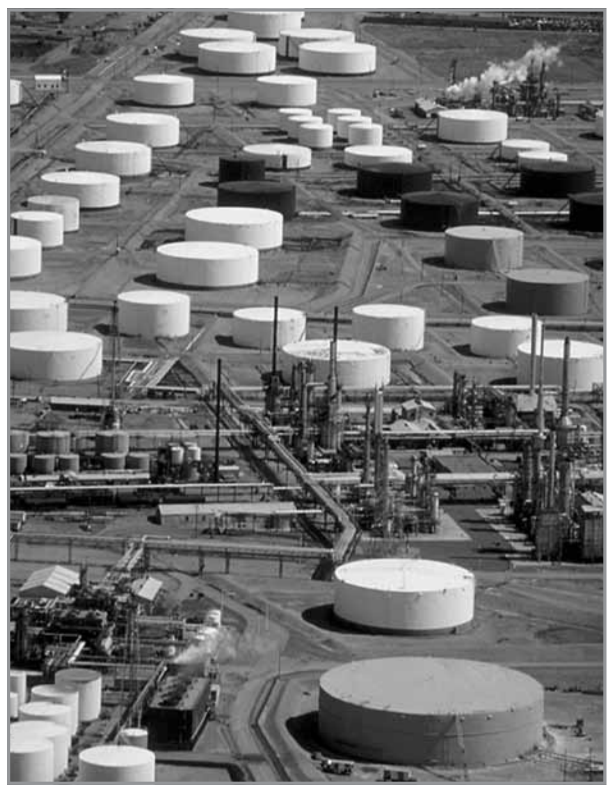
4.2 Mining, oil and gas exploration, and extraction

Energy production from conventional and unconventional sources brings a host of land-use impacts. These land uses range from surface mining to the footprint of individual wells to roads and pipelines associated with access and transport.

Surface mining can create significant land disturbance by re-sculpting or even physically removing land surface.[107] These disturbances can lead to greater erosion and sedimentation in streams and even changes in the local hydrology. The disturbance of surface mines, oil well sites, and cutblocks remain for several decades or longer.[108] Mining for aggregate (e.g., gravel) can result in dewatering of groundwater depending on the level of the water table, potentially affecting local water supplies and water levels of nearby surface waters. This type of mining can also lead to suspended solids in surface water.[109]

Oil sands mining in northeastern Alberta requires clearing of boreal forest and draining of wetlands before bitumen can be extracted. Oil sands mining by current operations will have an approved footprint of 61,762 hectares over the life of these projects. The total footprint of these projects and approved projects will be 134,079 hectares—approximately 40 percent of which are wetlands while the remainder is boreal forest.[110] Meanwhile, a more recent report states that already 65,040 hectares of boreal ecosystems have been lost to tailings ponds, mining pits, facilities, and infrastructure.[111] These operations result in the removal of natural vegetation on a major scale and significant alteration of the natural hydrology in part of the Lower Athabasca watershed. Because over 90 percent of the oil sands are too deep to mine, however, most of the bitumen is being extracted *in situ* by drilling wells. *In situ* operations use large volumes of water to produce steam to extract the bitumen and much of this comes from groundwater (both fresh groundwater and deeper, saline groundwater).

Photo: Danielle Droitsch



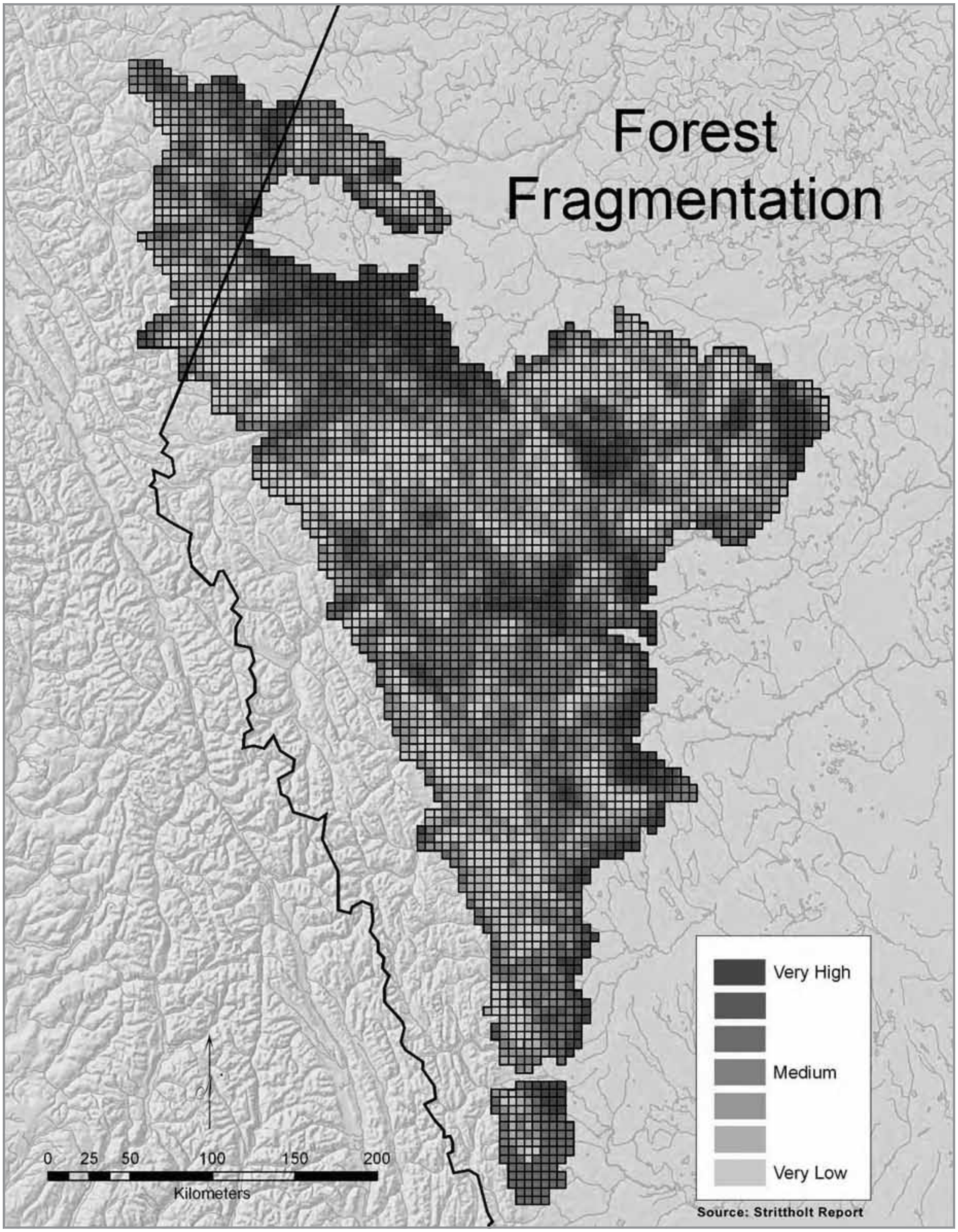
Conventional oil and gas development also has its impact. Since the 1950s, the number of producing natural gas wells has increased exponentially and is now in excess of 140,000 wells; producing conventional oil wells has increased exponentially to more than 90,000 wells in Alberta.[112] The annual number of wells drilled increased from 9,444 wells in 1999 to 19,800 wells in 2006, a record year.[113] In 2008, 15,471 wells were drilled.[114] By the end of 2008 there were 11,344 producing coal-bed methane wells (considered unconventional gas development) on Alberta's landscape.[115] As a result, 175,172 producing oil and gas wells, 22,358 oil batteries and associated satellites, 797 gas plants, 14,764 gas batteries, and 4,613 compressor stations—not to mention 412,555 kilometres of pipelines—are strewn across Alberta's landscape.[116] (These numbers do not include the significant number of abandoned wells and associated infrastructure that exist across Alberta. These wells, if not properly sealed, are excellent conduits for contamination into aquifers.)[117] The total footprint of the energy sector has increased to 600,000 hectares over the past century and will likely increase to 1.4 million hectares by 2105, likely amplifying current impacts on water and watershed functioning.[118]

