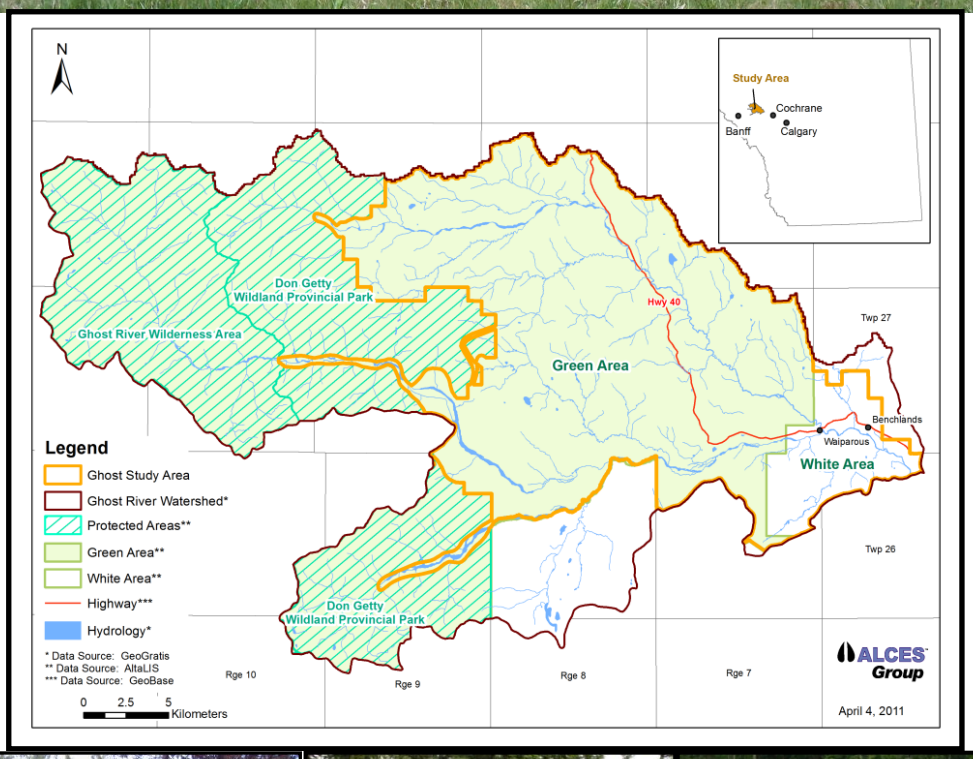
Ghost River Watershed Cumulative Effects Study

Phase 2: Beneficial Management Practices



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October, 2012

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The Ghost River Watershed Alliance Society's (GWAS) vision is to preserve and enhance the integrity of the ecosystem in the Ghost River Watershed. The GWAS seeks to identify ecosystem and environmental issues affecting the watershed of the Ghost-Waiparous, raise public awareness, and work towards resolving these issues.

This Phase 2 report examines the merits of Beneficial Management Practices (BMP) and was prepared under contract to GWAS by ALCES Landscape and Land-use Ltd. Ghost River Watershed Alliance Society gratefully acknowledges Alberta Ecotrust Foundation, Bow River Basin Council and the Calgary Foundation for their financial and non-financial support of this project.

Disclaimer

The information presented in this document was compiled and interpreted exclusively for the Ghost River Watershed Alliance Society by ALCES Landscape and Land-use Ltd. as an assessment of the cumulative impacts of land uses in the Ghost River watershed study area. ALCES Landscape and Land-use Ltd. has exercised reasonable skill, care, and diligence to assess the information acquired during the preparation of this report, but makes no guarantees or warranties as to the accuracy or completeness of this information. The information contained in this report is based upon, and limited by, the circumstances and conditions acknowledged herein, and upon information available at the time of its preparation. The information provided by others is believed to be accurate but cannot be guaranteed. ALCES Landscape and Land-use does not accept any responsibility for the use of this report for any purpose other than the assessment of cumulative land uses in the Ghost River Watershed study area and does not accept responsibility to any third party for the use in whole or in part of the contents of this report. Any alternative use, including that by a third party, or any reliance on, or decisions based on this document, is the responsibility of the alternative user or third party.

Specific analytical or methodological questions concerning this report can be directed to the ALCES Group at www.alces.ca.

A narrated powerpoint presentation describing the key findings of this project is available as a youtube video and can be viewed at: http://www.youtube.com/watch?v=x7ZTpwavwoY. If this link becomes inactive, please contact GWAS or the ALCES Group for a new active link.

EXECUTIVE SUMMARY

The watershed of the Ghost River lies in the upstream shadow of the burgeoning metropolis of Calgary and its surrounding bedroom communities. The Ghost River watershed possesses an exceptional abundance of natural resources, including forests, grasslands, rivers, diverse flora and fauna, and majestic scenery. It also hosts an abundance of consumptive natural resources including wood fiber, livestock forage, hydrocarbons, and wildlife and fish. During recent decades, a rapid increase in intensity of several landuses has occurred, as forestry, livestock grazing, oil and gas extraction, rural residential, hunting, and non-motorized and motorized recreation have all grown to satisfy increasing regional demand.

The historical management paradigm of the Government of Alberta for the East Slopes is best described as "multiple use". This strategy reflects the belief that multiple overlapping land uses can co-occur without meaningfully compromising the performance of key ecological, social, and economic indicators. Increasingly, quantitative and subjective assessments by the scientific community and the public have shown that the laissez-faire nature of the government's "multiple use" formula is no longer serving society well. In 2011, a Phase 1 report examining the cumulative effects of "business-as-usual" land uses within the Ghost River watershed identified a number of challenges to maintaining acceptable performance levels of ecological, industrial, and recreation indicators. Projections using the ALCES landscape simulator (www.alces.ca) quantified past and potential future declines in water quality, recreation potential, fish and wildlife indicators, and problems with sustainable forestry. The Phase I report can be downloaded from http://www.ghostwatershed.ca/GWAS/Home.html.

The Ghost River Watershed Alliance Society received funding from the Alberta Ecotrust Foundation and the Calgary Foundation to explore and assess beneficial management practices (BMP) that have the potential to improve performance of indicators relative to the business-as-usual (BAU) practices explored in Phase 1. Through a series of four independently facilitated workshops, the GWAS sought to engage local and regional communities, recreationalists, and government representatives in exploring potential solutions to enhance sustainable land stewardship for the watershed. Information obtained from these workshops was augmented with data obtained from other relevant projects examining the interface between BMP and ecological goods and services in Alberta's east slopes.

Based on guidance obtained from BMP workshops and other studies (Southern Foothills Study, Upper Bow Basin Cumulative Effects Study, South Saskatchewan Regional Plan), the following issues and BMP were explored for the Ghost River Study:

Issue: High level of landscape fragmentation
BMP: -Accelerated rates of reclamation of linear features such as seismic lines, minor roads, inblock forestry roads, and non-designated off-highway vehicle trails

Issue: High levels of vehicle accessibility

BMP: -Restriction of off-highway vehicle (OHV) activity to an engineered and designated OHV trail system that minimizes adverse effects on erosion and wildlife and provides safe and enjoyable OHV activity.
-Enforcement increased to minimize off-highway vehicle use on non-designated trails and contain use to a designated vehicle trail network

Issue: High Level of Watershed Discontinuity
BMP: Increased replacement of "washed out" or "hung" stream culverts

Issue: Loss of Riparian Habitat, Forest Structure, Wood Security
BMP: -Reduction of current annual allowable forestry harvest commensurate with increased in-block retention of trees, and increased buffers along watercourses and ephemeral streams

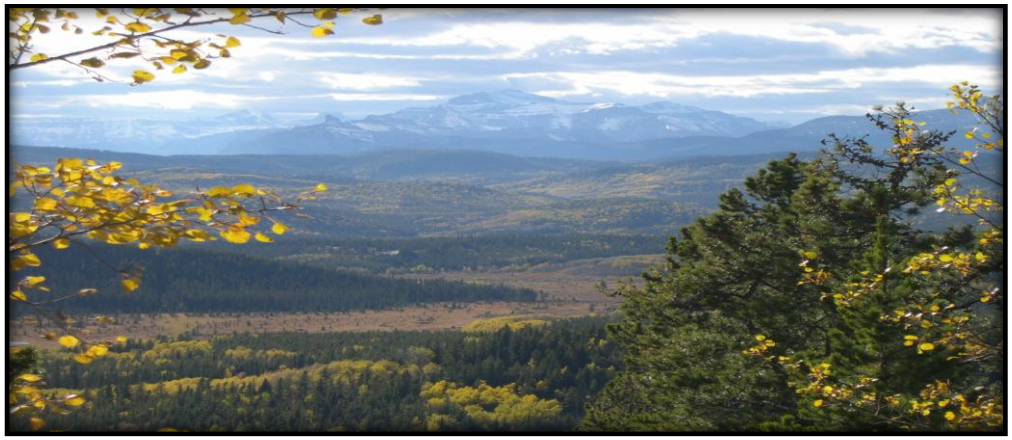
Issue: Reduced Water Quality from Elevated Nutrient Runoff
BMP: -Increased protective buffers along streams found within cutblocks and in croplands
-Restrictions of livestock from streams through off-stream watering and salting
-Accelerated reclamation of unvegetated trails that are not part of the designated trail network

Issue: Reduced Water Quality caused by human waste
BMP: -Provision of sanitation facilities at trail heads and designated campsites
Installment of advanced septic field technologies at rural residential sites

Relative to the "business-as-usual" simulations, the simulated adoption of beneficial management practices in the Ghost River Watershed improved all ecological indicators. Landscape level improvements in ecological indicators included a decrease in Grizzly Bear Mortality index, an increase in the Index of Native Fish Integrity, an improvement in water quality, an increase in recreation potential of the watershed, and a level of forest harvest that is more likely to be sustainable.

The results of this study highlight the significant opportunities to government agencies, land use sectors, and various recreational groups, to minimize loss of ecological goods and services and improve the sustainability of the Ghost River Watershed. Justification for adopting these practices are equally defensible from social, economic, and ecological perspectives. This work by the Ghost River Watershed Alliance Society is intended to catalyze a new conversation about sustainable management of the Ghost River watershed based on full cost accounting of a comprehensive list of performance indicators. The take-home message of this project is decidedly pro-landuse, but one in which land-use decisions functionally "optimize" (not maximize) a full suite of socio-economic and ecological indicators.

Although this Phase II report is written with the intent that it is a stand-alone document, stakeholders are encouraged to read the Phase I report as it contains additional information relating to the business-as-usual scenario.



In the summer of 1859, the Palliser Expedition was exploring southwest Alberta on horseback.

Dr. James Hector said to Peter Erasmus, a Metis hunter and guide on the Palliser Expedition
"You must prepare yourself and your associates to adjust to a new order in this country. The progress of civilization renders this inevitable."

Captain John Palliser adds,
"Your work with our expedition is but a phase of things to come. All the great territory now sparsely populated by a few wandering tribes will someday be the homes of thousands of prosperous people engaged in agricultural pursuit, stock raising, and other industries that always follows the settlement of vacant lands."

Extracted from **Buffalo Days and Nights**.
Peter Erasmus, as told by Henry Thompson.
Copyright 1999. Glenbow Institute.

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2. ACKNOWLEDGEMENTS

The Ghost River Watershed Study (Phases 1 and 2) can best be defined as "citizen science" in the truest sense of the term. As defined by Wikipedia, citizen science is "*performed by individuals, teams, or networks of volunteers. Citizen scientists often partner with professional scientists to achieve common goals".*

There exists a broad understanding by citizens who reside, recreate, and work in the Ghost River Watershed that this basin is undergoing a profound and troubling transformation. These degrading changes are not the result of an intentional objective by governing bodies, but rather the inevitable outcome of an outdated management paradigm that no longer serves citizens well on a landscape that has become so busy with overlapping land uses.

The citizens of the Ghost River Watershed are requesting a new management approach from municipal and provincial government that is systems-based, integrative in nature, and founded on ecological principles. The new management approach being advocated for this region is not a conservation strategy, per se, but rather a pro-business ideology that requires planners and land use sectors to demonstrate sustained, high performance across a meaningful range of social, economic, and ecological indicators. Inherent to this management philosophy is the recognition that the Ghost River Watershed is finite in both size, and in ability to sustainably produce a broad range of commodities (water, wood fiber, wildlife habitat, livestock, forage crops, recreation, and hydrocarbons).

The catalyst and foundation of this study was the Ghost River Watershed Alliance Society (GWAS). Broadly supported by their Board, and lead by Heinz Unger and Marina Krainer, this organization initiated an important discussion in 2010 about sustainable land use in this key watershed west of Calgary. A project of this nature required technical expertise in the use and interpretation of land use simulation models. This was performed by the ALCES Landscape and Land Use Ltd. team. Simulation models are only as good as the information that is placed within them. In addition, the scenarios these models explore need to be guided by a diverse stakeholder community who understand that "what-if" models are not used to "predict" the future but rather to learn about the likely outcomes of plausible and contrasting scenarios. The workshops that were sponsored by the GWAS for this project were critical to achieving these perspectives and all citizens and land use representatives who participated in these important discussions are thanked for their contributions.

Following the completion of the first draft, the project managers chose to distribute the report for critical review to several experts in the fields of hydrology (Dr. Bill Donahue), fisheries science (Lorne Fitch, Dr. Michael Sullivan), forestry (Tim Barker), and wildlife (Dr. Steve Hererro). The quality of the report was significantly improved by their thoughtful and constructive comments.

Most of all, the project organizers would like to acknowledge the government, for they perform a critical role in defining the policies and practices that will ultimately shape the socio-economic and environmental performance of this landscape. Alberta is at a cross-roads in terms of the principles that are chosen to define our regional management plans. The nascent Alberta Land Use Framework, properly structured and deployed, can lead to balanced land use plans that serve future generations as well as they do for people today. Our civil servants play a key role in meeting the diverse expectations of Alberta's citizens. This report, a reflection of the learnings of the watershed's citizens, is intended as a catalyst for an overdue conversation between governments and the people who live, recreate, and work in the Ghost River Watershed.

3. THE BIOPHYSICAL STAGE

The Ghost River Watershed and Study Area (Figure 1) is located upstream of Calgary, Alberta and within the larger Bow River basin. This Ghost Study Area, ~52,948 ha in size, spans significant elevational variation that includes the natural subregions of alpine (>2300 m a.s.l.), subalpine (1,600-2,300 m a.s.l.), montane. (1,300-1,600 m a.s.l.), and foothills (<1300 m a.s.l.). Rugged mountains, steep sided ravines and flat valley bottoms characterize this landscape. Dominant overstory tree species include white spruce (*Picea glauca*), lodgepole pine (*Pinus contorta*), Engelmann Spruce (*Picea engelmanii*), subalpine fir (*Abies lasiocarpa*), and trembling aspen (*Populus tremuloides*). Tree species composition changes markedly based on elevation, relief, and soil properties.

The climate is characterized by long cold winters and short cool summers (Janz and Storr 1977). Average annual precipitation varies greatly with elevation, from <500 mm along the foothills and montane , to ~800 mm in the subalpine and alpine zones (McKay et al. 1963). The coldest month is January and July is the warmest. Warm winter winds (Chinooks), created by dry Pacific air masses, frequently remove all or significant amounts of snowpack during winter months.

Wildfires have been a dominant natural process shaping the composition, structure, and age class of plant communities in this region since the retreat of glacial ice sheets several thousand years ago. The heterogeneity in plant communities created by fire contributed to equally diverse floral and faunal communities. During the past century, fire suppression has reduced the frequency and extent of wildfires, and this has lead to a forest biome that is older than those found in pre-Columbian times.

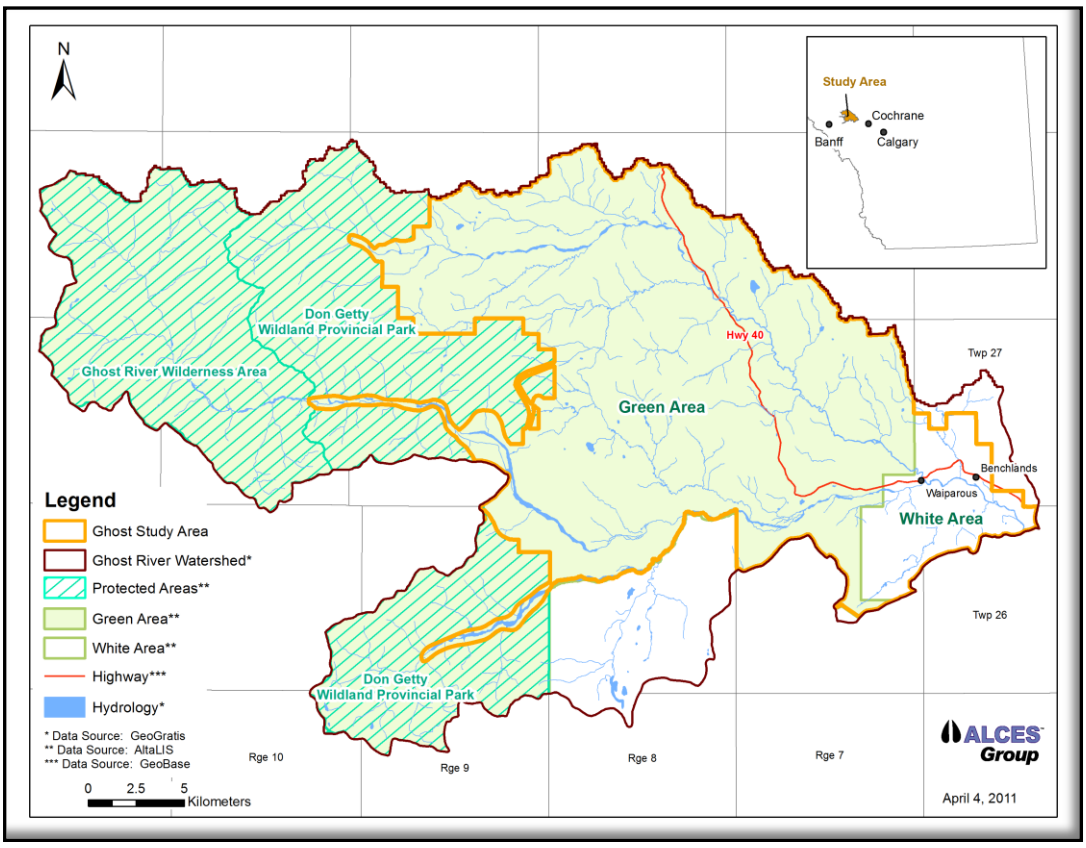


Figure 1. Ghost River watershed. Study area outlined in orange.

4. BACKGROUND AND PRINCIPLES

The Ghost River Watershed Alliance Society (GWAS) secured funding from Alberta Ecotrust and the Calgary Foundation to assess beneficial land management practices in the Ghost River Watershed. These management practices were explored to help ensure sustainable land uses within the area while maintaining the natural features and processes that local residents, regional populations, and recreationalists have always enjoyed.

The GWAS wished to explore modelling scenarios that would help develop sustainable land use strategies, and would also engage industry, government, recreationalists, and the local and regional community in the discussion of land use within the watershed.

A series of facilitated public meetings conducted by the GWAS were designed to engage this discussion and had a set of underlying principles that guided the process:

- **Inclusiveness** – It was important that stakeholders were given the opportunity to express their views and to be heard in a timely manner to meet the project deadline of June 2012. Stakeholders included the people who lived in the area, resource extraction companies, government, recreationalists, and other interested parties.
- **Openness** – All results of the study, as well as the process, were available to the public. There would be no hidden results or reports. Personal privacy would be subject to the Freedom of Information and Protection of Privacy Act.
- **Clarity** – Information was presented in as simple and clear a manner as possible to make it understandable to the lay person, though some of the information and planning issues were complex.
- **Effectiveness** – The study sought to identify specific objectives through local action and public knowledge in order to achieve results. It was not sufficient to simply review the challenges and create another report for future consideration.
- **Timeliness** – Significant development is planned for the study area, driven by economic and population pressures. The process therefore needed to move quickly to address issues before further development unfolded.
- **Flexibility** – Planning is a dynamic process, and while the ALCES Group and GWAS organized the process as carefully as possible, it was important to be open to adjustments that could address unforeseen circumstances.
- **Optimism** – It was important to recognize the opportunity to not only prevent damage, but to actually improve the watershed. Change is inevitable, but all stakeholders were challenged to examine ways their actions could improve the visual, ecological, productive and cultural aspects of this special place.

4.1 COMMUNITY OUTREACH PROCESS

The workshops were a key undertaking to identifying visions, attitudes, and solution sets held by a diverse stakeholder community. Each workshop was centered on the theme "The Future of the Ghost River Watershed: Exploring Solutions". Participants were invited to host their own discussion topics on issues, challenges or opportunities when it came to the future of the Ghost River Watershed. The workshop facilitators were responsible for recording electronic notes from workshop participants. A document was produced which contained the unedited discussion comments captured and written by forum participants. (See Appendix E; available as a separate document).

An invitation was sent to a wide range of potential participants, personal contacts and was advertised in local newspapers (See following page).

Information and ideas from the workshops were assessed by the ALCES modelling team and where possible used to develop a series of beneficial management practices (BMP) for evaluation in this Phase II BMP project. The ALCES model was modified in structure to accommodate the specific land use BMP levers, and parameterized with the best available information to explore their consequences. Specific technical questions on model function and its simulation of BMP can be directed to Dr. Brad Stelfox at bstelfox@alces.ca.

The underlying philosophy of this community outreach process was to provide an environment that welcomed all perspectives and all users of the Ghost River Watershed. The central belief was that the best opportunity for positive change in the Ghost River Watershed would occur if all users were invited to engage in respectful dialogue about the challenges and opportunities facing the region.

Workshops were advertised by personalized emails sent to representatives of many groups, organizations, businesses, government, and individuals (Table 1). Where phone numbers were known, GWAS members made personal phone calls.

Workshops were advertised in three local newspapers (Cochrane Eagle, Cochrane Times, and Rocky Mountain Outlook) in order to extend the invitation to the broader public. The Cochrane Eagle wrote an article on the workshops before the May 11th and 12th sessions. Flyers were put up on local notice boards and at local businesses. A sign was posted beside the road for the Open House event.

Several follow-up emails and phone calls were completed. GWAS also contacted the National Off Highway Vehicle Conservation Council (NOHVCC) asking whom to contact, and how to get OHV groups involved.

BACKGROUND

Many of us share the common goal of maintaining the Ghost River Watershed well into the future.

