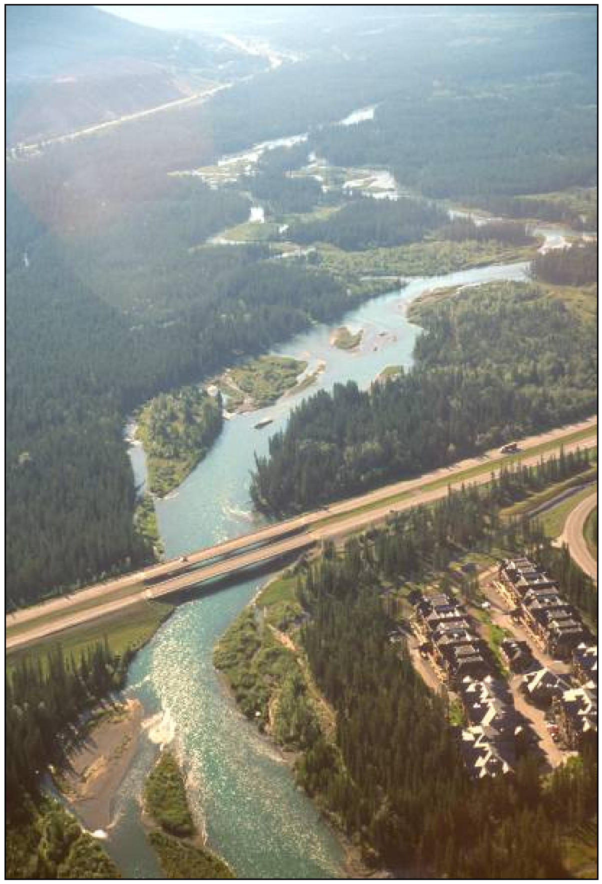
Improving the Ecological Function of the Upper Bow River: Bow Lake to Kananaskis Dam



YELLOWSTONE TO YUKON
CONSERVATION INITIATIVE

Technical Report #4
June 2008

By: Matt Blank and Tony Clevenger

YELLOWSTONE TO YUKON™

CONSERVATION INITIATIVE

Matt Blank, Research Scientist and
Tony Clevenger, Senior Research Scientist
Western Transportation Institute
College of Engineering
Montana State University
and
Yellowstone to Yukon Conservation Initiative

Cover photo by Matt Blank

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YELLOWSTONE TO YUKON
CONSERVATION INITIATIVE

1240 Railway Avenue, Unit 200
Canmore, Alberta T1W 1P4

FOR MORE INFORMATION CONTACT:

Yellowstone to Yukon Conservation Initiative

1240 Railway Avenue, Unit 200

Canmore, Alberta T1W 1P4 Canada

Telephone: (403) 609-2666

Fax: (403) 609-2667

Available for download from http://www.y2y.net

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DISCLAIMER

FOREWORD

by Rob Buffler
Executive Director
Yellowstone to Yukon Conservation Initiative

Rising from glaciers in one of the world's pre-eminent National Parks, the Bow flows clean and cold from the mountains of Banff out onto the high plains of southwest Alberta. It is one of the headwaters of the South Saskatchewan River system, which eventually flows through Lake Winnipeg, into the Nelson River and out into Hudson Bay. Many demands are made on the Bow. It is known as a world class fly-fishing destination, it provides power for hydroelectric generating facilities, and it is a source of Calgary's drinking water, a place for water-based recreation and a source for irrigation that makes possible agricultural activities in a vast area of southern Alberta.

But despite its famous blue colour and its reputation as an angler's paradise, all is not well within the headwaters of this famous river. Once abundant native bull and cutthroat trout have all but vanished from much of the river and its tributaries, and are now relegated to headwater feeder streams and alpine lakes. Portions of the river and some of its tributaries fluctuate dramatically as hydroelectric dams in the watershed hold back then release water for power generation, as Calgary and other Bow River communities sleep and wake each day. Rail and road culverts prevent fish and other water-dwelling animals from moving into tributaries to spawn and feed. Introduced non-native fish (such as rainbow trout – the very species for which the river is famous as a fly fishery) out-compete native species, and road de-icing chemicals pollute the river. In fact, the upper Bow River watershed – including its major tributaries, the Cascade, Spray and Kananaskis Rivers – is one of the most human-altered rivers in the entire Yellowstone to Yukon region.