4.3 Roads, linear features, and landscape fragmentation

Roads, seismic lines, and other forms of linear disturbance have a more limited footprint in terms of actual land disturbance and can have a substantial impact over large portions of land with a considerable impact on water sources.[119] These linear features, particularly in combination with other land uses, can damage stream channels and riparian areas thereby harming the healthy functioning of these surface water bodies.[120] Roads and pipelines crossing rivers and streams affect fish and benthic invertebrate populations by increasing or decreasing (as with dams) sediment inputs, fragmenting waterways that function as movement corridors for fish or altering flow regimes.[121]

A total of 200,000 kilometres of roads have been constructed over the last century in Alberta. Approximately 400,000 kilometres of seismic lines are visible in the province[122] and 412,555 kilometres of pipelines are networked across Alberta.[123] Based on projected infrastructure needs by forestry, energy, and rural residential trajectories, the road network is likely to increase four times over the next century.[124]

Photo: Meghan Beveridge



Source: James Strittholt, Nancy Staus, Gerald Heilman, and John Berquist. *Mapping High Conservation Value and Endangered Forests in the Alberta Foothills Using Spatially Explicit Decision Support Tools*. Report by Conservation Biology Institute for Limited Brands. May 2007, p. 45. Online at http://albertafoothillsnetwork.org/documents/ Strittholt%20report.pdf/ at_download/file

Construction of access roads is one of the biggest contributors of erosion and sedimentation in watersheds.[125] A watershed assessment study completed in southwestern Alberta found "the risk of surface erosion from land disturbance is the principal risk to watershed integrity in most of these 90 basins. Here, as in many other forested regions, surface erosion from land disturbance is overwhelmingly attributable to the extent of road development."[126]

Seismic lines disturbed the most land area between 1961 and 1999, affecting 728,608 hectares of Alberta's forested landscape, followed by agricultural leases (e.g., grazing leases, affecting 139,303 hectares), roads (131,033 hectares), and mineral surface leases (125,240 hectares).[127] Pipelines cross Alberta's waterways at thousands of points and have further fragmented Alberta's forests. If not properly designed and maintained or even removed once no longer needed, roads and other linear features increase erosion and degrade water quality by adding sediment to streams.[128]

FRAGMENTATION

Fragmentation is a process that occurs over time as development slowly transforms an undeveloped landscape into one littered with roads, seismic lines, electricity transmission lines, cultivation, towns, and reservoirs. The result is a dissected landscape where natural habitat is carved into smaller and smaller parcels.[129] This fragmentation interrupts natural pathways for water flow; cumulatively destroys natural land cover such as forest or grasslands; and disrupts habitat for birds, grizzly bears, and other wildlife.[130]

Land-use activities on Alberta's landscape have resulted in less than two percent of the foothills region remaining unfragmented or intact as wilderness while less than nine percent of townships in the boreal region retain intact or unfragmented forest.[131] Over 90 percent of Alberta's forests that are not protected as parks are fragmented by roads, seismic lines, pipeline right of ways, and other land uses.[132]

4.4 Agriculture: livestock grazing and croplands

Agriculture, a cultural and economic force for over a century in Alberta, also impacts water sources. The emergence of agriculture in Alberta, along with urbanization and industrial activities, has resulted in the loss of well over 60 percent of southern Alberta's native grasslands, removing the water regulation, erosion control and sediment retention services of grasslands and key habitat for the burrowing owl, swift fox, and peregrine falcon.[133]

Agricultural practices (including livestock grazing) can damage watershed functioning, impairing both natural hydrology and water quality. A study of grazing in fescue grassland near Stavely, Alberta, showed that heavy grazing reduced organic matter and nutrients in the soil, increased soil temperature, and decreased soil moisture, causing the soil to become more characteristic of a drier microclimate.[134] Another study of livestock grazing in mixed prairie and fescue grassland found that grazing overall reduces soil moisture but to varying degrees depending on grazing intensity, timing of grazing (e.g., early versus late season grazing), and depth of soil tested.[135]

Another study in Haynes Creek, a watershed east of Red Deer intensely used by agriculture, found that different types of agricultural uses had different impacts on surface water: spring runoff from cattle wintering grounds contributes nutrients, suspended solids, and bacteria into receiving water bodies; and runoff from cultivated fields can contain residues from pesticides applied the previous spring, along with dissolved phosphorus and nitrates and suspended solids.[136] A partner study found that intensity of agriculture (in this study defined by fertilizer expenses, chemical expenses, and animal unit density) influences stream water quality. More intense agriculture led to higher nutrient concentrations, mass load of nitrite+nitrate, and total dissolved phosphorus than did medium or low intensity agriculture.[137]

Largely as a result of livestock and cropland expansion in Alberta, where most growth has occurred between the 1920s and 1980s, and increased use of inorganic sources of fertilizer, levels of nitrogen, phosphorus, and sediment in Alberta's surface waters have increased three fold.[138] High levels of nutrients can cause algal blooms, which reduce oxygen levels in water and stress fish and other aquatic species. Polluted runoff from agricultural areas can also carry pathogens and pesticides; pesticide use has been on the rise over the last 40 years.[138]

Alberta's cattle population has increased by 50 percent since 1975.[140] The number of cattle has expanded from a few tens of thousands around 1900 to over six million head of cattle today, outnumbering people almost two to one and out-manuring people 31 to 1.[141] Grazing rangelands covers about 7.4 million hectares (or 11.2 percent) of Alberta.[142]

Cropland area increased from 19,050 hectares in 1905 to 9,829,180 hectares in 2005.[143] Increasing inputs of chemical fertilizers and pesticides, as well as crop breeding, have made this possible but not without negative consequences for Alberta's water sources.

Much of southern Alberta's cropland is heavily reliant on irrigation. Irrigation licences account for 77 percent of water allocated in southern Alberta (i.e., Bow, Oldman, South Saskatchewan, and Milk watersheds).[144] Irrigation can seriously reduce stream flow—particularly during late summer low flows in Alberta's southern rivers—and thereby increases water temperature, reduces aquatic habitat area, and stresses fish.[145] Irrigation can also contribute to water quality problems because of intensive fertilizer and pesticide use, as mentioned above, and can lead to soil salinization as high evaporation leaves the dissolved salts on irrigated lands.[146]

Agricultural activities not only affect downstream water users, such as towns and cities, but also the agricultural users themselves who often have more vulnerable private water systems. One study completed between 1994 and 1996 found 32 percent of the 857 wells sampled in Alberta exceeded federal guidelines for maximum acceptable limits for at least one parameter. The contaminants found—herbicides, nitrites which can cause gastrointestinal tract irritation, nitrates which can lead to lymphomas, and fecal coliforms, which might contain pathogenic strains of *E. coli*—pointed to land uses that were either contaminating the aquifer or contaminating the well directly.[147]

4.5 Residential and urban development

Urban land use, including surrounding country residential development, can also impact water quality, water movement (hydrology), and water supplies.