In 2011, a study was done of the cumulative impacts of current land uses in the Ghost River Watershed. Projecting current and proposed uses fifty years into the future, this Cumulative Effects study showed that water quality, recreational resources, along with fish and wildlife habitat, would decline if current and proposed land uses continue. This study can be viewed at www.ghostwatershed.ca.

It is important that we come together to create a sustainable future for this landscape. Through open dialogue and frank discussion, we are capable of solutions we haven't yet imagined. The wisdom and expertise to resolve the challenges of the Ghost River Watershed reside within us.

OUR GHOST RIVER WATERSHED FORUMS
Our upcoming series of workshops will begin the process of effective dialogue on the challenges and opportunities facing the Ghost River Watershed. We invite everyone interested in the Ghost River Watershed to bring their best thinking on the theme of the day, which is:

"The Future of the Ghost River Watershed: Exploring Solutions"

We will utilize an outside facilitator and an "open space" process for large group collaboration. The open space method will enable us to set an agenda which incorporates the topics most important to each of us on this theme.

In advance of the forum, please consider questions such as these:

- What makes the Ghost-Waiparous area special to you? What might ensure these special characteristics remain for our children to enjoy?
- How might we maximize benefits and minimize liabilities of the area's land uses?
- What might lead to increased opportunities for all users of this multiple use area?
- How might we improve water quality, recreational opportunity and resources, along with fish and wildlife habitat in the Ghost?

Please bring your passion for the Ghost River Watershed, your vision for its future, and your personal commitment to learning and contributing. We look forward to discovering solutions together at these upcoming sessions.

Yours truly,

Marina Krainer
Executive Director
on behalf of the Board of Directors of Ghost River Watershed Alliance Society

Dates and Locations:

Saturday, April 28	9:00 am – 1:00 pm	Cochrane Toyota Community Room
Friday, May 4	5:30 pm – 10:00 pm	Beaupre Community Hall
Friday, May 11	2:00 pm – 6:00 pm	Calgary Water Centre, Bow River Room
Saturday, May 12	9:00 am – 1:00 pm	Ghost River Fire Hall Open House

You may attend one or more sessions.
The Forums are **limited to 40 people per event**.
Please register by e-mail at office@ghostwatershed.ca
noting the session(s) you would like to attend.
Refreshments provided."

Table 1. List of invitees to BMP Workshops (not all invitees were able to attend the workshops).

Businesses:
- Cochrane Mountain Toys
- Cochrane Bow Ridge Sports
- Outdoor equipment stores
- The Crossing
- Capture the Flag Paint Ball
- Brewster's Adventures
- Lazy H Trail Company
- Saddle Peak Trail Rides

Industry:
- Spray Lake Sawmills
- Direct Energy

Local, Provincial and Federal Govt:
- Town of Cochrane
- City of Calgary
- Sustainable Resource Development
- Land-use Secretariat
- Tourism, Parks and Recreation
- Alberta Environment & Water
- County of Rocky View
- MD Bighorn Council & Staff
- MLA Banff-Cochrane
- Department of Fisheries and Oceans

NGOs and local groups:
- Ghost Hikers Group
- Morley Native Community
- Local developers
- Enviros Camp
- King's Fold Retreat
- Local residents and Ranchers
- Community of Benchlands
- Waiparous Village
- Alberta Equestrian Federation
- Friends of the Eastern Slopes
- Cochrane Environmental Action Committee (CEAC)
- Cochrane Camera Club
- Canadian Parks and Wilderness Society (CPAWS)
- Yellowstone to Yukon (Y2Y)
- Alberta Wilderness Association (AWA)
- Elbow River Watershed Partnership (ERWP)
- Trout Unlimited
- Cows & Fish
- GWAS Members
- Calgary Area Outdoor Council (CAOC)
- Biosphere Institute of the Bow Valley
- BRBC and its members
- Calgary Regional Partnership
- Action for Agriculture
- Water Matters
- Alberta Conservation Association
- Ducks Unlimited
- Miistakis Institute, University of Calgary
- Ghost Stewardship Monitoring Group
- ATV tours providers
- ATV safety course providers
- Quad, motorbike and 4x4 club representatives
- Alpine Club of Canada
- Calgary Hiking

Individuals:
- Motorized recreational users whom GWAS members knew personally
- Non-motorized recreational users whom GWAS members know personally

2.2 FORUM AND OPEN HOUSE PROCESS

Numerous planning discussions were conducted between January and April, 2011 (Figure 2), from which emerged the goal of ensuring the public sessions honoured and reflected the guiding principles of section 2.0: inclusiveness, openness, clarity, effectiveness, timeliness, flexibility and optimism.

These guiding principles were first used while choosing a theme. The theme had to be easy to understand, and welcoming to all viewpoints and users. The planning group chose "The Future of the Ghost River Watershed: Exploring Solutions" in an effort to attract all users who cared about the Ghost River Watershed and were interested in exploring possible future scenarios.

The design of the forums followed the structure of Open Space Technology in order to invite and validate all perspectives. This enabled any participant to help create the agenda for each forum based on the overall theme. In the forums, there was some overlap in participants and agenda topics, though each discussion session was unique. Discussion notes were taken by the participants.

Four forums were scheduled to run through late April and early May, 2011. One discussion in the first forum asked about attracting more motorized users to the forums. That led to a decision to sponsor an open house format on a day and location aimed at making it easy for motorized users to attend.

Figure 2. Discussion by participants at Beaupre Community Hall Workshop, 4 May 2012

SUMMARY OF THEMES

A wide cross-section of users was invited and the forums were open to anyone who cared about the future of the Ghost River Watershed. Based on their responses, concern for the Ghost River Watershed was a common attribute of all participants. Some of the themes that emerged from the conversations were:

Ecosystem Awareness, Planning and Management

There was consensus among the participants that more needs to be done to increase awareness of the Ghost River Watershed: as a source of drinking water for Calgary, as a wildland recreational place close to a thriving city, as a gem of beauty, and as a home for wildlife. Another outcome was that greater effort should be put into future planning to balance the many different and often competing demands of the natural resources of the Ghost River Watershed.

Sustainability and stewardship of the Ghost River Watershed emerged as a topic of conversation many times. This included suggestions to:

- Compile a baseline database of ecosystem services and landuses relevant to the watershed
- Ensure that ecosystem-based management plans are developed, monitored, and enforced.
- Join forces with aligned groups, like those working on the Ghost Reservoir Stewardship Plan
- Promote greater public awareness of the Ghost River Watershed and its challenges
- Encourage more people to participate in nature-based recreation

Lack of Government Leadership

The public perceives a confusing message from the Provincial Government, where words and actions do not match. There are policies and legislation that seek sustainable development, yet there is virtually no enforcement of the existing legislation and supporting regulations. Furthermore, there is limited funding for maintenance of existing infrastructure, facilities, and designated trails. These contradictory actions from government contribute to conflict among different land use groups.

OHV Use

Issues about off-highway vehicle (OHV) use often arose in workshop conversations. With the growth of Calgary and OHV sales, there is increasing pressure and demand on the Ghost's watershed for motorized recreation. It was the general view of workshop participants that OHV use and non-motorized use in close proximity is not compatible in the watershed. The current OHV trail system within the Ghost River Watershed is inadequate, which may be why some OHV use has been irresponsible and unsustainable in terms of its impact on the regional ecosystem. For the most part, OHV users chose not to attend these workshops. A special "open house", designed and held in the Benchlands area in order to provide easy access for OHV users to attend, was attended by only one OHV user.

Balance of Diverse Interests

The Ghost River Watershed area is enjoyed in many ways by many people. Participants appreciated the opportunity to exchange perspectives and ideas about how to make the Ghost River Watershed sustainable into the future. There was a desire to be inclusive of all users, no matter whether conflict currently existed. There was a sense that respectful dialogue among all users would lead to effective and sustainable approaches.

A summary of information and feedback from the meeting is available in Appendix E (separate document).

5. CONTEXT FOR BENEFICIAL MANAGEMENT PRACTICES

In comparison to the Phase 1 (BAU) land use study, the Phase II (BMP) project actively sought to improve the performance of indicators through the adoption of a modified set of land use practices and recreational activities. It is recognized by the project advisors that the set of BMP examined in this study are not the only land management levers that should be considered for improving the sustainability of the Ghost River Watershed. They are, however, intended to reflect a thorough collection of improved practices that reveal insight to stakeholders about the likely changes to indicator performance that could occur.

The indicators used in the Phase II BMP project were the same as used in the Phase I study (Figure 3).

Figure 3. Performance indicators used in the Ghost River Watershed Land Use Study.

These indicators were selected to help stakeholders answer the following question:

Can the Ghost-Waiparous landscape sustainably support ecological services, as well as aesthetic, recreational, agricultural and industrial demands for the future needs of our children and grandchildren?

More specifically, stakeholders wanted to know whether the adoption of BMP would affect the outcome to the following questions:

- Will the landscape continue to provide clean water for downstream users?
- Will there be healthy natural areas providing high quality wildlife habitat?
- Will the landscape satisfy motorized and non-motorized recreationalists seeking high quality non-urban experiences?
- Will natural resource extraction, such as forest harvest, remain sustainable?

The ALCES© simulation model[1] was used to quantify the "range of natural variation" (RNV) for water, wildlife, and forest indicators in the Ghost River watershed. The RNV simulation period, which is absent of all land use, infrastructure, and recreational activities, provides stakeholders a reference point against which to compare indicator performance under a suite of different land use trajectories and practices.

ALCES© was then used to assess indicator trends from 1900 to present day ("backcasting"), as well as "forecasting" future (next 50 years) changes using conservative estimates of land-use development under both business-as-usual (BAU) and beneficial management practices (BMP) scenarios. Among other benefits, the backcasting exercise allows the modeller and the stakeholders to better understand the pace of historical landscape change, and to uses these "observed" changes as context when exploring future changes. Backcasting and forecasting[2] results for both BAU and BMP were compared to the simulated range of natural variability to assess areas of concern and opportunity.

An analysis of recreation activity levels and some economic metrics were also completed. All findings presented in this report are from ALCES© model simulations, except where noted.

6. SELECTION OF BENEFICIAL MANAGEMENT PRACTICES

The conversation of BMP was based on the initial findings of the Phase 1 report: An assessment of the cumulative effects of land used within the Ghost River Watershed, Alberta, Canada.[3] This report clearly indicated the magnitude of reduction in performance of several key ecological indicators. The purpose of BMP is to demonstrate that land uses can be conducted in a way that improves the performance of key social, ecological or economic indicators. It is important that BMP be considered realistic in terms of cost, engineering, social acceptance, and regulatory practices. Equally, BMP should challenge current dogmas and encourage stakeholders to explore alternative management practices. It is equally important that the land use and landscape simulation model, in this case ALCES©, be structured to explore and contrast BAU with BMP. While it is understood that current

"business-as-usual" practices are actually the BMP of past decades (for land uses practices are forever evolving), it is important to explore the benefits of future BMP by contrasting them with current practices. This contrast provides stakeholders with a clear understanding of the required urgency to accelerate the pace of adoption of BMP to improve performance of key indicators.

The final selection of the BMP explored in Phase II were informed by several sources of information and past projects, including:

1. Feedback of facilitated BMP workshops for the Ghost River Watershed.
2. Discussions with Ghost River Watershed Alliance Society.
3. Review of Government Policy and Legislation; Alberta Land Use Framework.[4]
4. Southern Foothills Study.[5]
5. Upper Bow Basin Cumulative Effects Study.[6]
6. BMP discussed by multi-stakeholders within the South Saskatchewan River Regional Plan of the Alberta Land Use Management Framework[7].

Selection of Ghost River Watershed BMP that met cost and engineering constraints was addressed by referencing the BMP phase of the Southern Foothills Study[8]. During this study, experts in each land use sector participated in sectoral workshops to constrain BMP selection to those that are currently available to industry and can be deployed in a cost-effective manner. Furthermore, BMP adopted by this study are consistent in nature and detail with those being actively explored by the Alberta Land Use Framework in the South Saskatchewan Regional Plan.

A summary of BMP adopted in Phase II are provided in Table 2. With the exception of BMP, all other land use and natural disturbance regimes assumptions were identical between Phase I (BAU) and Phase II (BMP).

Table 2. Summary of BMP assumptions adopted in Phase II.

Activity	Key BMP Levers and Assumed Benefits
Cattle Grazing	25% reduction in nitrogen and phosphorus loading from grass rangelands, and 15% reduction in nitrogen and phosphorus loading from forest rangelands by reducing nutrient input to streams by strategic riparian fencing, off-stream salting, hard crossings, sensitive timing issues (spring), no overwinter feeding along streams. Reducing rangeland nutrient runoff by improving range structure through optimal grazing strategies (winter grazing of fescue, rotational grazing, greater dependency on perennial grasses for forage).
Cropland	Although croplands are currently small in area in the Ghost River Watershed, some small pastures and forage crops do exist and as such the cropland sector should be included in discussions of BMP. 50% reduction in nitrogen and phosphorus loading to streams by proper timing and application rates (based on phosphorus rather than nitrogen); better riparian management (perennial crops along all waterways); no till crops; improved crop rotations; stopping expansion of croplands into native prairie, wetlands, and improved pasture; emphasis on perennial crops rather than annual crops.
Forestry	**Cutblock Structure**: By adopting a suite of BMP that include improved riparian management on cutblocks (maintaining wider buffers along mainstem rivers and creeks and not logging ephemeral streams), by avoiding steep slopes and through increased retention of green trees on cutblocks, the following improvements will occur: 15% reduction in nitrogen and phosphorus loading, and 50% reduction in sediment loading to streams. **In-block Forestry Roads**: Reducing regeneration lag of inblock roads; managing access on forestry roads; installing bridges rather than culverts. **25% reduction in Annual Allowable Cut:** Achievement of cutblock structure (patches of green trees) and expansion of riparian buffer strips would require a reduction in AAC of approximately 25%.
Rural Residential	75% reduction in nitrogen, phosphorus, and sediment loading by improved septic technology; riparian management (maintaining buffers); cluster development.
Energy	**Oil and Gas:** 25% reduction in sediment runoff by riparian management (buffers); reduce regeneration lag of wellsite access roads; installing bridges rather than culverts. **Wells/Pad**: increasing number of hydrocarbon wells per pad. Immediate reclamation of wellpads and access roads following abandonment.

Activity	Key BMP Levers and Assumed Benefits
Recreation (general)	**Sanitation:** Relative to base case, a 15% reduction in nitrogen and phosphorus loading to surface water from recreationalists by providing toilet and sanitation facilities. **Garbage**: Relative to base case, a 15% reduction in nitrogen and phosphorus loading to surface water from campsite (designated or random) by providing waste receptacles.
Motorized Recreation	**OHV Access**: not allowing off-highway vehicles in waterways (streams, ponds, wetlands), and creating off-highway vehicle recreational trail networks that avoid streams and riparian crossings. **Engineering**: A properly engineered and constructed OHV trail network would be constructed. Location of the network would consider topography, slope and aspect and its design would minimize surface runoff of water and rutting. All stream crossings in this network would be bridged. In this study area, a modest increase in the length of the designated trail network would be completed (189 kilometers to 250 km). **Access Management**: Restricting motorized use to designated trails. 90% reduction in use of non-designated trails (enforcement). **Enforcement**: Effective and consistent manpower and funding to ensure that the motorized OHV community restrict their activities to the designated OHV trail network.
Reclamation	**Pulse reclamation** of 90 percent of seismic lines; reduces phosphorous, sediment and nitrogen loading to levels of adjacent land cover types; **Pulse reclamation** of 50% of minor roads reduces phosphorous, sediment and nitrogen loading to levels of adjacent land cover types. **Low Impact Avoidance Seismic Lines** (**<2 meter in width)** leads to immediate reclamation, in contrast with 2 meter width seismic lines which have 10 year lifespan, or seismic lines >2 meters in width have lifespans of 20 years' **Minor roads** leading to wellsites have a restricted lifespan of 20 years.
Culverts	**Replace 15% of existing hung culverts** each year. In addition, temporary or permanent bridges are adopted by the forest and energy sector where possible to replace culverts.

7. ANALYSIS: LOOKING BACK - THINKING FORWARD

Before it is possible to understand the potential value of BMP, it is important to understand the changes to the landscape of the Ghost River Watershed by both historical and the current suite of landuses. By examining changes to the landscape caused by land use footprints, and how these footprint influence ecological indicators, it becomes possible to focus discussion on those specific land use practices that can be improved. These practices are what this project refers to as Beneficial Management Practices (BMP).

7.1 LINEAR FEATURES

Human-caused linear features are an important and defining landscape driver for performance of many biodiversity indicators.[9] This is due to the direct and indirect disturbances caused by humans, animals, and plants that move along, or expand from, linear networks. In some cases, linear features can improve habitat for species such as moose and grizzly bear, by providing access to preferred younger plant communities and increased forage. These positive effects, however, can be overwhelmed by increased direct and indirect mortality from motorists, hunters, fishermen, trappers, and animal predators. Vehicle-wildlife collisions, intentional and unintentional disturbance or harassment, harvest, poaching, avoidance of habitat along linear features, increased erosion, and changes in predator-prey dynamics all contribute to the cumulative effects that define the interface between linear features and performance of wildlife indicators. [10]

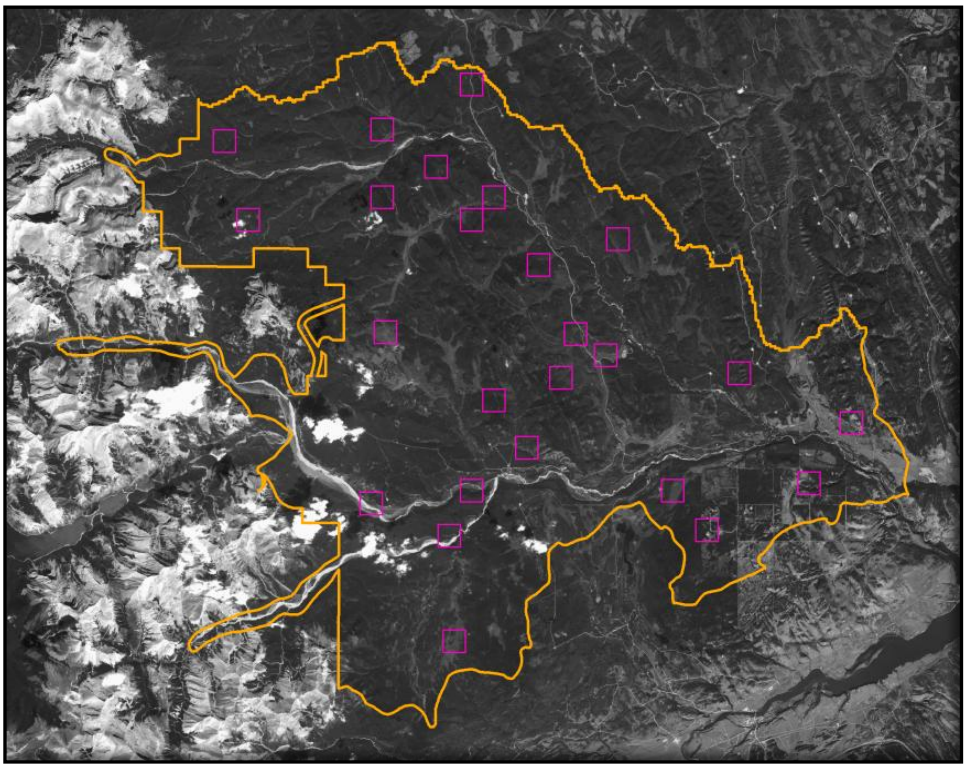
An accurate assessment of linear features is essential to understanding the impacts of land uses and recreational activities. Field assessments by the authors found many existing linear features were not readily visible on GIS satellite imagery, and were not part of the digitized database being used by the Government of Alberta in assessments of edge density (Figure 3). Field assessment of linear features by Alberta Forestry, Parks and Fish and Wildlife staff in 1997 identified approximately 2,000 km of trails in the Ghost area compared to 189 kilometres of officially designated trails.[11] Spray Lake Sawmills' detailed forest management plan assessed linear densities in the study area ranging from approximately 3.0 to 4.0 km/km^2.[12]

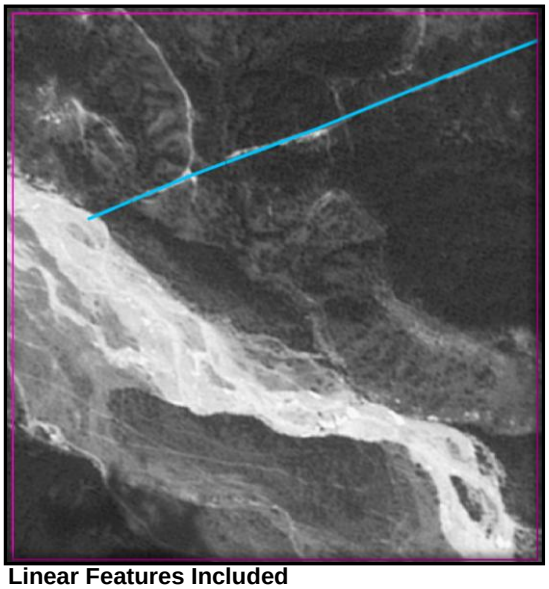
Analyses by the Alberta Biodiversity Monitoring Institute (www.abmi.ca) indicated that 0% of current habitat in the Foothills natural region remains as core native habitat when applying a 2 km buffer width from anthropogenic developments. Practically, this means that no functional habitat remains for those species or ecological processes that are meaningfully compromised within 2 km of anthropogenic features. When a 50 m buffer was applied to all linear features, 54% of the Foothills natural region is classified as core native habitat.[13] The rapid loss of core habitat in this region during the past several decades is a key concern to maintaining species and ecological processes that are adversely affected by linear features.

Figure 4. Example of an OHV trail not identified in the original "linear feature" data set.

To better estimate actual linear feature density, we randomly distributed 25 one km^2 polygons over the study area (Figure 4, top) and had a GIS analyst manually digitize all visible linear features within each polygon (Figure 5, bottom left and right).[14] This dataset allowed for the construction of a linear feature correction coefficient which was applied across the full study area.