And it doesn't stop there. The growing population of Canmore and new communities proposed downstream, growing industrialization within the Bow Valley, a changing climate and increasing pressure for water withdrawals will make maintaining the ecological health of the Bow and the fish, people and animals that depend on it even more challenging in years to come.

This study aims to catalogue, assess and understand the biological impacts of these alterations—dams, roads, channelization, culverts, stocked non-native fish, etc. Our goal is to assist stakeholders and river managers to improve their efforts to reverse these human caused impacts. We envision a day when native fish populations are restored and overall ecological integrity returns to this important and beautiful watershed. Informed by a significant collaborative process between government agencies, non-profit conservation groups, and river users, the process used to generate this report gives us hope that many will join together in working to realize the vision of an ecologically healthy upper Bow River.

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EXECUTIVE SUMMARY

In 2006, the Yellowstone to Yukon Conservation Initiative commissioned a review of the known factors affecting native bull and westslope cutthroat trout in the upper reaches of the Bow River. This work was overseen by an advisory committee including representatives of Parks Canada, Alberta Sustainable Resource Development, and commercial river users.

For the purposes of this report, the upper Bow River watershed was divided into three reaches. Each reach was assessed for the factors affecting the health of native bull and westslope cutthroat trout populations. Non-native species introductions and the impacts of highway infrastructure (impassable culverts and alterations to alluvial fan functioning) were identified as the primary factors in each of the three reaches.

Bull trout are ranked as "sensitive" in Alberta and have been under review by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) since 1998. Bull trout originally were found throughout the main stem and major tributaries of the Bow. At the time of writing, bull trout had disappeared from Bow and Hector Lakes, the Spray Lakes, the main stem of the Bow River below Bow Falls and the main stem of the Kananaskis River. Bull trout are negatively impacted by changes to aquatic habitat and flow regimes, loss of habitat connectivity (they need to move upstream to find spawning and rearing habitats), competition from non-native species, hybridization, and over-harvesting.

Genetically pure westslope cutthroat trout populations in Alberta are nationally Threatened (and likely to become endangered if limiting factors are not reversed). Decades ago, this species was found throughout the Bow River drainage, from headwater streams through the main stems and into the prairies. Present distribution is confined to headwater streams. Hybridization is the greatest threat to this fish.

The effects of fish stocking and water-regulation activities have affected more than 41.5% of the flowing waters of the Bow River within Banff National Park. Between 1901 and 1972, more than 17 million fish were stocked to improve recreational fishing within the park. Ten species of non-native fish are now found within the park's boundaries: brown trout, brook trout, rainbow trout, Yellowstone cutthroat trout and lake trout have all been introduced and their hybridized offspring inhabit many of the main stem rivers. Non-native fish compete with native fish for habitat and food. They hybridize to dilute genetic purity and also are thought to destroy bull trout redds (nests).

Restoration projects in fishless lakes inside the Park have proven successful. Where introduced species were removed, native zooplankton species returned or were successfully reintroduced.

As serious as the impacts are within the park, we are able to catalogue them because Parks Canada has done a significant amount of work to inventory fish populations, identify ecological impacts, and take steps to address them. On provincial lands, Alberta has yet to undertake a systematic assessment of the impacts of transportation infrastructure or introduced non-native fish. Hydroelectric power dams and facilities exist on the Cascade, Spray and Kananaskis

Rivers. Dam operations alter daily flow patterns, affecting available habitat and changing water temperatures.