Urban development has four key impacts on water sources:
1. Impervious cover from pavement and buildings creates more runoff
2. Runoff picks up pollutants from pavement, which is taken through storm sewers and often ends up in rivers or lakes
3. Impervious cover (roofs, pavement) reduces groundwater recharge
4. Demand for water reduces river flows

Land use in the form of roads, residential development, and agriculture either removes or impairs key ecological goods and services such as the water filtering and storage functions of wetlands.[148]

Typical land development practices can generate anywhere from 5 to 100 times more runoff compared to predevelopment conditions depending on extent, intensity, and scale.[149] Development in the Nose Creek watershed in the north of Calgary, for example, has caused increased stormwater rates and decreased water quality because of greater impervious cover, removal of wetlands, and development along riparian areas.[150]

One study in Atlanta, Georgia, examined how much water was not being absorbed by the landscape but was "lost" to runoff and evaporation because of impervious surfaces. The study found that this loss ranged from 57 billion to 133 billion gallons annually in the Atlanta area alone, enough water to supply daily household needs of 1.5 million to 3.6 million people per year.[151]

In Alberta, the growth of residential areas away from urban centres (often called urban sprawl) has converted productive farmland and open space to developed land with impervious land cover. As urban areas sprawl in Alberta, the residential area is projected to increase from 250,000 hectares to 1.2 million hectares by the end of the century, mostly in the Edmonton-Calgary corridor, eating up natural areas and prime agricultural land.[152] If Calgary continues to grow at its average annual rate over the last century of 4.5 percent, Airdrie, Langdon, Okotoks, Redwood Meadows, and Cochrane will become part of Calgary by 2050.[153] According to an analysis of human density in Canadian cities, Calgary's total density and inner city density was less than Montreal, Toronto, Ottawa, Vancouver, Winnipeg, and Edmonton.[154] Edmonton's inner city density was second only to Calgary's. Thus, more land per capita is disturbed and paved over by the major urban centres in Alberta than in other more densely populated cities.

4.5.1 Stormwater

Stormwater is water that accumulates on land as result of storms and can include runoff from urban areas such as roads and roofs. It often runs directly into streams and rivers without treatment and carries sediment and contaminants with it. Research shows that stormwater from residential development in Alberta's two largest cities, Calgary and Edmonton, decreases water quality.

Photo: Water Matters

In Calgary, in 2002, stormwater contributed 10,600,000 kilograms per year of total suspended solids (TSS), compared to 1,230,000 kilograms per year of TSS from wastewater treatment plants. The level of biochemical oxygen demand (BOD), which indicates how much organic material such as sewage is in the water by how quickly biological organisms are using up oxygen, was higher in Calgary's stormwater (710,000 kg/year) than its wastewater from treatment plants (605,000 kg/year) in 2002.[155]

Stormwater in Edmonton contributes phosphorus, ammonia, and *E. coli* and creates biochemical oxygen demand. It is also the largest contributor of TSS, contributing more than 75 percent of an average daily rate of 27,072 kilograms per day.[156]

4.5.2 Septic systems

Septic systems, while an excellent way to address household wastewater in low-density or rural areas, can negatively affect groundwater in certain circumstances. A septic system collects domestic wastewater in an underground tank. However, if too much wastewater is released into an area from multiple private septic systems, the ground can become saturated with contaminants, and groundwater quality can be compromised, especially where there are high groundwater tables.[157] As private septic systems are used over time and become saturated, they can be one of the greatest contributors of nutrients and pollutants in low-density rural residential landscapes.[158] The performance of a septic system depends on the system's age, maintenance of the system by private landowners, and the location (e.g., the types of soils) of the system. As the density of septic systems increases and the soil's assimilative capacity is exceeded, the potential for groundwater contamination increases.[159]

5 Incorporating Ecosystem Goods and Services of Water Into Decision Making

Many suggest that while there is a general recognition that watersheds are important, there is little recognition of that value in land-use decision-making processes. The International Union for the Conservation of Nature (IUCN) says that when economic planners evaluate costs and benefits of water use or the cost of providing a particular water service, the valuation does not recognize that ecosystems are in fact economic users of water and components of the water supply chain.[160] To "correct the balance sheet," the IUCN suggests the following must occur:

1. Build an understanding of how ecosystems contribute to human welfare
2. Recognize that ecosystem values have been ignored in decision making
3. Consider ecosystem values to avoid costs and safeguard profits in the future
4. Build a framework that considers total economic value to include not only direct values but also indirect values (e.g., flood control, maintenance of water quality)
5. Ensure that economic valuation not be considered the only aspect of the equation
6. Define the scope of the valuation[161]

This next section outlines a general three-part approach for decision makers indicating how to integrate the value of watershed goods and services into land-use planning processes.

- Measure the cumulative impact of land uses considering current and future impacts based on estimates (can be part of general land-use planning process for project-specific applications)
- Identify objectives for the protection of ecosystem goods and services including indicators for water quality and quantity but also objectives for wetlands, riparian areas, etc.
- Implement specific management strategies including, but not limited to, market-based instruments to implement preferred course of action

The next three sections outline each of these steps. It is, however, beyond the scope of this report to provide an exhaustive description of each of these steps.

5.1 Measure the cumulative impact of land use

To properly manage land uses to protect water resources, decision makers must first assess cumulative impacts evaluating the effects of multiple land uses within an entire watershed over time. Cumulative watershed effects are defined as "environmental changes that are affected by more than one land-use activity and that are influenced by processes involving the generation or transport of water."[162] Cumulative impacts also need to be assessed across time, measuring the impacts still persisting from past activities in addition to impacts of current activities as well as anticipation of future changes in land use (e.g., proposed growth) and climate (e.g., extreme rainstorms or drought). Cumulative impacts need to be assessed not only within one site or river reach but also across the watershed. This is especially true when considering water-related impacts because water inevitably flows somewhere else.

Significantly for decision makers, a cumulative effects analysis allows for the development of management objectives as discussed in the next section. The cumulative effects process must not only provide decision makers with an estimate of the current effects of the landscape. Perhaps more importantly, the process must allow for a comparison of different management or use scenarios so decision makers may understand the choice between alternative uses of land, water, and other resources. This information allows decision makers to compare changes in values from different management or use alternatives. (While this report considers the use of indicators and thresholds to address cumulative impacts at the watershed level, other cumulative impact management activities can be applied including land-use planning, cumulative effects assessment, and individual project or joint management of one or two projects for cumulative effects.)

5.2 Identify objectives for the protection of ecosystem goods and services

As discussed above, a cumulative impacts assessment can identify management objectives. One approach increasingly favoured in Alberta is the identification of land-based indicators and the subsequent establishment of thresholds that act as limits preventing watershed health from becoming unacceptable.

Examples of land-based indicators for the protection of water resources include percent of land covered by vegetation, predicted soil erosion rates, rangeland health measurements, and riparian health measurements.[163] Other indicators can include dwelling unit density, human-altered land and constructed features, and amount of pesticides applied to the land.

Alberta Environment suggests the following indicators as a measure of the ability of the landscape to perform water-related functions:

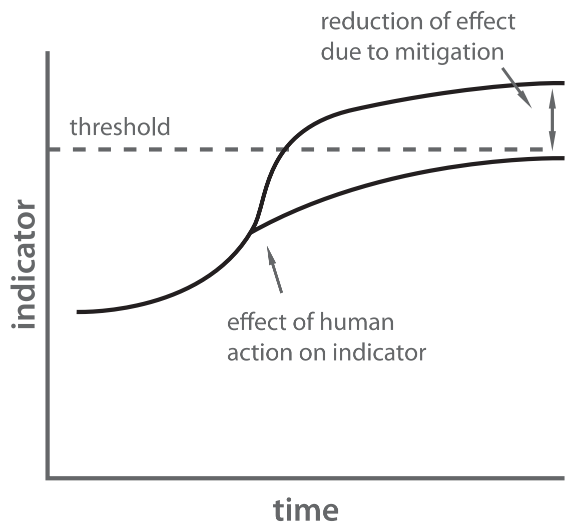
1. Ability to resist erosion and sedimentation in water bodies
2. Ability to filter runoff
3. Ability to regulate storage and discharge of runoff
4. Ability to allow for groundwater recharge[164]

INDICATORS AND THRESHOLDS

Indicators and thresholds help measure and manage cumulative impacts on the landscape.