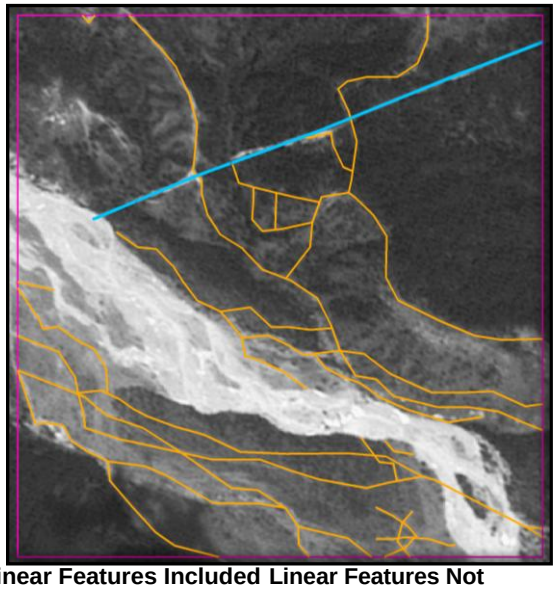
The analysis showed that the area and length of linear features have been under-estimated by the Government of Alberta by ~72% in the Ghost River Watershed. For the study area, the original Government of Alberta data set indicated an average linear density of 1.42 km/km^2, whereas the corrected dataset suggested a linear density of 5.12 km/km^2. [15]





Linear Features Included in Original Dataset

Seismic Line



Linear Features Included in Original Dataset

Seismic Line

Linear Features Not Included in Original Dataset

OHV Trail

Figure 5. Location of 1 km^2 samples to quantify actual linear feature density in the Ghost River Watershed (upper). Lower images reveal differences between initial dataset values (left) and actual linear features (right).

Under the business-as-usual scenario, linear feature density is projected to increase from current levels of ~5 km/km^2 to ~10 km/km^2 during the next five decades. To assist readers in visualizing these levels of linear edge density, two 1 km^2 squares displaying these densities are shown (Figure 5). At an edge density of 10 km/km^2, any given location is, on average, no greater than 50 m from an anthropogenic feature such as a road, pipeline, recreational trail, well pad, cutblock, or seismic line.

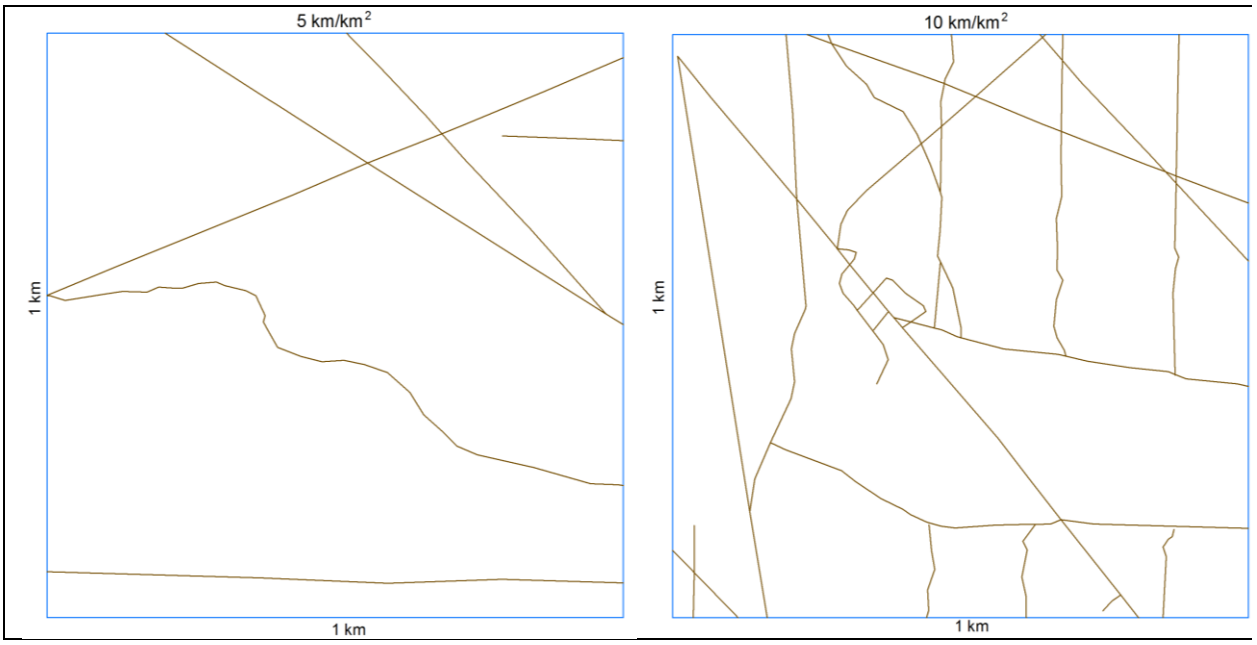


Figure 6. Examples maps indicating differences between 5 and 10 km/km^2 of linear features.

Assuming a single pulse reclamation event of 90 percent of seismic lines and 50 percent of minor roads in conjunction with reclamation-enabled access management, there is an immediate reduction in linear edge density within the study area from approximately 5 km/km^2 to under 2 km/km^2 (Figure 7). These BMP "pulse" practices would require the physical roll-back of obstruction materials (earth, trees) on relevant roads and seismic lines such that motorized recreational activity would cease to use these linear features. With implementation of a reduced forest harvest volume of 25% there is an additional reduction in the density of linear features (Figure 6). In the pulse event shown below, the reclamation effort occurs as one pulse event occurring "today" (2012). Obviously, this is not the only, or most expedient, approach. For comparison, an incremental approach to adoption of BMP (5 pulses occurring at decadal intervals) is included.

Even following a full deployment of BMP, and its initial steep decline in edge density (from 6 to 2 km/km^2), these features would subsequently increases to ~3.8 km/km^2 into the future as the future rate of linear feature construction exceeds the rate at which linear features are reclaimed. The key point is that deployment of BMP results in a net reduction of ~6 km/km^2 of man-made edge and hence a significant improvement in performance of those species and ecological processes that are sensitive to edge. Given the adverse effects of linear features on

numerous environmental indicators, the projected reduction in linear features caused by BMP should have significant positive effects within the Ghost River Watershed.

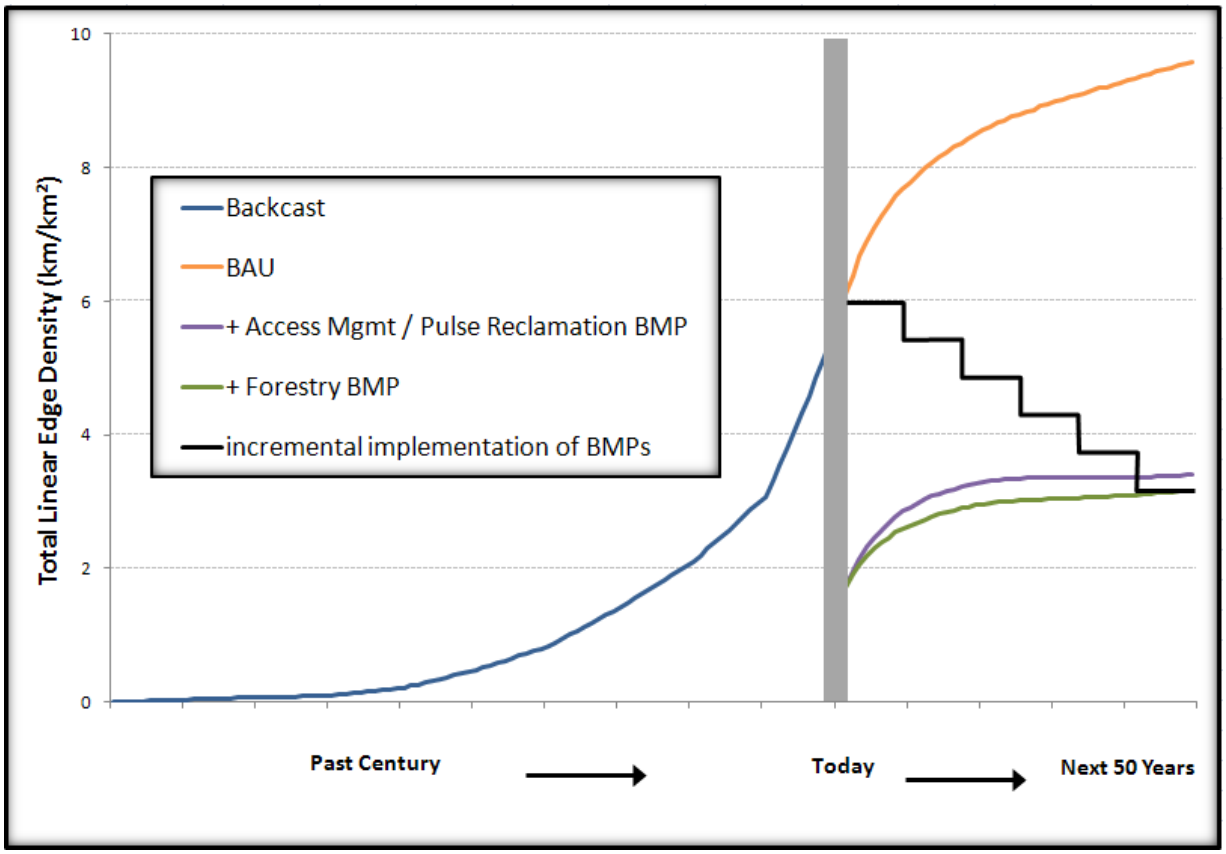


Figure 7. Changes in linear edge density attributed to BMP as compared to BAU (orange line). The immediate reduction in edge density at Time 0 (today) reflects the full and immediate adoption of each of the BMP levers. In contrast, the black line reflects projected changes in edge density if BMP were implemented at 20% adoption levels for each of 5 successive decades.

7.2 WATER QUALITY

Livestock, equestrian, and vehicle crossings or activity in wetlands and streams (Figures 7, 8) can contribute to significant increases in sediment loading and pollution into standing and moving water.[16,17,18,19,20,21] Livestock grazing has the potential to negatively impact riparian health and decrease water quality by causing stream bank erosion, vegetative cover loss and increased loading of nutrients and pathogens into waterways.[22,23,24] Pathogens that are deposited in water bodies will attach to fine sediments and settle to the bottom. These pathogens are mobilized and can move downstream during flood events or if the sediment is disturbed by vehicles, people, or animals travelling in or across the water body.[25]

Riparian regions often support comparatively high levels of biodiversity, biomass, and higher frequencies of seeps and springs.[26] Although overland sediment transport and bed load sediment movement are natural components of foothill stream basins, the additive sediment load contributed by roads, trails and de-vegetated streambanks can significantly increase total sediment load and impact both water quality and stream ecosystem processes.[27,28]

The Cows and Fish Program (www.cowsandfish.org) of the Alberta Riparian Habitat Management Society has made significant contributions in Alberta to the dialogue between ranchers and wetland managers about grazing practices that minimize adverse effects or help restore riparian systems. A thorough review of these practices are available at their website.

Figure 8. Livestock grazing within riparian habitat.

Figure 9. Motorized vehicle crossing of wetland causing loss of vegetation cover and increased potential for sediment movement (Ghost study area).

A water quality study of Waiparous Creek, Fallentimber Creek, and Ghost River, prepared for Alberta Environment in 2006, found sediment loading of Waiparous Creek and the Ghost River was much greater than would be expected in rivers draining similarly forested environments in the upper foothills of southern Alberta.[29] Sediment loading in Waiparous Creek was up to ten times higher in areas downstream of OHV use than in upstream areas without OHV use (Figure 9).[30] Off-road vehicle activity was identified as the factor causing increased erosion and sediment loading into waterways, thereby reducing water quality.[31] Increases in nutrients, bacteria and certain metals (aluminum, iron) are often associated with high sediment loads.[32]

Numerous multiple-use trails in the study area, used predominately by OHVs, cross directly through streams, rivers and wetlands (Figure 10,11). While suspended sediments in rivers do tend to increase naturally as one travels downstream from headwaters[33], anthropogenic travel corridors also contribute large sources of sediment and pollution to water bodies.[34] This is because, during and after rainfall and snowmelt events, sediment is transported directly from trails into watercourses.[35] Increases in erosion and water quality issues due to off-highway vehicles are the most conspicuous and consistently observed impacts by researchers examining OHV use.[36,37,38]

Figure 10. (Upper) Photographs demonstrating water turbidity in Waiparous Creek upstream of significant landuses (forestry, inblock roads, OHV activity, grazing, campgrounds and recreational facilities) - (Lower) Image showing water turbidity in Waiparous Creek downstream of landuses. Both images taken on 29 May 2011, two days after a significant spring storm event.

Figure 11. Example of an un-vegetated motorized trail at Waiparous Creek that would contribute sediment during rainfall events.

Figure 12. Meadow and wetland damage by OHV use, Meadow Creek, Critical Wildlife Zone Ghost Study area.[39]

There is extensive use by OHVs of "closed" trails within the study area (Figure 12).[40] During field assessments, 93% of linear features and trails examined showed recent OHV use.[41] Similar use of closed OHV trails was documented in recent studies of the Castle Forest Land Use Zone in southern Alberta[42] and in the Bighorn Wildland Park[43]. The chronic disturbance of non-designated trails and seismic lines by OHVs impairs the natural revegetation of many linear features in these regions.

Figure 13. Non-designated OHV trail (seismic line) showing lack of vegetation due to vehicle use.

Natural disturbances (such as fire and avalanches) and human land uses (including forestry, agriculture, energy development and transportation) that permanently or temporarily remove vegetative ground cover can also contribute to loss of soil and increased sediment loading to streams and rivers.[44,45,46,47] As described above, periodic sediment movement into surface water is a natural phenomenon.[48] The concern, however, is that the additive effects of the various land uses (cutblocks, inblock roads, access roads to cutblocks, camping, livestock grazing and un-vegetated OHV trails) can significantly increase the cumulative amount of sediment loading beyond that expected from natural processes (Figure 9).

A recent riparian health assessment of the Waiparous Creek watershed states that, "... most riparian areas within the Waiparous Creek watershed appear to be in proper functioning

(healthy) condition." However, "Degraded water quality may also indicate that land uses in the Waiparous Basin may be overtaxing the buffering ability of riparian areas, even those in a healthy condition. If the health and condition of adjacent uplands is degraded, erosion and loss of upland vegetation cover (e.g. logging) can overwhelm the ability of riparian areas to absorb and filter sediment from overland runoff."[49]

The majority of sediment movement arising from land use footprints and natural processes occurs during and immediately following major precipitation or snow melt events.[50],[51] Figure 13 illustrates an example of sediment movement associated with clear-cut logging in the study area during a precipitation event.

Figure 14. Sediment erosion from inblock roads, Meadow Creek area cutblock, Ghost River Study area, 27 May 2011.

The total contribution of sediment loading to rivers from each land use sector within the study area is variable. Under the BAU scenario, greatest contributions are from the transportation sector (major roads, minor roads), multi-use recreation trails, and forestry cutblock roads (Figure 14).

Significant reductions in potential sediment runoff occurred when BMP were deployed, with the most noticeable reduction occurring for transportation, OHV trails and forestry BMP (Figure 14). The greatest reductions in potential sediment runoff was associated with Off-Highway recreational trails as a result of reclamation of non-designated trails and seismic lines, with motorized use being largely confined to the expanded designated trail system.

Landscape specific run-off coefficients for sediment, nitrogen and phosphorus used for this analysis were based on information developed for southern foothill Alberta landscapes.[52]

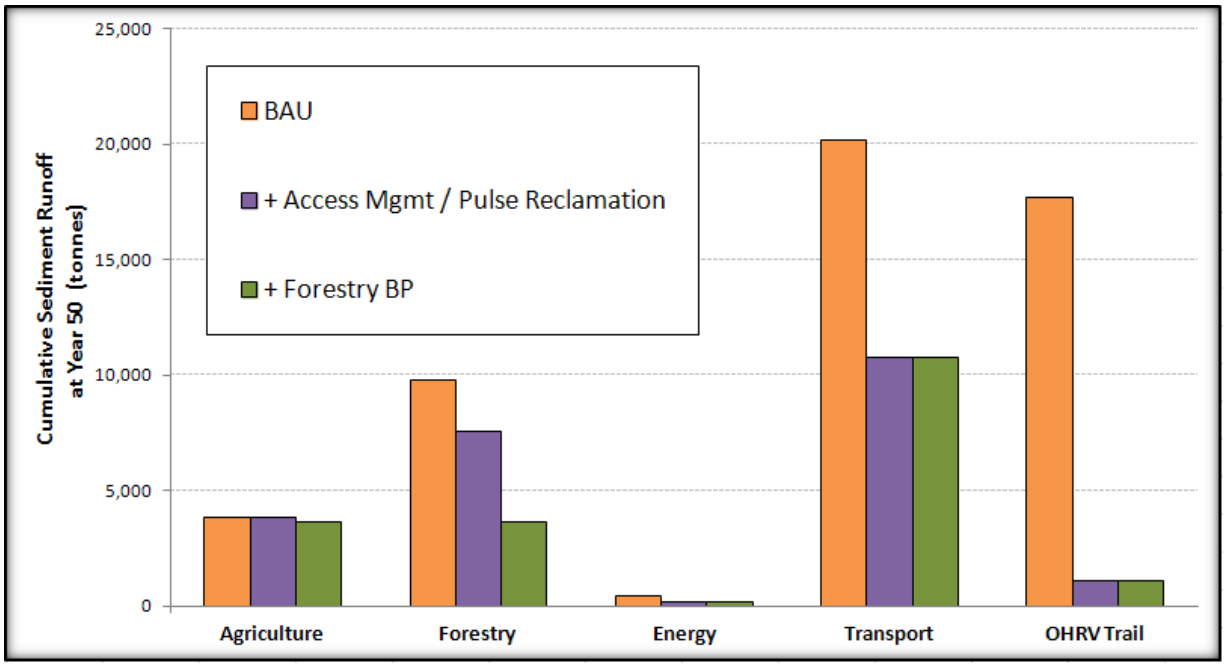


Figure 15. Improvement in relative sectoral contribution of sediment runoff with adoption of BMP in comparison to BAU.

Agricultural activity in the study area is primarily associated with livestock, with cattle and horses grazing on private lands and forestry grazing allotments. Grazing allotments issued by the Alberta government have been in existence within the Forest Reserve portion of the study area for more than 50 years.[53] Livestock grazing has the potential to decrease water quality by causing stream bank erosion, and to increase nutrient loading into waterways from manure.[54,55]Forest harvest cutblocks and associated transportation features are also sources of increased sediment and nutrient loading.[56,57] Significant parts of the study area are projected to be harvested over the next 50 years. For the purposes of this study, equal areas of logging occurred each year, although logging is more likely to be episodic during the next 50 years.

Under the BAU scenario, increases in sediment, phosphorus and nitrogen loading are projected to occur, leading to further declines of relative water quality within the watershed (Figure 15). A moderate, though significant, improvement in water quality was projected to occur with the implementation of BMP as illustrated in Figure 15. The index of relative water quality suggests that combined sediment, nitrogen and phosphorus loading may be four times greater in 50 years than levels occurring during the RNV period. As described in greater detail in Appendix C, the water quality index reflects the relative change (increase or decrease) in landscape loading of nitrogen, phosphorus and sediment associated with changes in landscape types, forest age class structure, prevalence of anthropogenic features,

and density of people and livestock. It is important to note that an increase in landscape loading does not necessarily translate to a linear increase in nutrient loading into surface water. Despite this caveat, however, it is generally understood that landscapes that have higher nutrient loading potential also have higher levels of nutrients entering surface water. In contrast to the BAU scenario, watershed simulations suggest that there will be an immediate improvement in water quality with the application of BMP, and water quality could remain above today's conditions in 50 years.

For a detailed description of relative water quality index, as modelled in this study, see Appendix C.

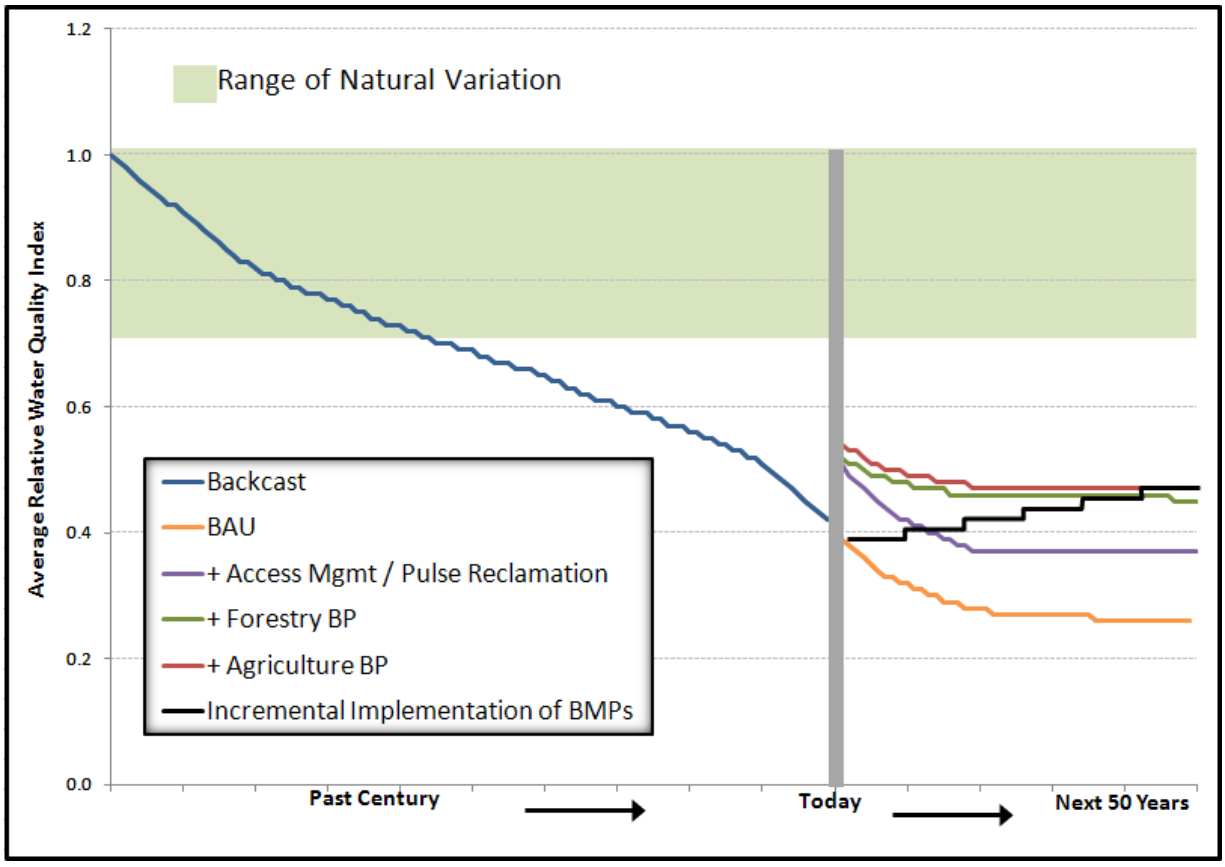


Figure 16. Changes in relative river water quality index attributed to BMP as compared to BAU. The immediate increase in performance of water quality at Time 0 (today) reflects the full and immediate adoption of each of the BMP levers. In contrast, the black line reflects projected changes in water quality if BMP were implemented at 20% adoption levels for each of 5 successive decades. The BMP lines reflect the additive effects of the previous BMP (for example, the Forestry BP line reflects the effects of forestry and the previous effects of access management).

7.3 NATIVE FISH

Within the 510 km^2 study area of the Ghost River Watershed, there currently exists ~800 km of streams and rivers and ~2,900 km of roads, seismic lines, inblock forestry roads and recreational trails. It is not surprising, therefore, that there are an abundance of crossing between linear features of landuse and the surface water and wetlands of the watershed.

To reduce damage to streams, and to minimize sediment flow into watercourses, culverts are often installed for vehicle crossings. However, culverts can fragment aquatic ecosystems because of their tendency to become "hung" during flood events. A hung culvert occurs when the downstream end of a culvert hangs above the downstream water level as a result of scouring of the stream bed caused by high volumes of water exiting the culvert during snowmelt or storm runoff (Figure 16).[58] These hung culverts create barriers to the upstream movement of fish and hence create a discontinuity to watershed function.

Figure 17. An example of hung culverts that prevent upstream fish movement. Waiparous Creek area, May 2011.

Hanging culverts that fragment fish habitat can compromise population viability and distribution by acting as one-way valves that permit downstream movement but preventing upstream movement, thereby isolating populations, and potentially decreasing access of fish to spawning and rearing areas.[59,60,61]

An assessment of trout abundance and distribution in the Waiparous Creek drainage showed non-native brook trout outnumbered native cutthroat and bull trout. Depending on the stream section sampled, brook trout outnumbered bull trout by a ratio of 15-33:1. Cutthroat trout were outnumbered by brook trout by a ratio of 7-14:1.[62]

Native fish species such as westslope cutthroat trout are considered an indicator species for watershed quality.[6364] As noted by Jackson (2008) "... it is likely that catchments subject to higher densities of landscape disturbances by land use (i.e. clear-cuts, roads/OHV trail and stream-crossings) will be associated with lower westslope cutthroat densities and factors of condition."[65] There are a variety of physical and biological changes in fish habitat quality associated with natural and anthropogenic disturbance of riparian zones and surrounding watersheds.[66,67] For example, removal of riparian forest cover can reduce available fish habitat by increasing water temperatures[68] and UV radiation exposure[69], and decrease invertebrate food abundance for fish.[70] Increased sediment releases into fish bearing watercourses from catchment disturbance also can have detrimental effects on spawning areas and food production for cutthroat and bull trout.[71] Elevated levels of sediment deposition to streams and rivers can lead to a "hardening" of watercourse substrate and interfere with fish lifecycle requirements such as spawning and production of invertebrate foods important to salmonids.[72,73]

A cumulative effects analysis of the Carbondale River watershed in southwest Alberta found that watersheds with higher clear-cut densities were generally associated with lower westslope cutthroat trout relative abundance, biomass density and average relative weight.[74] The abundance of bull trout in the Kakwa River watershed of northwest Alberta was negatively related to the percentage of fine sediment substrate and sub-basin forest harvest. Local elimination of bull trout from 24% to 43% of stream reaches was predicted as a result of forest harvesting.[75] Mayhood (2009) notes "Roads are the principal source of fine sediments to streams in forestry operations, typically being much greater than that from all other land management activities combined"[76] and "even small increases in fine sediment loading to spawning areas can cause dramatic losses of early life-history stages of salmonids."[77]

As noted in the Annual Operating Plan of Spray Lakes Sawmill, "The primary strategy of maintenance and protection of aquatic environment and fish habitat values is to maintain treed buffers along watercourses and water bodies and adopt rigorous watercourse crossing and erosion control measures."[78]

An assessment of forestry related disturbance in south-eastern B.C. found that logging of non-fish bearing perennial and ephemeral streams is a major limiting factor to the conservation of cutthroat trout.[79] Ephemeral (intermittent) streams greatly outnumber the larger streams into which they flow in both area and edge, and seldom receive protection from logging activities when encountered within cutblocks. The logging of ephemeral streams was observed on cutblocks in the Meadow Creek area during May 2011, as illustrated in Figure 17.

Risk to extirpation of bull trout in the Ghost River Watershed has been rated as "high".[80] In a presentation to Alberta's Endangered Species Conservation Committee, December 2010, Dr. Michael Sullivan stated, "A few bull trout (populations) in our protected areas (e.g., Banff, Jasper, parts of Kananaskis Country) are recovering, but areas with continued habitat degradation and development pressure show continued declines and lack of recovery. Our failure to recover bull trout is clear evidence of the link between the cumulative effects of land use and fish population health."[81]

A study of foothill streams in the Wapiti River watershed near Grande Prairie, Alberta showed that once-healthy bull trout and arctic grayling populations were lost when disturbance (cutblocks, agriculture, roads, etc.) exceeded 20% to 30% of the watershed area. A major cause of these fish losses appeared to be increased run-off of phosphorus, resulting in algae blooms and serious declines in stream oxygen levels. In the most developed watersheds, oxygen levels during winter were so low that no fish or other aquatic life could survive (Norris 2012).

The BMP scenario assumed that bridges would be constructed where streams are intersected by major roads, major forestry haul roads and OHV trails. Culverts would be installed for stream crossings by minor roads, inblock roads, and wellsite access roads.[82]

Past cumulative effects of recreation, agricultural, forestry, transportation and industrial activity have resulted in decreased relative water quality, watercourse fragmentation, streambank erosion and increased fish catch and over-harvest due to high human access levels. Ongoing development and activity under BAU assumptions will likely lead to a further decline in native fish habitat and populations (Figure 18). However, Figure 18 demonstrates that BMP may have a significant positive effect on the index of native fish integrity, with positive effects identified with culvert replacement, access management and forestry beneficial practices.

Figure 18. Logging of ephemeral streams, Meadow Creek cutblocks, Ghost River study area, 27 May 2011.

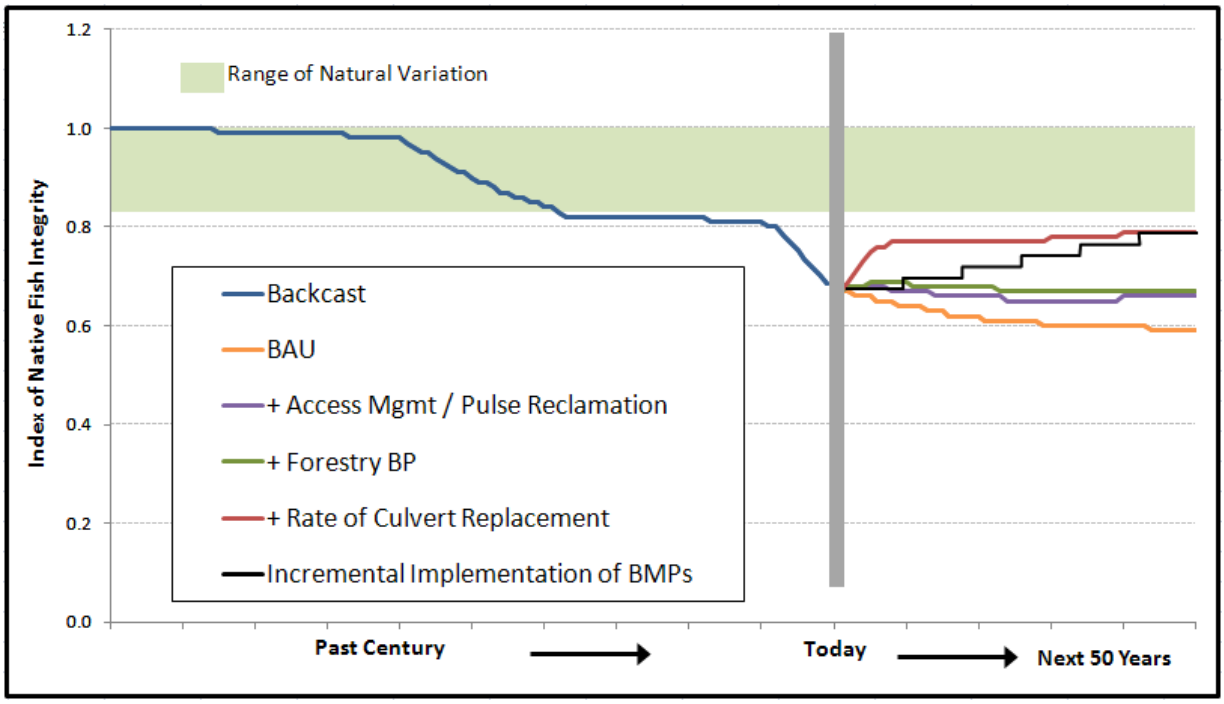


Figure 19. Projected changes in Index of Native Fish Integrity (INFI) attributed to BMP as compared to BAU. The immediate increase in performance of INFI at Time 0 (today) reflects the full adoption of each of the BMP levers. In contrast, the black line reflects projected changes in INFI if BMP practices were implemented at 20% adoption levels for each of 5 successive decades.

A high native fish integrity index (INFI) value for the Ghost River watershed (i.e., 0.8 to 1.0) indicates a relatively undisturbed native fish community comprised of sensitive fish species, rare fish, top predators and long-lived individuals. Fish species commonly occurring at high index values in this ecozone include bull trout, cutthroat trout, and rocky mountain whitefish. Most people would interpret this fish community condition as one that provides "good fishing".[83] Additionally, cutthroat trout in this watershed are listed as "threatened" by the COSEWIC. The Allowable Harm Assessment for this species requires that human access and sport fishing pressure to these streams be kept very low, otherwise sport fishing for all fish species may be closed as a necessary conservation measure (Sullivan 2007).

The estimated current INFI value (~0.68) indicates that the health of the native fish community is below what would be expected under natural conditions. BAU simulations predict a further decrease to below 0.60 in 50 years. This future index level suggests native fish populations will be mostly self sustaining, but with threats of serious declines in abundance and diversity possible.[84] Angling experiences for native fish species will remain sub-optimal or potentially closed.

The deployment of a combination of beneficial management practices has the potential to improve the diversity and abundance of the fish community and to provide better fishing opportunities for native fish species.

7.4 GRIZZLY BEAR

Grizzly bear numbers are relatively low in regions outside mountains, foothills parks and protected areas because they are likely to be killed near roads, trails, residences, and facilities.[85,86,87] The current high density of linear features (5 km/km^2)[88] being used by motorized recreationalists exceeds the maximum management target of 1.2 km/km^2 recommended by the Alberta Grizzly Bear Recovery Plan.[89] Foothill and mountain ecosystems with high linear feature densities, as currently found in the study area, may be avoided by grizzly bears, resulting in a potential net loss of habitat[90,91,92] and in potential negative impacts on populations. It is also possible that elevated mortality rates of grizzly bears moving into the Ghost River Watershed may contribute as a population sink factor to nearby protected populations. A population sink is a region within a population's range where mortality is generally high and reproduction is generally low. Although individuals may be found in the sink, its area does not contribute to maintenance of the population and may even contribute to its reduction.

There are many features of the Ghost-Waiparous region that limits its potential capacity to maintain grizzly bear populations, including high densities and motorized use of linear features, forestry clearcuts, poor management of attractant foods by random campers[93], and lack of food storage and garbage facilities (Figure 19).[94] Recent research in Alberta suggests that although bears may find more food in clearcuts, the associated high level of human access leads to unsustainable levels of mortality.[95]

Figure 20. An example of bagged attractant organic garbage left behind at a random campsite not provided with government removal services, 2 August 2010.

Under BAU assumptions of future land use, the index of grizzly bear mortality is expected to increase in the future (Figure 20). The mortality index in the area is currently twice what would be expected under natural conditions. Simulation modelling indicates the mortality index will rise to approximately five times natural rates as forestry and recreational developments increase human access throughout the study area (Figure 20). Such potentially high mortality rates suggest that maintaining viable populations of grizzly bear within the study area will be challenging.

The beneficial management practices assessed in this project demonstrate a significant opportunity to reduce the Grizzly bear mortality index relative to BAU. However, even with full deployment of BMP, the mortality risk index is expected to increase from current levels, as linear edge densities and access increase due to ongoing land use development.

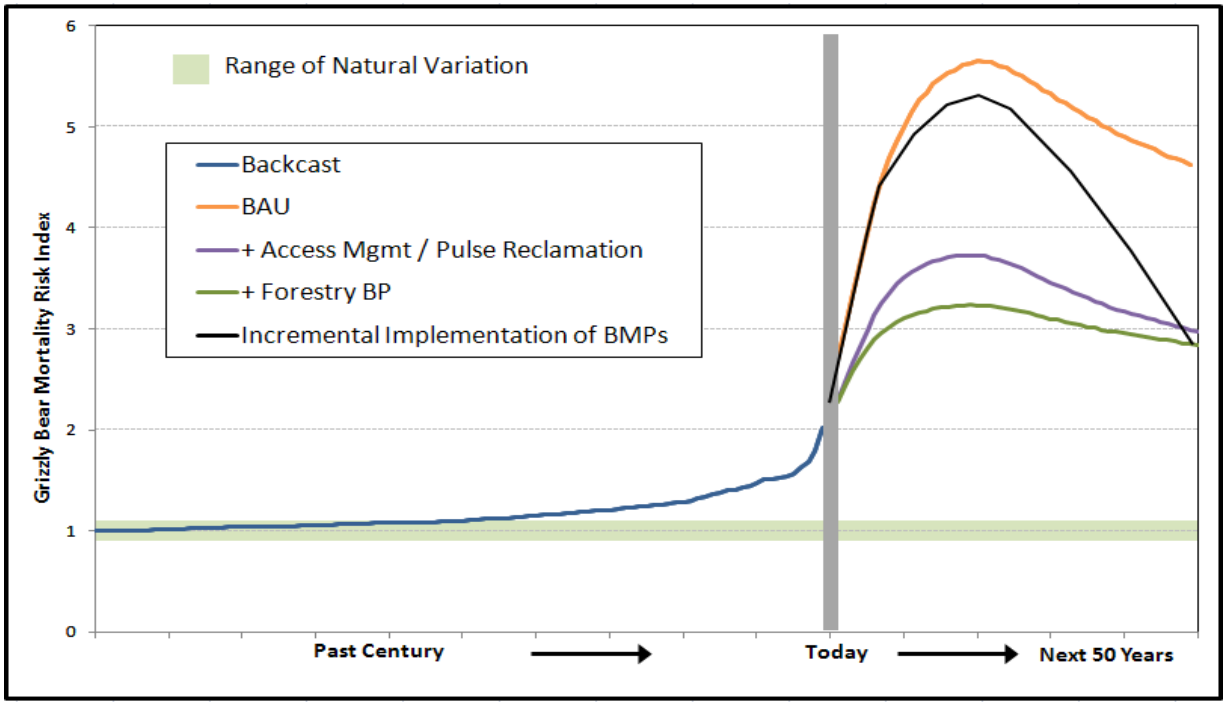


Figure 21. Projected changes in the grizzly bear mortality index attributed to BMP as compared to BAU.

In the Government of Alberta's Status of the Grizzly Bear in Alberta (2010) report, they state that "The persistence of grizzly bears in Alberta hinges directly on reducing human-caused mortality. That reduction can best be achieved through limiting motorized access to grizzly bear habitat, including road closures and disallowing off-road vehicles."[96] This conclusion is also emphasized by Steve Herrero, who states "Management of access, in particular open roads, and human food and garbage, and hunter education are critical issues with respect to managing grizzly bear mortality"[97]. Educational programs, such as BearSmart (www.srd.alberta.ca/Recreation PublicUse/AlbertaBearSmart/Default.aspx), that inform residents and recreationalists about how to minimize food attractants and avoid encounters with grizzly bears, will also contribute greatly to maintenance of grizzly bear populations.

7.5 FORESTRY

7.5.1 Preamble

Currently, forest harvest operations in the study area are conducted primarily by Spray Lake Sawmills of Cochrane, under the license of a Forest Management Agreement (FMA). As stated in Spray Lake Sawmills Detailed Forest Management Plan, "The primary use to the FMA is to establish, grow, harvest, and remove timber."[98] A key element of the Ghost River Watershed Project is to encourage a broader conversation on the role that FMAs play in delivery of a broader suite of services (commodities) to society. While wood production should remain a key objective of any FMA, it should be viewed as only one of several, and often competing, key commodities that include water quality, water quantity, wildlife habitat, recreational opportunities, and carbon dynamics. Whereas it is easy to suggest that the forest sector needs to evolve to satisfy a broader suite of demands from society, the policy and market-based work required to make this happen is far from simple. Devising the correct toolkit (carrots, sticks) of market-based instruments to induce FMA holders to achieve this new balance will be a difficult, awkward, and lengthy discussion. There is no better time than now to start this important progression toward a new forest sector ideology that maintains and encourages a broad societal support. It can be argued that the survival of the Spray Lakes FMA depends on this new conversation.

7.5.2 Forest Harvest Sustainability

Annual harvest volumes and cutblock area will exhibit inter-annual variation (because of fire salvage, insect abatement programs, and when specific operating units are auctioned for harvest) but have been estimated to be ~52,000 m^3/yr within the study area.[99] Computation of subjective deletions, merchantable landbase, and forest growth in ALCES were based on information extracted from the Detailed Forest Management Plan of SLS and the timber growth and yield curves provided by the Timber Supply Analysts of Sustainable Resources Development for the Southern Foothills Study.

Our analysis of the Ghost River study area indicates that current forest harvest rates by Spray Lake, in the absence of future fire events, are likely to be sustainable from a fiber perspective over the next several decades. This conclusion of fiber harvest sustainability does not hold, however, if a future fire regimes occurs at rates similar to those estimated in the past few centuries. Following eight decades, the additive effects of both logging and fire are projected to create a progressively younger forest landbase (Figure 22). The cumulative effect of concurrent logging and fire would necessitate an adjustment (reduction) in wood harvest levels if a future volume fall-down is to be averted. There are two reasons for this conclusion. The first is that current calculations of Annual Allowable Cut (AAC) generally ignore the occurrence of fire from a planning perspective. The effects of fire on AAC in Alberta are generally addressed "after the fact". Since the Ghost River Watershed has not received significant fire area in recent decades this region currently contains a high proportion of merchantable age forest stands. If one or more large fire events occur within this merchantable forest landbase, then the AAC will need to be adjusted accordingly.

If the forest operator or management agencies do not account for the effects of future fire on timber supply, a fall-down (=shortfall) in harvest is expected (Figure 23). In practice, however, the government would likely adjust the AAC "on the fly" following major fire events. The conclusion remains the same: current harvest rates will eventually require downward adjustment as the cumulative effects of logging, fire, and insects manifest themselves.

It should be emphasized that both AAC adjustment strategies ("up-front and preventative" vs "after-the-fact and corrective") have unique merits and liabilities. In the first strategy, the effects of both logging and fire are endogenized into the computational math of AAC. If fires do not occur in the next few decades (because fire is random and episodic), then "extra" wood fiber is left on the landscape. This "wastage", is not desirable from a wood revenue perspective, but does provide significant ecosystem value to the Ghost River Watershed in terms of wildlife habitat, water quality, biotic carbon and aesthetic value. The liability of this approach is directly tied to the loss in wood volume harvest and the jobs and royalties associated with this "unrealized" harvest. One can distill all of these complexities to a simple comparison. If the true destiny of the Ghost River Watershed is to maximize wood volume harvest, then the current management strategies of Spray Lakes Sawmill and the Government of Alberta is well suited to realize these longterm goals. In contrast, if the future contributions of the Ghost River Watershed are best described as multi-sectoral and realized through achieving a diversity of social, economic, and ecological services, then the current management strategy must quickly evolve to a new approach that is embraced by a broad society expecting a broad suite of services.

Based on clear messaging by workshop participants for a broad "sustainability" focus for the watershed, the ALCES simulator was structured to evaluate different forest harvest strategies and assumptions that would optimize ecosystem performance and minimize the probability of future wood shortfalls.

First, ALCES explored the likelihood of a timber harvest fall-down under varying forest growth and yield assumptions. Timber production is heavily influenced by the growth and yield curves that reflect historic records of tree growth based on empirical sampling. Much of Alberta's existing forest growth knowledge, particularly older stands, is based on tree growth data collected following fire events and only in recent decades has the industry begun to assemble information on tree growth following commercial forest harvest. There remains much uncertainty as to whether post-logging growth of forests will be less than, equal to, or exceed growth rates observed for forests regrowing after fire events. Furthermore, forest ecologists are concerned that warmer and drier conditions associated with climate change may influence both forest growth and fire regimes – both of which could have a profound effect on timber sustainability.

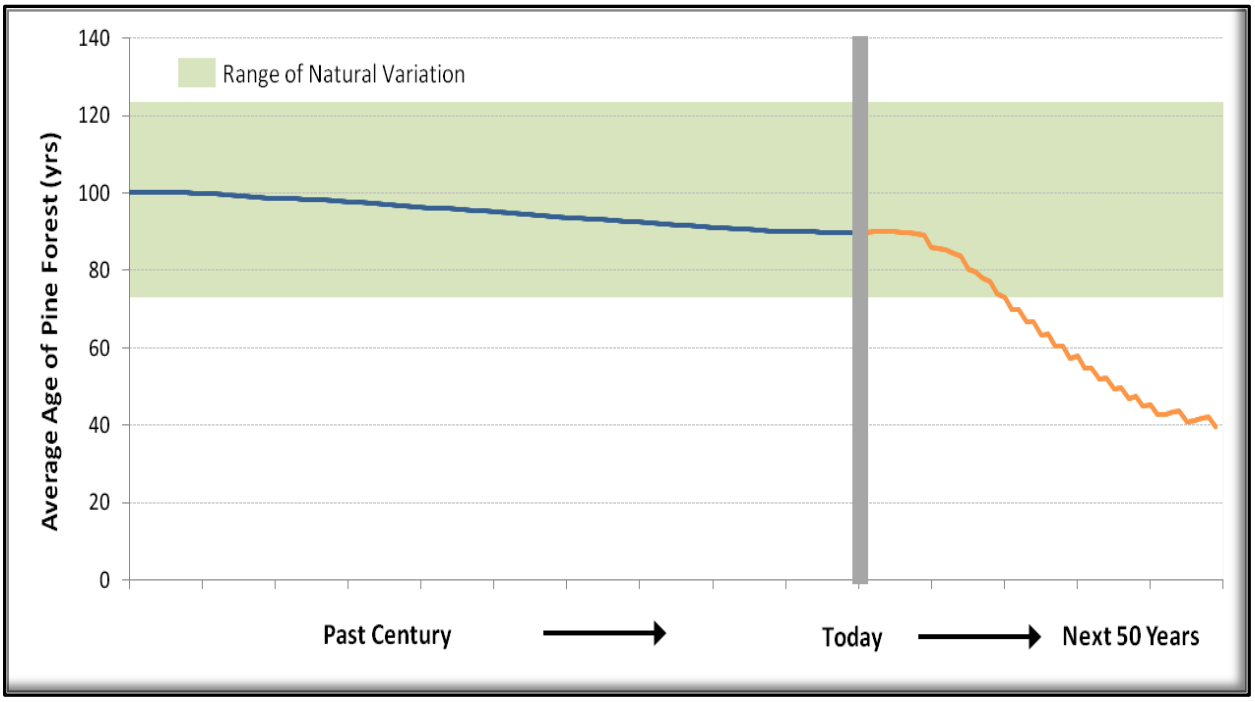


Figure 22. Projected changes in average age of pine forest stands in the study area. Although the current average age (~90 years) of pine is well within the range of natural variability (RNV) of this landscape, the average age will decline to ~40 years within 50 years because of the additive effects of both logging and fire.