Indicators are "specific physical, chemical, and biological attributes or components of the environment that play an important role in affecting environmental outcomes. Indicators are always part of the cause-and-effect relationship between human activities on the landscape and the environmental response to those activities."[165] Indicators for the protection of water sources include water quality, water supply and demand, environmental fragmentation, and percentage of land in natural vegetation.[166]

Thresholds are values of indicators that reflect a problem condition, while targets are values that reflect a desirable outcome.[167] The point at which an indicator changes from an acceptable to an unacceptable condition is the threshold for that indicator.[168] Thresholds can be based on science and/or social values. These thresholds can then be used to manage cumulative effects through regional planning or individual project reviews.[169]



Source: Peggy Holroyd

Once indicators are identified, thresholds can be established to set limits on how much the indicators should change. Alberta Environment suggests that thresholds for the above indicators could be defined so as to ensure runoff and base and peak flows of rivers support water quality and quantity requirements for both human, aquatic, and riparian ecosystem health.[170]

IMPLEMENTING A THRESHOLD FOR ROAD DENSITY

Road (or linear disturbance) density, and other road-related measures, is one of the best indicators of land-use intensity and an important indicator for watershed health. Almost all land-uses require roads. One of the most effective solutions to damaging land use is to remove roads and restore the land to a natural condition by recontouring and revegetating rights-of-way. Risks of stream siltation, flow increases, and channel damage, in forested areas, at least, could be substantially reduced by following this relatively simple and inexpensive step.[178] Alberta has some of the highest densities of linear disturbance in western North America.[179] To minimize the damage of roads in Alberta's landscape, thresholds can set out the maximum density of roads an area should have to protect desired characteristics. For example, a threshold for road density might be 0.3 kilometres per square kilometre (km/km^2) or up to 2.4 km/km^2 depending on how much risk is deemed acceptable for the cumulative risk to peak flow and erosion. For sensitive fish, threshold values could range from 0.2 km/km^2 up to 1.2 km/km^2 depending on the level of risk deemed acceptable to that fish.[180]

SETTING INDICATORS FOR LAND IN A NATURAL STATE

Decision makers may consider one indicator as a central component to the protection of water sources: the amount of land in a given watershed that remains in a natural state. A recent Alberta Environment report states: "[l]and quality should be measured as the amount of land remaining in a natural state and as the ability of all land in an altered or natural state to perform basic water-related functions such as resisting erosion, filtering runoff, regulating the storage and discharge of runoff, and allowing for groundwater recharge."[171]

In an undeveloped watershed that is largely characterized by natural vegetation, approximately 50 percent of the precipitation infiltrates the ground and only approximately 10 percent flows over the land surface as runoff. By contrast, in a highly developed watershed with more impervious surfaces and less vegetation, only about 15 percent of the water infiltrates and 55 percent becomes surface runoff that carries pollutants to surface water bodies.[172]

According to a study in 2002 of 27 water suppliers by the Trust for Public Land and American Water Works Association, for every 10 percent increase in forest cover (up to 60 percent forest cover) in their source protection area, the costs for treatment and chemicals decreased about 20 percent. The study concluded that 50 to 55 percent of the variation in treatment costs could be credited to the percentage of forest cover in the upper watershed.[173]

- Special designation whether by land acquisition or by a zoning approach can recognize particularly critical land resources such as recharge areas, riparian zones, and forests.
- The city of Vancouver acquired private land, leased Crown land, and prevented public access to 585 square kilometres of mountainous land to maintain safe, high quality water to over two million people.[174]
- Nova Scotia under its Drinking Water Strategy (2002) has designated at least 24 of 82 municipal water supplies as Protected Water Areas or put in place a comprehensive water supply protection strategy.[175]
- The Oak Ridges Moraine, north of Toronto, where groundwater is an important source of water supply, now receives greater protection from further development so as to protect this important headwater and groundwater recharge area for Toronto's drinking water supply.[176]
- To protect riparian areas, some jurisdictions set guidelines or regulate the distance that development must be from the edge of streams, rivers, lakes, or wetlands. These distances can be set based on such parameters as size of water body or slope of the riparian area. Setting these land-use restrictions is critical for maintaining water quality in local water bodies.
- In 2007, the City of Calgary approved an updated environmental reserve setback policy for new development requiring wider riparian zones depending on the slope and type of water body. The Nose Creek Watershed Water Management Plan (2007) recommends that resource managers use site-specific information to set riparian zones.[177] Other municipalities with riparian policies include the Municipal District of Rocky View whose policy (2005) stipulates a specific width for riparian zones.

5.3 Identify management strategies to implement thresholds or other objectives

Once cumulative impacts are identified and thresholds are set for particular indicators, decision makers must then identify and implement management strategies that ultimately lead to on-the-ground practices. Managing land use to protect water sources requires a comprehensive approach that accounts for multiple land-use activities—considering past, present, and future impacts—and landscape features throughout an entire watershed system. A comprehensive approach embraces the use of a diversity of strategies including "conservation and restoration, land-use monitoring, proactive land-use regulations, on-site field inspections, education, planning, emergency spill response, and incentives."[181]

There is a vast array of resources available to decision makers to identify management tools to implement land-based thresholds to protect water quality. While a comprehensive profile is beyond the scope of this report, we outline three general approaches that are specifically designed to minimize the impact of land use on water resources. Because each of these management strategies approaches the relationship between land and water in a different manner, they can easily be applied simultaneously although it is not necessary to do so.

5.3.1 Source water protection

Source water protection strategies require the prioritization of land areas needing protection based on natural landscape features and connections that are important for watershed functioning (i.e., ecological infrastructure that produce ecological goods and services) as well as areas that are considered vulnerable to land-use activities negatively impacting water. A source water protection plan would include strategies for managing threats to source water, whether land-use activities, direct pollution, or water-use threats.[182]

More generally, source water protection is the first step in "a series of safeguards along the water supply route to prevent or reduce contaminants from making it through the drinking water system."[183] This precautionary approach to protecting drinking water takes a preventative and comprehensive approach to water treatment for drinking water. It goes beyond the traditional water treatment option that treats water at the treatment plant. In very simple terms, protecting the "source" of drinking water is the next major advancement in assuring safe drinking water.

With respect to groundwater, historical efforts have focused on protecting areas around groundwater wells (wellhead protection) because consequences of contamination at the wellhead are more immediate. However, because groundwater often enters the ground some distance away, recharge areas as discussed in Section 2 also need protection from contaminants.[184]

Source water is untreated water from rivers, lakes, or aquifers. Source water protection seeks to protect sources of drinking water from contaminants and excessive withdrawal. Because land use dramatically affects water sources, comprehensive source water protection aims to reduce the negative effects of land use.

THE MULTI-BARRIER APPROACH

The "multi-barrier approach" to source water protection means (1) keeping the water clean; (2) treating the water to make it safe; (3) monitoring the water to ensure it remains safe; and (4) taking action if a problem occurs.

The Province of Ontario is one of the few jurisdictions in Canada that has embraced source water protection into its legislation and watershed planning. With guidance from watershed-based conservation authorities, multi-stakeholder committees in 19 regions are working through a source water protection planning process. Currently many of these committees are in the process of assessing threats and will soon be planning how to manage them. The result will be source water protection plans that guideline land-use decision making.[185]

To date, all committees have adopted a general terms of reference for their work. Assessment reports are due in 2010. Source water protection plan are due to be completed 2012–2013. While the planning process will benefit 90 percent of Ontario's population (11 million people), it still does not cover all water systems. Also, private wells are not covered or protected unless their status is elevated by the source protection authority.

5.3.2 Wet growth

Wet growth derives from smart growth principles and guides development to take account of water quality and water hydrology and supply. The wet growth approach specifically considers the ecological infrastructure in an area.

Smart growth can be characterized as follows: 1) high density development; 2) development in existing or immediately next to existing development; 3) development design that promotes pedestrian patterns and minimizes the number and length of vehicular trips for each person on a daily basis; and 4) residential development that is clustered and mixes uses to minimize impact on the natural environment while increasing the sense of community.[186] The wet growth approach integrates "concerns about water quality and the availability of water supply into the density, form, pattern, and location of development."[187]

Applying the wet growth concept can shape development so that it accounts for the natural limitations of local watersheds. Examples of wet growth approaches include the following:

- Proof of adequate water supplies before a development is approved. For example, California, in Senate Bill 221, requires water assessments of residential, commercial, and industrial developments before approval.[188]
- Location-specific restrictions on land uses in sensitive areas including riparian areas, aquifer recharge zones, wetlands, and critical drainage areas.[189] For example, San Antonia, Texas limits development on critical aquifer recharge areas to protect the city's drinking water source.[190]
- The 2007 Nose Creek Watershed Management Plan (watershed located north of Calgary) sets out a plan to curb development along riparian areas and to address the fact that the permitted release rate for stormwater management is nearly twice that of predevelopment conditions.[191]

5.3.3 Explicit recognition of the value of ecosystem goods and services

One area being seriously considered for application in Alberta is the adoption of a policy framework adopting market-based instruments that explicitly recognize the value of ecosystem goods and services. The emergence of a market-based instrument framework is also expected following passage of the Alberta Land Stewardship Act (ALSA) adopted in 2009. ALSA effectively established a framework with the adoption of regulations (not yet adopted) creating an exchange for the issuance and trading of stewardship credits. A stewardship credit is an activity that counterbalances the effect of a land-use activity. A stewardship credit is expected to provide an additional incentive to voluntary activities such as committing to restoration of land, acquisition of land, and donation or creation of a conservation easement.[192]

In 2008, the Alberta government established the Institute for Agriculture, Forestry and the Environment (IAFE) to recommend a framework for the development and implemention of market-based policies and processes under the Alberta Land Stewardship Act.[193] The IAFE is expected to issue a draft framework in 2010.

The setting of targets and identifying thresholds for cumulative effects goes hand in hand with market-based instruments, which are often most effective with the setting of limits. There are a range of market-based instruments including tradable permits, compliance offsets, transfer development rights, environmental taxes, user fees, payment schemes, and tax credits. There are two types of market-based instruments. The first is price-based whereby a price is assigned to environmental impacts through positive instruments (e.g., payment, auctions, and grants) and negative instruments (e.g., charges and taxes).[194]

One price-based instrument often used for protection of water services is payment schemes whereby downstream communities pay upstream communities or private landowners to maintain land-use practices that are not harmful to the watershed and its functioning. Accessing an ecosystem service such as water filtration in a healthy functioning watershed can be cheaper than replacement water treatment costs. Meanwhile the downstream communities receive cleaner drinking water, flood regulation, and more consistent water supply.[195]

For example, Ecuador's capital, Quito, has a population of 1.5 million people who rely on 520,000 hectares of protected high-altitude grasslands and cloud forests for about 80 percent of their water. About 27,000 people live in and near the protected area and conduct dairy and cattle farming and timber harvesting, all of which have impacts on quality and quantity of water. In 2000, a trust fund was created with voluntary donations by downstream beneficiaries—primarily from Quito's municipal water supplier—for the acquisition of critical lands, improvement of agricultural practices, and the implementation of watershed protection measures.[196]

Gardner et al suggested a market approach for application in Alberta utilizing the conservation easement concept in order to overcome the barriers of traditional conservation easements and create a source of annual revenue for landowners rather than a one-time tax benefit.[197]

A quantity-based instrument is based either on establishing a cap-and-trade system or a credit system. A cap-and-trade system requires the setting of limits on the total allowable environmental impact that goes hand in hand with cumulative effects thresholds. A system such as this could establish a cap on total land disturbance in a given area (e.g., a watershed) and easily tie into a stewardship credit system as proposed by the Alberta Land Stewardship Act. Another type of quantity-based instrument is a credit system allowing for the earning of credits that can then be sold to other entities.[198]

6 Case Studies

The following three case studies from Alberta illustrate how the cumulative impacts from land use affect water sources and how these impacts might be assessed and addressed.

6.1 Elbow River watershed

The Elbow River watershed is a good example of how land use can affect water quality and quantity. There are no approved point source discharges upstream of the Glenmore Reservoir; only non-point source pollution including nutrients, sediment, and bacteria from different types of land uses are at issue. Efforts by Alberta Environment and other partners to identify critically sensitive areas that provide ecological goods and services may help protect water quality.

The Elbow River runs from the Rocky Mountain East Slopes through the foothills past Bragg Creek into southwest Calgary's Glenmore Reservoir and then meets the Bow River in downtown Calgary. Historically this river has been relatively well protected as a pristine source of water for Calgary's growth, now providing drinking water for more than 40 percent of Calgarians. More recently, land use along the river and its tributaries has caused the Elbow's water quality to decline. Agriculture, septic fields, and growing urban development on the southwestern edge of Calgary are contributing to this decline, according to a study by Alberta Environment and the City of Calgary.[199]

The 2006 study indicated a deterioration of water quality for three pollutants upstream of Calgary: dissolved phosphorus, turbidity, and coliforms.[200] Land uses indicated as source of these worrying trends include residential developments and agriculture.

6.1.1 Residential development

Residential development, which contributes increasing amounts of stormwater, likely contributes the largest proportion of these contaminants during low to average river flows.[201] Upstream of Glenmore Reservoir, two stormwater outfalls discharge directly into the river; another three stormwater outfalls discharge first into stormwater retention ponds for pretreatment and then the river.[202]

Figure A: Elbow River Watershed - Watershed Sensitivity and Values

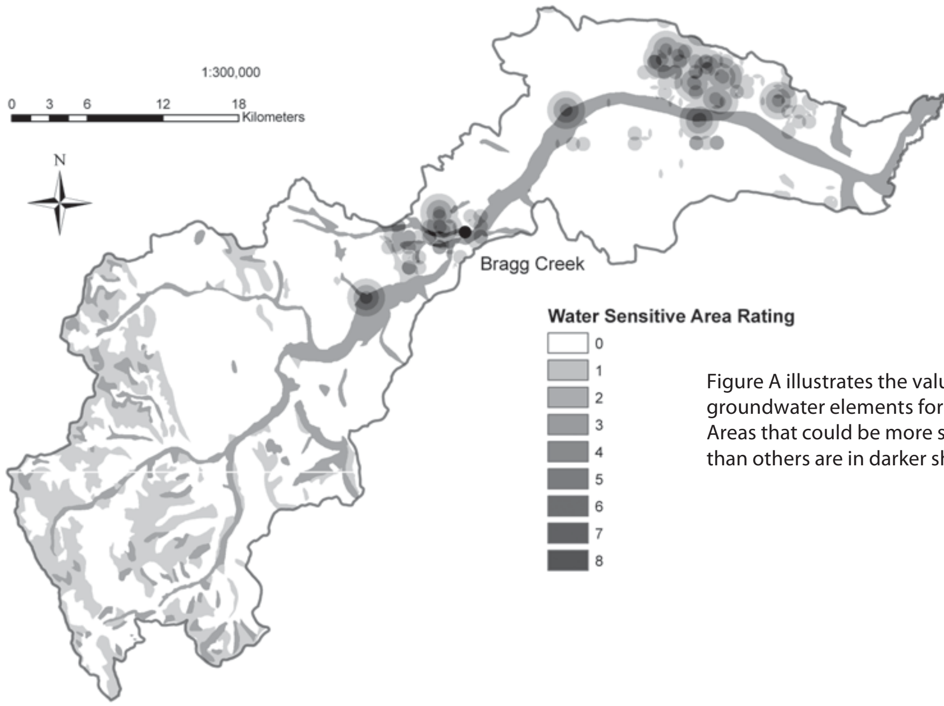


Figure A illustrates the valued areas related to surface and groundwater elements for the Elbow River watershed. Areas that could be more sensitive to landscape change than others are in darker shades.