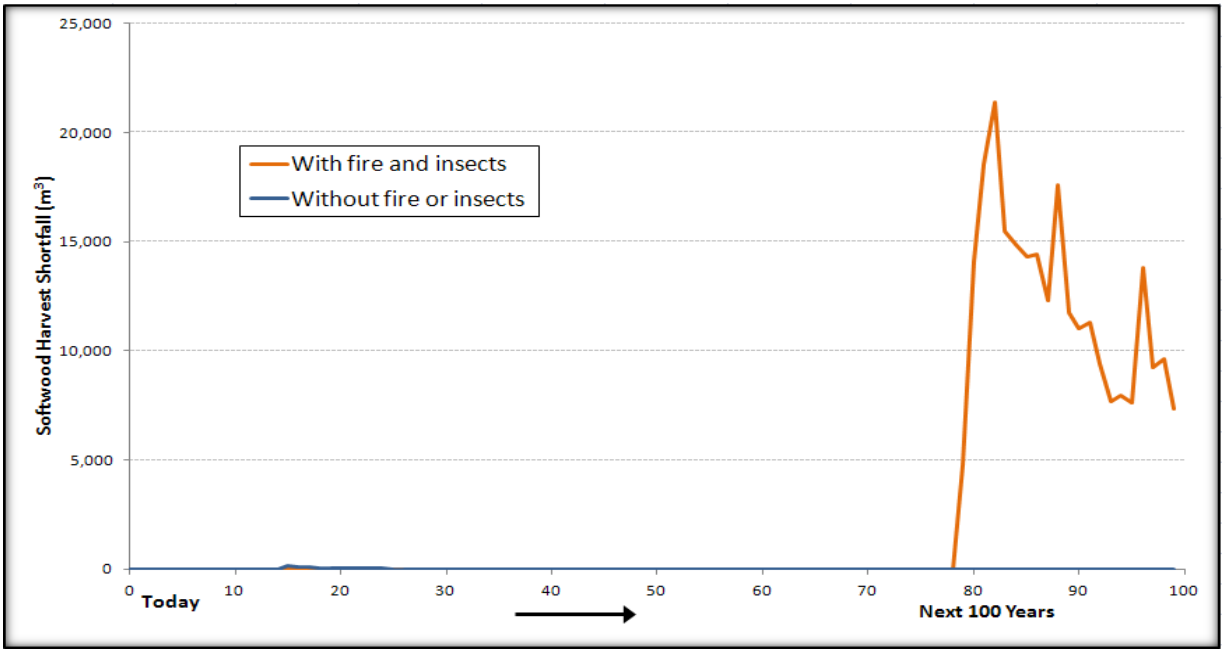


Figure 23. Projected softwood harvest shortfall in simulation scenarios with and without fire and insect related mortality of trees. Note that in the absence of fire or insect-related mortality (blue line), the current level of softwood harvest is sustainable for the full extent of the future simulation (100 years). In contrast, logging and fire co-occurring on the landscape (orange line) leads to a softwood shortfall (also called a fall-down) in about 8 decades.

Under a range of growth and yield assumptions, varying from 75% - 125% of baseline forest growth and yield, ALCES assessed timber harvest sustainability over a 200 year period. Under all scenarios (with both logging and fire active) a fall-down eventually occurred under current wood harvest volumes (Figure 24). The magnitude of falldown, and how quickly the falldown expressed itself, increased with progressively slower post-harvest growth and yield performance.

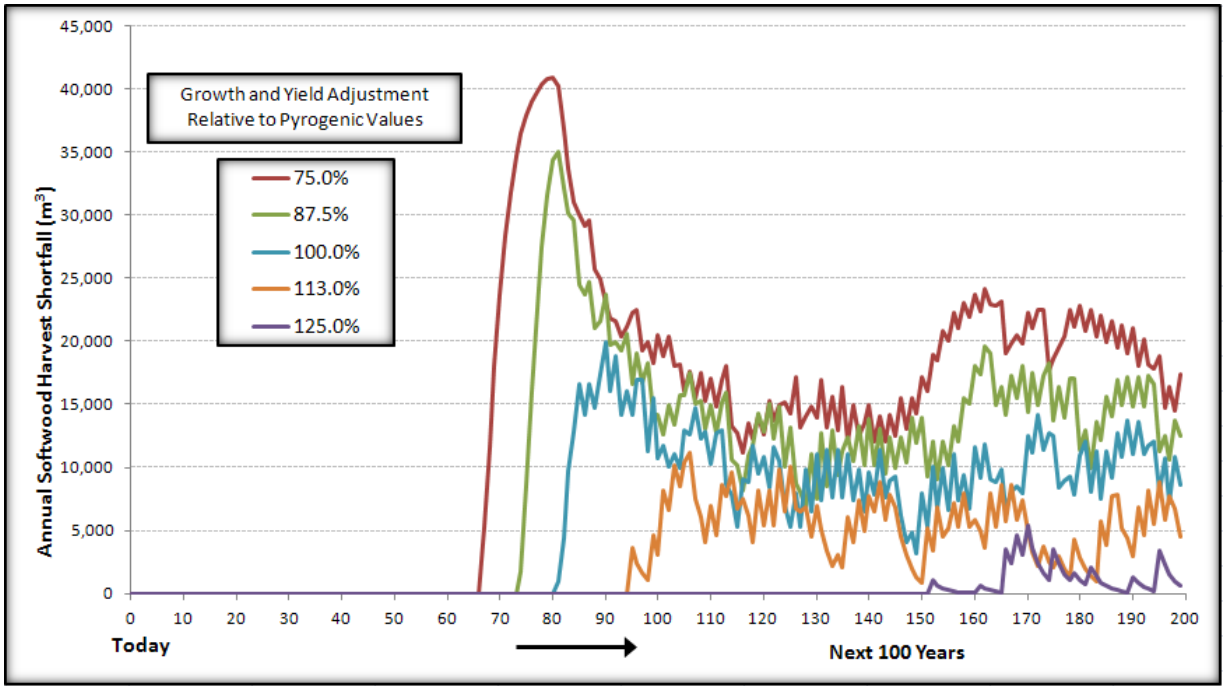


Figure 24. Projected softwood fall-downs under a range of forest growth and yield scenarios. This scenario includes the presence of a fire regime. Each line represents the consequence to softwood harvest shortfall if harvested stands are growing at rates equal to, higher, or lower than the current accepted pyrogenic growth and yield curves. Unsurprisingly, the slower the trees grow in volume, the more quickly a shortfall occurs and the greater its magnitude.

ALCES was used to quantify the long-term forest harvest volumes could be sustained (with a concurrent fire regime) without inducing a harvest fall-down. The simulated harvest reductions started at 50 percent of current levels and were increased until a fall-down event was observed. The simulation results indicate that a reduction in harvest of at ~20% is required to ensure a sustainable harvest outcome on the Ghost River Watershed's merchantable forest landbase that is experiencing both fire and logging (Figure 25).

As a result of these simulations, a reduction in harvest volume of 25% would likely ensure longterm forest harvest sustainability and therefore was adopted as a beneficial management practice of the forest sector. From the perspective of SLS, a reduction of wood harvest by ~25% on the merchantable Ghost River Watershed landbase is neither good or welcome news. This speaks to the need to balance the adoption of new forest sector

policies/practices with economic rewards tied to improved water quality, water quantity, biotic carbon, and wildlife habitat.

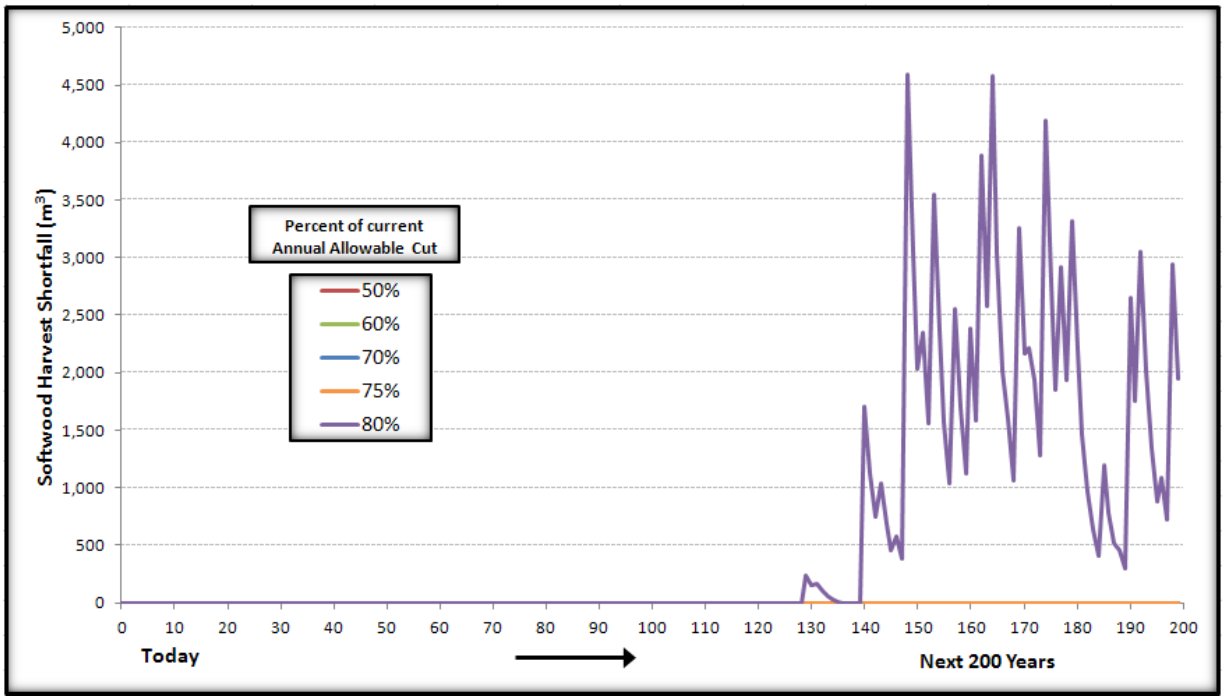


Figure 25. Projected softwood harvest "falldown" using different annual allowable cut levels relative to current harvest levels. Important to note that simulation lines for 50%, 60%, and 70% cannot be seen as they are hidden behind the line for 75%. What this sensitivity simulation illustrates is that a reduction in softwood harvest of ~20% (=80% of current levels) is required to minimize the likelihood of a softwood shortfall in this watershed if both logging and fire persist.

"While threats for forest sustainability may not be immediately apparent, the ongoing risk of fire and the cumulative impact of oil, gas and other forest land development throughout the province (Alberta) do point to the potential for risk to the long-term economic viability (i.e., sustained timber supplies) of some forestry operations."[100] The analyses of the Ghost River Watershed Alliance Society presented here should prompt forest managers and public policy decision makers to assess alternative management approaches and mitigate risk. It also points to the need to consider the potential impact of forestry on the economics of recreation and the cumulative impact of both natural and human related disturbances when developing long-term timber supply strategies.[101]

An example of the past pattern and intensity of forest harvest occurring within the Spray Lake FMA is shown in Figure 25;[102] (this image is from an area situated north of the study area).

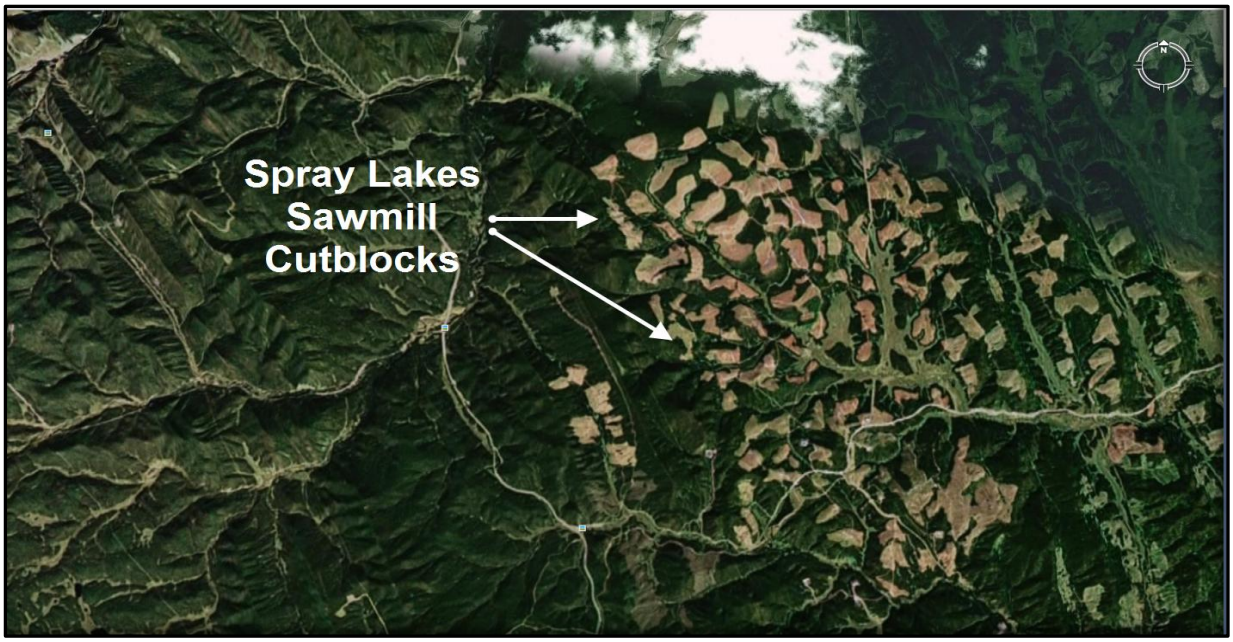


Figure 26. Example of Spray Lake Sawmill forest harvest activities adjacent to the Ghost River Watershed depicting possible harvest patterns to be expected in study area. Source: Google Earth.

In the pre-industrial era, fire was the primary architect of forest age class structure in the Ghost River Watershed. Fire rates used in this study differed by forest types, but ranged in annual rate from 0.010 (100 year cycle) to 0.014 (70 year cycle). When fire regimes were simulated as "random", they were computed as a draw from a negative exponential distribution. The "average" natural forest age structure of the study area experiencing a constant natural fire and insect regime is shown in Figure 27. This pattern approximates a negative exponential distribution whereby older forest age class become progressively less common than the next younger forest age class.[103] The oldest forest age class (nominally 160-200 years) is actually a combination of all seral stages older than 160 years and likely includes some stands as old as 300 years. In reality, however, there is no such thing as an "average" insect and fire-induced forest age class structure, because insect infestations and fire are highly episodic in nature. The "average" presented here represents a "generalized" reference pattern when comparing many different simulation scenarios.

In contrast to the forest age class structure created under natural conditions, a regulated forest age class distribution created by logging (but without fire or insects) will contain approximately equal amounts of area for each seral stage younger than "rotation age" (Figure 27). Older forests that do remain on the Ghost River Watershed are those found outside of the SLS FMA or those within the FMA that are too close to water or too steep to log.

Rotation age refers to that forest age that is optimal for harvest. Stands younger than rotation age are not generally harvested because they are quickly adding incremental volume whereas older stands are suboptimal from a fiber perspective because of less desirable

growth form or because of increased rates of tree mortality (Figure 27). The harvest rotation length for logging in the SLS FMA is 80-100 years.

In reality, the forests of the Ghost River watershed will be shaped by the combined effects of logging, insects and fire.[104] Current policies regarding logging and practical constraints regarding insect control and fire suppression indicate that these natural and anthropogenic disturbances are likely to persist in the future. Unsurprisingly, the forest age class structure created by logging, insects and fire reflects a significantly younger landscape whose age class structure indicates a hybrid between the two patterns described above (Figure 27). To complicate issues further, plant community ecologists studying the potential effects of a "climate change" future for Alberta would remind managers that incidence of both fire and insect outbreaks is likely to increase in future decades.

Forest landscapes characterized by extensive young stands and a reduced frequency of old forests, such as shown in Figure 27 , will likely experience reduced biodiversity[105]. Furthermore, younger forest landscapes generally have increased sediment and nutrient loading to surface water as older forests generally release less sediment and nutrients than do clearcuts and young forests. [106,107,108] Maintenance of largely intact forest cover in source-water areas is a key principle for production of clean and inexpensive water supply for downstream users.[109,110,111] The South Saskatchewan Regional Advisory Council's report submitted to the Alberta LandUse Management Framework states "Headwater and source-water protection and the need to manage land use to sustain water production and water quality are critically important."[112]

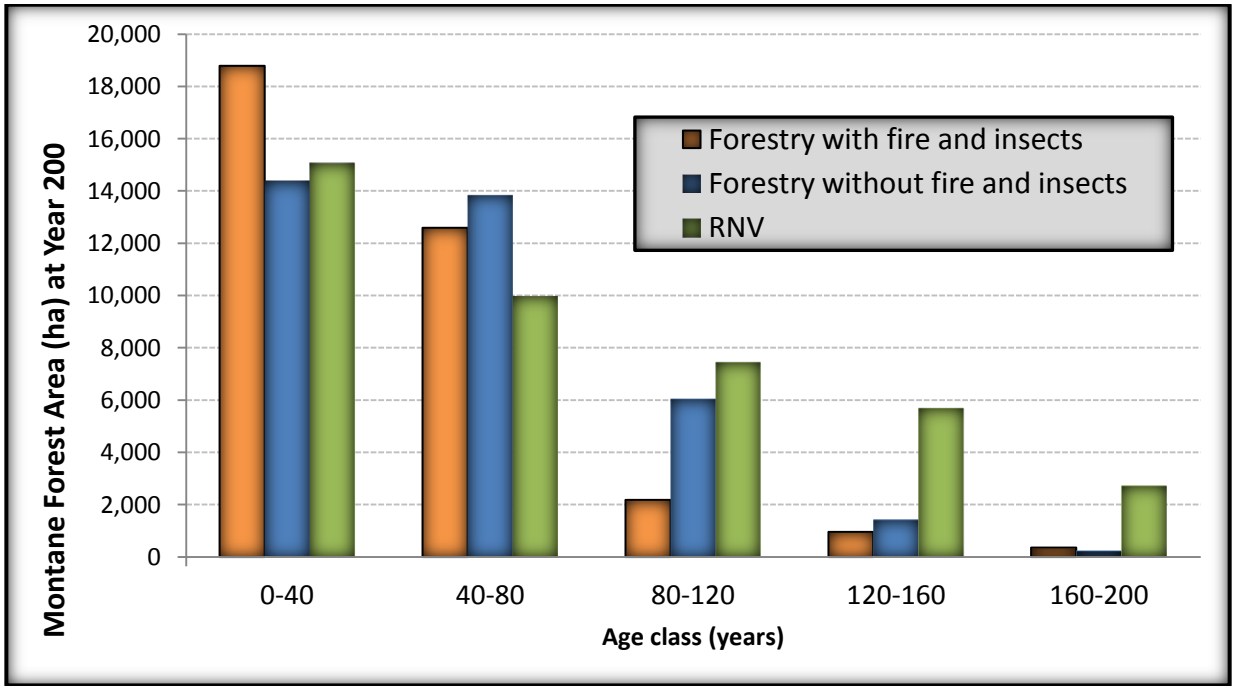


Figure 27. Comparison of average forest age class structure on study area after 200 years under three scenarios: fire (representing RNV) (green), logging (blue), and logging and fire (yellow). This graph illustrates that fire regimes maintain a greater representation of old forests than does

logging. Furthermore, the combined additive effects of fire and logging is to significantly shift the forest age class structure to younger stands.

7.5.3 Ecological Goods and Services and Recreation Value

Lumber and wood fibre production is important to Alberta's economy and quality of life.[113] However, forests also provide society with a host of ecological goods and services that include carbon storage, recreation, climate regulation, water treatment, and provision of wildlife habitat and biodiversity. Non-timber values for forests have been estimated to be up to ten times the value of timber revenues.[114] Given the proximity of the Ghost-Waiparous watershed to Calgary, Cochrane and Canmore, this basin helps satisfy the significant and growing demand for ecosystem-based services and recreation of the surrounding regional population.

Recreational activities, in the form of camping, hiking, skiing, horse-back riding, and OHV activity, have a significant economic value to Albertans. Phase 1 simulations estimated ~141,000 people currently visit the study area annually,[115,116] generating ~$33 Million (M) in direct spending.[117,118] These annual expenditures were forecast to increase to exceed $70 M in the future.[119] In comparison, forest harvest direct revenues are estimated at approximately $21 M/yr[120] (Figure 28).[121] If these sectoral revenue estimates are reasonably accurate, it would indicate that forest harvest practices should be conducted in a manner that does not compromise the higher value and more lucrative recreational sector.

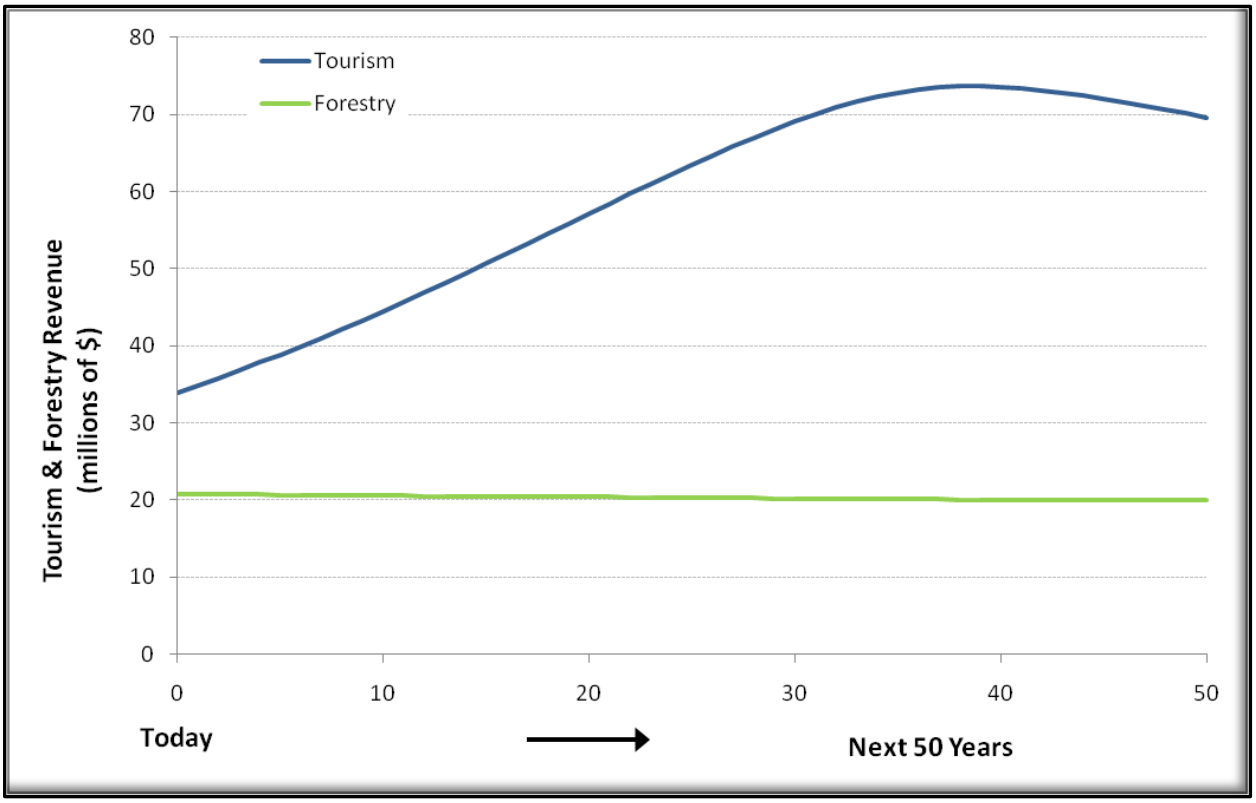


Figure 28. Projected Tourism Expenditure and Forestry Revenue. Increased growth in tourism revenues during the initial 35 years reflects a growing regional population. Reduction in tourism based expenditure at year 37 reflects the discounted value of the landscape due to the prevalence of clearcuts and forest under 40 years of age that are perceived as less desirable recreational landscapes than mature forests. Dollar values were held constant and not adjusted for inflation.

Similar differences in economic values of tourism and forestry have been shown elsewhere in Alberta using gross domestic product (GDP) as an index of value. The Alberta Southern East Slopes Integrated Land Management Pilot Project estimated a forestry GDP value of $12.63/ha/yr, recreation GDP value $59.58/ha/yr, and non-resource sector GDP of $1,700.70/ha/yr.[122]

Outdoor recreationalists generally prefer older forests (Figure 29) and avoid clearcuts (Figure 30) for recreational activities.[123,124,125] In Sweden and Australia, research has demonstrated selective cutting of forests creates a forest landscape with the highest perceived recreation value while clearcutting generates the lowest value.[126,127] Figure 31 illustrates a selectively cut forest in Fernie B.C. intended to maintain biodiversity, decrease wildfire potential and maintain recreational value. This area was harvested approximately six months prior to the photograph with the non-motorized multi-use recreational trail left intact.

Forestry practices in the Ghost selectively target mature timber stands and deploy clearcut harvest methods (Figure 30). Although this traditional harvest strategy may be preferred for maximizing wood fiber production, it generally leads to a landscape of lowered recreational value.

The B.C. government`s Forest Practices Branch states:

> *"One of the clearest messages is that most people do not like the appearance of clearcuts or the effects clearcutting has on tourism and recreational experiences such as hiking and fishing. One of the challenges for the Forest Service is to further integrate the objectives of aesthetics, recreation and timber harvesting creatively using a variety of silvicultural systems."*[128]

Figure 29. Old growth lodgepole pine forest (with spruce understory), Ghost River watershed, photo courtesy of Herb Hammond, Silva Consultants Ltd.

Figure 30. Clearcut on the western edge of the study area, 1 August 2010, picture taken from a well-site access road, demonstrating lack of vegetative screen along roadway margins for aesthetics or wildlife vulnerability.

Figure 31. An example of a cutblock using selective harvest approach, Tembec Industries Ltd. - Fernie B.C. May 2012

Forest harvest which significantly reduces the average age of forests and creates landscapes with a large proportion of clearcuts may adversely impact future tourism revenue as the forest becomes potentially less desirable for many recreationalists.[129] Clearcuts, by their very nature, may create an "industrial" landscape with vegetation removal, slash debris such as limbs and stumps and rough uneven ground created by heavy machinery. Such areas may be visually unappealing for recreationalists[130,131]. Selective logging has the potential to mitigate negative attributes for recreationalists (Figure 33).

Spray Lake Sawmills' detailed forest management plan and timber harvest planning and operating ground rules[132] recognize the possible impact of timber harvesting on aesthetics. The detailed forest management plan states, "Scenic values can be addressed through varied block sizes, avoidance of geometric shapes, irregular edges, retention of trees or other structure, block positions and distribution on the landscape, use of visual screens and harvest system."[133]

Recreational demand and direct expenditure opportunities in the Ghost River basin associated with recreation are projected to increase in proportion to the expanding regional population (Figure 32). The regional human population is anticipated to grow at a rate of 1.5%/yr.

However, as younger forests and clearcuts become more prevalent in the Ghost River basin, simulation modelling suggests the landscape will become less desirable for recreationalists, and visitations and associated expenditures will begin to decline ~4 decades in the future. This trade-off pattern between tourism activity days and logging is based on the assumption that commercial logging will occur at a constant rate in the future, and that a full logging rotation will require approximately 100 years to complete. This assumption may not be valid, however, as forest harvest plans may elect to remove much of the merchantable wood in this watershed during a shorter interval due to the existing unbalanced forest age class structure.

Simulations of forest sector BMP based on lower harvest volume (25-50%) and higher tree retention levels (selective logging) indicate a significant positive impact on the recreational potential in the watershed while still supporting ongoing forest operations (Figure 33).

The Ghost River Watershed Alliance Society is completing a ecosystem-based conservation plan prepared by Herb Hammond of Silva Ecosystem Consultants Ltd[134]. This project, which focuses on the forest sector, outlines a "bottom-up" approach intended to maximize ecological goods and services and quantify a level of logging volume that achieves those goals.

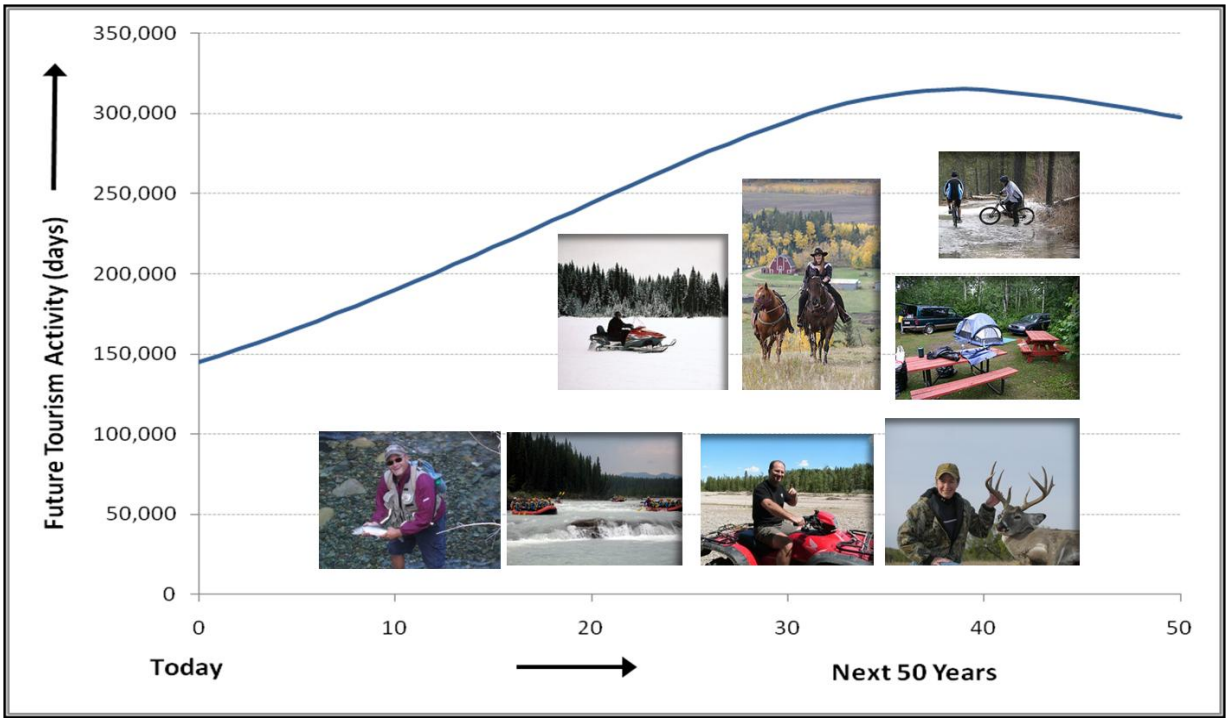


Figure 32. Simulated Business-as-Usual (BAU) projection of future "tourism activity days" of the Ghost River Watershed basin.

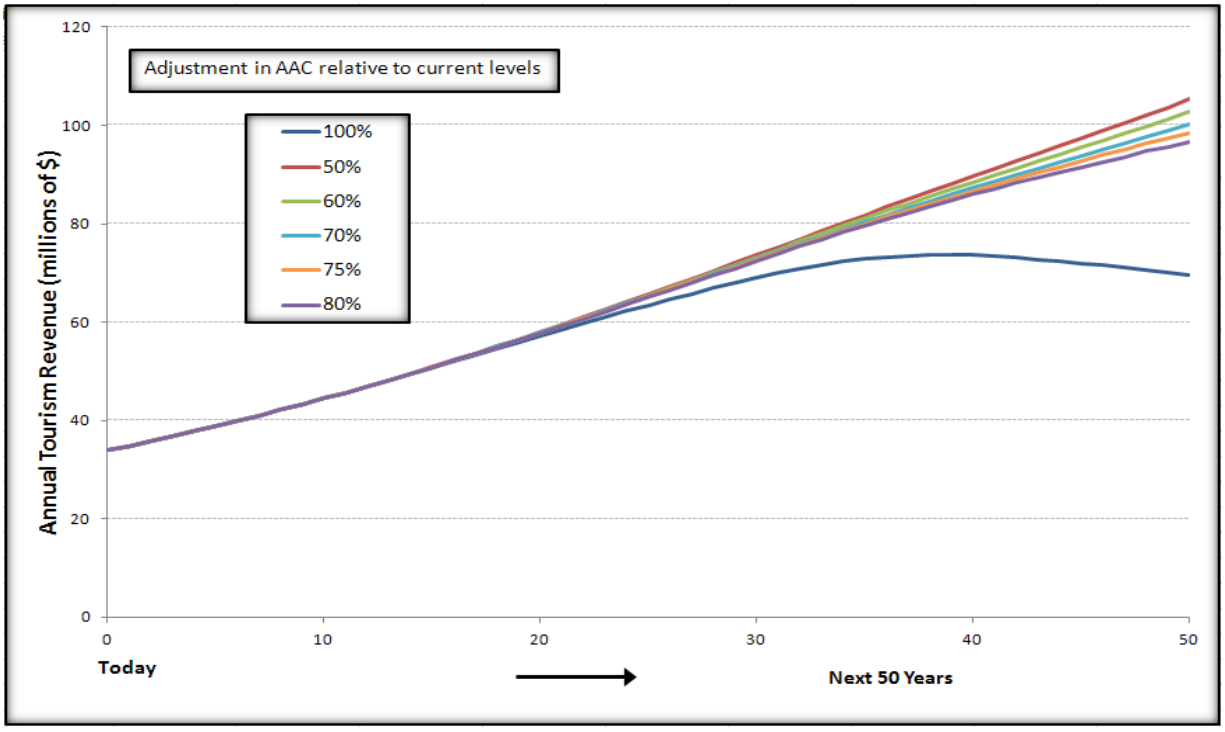


Figure 33. Projected change in potential tourism revenue as caused by reduced forest harvest levels. The loss of tourism revenue in the business-as-usual forest harvest rate (index of 1.0) reflects a landscape that is progressively less appealing to the tourism sector. As forest harvest rates are reduced, tourism revenues are increased.

8. RECREATION CONFLICTS

The majority of recreational activity within the study area is by motorized recreationalists (Figure 34, Figure 35).[135] Past policies such as the Policy for Resource Management on the East Slopes (1984) have approved these activities as appropriate for this landscape as part of a mix of multi-use recreational activities. Hikers, mountain bikers, equestrian users and other non-motorized recreationalists also use the landscape, but in lower numbers than motorized users.[136] This difference in use patterns between motorized and non-motorized users may be partly due to a management focus favouring motorized recreation. An example of this would be brochures and signage provided for motorized trails and activities while minimal identification of hiking, biking or equestrian trails or other non-motorized recreational opportunities exists.[137]

As noted previously and described further below, many linear features within the study area are used by motorized vehicles, even though they are signed as closed or not signed as open.[138] Research in Utah and Colorado suggests that most riders knowingly ride off designated routes.[139,140] Widespread motorized recreational activity within the study area may lead to perceptions of user conflict, as found in the Ghost-Waiparous Access Management Plan user survey (Figure 36), or geographically displace other legitimate non-motorized activities.[141,142,143,144,145]

Motorized recreationalists can geographically displace non-motorized users, and the two activities are largely seen as incompatible by non-motorized users.[146,147,148,149] This pattern of conflict is underscored in a survey by the American Hiking Society, where hikers indicated "a strong preference for separated areas for motorized and non-motorized use, given the significant disturbance, noise, pollution, resource impacts, and safety and health threats."[150] A survey conducted by the American Hiking Society of member organizations with a combined membership of over half a million people, found that off-road vehicle use was displacing hikers in all regions of the country.[151] There are numerous references in the literature of non-motorized recreationalists being displaced, or leaving areas altogether where motorized use is frequent.[152,153,154,155,156,157]

Similarly, in an Alberta Government survey, respondents identified motorized recreationalists as having the greatest adverse impact on enjoyment of the Ghost-Waiparous by other users (Figure 36).[158]

Equestrian outfitters within the study area identify OHV use as negatively affecting their business due to a high incidence of "non-repeat" customers who indicated that OHVs detracted from their wilderness experience.[159]

Figure 34. Example of random campsite of motorized recreation.

Figure 35. Multiple use trail open and signed as open to motorized use, July 2010, Ghost River Forest Land Use Zone.

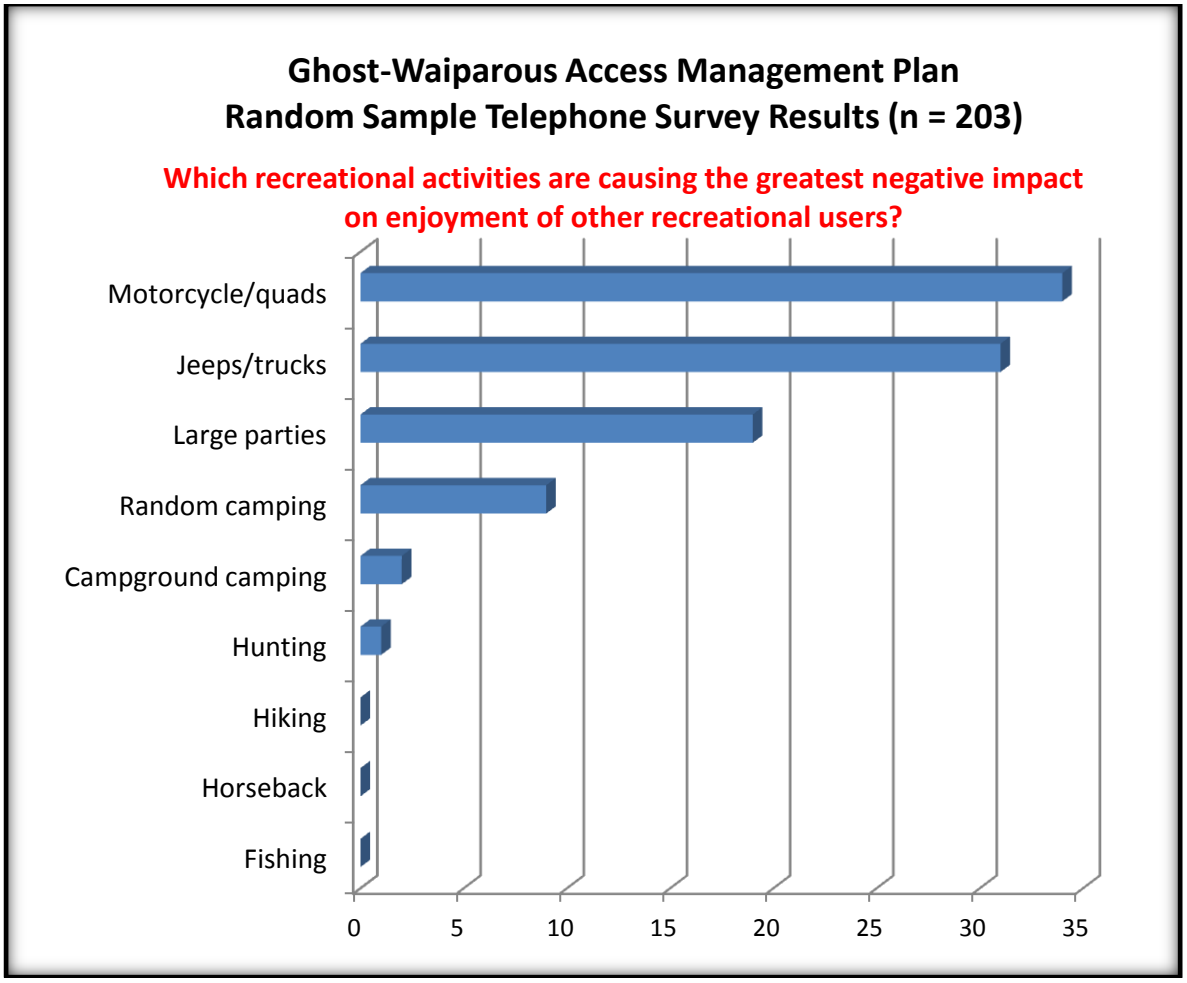


Figure 36. Public perception of recreational activities responsible for negatively impacting recreational enjoyment of the Ghost-Waiparous region.

Within the study area, any random location, on average, is likely no further than 100 to 200 m from the closest linear feature. Field visits during the 2010 non-snow season showed that OHV use occurred on 93% of the linear features assessed.[160] Based on literature that motorized recreation can displace non-motorized users through both direct physical presence and noise,[161,162,163] we simulated the fraction of the study area that would likely be suitable for non-motorized users. These analyses were completed by creating a buffer of 50-75 m from all linear features (Figure 37). In this buffer, a 90% reduction of use by non-motorized users was simulated due to physical presence, noise, or visual detection of OHV vehicles. The authors recognise that further data collection and analysis should be completed to quantify more precise avoidance patterns of non motorized users from roadways and trails used by motorized recreationalists. Some non-motorized uses may be more or less tolerant of motorized vehicle use and the "measured" avoidance metric may be higher or lower than the values used in these analyses. However, the analyses presented here are instructive to estimate the fraction of the watershed that is suitable for non-motorized recreation.

Figure 37. Showing 50 meter theoretical area of avoidance by non-motorized recreationalist along linear features used by vehicles.

Under these assumptions, simulation results demonstrate that ~27-50% of the area is currently suitable for non-motorized users in the study area. As the intensity of linear disturbances increase, along with associated motorized recreational use, the fraction of the landscape eligible for non-motorized recreational users would continue to decrease to ~7-29% by year 50 (Figure 38). Without significant improvements in the enforcement of existing OHV regulations, which restrict motorized recreation to designated roads and trails, the potential use of the study area by hikers, mountain bikers, and equestrian users will likely continue to decline in the future. The “multiple-use” legislation that applies to this study area legitimizes many outdoor recreational activities, but these analyses highlight the actual economic and social trade-offs that are occurring between recreational users when managers of a multitude of recreational activities adopt an “everyone, everywhere, all the time” approach.

The assessment of OHV BMP using the ALCES simulator involved restricting OHV to the designated off-highway recreational vehicle trail network and placing a 50 m buffer on this network. This buffer was then given a reduced value for non-motorized recreational users. Relative to the BAU scenario, the OHV BMP scenario indicates a significant improvement in recreation potential for non-motorized users in the study area. If OHV users utilized the designated OHV trail system, and refrained from using the non-designated trails, over 80 percent of the area would be suitable for non-motorized recreation (Figure 39).