Figure B: Elbow River Watershed - Watershed Sensitivity and Values

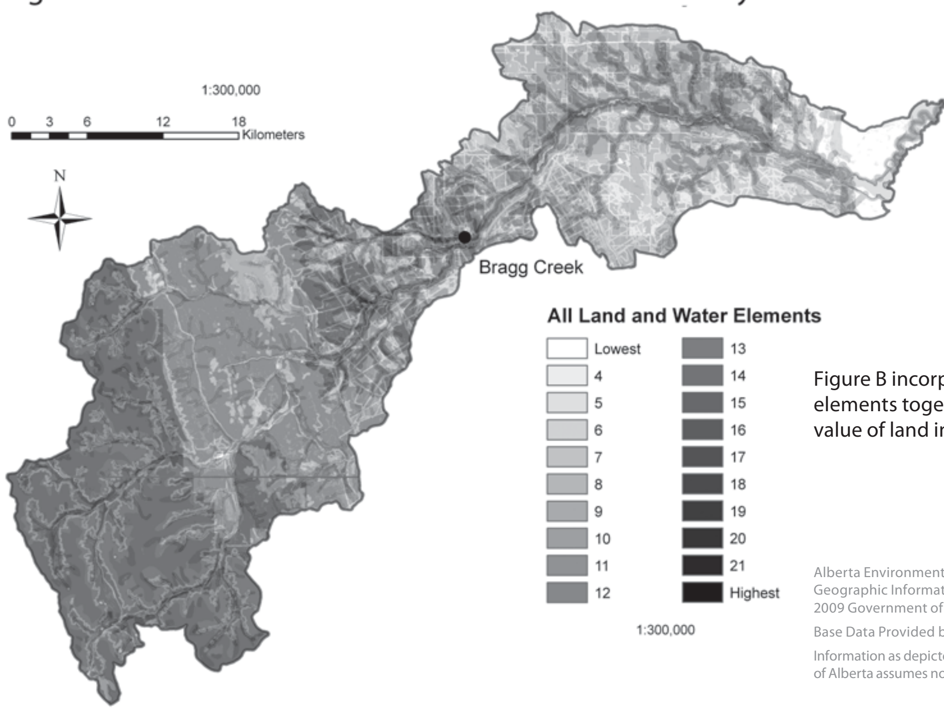


Figure B incorporates both land and water elements together illustrating the higher value of land in the upper watershed.

Alberta Environment
Geographic Information Office, Red Deer
2009 Government of Alberta

Base Data Provided by the Spacial Data Warehouse

Information as depicted is subject to change, therefore the Government of Alberta assumes no responsibility for descrepancies at time of use.

CONCERNS WITH PHOSPHORUS, SOLIDS, AND COLIFORMS

Excess phosphorus in water causes excessive plant growth and leads to depletion of dissolved oxygen in the water when the plants die and decay; fish and other aquatic life require this dissolved oxygen to live. Excessive nutrient inputs, usually nitrogen and phosphate, have been shown to be the main cause of eutrophication over the past 30 years. This aging process can result in large fluctuations in the receiving water quality and trophic status and in some cases periodic blooms of cyanobacteria. Possible sources of the phosphorus are urban runoff from new and old residential developments, agriculture, groundwater, and other non-point sources.[203] Major human-influenced sources include partially or untreated sewage, agricultural runoff (animal waste and crop fertilizers), and lawn fertilizers.

Suspended solids including fine silt and clay, organic matters, and small organisms carry nutrients and toxic pollutants, kill aquatic life when settled on stream bottoms, and make water treatment more difficult.[204]

Fecal coliforms, including bacteria such as E.coli, are a measure of sewage or manure in a water source. Coliforms can cause illness and even death, as in the case of Walkerton. While no evidence points to human sewage as a problem in the Elbow River watershed, runoff from residential developments, agriculture, groundwater, and other nonpoint sources may have contributed to increasing fecal coliform counts.[205]

The 2006 study results are not entirely surprising as studies dating back to the mid 1980s pointed to the potential risk of increasing urbanization to water quality in the Elbow River watershed.[206]

6.1.2 Groundwater

Potential pressure on the Elbow River's water quality might also be coming from groundwater. Water flows between the Elbow River and its alluvial aquifer in the river's floodplain suggesting a direct connection between groundwater and surface water. The soils above the alluvial aquifer are also quite porous, allowing for recharge of the aquifer as well as inflow to the river. This relatively easy movement of water also provides for easy movement of contamination into the groundwater from the river and vice versa. The best example of this relationship is how residential development in Bragg Creek, a popular community that lies beside the river and over the alluvial aquifer, may be contributing to poor water quality. According to a University of Calgary study, the Hamlet of Bragg Creek contributed about 10 percent of the chloride in the downstream Elbow River.[207] Rural and urban residential development, private septic systems, and agricultural land uses over the alluvial aquifer may further pressure the Elbow's capacity to absorb more contaminants.[208]

6.1.3 Mapping watershed sensitivity

A recent pilot study by Alberta Environment (AENV) to map the Elbow River watershed's sensitivity to land development has the potential to limit land-use impacts to water quality and quantity. The study uses Geographic Information System (GIS) based analysis of the Elbow watershed on groundwater, surface water, and land as layers of information to be mapped across the watershed. The resulting maps identify areas that have high environmental and social value as well as areas that could be more sensitive to landscape change than others. AENV's pilot project is still in draft stage, and further work is still required to review the analysis, refine some of the datasets used, and consider some different or additional parameters that should be included. The results thus far, however, clearly illustrate vulnerable areas and help identify high priority areas to consider as land use expands in southern Alberta.

The GIS-based overlay analysis used digital data on features of groundwater, surface water, and land. Groundwater features included density of domestic groundwater wells, buffer area distances around wells, and groundwater vulnerability to contamination from the surface using surficial geology characteristics. Surface water features include upstream areas contributing to surface water intake (i.e., 20 kilometres upstream and 250 metres on either side of the watercourse), fish-bearing stream classification, and riparian area buffers. Land features included patches of native land cover (e.g., fescue grasses), parks and protected areas, slopes unsuitable for development, potential bird and animal species richness, and land suitability for production of spring-seeded small grain crops such as wheat.

The mapping shows moderate watershed sensitivity, values, and indicator ranking for all of the mapped features in the entire watershed with the exception of park area, which was rated as good. The mapping summary results indicate municipal buffer intake areas and riparian buffers as being elements of concern. In general, Figure B that highlights sensitivity for all land and water elements demonstrates the upper watershed has a higher value than does the middle and lower portions of the watershed. However, Figure A demonstrates there is a high sensitivity to land use where there is already land development. Corresponding with greater land use is greater groundwater and surface water use, where the map shows the importance (or reliance) on groundwater wells and surface water for water supply. Based on resource use, sensitivity of these areas, and relative intactness of the watershed areas, these maps highlight areas to either avoid or adopt more protective management practices in future land-use decision making. With the addition of important groundwater recharge areas and native fish populations and spawning areas, as well as inclusion of wetland inventory data, this type of analysis will be increasingly valuable.