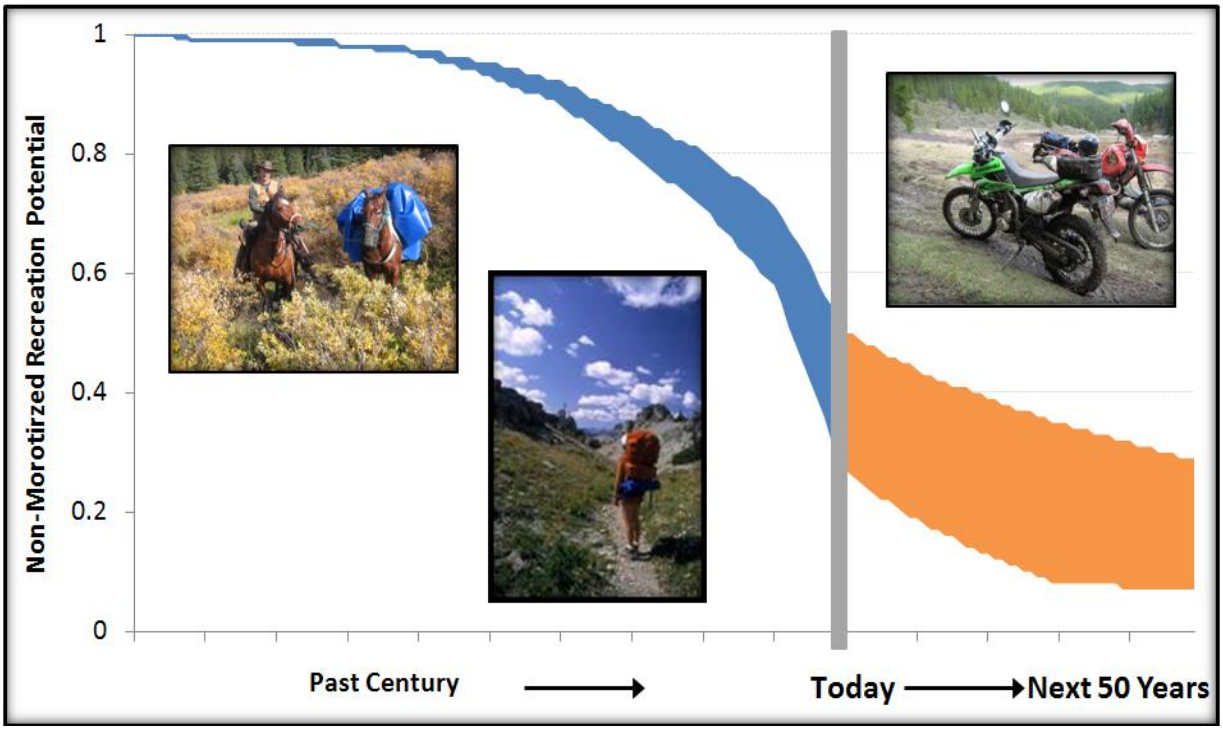


Figure 38. Fraction of study area preferred for use by recreational non-motorized users under business-as-usual scenarios. The upper and lower range reflects a 50 and 75 m avoidance buffer.

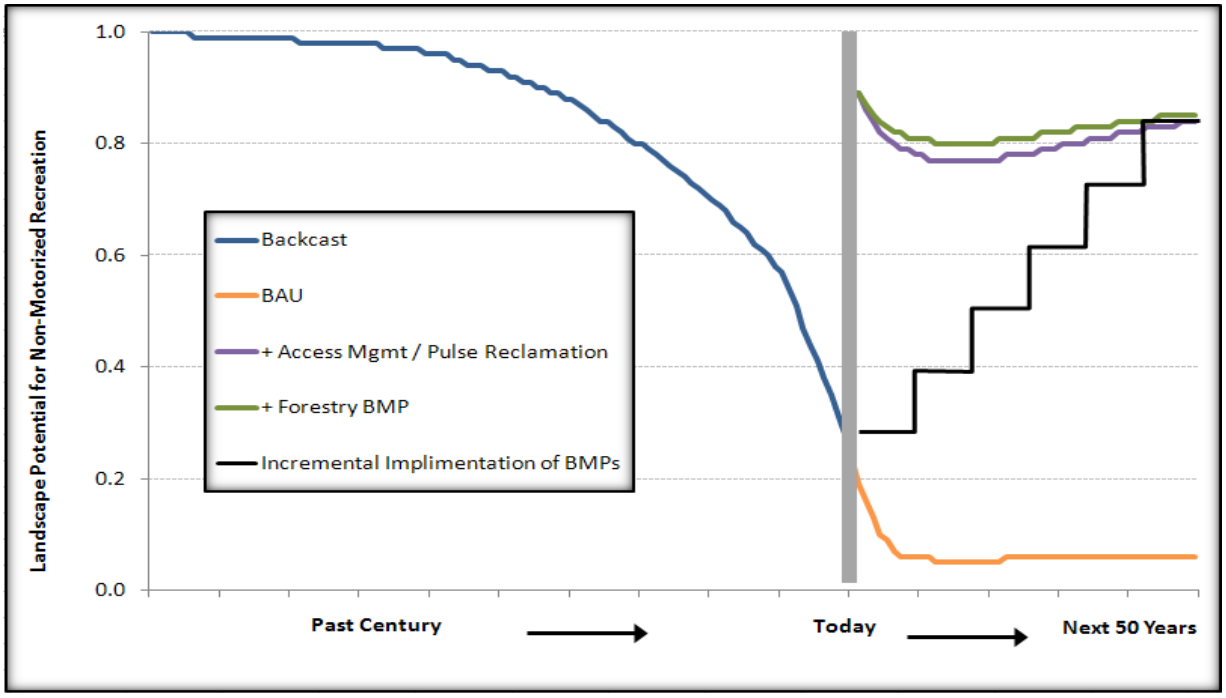


Figure 39. Projected changes in non-motorized recreation potential, when comparing BAU to BMP. The immediate improvement in non-motorized recreational potential at Time 0 (today) reflects the full and immediate adoption of each of the BMP levers. In contrast, the black line reflects projected changes in non-motorized recreational potential if BMP were implemented at 20% adoption levels for each of 5 successive decades.

9. CONCLUSIONS

The Ghost-Waiparous watershed is typical of many of Alberta's Eastern Slopes landscapes where increasing industrial and recreational pressures challenge current management strategies and policy. Our future population, footprint, and resource demands are all likely to increase as affluent regional populations and industrial and recreational land uses continue to expand. The reality of increasing environmental degradation and of potential future loss of revenue has prompted discussions regarding the inability of current land use planning to deliver the social, economic and environmental services that Albertans expect.[164] Current forward-looking legislation and policy such as the Alberta Land-use Stewardship Act and the Alberta Land-use Framework are intended to help address regional issues associated with land-use planning. Market instruments such as the Forest Stewardship Council may also encourage forest companies to manage forests to the highest possible standard.

Beneficial management practices (BMP) explored in the Ghost River Watershed using the ALCES landscape simulator demonstrated significant benefits to all indicators and resource users in terms of longterm sustainability.

Will the Ghost River Watershed contribute clean water supply for downstream communities such as Cochrane and Calgary?

Phase 2 modelling demonstrates that beneficial management practices can increase water quality above today's current levels. Such improvements decrease downstream water treatment costs[165,166] and benefit fish, wildlife, and recreational users.

Will there be healthy natural areas in the Ghost River Watershed providing quality fish and wildlife habitat?

Relative to the Business-as-Usual scenario, the Beneficial Management Practices scenario had a significant positive effect on regional grizzly bear survivorship by reducing their exposure (mortality) index. However, the exposure index, even with BMP, was projected to increase during the next half century, indicating that additional BMP will be required to ensure persistence of viable grizzly bear populations.

Such programs as "Alberta BearSmart by Alberta Environment and Sustainable Resource Development"[167] promote a number of practises such as bear resistant garbage disposal containers. However, such containers are only available at developed campsites within the study area. Random camping is widespread and generally occurs in locations without access to bear resistant containers. Many random camping sites in the study area are not well located in terms of minimizing bears encounters. Public education brochures and information are not readily available in the area.

Access management, forestry BMP, and increased replacement of hung culverts had a significant positive effect for the Index of Native Fish Integrity with potential to raise the index from today's current situation to one where the fishery would provide good angling opportunities for native species in this watershed, as well as the restoration of a threatened species (Westslope Cutthroat Trout).

Will the landscape satisfy motorized and non-motorized recreationalists seeking quality non-urban experiences?

Beneficial management practices show that with effective access management there is potential to improve upon recreational opportunities for both motorized and non-motorized use. However, this long-term benefit requires the motorized vehicle community to be prepared to restrict their activities to a designated trail network with government enforcement and self enforcement levels that ensure activity does not expand onto non-designated trails.

Forestry BMP such as higher in-block tree retention levels can minimize negative impacts to recreational resources for both motorized and non-motorized users.

Will natural resource extraction such as forestry remain sustainable?

Timber supply analyses for the Ghost River Watershed demonstrates that the current forest harvest rate is unlikely to be sustainable over the long term. Current harvest volumes are predicated on the absence of fire and insect perturbations, and no anticipated change in the area of the merchantable forest landbase. Collectively, these existing set of assumptions are unlikely to occur in the longterm. A more realistic future suggests that fires and insect infestations will occur and likely to increase in a climate change scenario, land use footprints of the energy and recreational sector will expand, and that reductions to forest harvest will be inevitable. The most significant factors likely affecting future forest harvest levels are fire rate and the extent to which the recreational community influences forestry policy through changes to logging rotation age (determinant of old forest frequency) and tree retention levels on this high-profile landscape (determinant of landscape aesthetics).

Current land use trends and practices in the Ghost River Watershed, as conservatively assessed in Phase I and in this report, will need to change if this landscape is to provide a healthy suite of ecological and societal services, such as quality water production, healthy fish and wildlife habitat, quality recreation and sustainable forestry. Similar to other areas on Alberta's Eastern Slopes, the study area does not appear to be achieving goals established in government mandates, policy and legislation.[168,169,170] Significant aspects of the Ghost River Sub-Regional Integrated Resource Plan and the Ghost-Waiparous Operational Access Management Plan have not been implemented, with resultant negative impacts on both natural and recreational resources.

Albertans are indeed concerned about their water, forests, and biodiversity. In a survey sample of 2,881 Albertans, conducted for the Alberta Forest Products Association, 90% of respondents were either "somewhat" or "extremely" concerned about the management of Alberta's forests; only 10% were "not very" or "not at all" concerned. Eighty three percent of Albertans felt that "access and use of forests should be based on preserving and protecting the environment, and sustaining wildlife habitat at the expense of sustained economic benefits and jobs."[171] In response to the question of which environment-related issues will have the greatest impact on Alberta's future economic prosperity, the top three issues

identified by respondents were: rivers and watershed management (21.43%), water quality (18.9%) and maintaining biodiversity (14.33%).[172]

In response to such concerns, the Ghost River Watershed Alliance Society's goal is to create an ecosystem-based conservation plan that incorporates people into the Ghost River Watershed ecosystem, in ways that sustain the land, water, plants, animals, soil and other processes that comprise a fully functioning ecosystem while also providing for diverse, community-based economies.[173]

Phase II of the Ghost River Cumulative Effects study demonstrates the potential positive benefits of beneficial management practices on ecological indicators, sustainable forestry and recreational activities.

As told in the preface to this report, the 1859 conversation between John Palliser and James Hector of the Palliser Expedition, and their guide Peter Erasmus, was indeed a harbinger of what was to come to southwest Alberta. The land use challenges that now confront this region in general, and the Ghost River Watershed more specifically, will require new approaches, policies, and regulations if their defining natural capital is to be maintained for future generations. These landscapes can no longer be viewed and managed as if they are massive with few people and equally sparse demands. Rather, these east slopes watersheds are remarkably small and vulnerable relative to the pace of industrial and recreational demands being placed upon them.

Now is the time for Albertans to embark on a new grassroots conversation about the destiny of these special headwater basins.

Some General Comments of the Ghost River Watershed Cumulative Effects Project by the External Reviewers

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Across Alberta, communities of interests are forging plans for the landscapes of the future. Fortunately, the Ghost River Watershed has one of those initiatives, fostered by people who realize if you don't know where you're going, any road will take you and the final destination may be a surprise. Unfortunately the Ghost River Watershed has many roads. Some roads are real and others are metaphors for the many directions people think the watershed should head. Without a sense of history, of perspective and of trends we are unable to see following all those roads will not take us to a future of sustainability, watershed integrity and stewardship of shared resources. We use and interact with the watershed in different ways and value it for different reasons. Neither the planning path, nor the watershed can satisfy everyone's interests all the time, everywhere. We have to acknowledge, in our hearts and minds, that limits exist and have been exceeded. Beyond those limits the attributes and functions of the watershed are at risk, many will deteriorate and some will be lost. Cumulative effects modeling uses evidence-based science to help define the limits and allow the setting of thresholds for uses and activities in the watershed. The people that reside, work or play in the Ghost, as well as those who never set foot in the watershed but still value it, need the tools of this report to inform decisions about the future. Like a road, the future isn't just a place we're headed; it can be a place we get to create.

Lorne Fitch is a Professional Biologist, a retired Fish and Wildlife Biologist and an Adjunct Professor with the University of Calgary.

The Ghost River Watersheds' lands, waters, plants, animals and other resources provide an abundance of benefits to Albertans, especially nearby Calgarians. A new study with extensive public involvement and using state-of-the-art modelling clearly shows that people are loving this landscape into decay. Waters that were once clear and productive, healthy forests, abundant wildlife, and other resources, are all headed on a downward spiral. Study results show this does not have to be. Nature can be restored and sustained by adopting identified management strategies. To do this the study shows concerned people must be willing to work together with sustainability as a goal . The Government of Alberta must provide the legislative framework and on the ground management. The Ghost River Watershed can once again shine as a jewel of nature.

Steve Herrero is a retired Professor from the Faculty of Environmental Design, University of Alberta and has completed extensive studies on the ecology and management of grizzly bears.

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10. GLOSSARY

Access Management. An approach to land use whereby spatial and temporal restrictions are imposed on the public or other stakeholders to minimize the adverse effects of motorized or non-motorized activity.

Annual Allowable Cut (AAC). The annual amount of wood harvest authorized to achieve stated wood fiber or landscape objectives. The actual harvest in any given year may exceed or be less than the longterm average AAC.

Anthropogenic. Made by humans.

Backcasting. Simulations addressing historical patterns.

BAU. Business-as-Usual

Buffer. The area adjoining linear or polygonal features that experiences either lower or higher levels of density or activity of wildlife species or ecological function.

INFI. Index of Native Fish Integrity.

Clear-cutting. A form of forest harvest where all, or nearly all, merchantable trees are removed during a single harvest event.

Core Area. That fraction of a forest stand that is interior to a buffer adjoining linear features.

Correction Coefficient. A numerical value that when multiplied by a different value, created an adjusted value.

Driver. An important component of an ecological system that affects the performance of the overall system.

Edge. The length of a land use footprint (such as roads, pipelines, edge of wellpad). It is against the edge of a footprint that buffers are applied.

Edge Density. The amount of landuse footprint edge expressed per unit of area, generally km/km^2.

Engineered Trail Network. An intentionally designed network of trails that minimized adverse effects on ecological indicators and provides safe and enjoyable experiences for users.

Equestrian. People who participate in riding of horses.

Fire Regime. A numerical description of fire, including such metrics as average fire rate, fire return interval, fire size distribution, and pattern of inter-annual fire events.

FMA. Forest Management Agreement.

Forecasting. A simulation event focusing on future events.

Forest Age Class. A terms that describes the distribution of different forest age classes (seral stages)

Forest Cover. A description of the tree species composition of a forest. Term can also refer to the fraction of the stand that is occupied by the canopy of trees.

GIS. Geographic Information System.

Growth and Yield. Values that describe how trees grow in volume or height as they age.

GWAS. Ghost River Watershed Alliance Society.

Harvest Fall-Down. A shortfall, or deficit, in available harvest volume relative to desired or authorized volume.

Hung Culvert. A culvert whose downstream exit is elevated above the average water level of the stream. This situation is caused by incorrectly installed culverts or culverts that are too small relative to flow levels.

Inblock Forestry Road. Permanent or temporary roads constructed within forestry cutblocks for the purpose of removing harvested wood.

In-Block Retention Levels. The fraction of green trees within a forestry cutblock that are not harvested and left as residual green trees.

Land Use Footprint. Anthropogenic (man-made) features associated with land use. Examples include cutblocks and inblock roads (forestry), seismic lines, wellsites, pipelines (energy), farmyards, acreages, towns (settlements).

Linear Feature Disturbance. A land use footprint that is long and narrow such as roads, pipelines, and seismic lines.

Market Instruments. Economic transactions in a market that encourage preferred behavior.

Merchantable Age. The age of a tree that makes it eligible for harvest.

Metrics. Numbers that help define features that are either anthropogenic or natural.

OHRV. Off-highway recreational vehicle

Patch Cutting. A form of forest harvest

Polygon. A GIS term that describes an area of the earth that is relatively homogenous and contiguous.

Population Sink. A breeding group that does not produce enough offspring to maintain itself in coming years without immigrants from other populations.

Pulse Reclamation. A management strategy intended to accelerate reclamation of unwanted land use footprints by intentional pulses of reclamation.

Range of Natural Variation. The natural temporal variation in the performance of ecological indicators in systems characterized only by natural processes.

Riparian. Plant communities close to surface water.

RNV. Range of Natural Variability.

Rotation Age. The average age of forests when harvested. This value equates to the average number of years between successive harvest events on a given forest stand.

SASS. Southern Alberta Sustainability Strategy

Seismic Lines. Long, thin disturbances created by the energy sector to assist in the spatial delineation of hydrocarbon reserves.

Selective Cutting. A form of forest harvest that is not clear-cutting. This approach intentionally retains a significant fraction of green trees within the boundary of a cutblock.

Seral Stage. Group of plants within a successional sequence of similar age.

SLS. Spray Lakes Sawmill

Stakeholder. A person, or group, having a defined interest in the outcome of management decisions.

UBBCES. Upper Bow Basin Cumulative Effects Study.

Watershed. The region draining into a river, river system, or other body of water.

11. APPENDIX A: ALCES® III LANDSCAPE SIMULATION MODEL

ALCES and its companion mapping tool (ALCES Mapper) provide strategic land use planning guidance by examining inter-relationships among the full range of relevant land-use sectors and natural disturbances, and exploring their environmental and socioeconomic consequences at large temporal and spatial scales. ALCES is a stock and flow model built using the Stella modelling platform (www.iseesystems.com). The model was first developed by Dr. Brad Stelfox in the mid 1990's and has gradually expanded in scope to meet the needs of various regional planning initiatives in western North America. The following description provides an overview of ALCES structure and function. More details can be found on the ALCES Group website (www.alces.ca).

To achieve a synoptic view of regional cumulative effects, a wide-range of land uses and ecological processes are incorporated into the model as drivers. The various land uses and ecological processes can be turned on or off depending on the needs of the scenario analysis. For each land use operating in a region, the user defines development rates, the portion of the landscape available for development, and management practices such as the intensity and lifespan of associated industrial footprints. The influence of natural disturbances (fire and insects) and plant succession on landscape composition are also tracked. Hydrological processes are addressed with surface and groundwater modules, and climate change effects can be incorporated by defining temporal changes in natural disturbances rates, successional trajectories, landcover, meteorology and hydrology.

The first-order effects tracked by ALCES are landscape composition and resource production/supply. Using an annual time-step (although monthly time steps can be used for the meteorology module) the model modifies the area and length of up to 20 landcover and 15 anthropogenic footprint types in response to natural disturbances, succession, landscape conversion, reclamation of footprints, and creation of new footprints associated with simulated land-use trajectories. ALCES is a spatially stratified model, meaning that it tracks the area, length, and quantity of each footprint separately for each landscape type. ALCES does not, however, track the explicit geographic location of these features (e.g., latitude and longitude), a feature that greatly speeds up processing time (less than 1 second per simulation year) relative to a spatially explicit modelling approach. ALCES also tracks resource production and supply using approaches that are typical of sector-specific models such as forestry timber supply models. By tracking resource supply, ALCES can reduce or stop the expansion of a land use if resource supply becomes inadequate. Changes to water quantity are also tracked by applying water use coefficients associated with each land use.

Land base composition and resource production attributes are translated into indicator variables using coefficients. A wide range of indicators are available so that trade-offs between diverse ecological and socioeconomic objectives can be assessed. Types of indicators that can be tracked by ALCES include wildlife habitat and populations, water

quality and quantity, biotic carbon storage, air emissions, employment, gross domestic product, and social indicators such as family income and educational attainment.

By applying ALCES Mapper, ALCES tabular and graphical output can be augmented with maps illustrating the plausible future condition of landscapes and indicators. ALCES Mapper is a companion tool to ALCES developed by Alberta Innovates Technology Futures (formerly Alberta Research Council) as an ArcGIS application (www.esri.com). The tool divides the study area into grid cells of user-defined size, and calculates the initial landscape and footprint composition within each cell. Footprint growth and reclamation, landcover change, natural disturbances, commodity production and other variables as reported by ALCES are then applied to each cell, tracked, and displayed spatially. ALCES Mapper allows users to specify the general location (i.e., where specified land-use footprints can or cannot occur) and pattern (e.g., dispersed versus contagious) of future development. This feature provides flexibility to map transformations of landscapes through time according to different spatial rules, and is useful for visualizing the implications of different zoning or resource utilization strategies. Maps of future landscape condition can then be analyzed to evaluate the spatial response of indicators such as wildlife habitat to potential future landscapes associated with land-use scenarios.

To prepare for ALCES® scenario modelling, data must be entered that describe the study area, land uses and other parameters such as climate, water balance and use coefficients, and footprint reclamation rates and trajectories. For this project, assumptions were drawn from previous work conducted by the Upper Bow Basin Cumulative Effects Study, Alberta Environment Southern Alberta Sustainability Strategy, Southern Foothills Study, and Alberta Environment/Alberta Sustainable Resource Development Southern East Slopes Study.

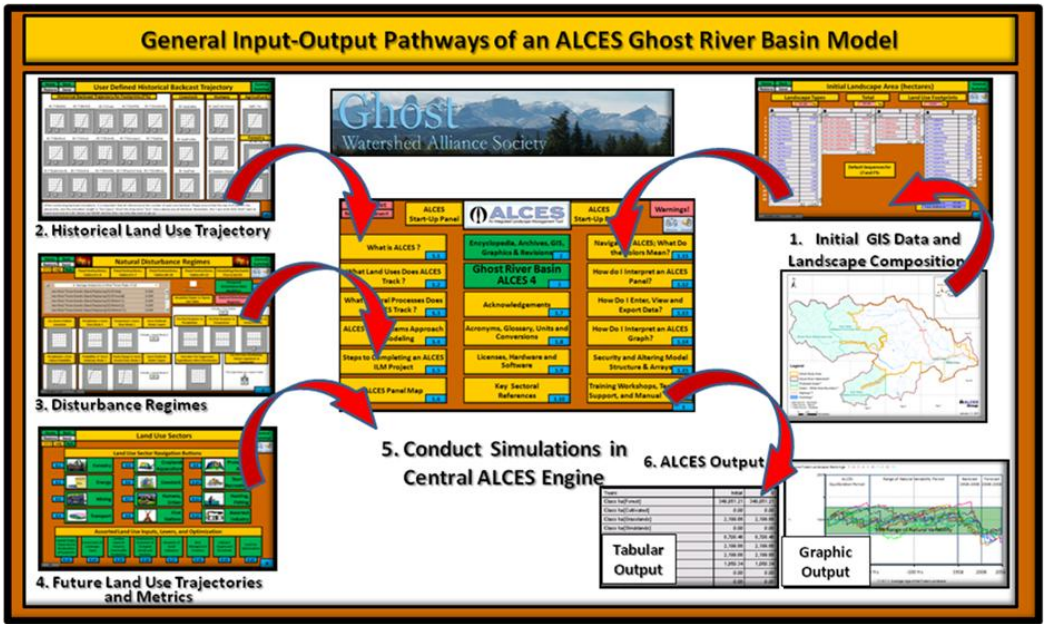

Figure 40. Graphic schematic of overview of ALCES land use simulation model.