6.2 Watershed health in southern Alberta

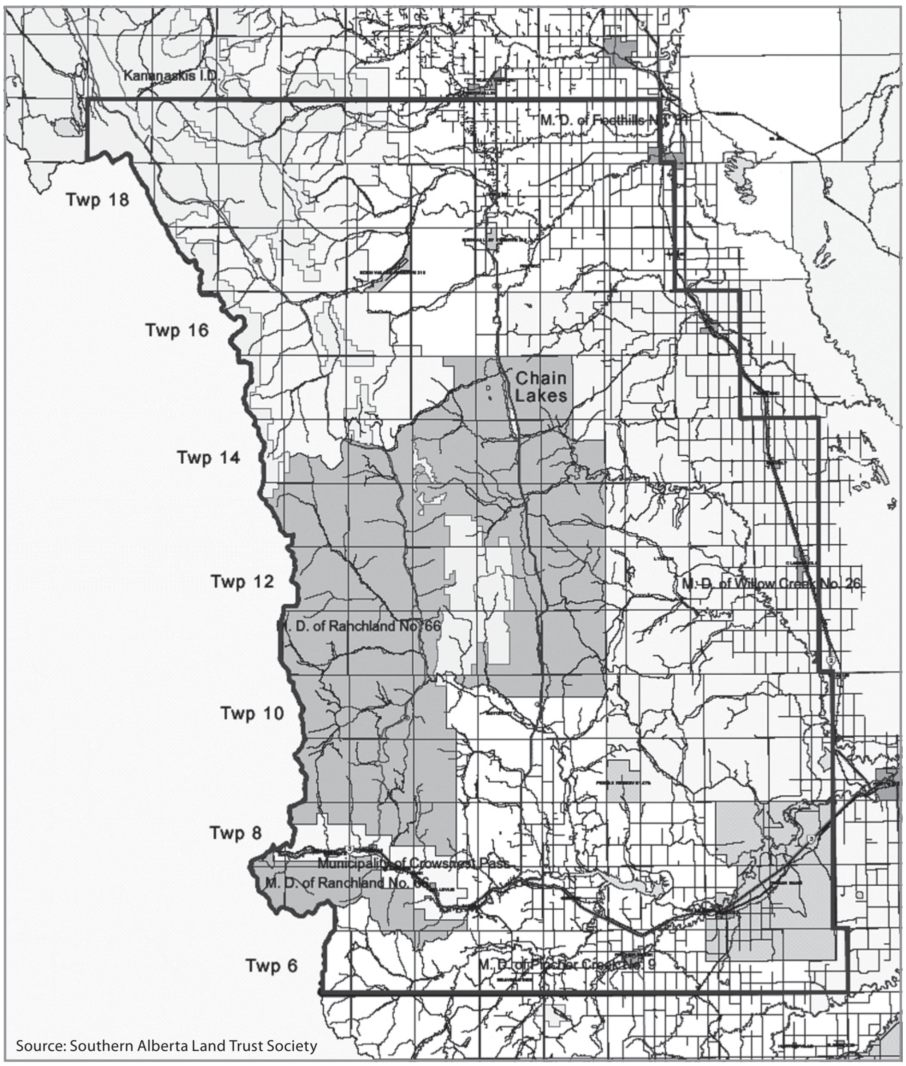
A study of Alberta's southern East Slopes and foothills, the site of multiple land uses for decades, proposes the use of land-based "thresholds" to manage cumulative effects.

Ranching, forestry, mining, oil and gas development, and more recently off-highway vehicle recreation have competed and cooperated for decades across the southern East Slopes of the Rocky Mountains and rolling foothills. A significant seat of wealth in Alberta, the region is not without the ecological damage that goes hand in hand with multiple activities occurring over the same landscape.

The *Southern Foothills Study* commissioned by Southern Alberta Land Trust Society analyzed the impacts of current land use as well as projected impacts of similar land-use trends over the next 50 years. This *Southern Foothills Study* projected that without any further limits on land use (called "business as usual" scenario) the human population of the study area would more than double, the number of cattle present on the landscape would increase by approximately 56 percent, the cut-block edge would increase from 2,500 to 6,500 kilometres, 300 to 500 kilometres of seismic lines would be added annually, and the number of wells on the landscape would increase by approximately 25 times—all in the next 50 years.

This "business as usual" scenario will lead to a slow but steady environmental degradation, including deteriorating water quality, reduced water quantity, loss of native fescue grassland, greater fragmentation, and degraded wildlife habitat.[209]

Building on the *Southern Foothills Study*, a study *Towards Acceptable Change: A Thresholds Approach to Manage Cumulative Effects of Land Use Change in the Southern Foothills of Alberta* recommends thresholds to set limits on the cumulative effects of land-use activities on the three ecosystem components: water, native fescue grassland, and grizzly bear habitat.[210] Thresholds help watershed



Source: Southern Alberta Land Trust Society managers set limits for the scale, timing, and amount of land-use activity on a landscape before lasting damage occurs.[211] The study identified threshold values for water quality, road density, stream crossings, total landscape disturbance, and riparian buffers.

To define thresholds, Holroyd first determined indicators. Ecological indicators included productive capacity of aquatic habitat, which can apply to species density or area of habitat, and riparian health and buffers.[212] Land-use indicators included forestry-equivalent clearcut area; exposure of rangelands soil; road densities in the watershed, at high elevations, on erodible soil, and in sensitive-fish areas; and stream crossings by linear disturbances (e.g., seismic lines, pipelines, roads, transmission lines).[213]

Water quality is the most constraining goal for land-use decision making in the southern foothills, according to Holroyd.[214] Water quality thresholds are important to manage water quality and quantity for local and downstream communities, even as far as Lake Winnipeg, as well as for aquatic ecosystem health. Holroyd proposed the following thresholds for water quality: The Canadian and Alberta Water Quality Guidelines should be met and perhaps exceeded throughout the study area; and the threshold for percent change in water quality from baseline measurements can be determined by stakeholders' willingness to trade off water quality for land use.

Because roads are the biggest contributor of sediment in waterways in the southern foothills, controlling road density is a key factor in protecting watershed health.[215] Holroyd recommends 0.9 kilometres or less of road km/km^2 to maintain a low risk for negative changes to peak flows and erosion and to protect fish populations.[216] However, to protect grizzly bear habitat, the threshold should be 0.6 km/km^2.[217] Road density should be lower at higher elevations, on erodible solids, less than 100 metres from a stream, or on unstable slopes. Based on one watershed assessment, almost 88 percent of watersheds in the southern foothills already have a high potential for erosion damage because of roads on erodible soils.[218]

Holroyd recommends a range between 0.24 and 0.5 km/km^2 of stream crossings by linear disturbances as a threshold, depending on the management objective (e.g., surface erosion hazard or fish spawning habitat).[219]The number of stream crossings by linear disturbances can be an indicator of soil erosion, water temperature change, fishing pressure, and barriers to fish movement.[220]

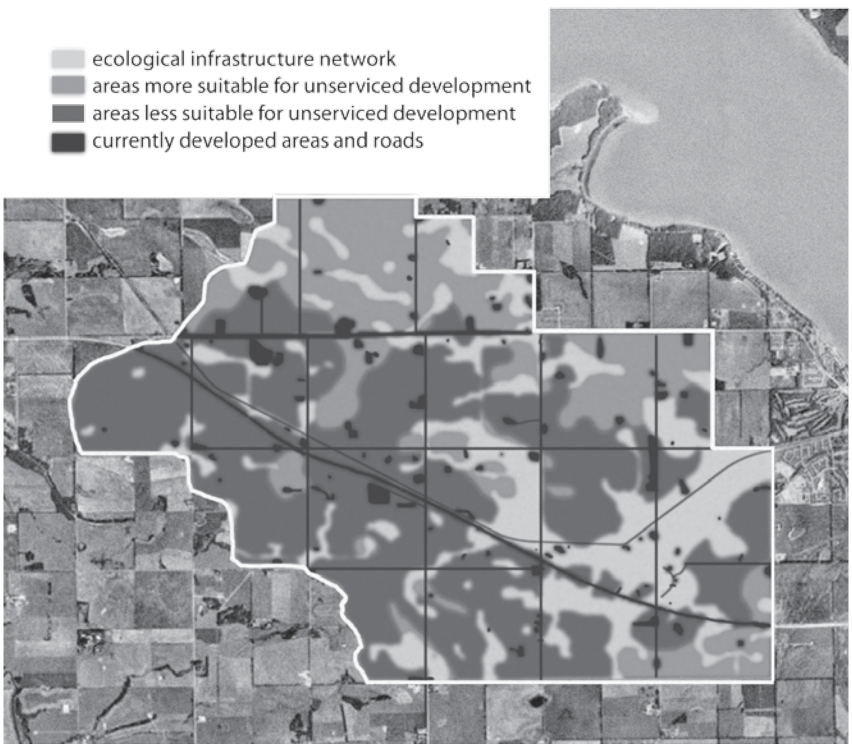
Holroyd recommends 20 to 30 percent total landscape disturbed as a threshold for the southern foothills. Total landscape disturbed is the total amount of land cleared of vegetation at any one time and includes agricultural cropland because vegetation is removed and soil disturbed on an annual basis.[221] The amount of vegetated land is an indicator for soil erosion, sedimentation, and peak stream flow.[222]

Recommendations for riparian buffers should reflect each site's unique characteristics and be set with the goal to protect wildlife habitat, species diversity, and water quality. Some suggested standards are minimum of 25 metre buffers to manage pollutant and nutrient runoff; 30 metres to regulate temperature and microclimate and sedimentation; 50 metres for bank stabilization; 100 metres for wildlife habitat; 200 metres for larger rivers; and 100 metres from high water mark for water bodies on native prairie landscape.[223] Roads should not be within 500 metres of streams and stream crossings for habitat protection of bull trout, a native fish at risk in southern Alberta. There should be less than five percent of bare ground or vegetation loss for good riparian health and functioning.[224]

6.3 Sylvan Lake watershed

Residential development, with careful analysis and planning, can be compatible with healthy functioning watersheds that provide ecological goods and services for water. A study of a 4,335.8 hectare rural residential and farming landscape in the Sylvan Lake watershed in central Alberta showed that that 23 percent or 997 hectares of the study site could support low-density residential development with individual water and wastewater systems while protecting the natural watershed functions of the site.[225] This percentage translates to 2,095 dwellings based on the density values in the Municipal Development Plan for Red Deer County at the time of the study.

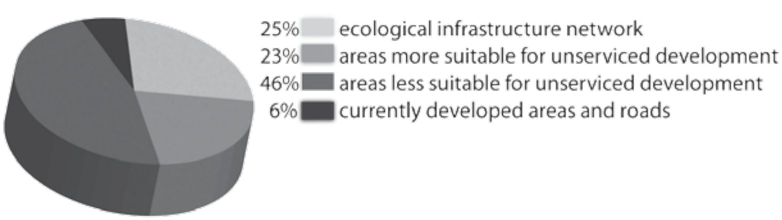
Spatial "fit" of spatial landscape patterns



Source: Carla Stevens

Identifying and planning around ecological infrastructure (the network of spatial interactions within a landscape that are responsible for the production of ecological goods and services such as water treatment) in municipal land use planning and infrastructure management can help reduce that cost. Ecological infrastructure was mapped in the Sylvan Lake watershed in Red Deer County focused on maintaining areas important for groundwater infiltration, as groundwater recharge is considered to be an important watershed function in this watershed.

Spatial distribution of landscape categories



Ecological infrastructure was determined to make up 1,071 hectares (25% of the study area). 985 hectares (23%) was determined to be suitable to support low density residential development without additional investment in water and wastewater services. 1971 hectares (46%) was determined to be less suitable for supporting low density development (i.e. some form of water and wastewater infrastructure would be required). The remaining 257 hectares (6%) was already developed.

CASE STUDY

Because Sylvan Lake relies almost entirely on groundwater for water inflow, land uses in the area can negatively affect groundwater quantity and quality and impair water quality for the area's residents and impair the general health of the lake and the aquatic life it supports. In the study, an ecological infrastructure approach was used to determine how a rural residential and farming landscape in transition to a more developed residential landscape could incorporate country residential development without negatively affecting groundwater and Sylvan Lake.[226]

Based on the analysis, the ecological infrastructure network accounted for 25 percent or 1,083.7 hectares of the study site. Ecological infrastructure is the natural features and their interactions that perform ecosystem services, such as flood regulation, or provide ecological goods, such as high quality water. Sustaining the ecological infrastructure is not only about maintaining the individual natural features, such as trees or a pond, on the landscape but maintaining the connections and interdependencies among these features, such as the process of water infiltrating through soil to become groundwater and in the process purification by microorganisms.

Because country residential development is low density and the cost of tying each home into a regional water services system (drinking water and wastewater) is prohibitive for the local municipality, these types of development usually have individual water supply (e.g., on-site groundwater wells) and wastewater treatment systems (e.g., septic systems). In the study, Stevens analyzed the landscape to determine what features of the landscape provided important water-related services; consequently, she could arrange where on the site, rural homes, groundwater wells, and septic systems would be most appropriate to minimize their effect on the ecological infrastructure network.

Using the ecological infrastructure of the landscape to provide goods and services such as clean water and wastewater assimilation minimizes the need for costly human infrastructure. However, if the intensity of this type of development is too much for the landscape to handle, it can fragment and impair the performance of the ecological infrastructure. For example, the soil can absorb and purify only so much wastewater. Therefore understanding the carrying capacity of a landscape or watershed and identifying the "critical threshold" at which point the amount or intensity of the land use becomes too much for ecological processes to function properly are critical for sustainable land-use planning.

Taking account of ecological infrastructure in land-use planning is one approach to minimizing land-use effects on water sources. This approach explicitly recognizes the value of the goods and services that watersheds provide. This study illustrates the potential to integrate both development and healthy ecological infrastructure of natural features and ecological functions.

7 Conclusion

Now more than ever, with the adoption of the Land-use Framework, there is the possibility for full consideration of the value of ecosystem goods and services from watersheds. This is real progress.

With respect to the current process of regional planning under the Land Use Framework, we make six recommendations for decision makers to protect the ecological goods and services offered by watersheds:

1. Adopt indicators that are specifically geared to watershed protection such as ability of land to resist erosion and ability of land for groundwater recharge as well as objectives such as goals for riparian health and wetlands. (Section 5.2)
2. Ensure that in every regional plan, decision makers adopt a threshold for the amount of land in a given watershed that remains in a natural state. This percentage of land is an excellent indicator of watershed health. (Section 5.2)
3. Ensure that in every regional plan, decision makers adopt a threshold for road density as it is an excellent indicator of watershed health.
4. Consider the adoption of a framework of source water protection at the macro-level with the regional planning process and then local adoption for more specific implementation by municipalities. (Section 5.3.1)
5. Adopt market-based instruments that are designed to help reach objectives set for watershed health.
6. Continue to aggressively promote an awareness and understanding of the value of watersheds to provide critical ecological goods and services.

With respect to the last recommendation, we cannot emphasize enough the importance of this awareness. The public process that led to the adoption of the Land Use Framework did an outstanding job to help Albertans understand how unsustainable land use affects social, economic, and environmental outcomes. Citizen engagement contributed to the larger discussion in Alberta's watershed community and promoted awareness of the importance and value of watersheds.

Because land use planning ultimately comes down to societal choices about how to best balance economic, social, and environmental outcomes, the process of deepening our understanding must continue. While the public ranks water high as an issue of concern, many still do not fully understand how unsustainable land development practices or intensity can affect watersheds and what watersheds offer. A lack of understanding can translate into land-use objectives that will not support the ability of a watershed to provide ecological goods and services.

Many expect a stewardship credit system will now allow for consideration of these values in the land-use planning processes in a way that has never occurred before. We encourage a continuation of the process of broadening awareness and understanding of the value of ecological goods and services because it will be central for support of the market-based system and a more general adoption of tools to protect watersheds.

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Formed in 2007, Water Matters champions watershed protection in Alberta. We take action on watershed protection for the public interest, raise public awareness, promote progressive politics and practices, and empower people to take action in their community.

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