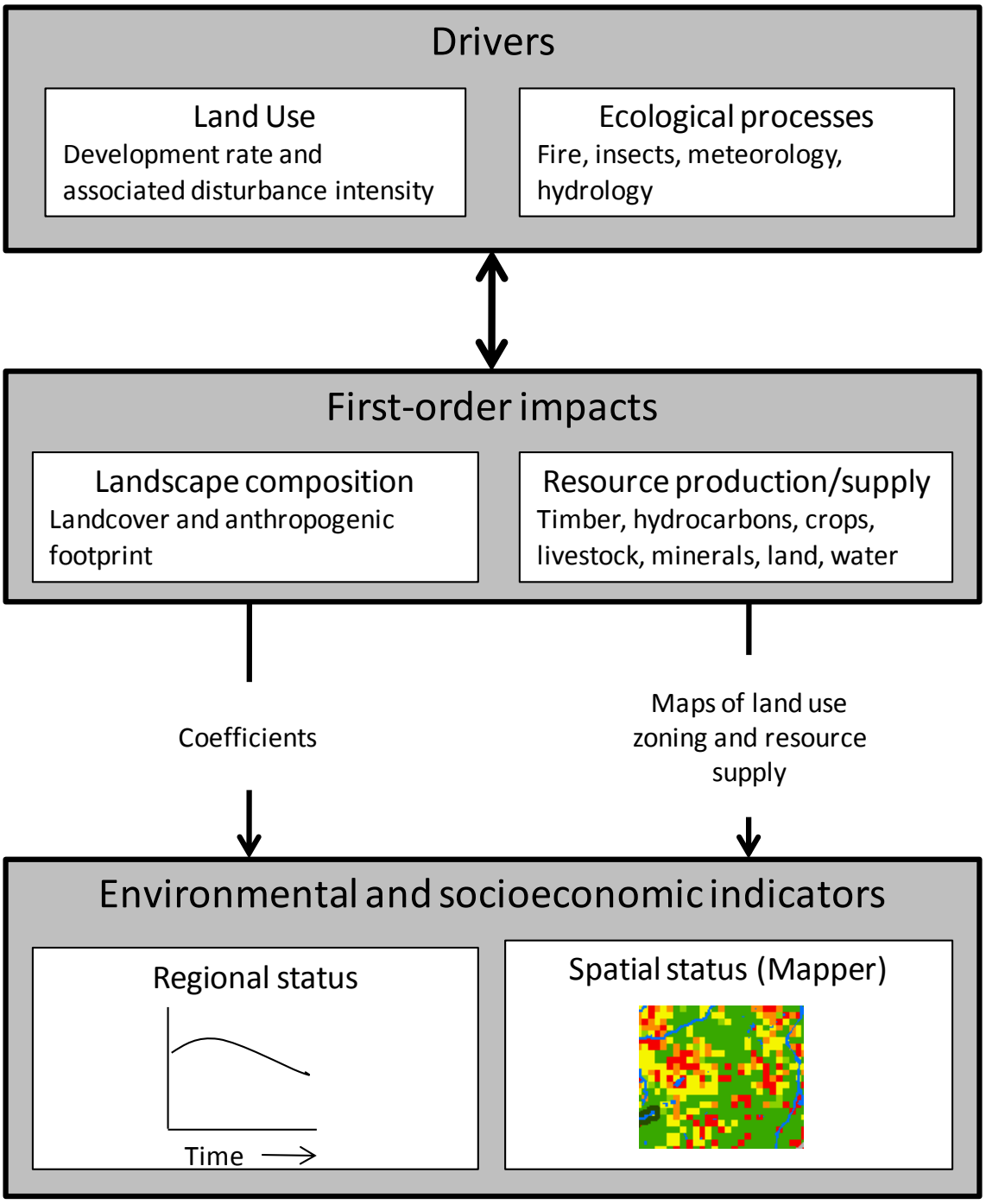

Figure 41. Overview of the ALCES land use simulation tool.

12. APPENDIX B: PHASE 1 (BUSINESS-AS-USUAL) ASSUMPTIONS

GIS Inputs

ALCES® requires three basic GIS data inputs:

Landscape Type (LT) classification – these are the natural, non-anthropogenic landscape classes that characterize the earth surface. The classification is user-defined, and can be derived from any type of spatial information, either raster (classified satellite imagery) or vector (forest cover mapping, etc). ALCES® can utilize a maximum of 20 LTs.

Footprint Type (FT) classification – these are the anthropogenic features/disturbances on the earth surface. The classification is user-defined, and can be derived from any type of spatial information, either raster or vector. Vector GIS data (e.g. .shp, .e00, etc) usually works best for the FT mapping, as linear features and feature geometry are better represented. ALCES® can utilize a maximum of 15 FTs.

Landscape Type age – the time since disturbance age-class of LTs is required to understand age-class related plant community dynamics. This is more critical for Forested LTs, but ALCES® also has the ability to model succession in non-forested LTs.

GIS information developed for the South Saskatchewan Regional Plan area was provided by Alberta Sustainable Resource Development for use by the Upper Bow Basin Cumulative Effects Study /Ghost River. The South Saskatchewan Regional Plan also used the ALCES® model for scenario simulations, so GIS information was already divided into ALCES® -compatible LTs and FTs.

Table 1. Initial landscape and footprint type composition of the Ghost River Study Area.

Landscape Type	Area (ha)	Area (%)	Footprint Type	Area(ha)	Length(km)
Forest Types			Major Road	203	48
Hardwood	514	1.01%	Minor Road	299	203
Mixedwood	180	0.35%	Recreational Trail OHV	646	2059
Spruce	1,976	3.87%	Coal and Gravel	11	
Pine	10,536	20.63%	Industrial / Recreational	226	
Montane	26,095	51.10%	Agricultural Residences	9	
		0.00%	Town City	1	
Other Types		0.00%	Rural Residence	89	
Wetlands	6,412	12.56%	Seismic	217	382
Foothills Fescue	3,024	5.92%	Wellsite	59	
Rock/Ice	210	0.41%	Pipeline	115	87
Reservoir	1	0.00%	Canal	8	4
Lakes	232	0.45%			
River/Stream	1,356	2.66%			
Pasture	529	1.04%			
TOTAL	**51,065**	**100**	**TOTAL**	**1,883**	**2,783**

13. APPENDIX C: RELATIVE WATER QUALITY INDEX

Aquatic health can be measured using various chemical, physical, and biological criteria (North/South 2007). One metric – water quality – was identified as a high priority issue by the Upper Bow Basin Cumulative Effects Study (UBBCES) Steering Committee and the Ghost River Watershed Alliance Society. A survey commissioned for the Southern Foothills Study found that maintaining high water quality was the most important issue for both rural and urban residents of the region (SALTS 2007).

One of the challenges of defining water quality is that it can convey different meanings to different people. For example:

- most **residents** are concerned about the quality and safety of water that comes out of their taps or wells and used for domestic purposes;
- **recreational users and acreage owners** are concerned that water in lakes and streams looks clean, is safe to touch and recreate in, to drink with minimal treatment, and supports healthy plant, fish, and wildlife communities;
- **water and wastewater managers** are concerned that regulated 'point source' water discharge quality (e.g., sewage treatment plants or industrial plant outfalls, Figure 1) complies with drinking, recreational, or aquatic life water quality guidelines and that upstream activities do not inadvertently increase their treatment costs;
- **ranchers and farmers** are concerned about the safety of stock water in dugouts, ponds, and streams; and
- **fish and wildlife managers** are concerned about chronic (long-term low dose) effects of unregulated 'non-point' sources (e.g., runoff from urban areas and agricultural lands, Figure 2) that gradually alter habitat quality, even where short-term water quality guidelines have been exceeded infrequently.

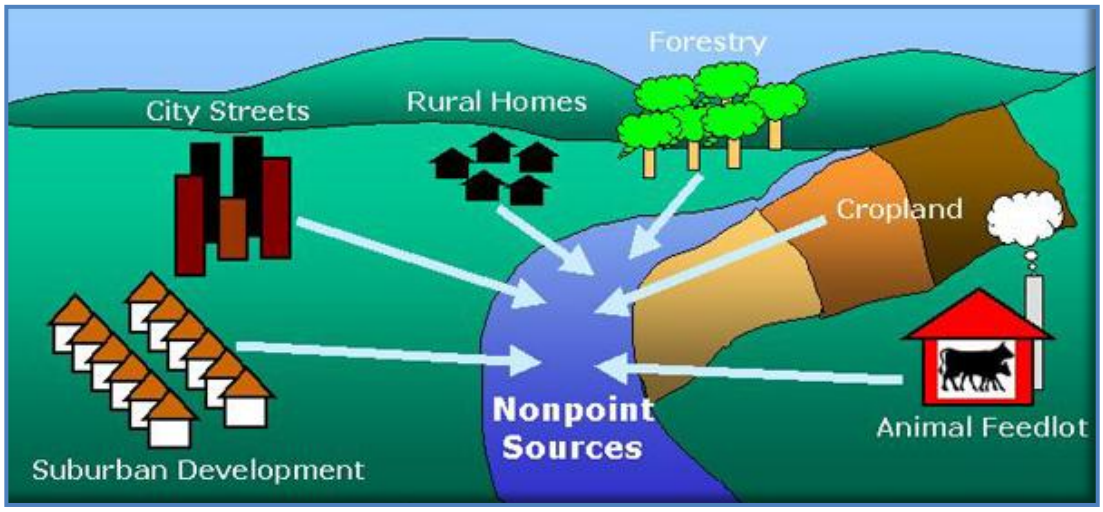

Figure 1. Non-point sources of water pollution (from LCEA nd).

Most definitions of water quality incorporate the instantaneous or average measurements of physical elements (e.g., sediment, temperature), biological inputs (e.g., organic carbon), nutrients, metals, and ions (e.g., nitrogen, phosphorus, chloride), and toxic compounds (e.g., pesticides, trace organics) in a waterbody (river, lake, pond). Instantaneous or average water quality may be affected by both point sources and non-point sources (Figures 1).

The concept of the "Relative Water Quality Index" index', as used in the ALCES landscape simulator, focuses on both non-point and point sources and is based on the principle that equal areas of different landscape types release statistically defined rates of nutrients and sediment that have predictable probabilities of reaching surface waterbodies. As nutrient and sediment emitting landscape types (for example; cultivated crops, roads, settlements, feedlots, acreages) become more common, and absorbing landscape (e.g., riparian vegetation, native grasslands) become less common, loading to surface waters increases in a predictable fashion. The general statistical approach was endorsed by Alberta Environment's (AENV) Southern Alberta Sustainability Strategy (SASS) initiative at a workshop held in June 2003, with participants from AENV (Al Sosiak, Wendell Koning, Pat Kinnear), academia (Dr. David Schindler and Dr. Bill Donahue, University of Alberta), and the ALCES Group (Dr. Brad Stelfox, Dr. Dan Farr).

The 'Relative Water Quality Index', as used in the ALCES model, reflects the relative landscape loading of three water quality parameters: two nutrients (total nitrogen and total phosphorus) and sediment (non-filterable residue or total suspended solids). Increased loadings of these components from landscape changes are negatively and linearly related to overall water quality in this model. In "real-world" situations, however, changes in water quality from increased nutrient and sediment loadings may not be linear but exhibit exponential or asymptotic relationships.

Water quality deterioration has been widely shown to be correlated with landscape and land use features such as forested area and composition, fire history, road density, agricultural extent, urban sprawl, livestock density, and Off-Highway Recreational Vehicle use (Anderson et al. 1998a; Carpenter et al. 1998; Cooke and Prepas 1998; Carignan et al. 2000; Beaudry 2004; Burke et al., 2004; Croke and Hairsine 2006; Clearwater 2006; Ouren et al. 2007; Cows and Fish (no date provided). Although consistent correlations between landscape composition and water quality are reported in the primary literature, it is important to note that landscape composition may not predict water quality accurately at small spatial or temporal scales, where topography or specific precipitation events emerge as better short-term predictors.

Sediment and nutrients were also used as aquatic health indicators in a recent provincial Water for Life assessment (North/South 2007). As stated in that assessment, "These indices are not intended to replace the conventional process of analyzing and interpreting water quality data in detail; rather, they should be utilized as qualitative and complementary assessment tools."

When considered alone, or combined into what we refer to here as our Relative Water Quality Index, total nitrogen, total phosphorus and sediment releases provide a useful measure of relative changes in the regional export of these parameters from the study area over time. The ALCES® model provides the user with the option to adopt one of two approaches:

1. Calculate total nitrogen, total phosphorus and sediment loads or combined loads of the three parameters in the study area relative to average "range of natural variability" loading to forecast relative changes in nutrient and sediment release; or
2. Estimate the portion of total surface nitrogen, total phosphorus and sediment loading that is deposited into waterbodies by including a 'discount' coefficient caused by 1) vegetation types that intercept and deposit nutrient and sediments Corley et al. 1999), or 2) for physical and chemical processes that occur within waterbodies (Wetzel 1975). With this approach, simulated nutrient loads can be calibrated against measured average water quality values to ensure that they reflect historical or current landscape composition.

Option 1 was selected for the UBBCES study because AENV and City of Calgary water managers were concerned that results could be misinterpreted by a non-technical audience. With this option, the Relative Water Quality Index (RWQI) is reported as a value between 0.00 and 1.00, where 1 reflects average natural conditions of RNV, and 0 represents extremely high loading (very poor water quality). An increase loading of 200% of natural conditions would equate to ½ or 0.5 RWQI. In other words, relative water quality is considered to degrade from excellent to poor as values become smaller.

Regional sediment, nitrogen, and phosphorus inputs and outputs were calculated based on water quantity simulations and coefficients defining the rates (tonnes/ha/yr) at which nitrogen, phosphorus, and sediment are exported from various landscape and footprint types. Coefficients used in this study were based on Southern Alberta Sustainability Strategy (SASS) compilation study of Jeje (2003). Nitrogen runoff coefficients for roads were based on Davidson et al. (2010) because these values were not provided in Jeje. Table 1 summarizes the water quality coefficients used in this study to compute relative water quality index.

Nutrient and sediment coefficients derived for South Saskatchewan Regional Plan modeling and results of the CAESAA water quality monitoring program (Anderson et al. 1998a,b; Casson et al., 2008; Jedrych 2008; Lorenz et al., 2008), were also considered at the request of AENV and Alberta Agriculture and Rural Development. Small watershed nutrient export rates documented by the CAESAA water quality monitoring program were lower than those provided in Jeje (2003), and were shown to be correlated with surface runoff rate and landscape characteristics; sediment export rates were not provided. In general, streams in higher agricultural intensity watersheds (based on census data rather than land use metrics) had the highest concentrations of nutrients (Lorenz et al. 2008).

There is no doubt that sediment and nutrient loading for any given catchment or sub-catchment is strongly correlated to the areal water yield, which varies over time from drought to flood conditions. However, there also is no doubt that strong associations exist between loading rates and the various land cover types and landuses with a catchment or sub-catchment. Unfortunately, there have been no detailed assessments in Alberta of sediment and loading rates that quantify the degree to which precipitation, runoff, or water yield affect loading rates. For this reason, anyone who attempts to model the effects of landuse change on water quality is necessarily limited to using values for loading rates that derive from academic and government studies performed in Alberta or elsewhere. For the purposes of this study, we have used loading rates from studies performed in Alberta.

It is arguable that we should be using broader statistical distributions of loading rates for each different landscape or footprint type that would yield a range of water quality index changes that internalizes varying water yields over time. However, the results from our backcasting scenarios are consistent with historical changes in water quality that have been identified and described throughout Alberta, and act as an appropriate calibration test for this approach. It is for this reason that we describe here relative changes in water quality on broad temporal and spatial scales, that are associated with large-scale changes in landuse.

Table 1. Relative water quality loading coefficients used for the Upper Bow Basin and Ghost River Cumulative Effects Studies.

Landscape or Footprint Type	Nitrogen Runoff (tonnes/ ha/yr	Source	Phosphorus Runoff (tonnes/ ha/yr)	Source	Sediment Runoff (tonnes/ ha/yr)	Source
Hardwood Forest	0.00051	foothills parkland from Jeje 2003	0.0000575	foothills parkland from Jeje 2003	0.3049	foothills parkland from Jeje 2003
Mixedwood Forest	0.00051	foothills parkland from Jeje 2003	0.0000575	foothills parkland from Jeje 2003	0.3049	foothills parkland from Jeje 2003
Spruce Forest	0.00275	subalpine from Jeje 2003	0.0002	subalpine from Jeje 2000	0.251	avg forest from Jeje 2003
Pine Forest	0.00275	subalpine from Jeje 2003	0.0002	subalpine from Jeje 2001	0.251	avg forest from Jeje 2003
Montane Forest	0.00275	subalpine from Jeje 2003	0.0002	subalpine from Jeje 2002	0.251	avg forest from Jeje 2003
Prairie Treed / Riparian	0.00051	foothills parkland from Jeje 2003	0.0000575	foothills parkland from Jeje 2003	0.3049	foothills parkland from Jeje 2003
Wetlands	0.00055	from Jeje 2003	0.00001	from Jeje 2003	0.251	avg forest from Jeje 2003
Foothills Fescue	0.00061	from Jeje 2003	0.00011	median from Jeje 2003	0.0621	median from Jeje 2003
Badlands	0.0018	1/2 montane; per Jeje 2003	0.00009	median alpine from Jeje 2003	0.502	twice forest
Rock Ice	0.0018	1/2 montane; per Jeje 2003	0.00009	median alpine from Jeje 2003	0.251	avg forest from Jeje 2003
Reservoir	0		0		0	
Lentic (lakes and ponds)	0		0		0	
Lotic	0		0		0	
Annual Crop	0.0012	from crowfoot crk median, Jeje 2003	0.00032	from crowfoot crk median, Jeje 2003	1.44	S AB, from Jeje
Specialty Crop	0.0012	from crowfoot crk median, Jeje 2003	0.00032	from crowfoot crk median, Jeje 2004	1.44	S AB, from Jeje
Pasture, Forage, Tame Grass	0.0051	avg from Jeje 2003	0.0007525	avg from Jeje 2003	0.457	avg from Jeje 2003
Major Road and Rail	0.01	Davidson et al. 2010, water air soil polln	0.0035	from Jeje 2003	2	SASS - urban from Jeje 2003

Table 1 Relative water quality loading coefficients used for the Upper Bow Basin and Ghost River Cumulative Effects Study (cont).

Landscape or Footprint Type	Nitrogen Runoff (tonnes/ ha/yr	Source	Phosphorus Runoff (tonnes/ ha/yr)	Source	Sediment Runoff (tonnes/ ha/yr)	Source
Minor Road	0.01000	Davidson et al. 2010, water air soil polln	0.00350	from Jeje 2003	2.000	SASS - urban from Jeje 2003
Recreational Trail OHV	0.01000	Davidson et al. 2010, water air soil polln	0.00350	from Jeje 2002	1.000	half major and minor roads
Inblock Roads	0.01000	Davidson et al. 2010, water air soil polln	0.00350	from Jeje 2003	1.000	half major and minor roads
Transmission Lines and Wind Farms	0.01000	Davidson et al. 2010, water air soil polln	0.00350	from Jeje 2003	1.000	half major and minor roads
Mines	0.00860	from Jeje 2003	0.00150	from Jeje 2003	0.869	industrial from Jeje 2003
Feedlot	1.95000	from Jeje 2003	0.25500	median from Jeje 2003	2.000	SASS - urban from Jeje 2003
Industrial Plant\ Recreational	0.00225	from Jeje 2003	0.00795	from Jeje 2003	0.869	industrial from Jeje 2003
Agricultural Residence	0.00152	lawns from Jeje 2003	0.00050	mixed ag from Jeje 2003	0.209	residential from Jeje 2003
Town or City	0.00525	avg from Jeje 2003	0.00123	avg from Jeje 2003	2.000	urban from Jeje 2003
Rural Residential	0.00152	lawns from Jeje 2003	0.00050	mixed ag from Jeje 2003	0.209	residential from Jeje 2003
Seismic	0.00152	lawns from Jeje 2003	0.00019	lawns from Jeje 2003	0.209	residential from Jeje 2004
Wellsite	0.00152	lawns from Jeje 2003	0.00019	lawns from Jeje 2003	0.209	residential from Jeje 2005
Pipeline	0.00152	lawns from Jeje 2004	0.00019	lawns from Jeje 2004	0.209	residential from Jeje 2006
Canal	0		0		1.440	S AB, from Jeje

Note: Please refer to the Upper Bow River Basin Cumulative Effects Study – Phase 1 & 2 Technical Report for citations.[174]

14. APPENDIX D: LINEAR FEATURE CORRECTION METHODOLOGY

Purpose Determine the amount of trails and linear features that were not included in the Government of Alberta GIS dataset used for the Ghost project; to compute a correction factor that reflects extent of over-estimate or under-estimate. Randomly located twenty five 1 km x 1 km polygons (approx 5% of area) throughout the study area.

Step 1. All sampling polygons were randomly located. Karen Manual created a 1 km x 1km grid of the study area, numbered the polygons. Using a random number generator, generated a list of 25 polygons (25 polygons is ~ 5% of the study area. Random numbers generated July 13, 2010 at 12:52:15 by www.psychicscience.org.

Step 2. Overlaid the Upper Bow Basin Cumulative Effects Study / South Saskatchewan Regional Plan GIS dataset - linear features only - over a 2007 Satellite image (2.5 m resolution) of the study area.

Step 3. Digitized the linear features that were evident in the imagery and also included in the GIS dataset, per polygon.

Step 4. Digitized the linear features that were evident in the imagery and NOT included in the GIS dataset, per polygon - these were almost exclusively multi-use OHV trails of 1-3m width.

Step 5. The tab 'linear feature counts' provides the results of the digitization. The tabs ‘pivot' and ‘summary' contain the summarized data.

Step 6. For each polygon, calculated the total km of OHV trails visible and delineated in the satellite imagery but not included in the GIS dataset.

Step 7. The average km per km^2 of linear features and trails under represented is 3.7 km per km^2. This number was applied to the study area for a combined linear density calculation of 5.12 km/km^2

15. APPENDIX E. COMPILED OUTPUT FROM THE MULTI-INVITATIONAL USER FORUMS AND OPEN HOUSE

The compilation of forum comments are provided as a separate pdf file and are available from the Ghost River Watershed Alliance Society.

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