The author recommends a number of areas for further research of factors affecting bull and westslope cutthroat trout:

- determine the distribution of native and non-native species and the genetic structure of each
- develop climate change scenarios specific to the upper Bow River and its major tributaries; model of fish distribution and anticipated changes in response to warming temperatures
- inventory all railroad crossings and complete the road crossing inventory
- quantify the effect of transportation infrastructure on geomorphology
- assess the affects of winter highway maintenance activities on different types of aquatic habitat and organisms
- study the effect of winter water withdrawals on aquatic habitat and fish behaviour, particularly in Reach 2
- assess the effect of roads on hydrologic connectivity
- determine the impacts of the algae *Didymosphenia geminata* on aquatic ecosystems, especially in Reach 2
- assess the effect of the Lac Des Arcs dyke on the aquatic ecosystem and
- quantify the amount of dust (from cement plants) that is reaching the aquatic ecosystem and its effects on organisms and habitat.

A number of potential restoration initiatives were identified that could be implemented across all three reaches of the upper Bow River watershed:

1. Perform an integrity assessment of the watershed study area to identify areas for protection and restoration.
2. Quantify all aquatic barriers, both man-made and natural, and identify the critical barriers that may be limiting access to certain habitat.
3. Assess the effect of climate change on water quality, hydrologic regimes and cold water aquatic habitat; monitor biophysical indicators of change.
4. Study the feasibility of modifying existing dams and operations; assess the potential for improving watershed flow regime as a whole.
5. Identify geomorphic restoration projects and methods that improve the river's access to its floodplain and natural sediment and woody debris inputs; establish natural geomorphic processes within the present constraints of rail and highway infrastructure.
6. Investigate other habitats that intersect road and rail corridors; target specific periods of the year relative to the life histories of bull and westslope cutthroat trout; identify and implement best management practices.

The Yellowstone to Yukon Conservation Initiative and its partners will work toward prioritizing and implementing a number of these research and restoration efforts in the Upper Bow river watershed in the coming years.

1. INTRODUCTION

Aquatic resources across North America have been degraded by human activities. The upper Bow River is an example of an aquatic system that has been affected in a variety of ways. The Bow River rises at Bow Glacier in Banff National Park (BNP), flows south and east through the Hamlet of Lake Louise and the Town of Banff, exits the park and flows through Canmore, before being ecologically isolated from the middle and lower sections of the Bow River by Kananaskis Dam at Seebe, Alberta. The *Banff National Park Management Plan* identifies several major stressors to the river, including landscape fragmentation due to human activity and facilities, loss of habitat connectivity, loss of aquatic and riparian habitats, stream channelization, water regulation, effects of human activities on water quality, and introduction of non-native fish (Parks Canada 1997, 2004). Water regulation activities in over 41.5% of the flowing waters in the upper Bow River watershed in BNP have had dramatic effects on the ecological integrity of aquatic resources (Schindler and Pacas 1996). Other factors that affect the watershed include infrastructure impacts (e.g., impassable culverts), non-point and point source pollution, angling, tourism pressure, and climate change.

1.1. Purpose and Content of Report

The purpose of this project is to improve the information base available to manage the ecological integrity of the upper Bow River watershed upstream of Kananaskis Dam. This report identifies the major factors affecting native populations of bull trout (*Salvelinus confluentus*) and westslope cutthroat trout (*Oncorhynchus clarkii lewisi*) in this watershed. Bull trout and westslope cutthroat trout are considered indicator species of the health of the ecosystem. The report includes a summary of existing data for each of the factors. The report also provides a summary of data gaps, suggested research ideas and restoration projects that could be pursued to improve the state of knowledge about these factors and to restore habitat. By implementing research and restoration projects to improve conditions within the watershed for bull and westslope cutthroat trout, the health of the entire ecosystem will be improved.

For the purposes of this study and based on ecological considerations and discussions with the advisory committee, the watershed was divided into three Reaches: (1) the headwaters of the Bow River (Bow Glacier) to its confluence with Bath Creek, (2) Bath Creek confluence to Bow Falls, and (3) Bow Falls to Kananaskis Dam. Figure 1 shows the boundaries for each Reach.

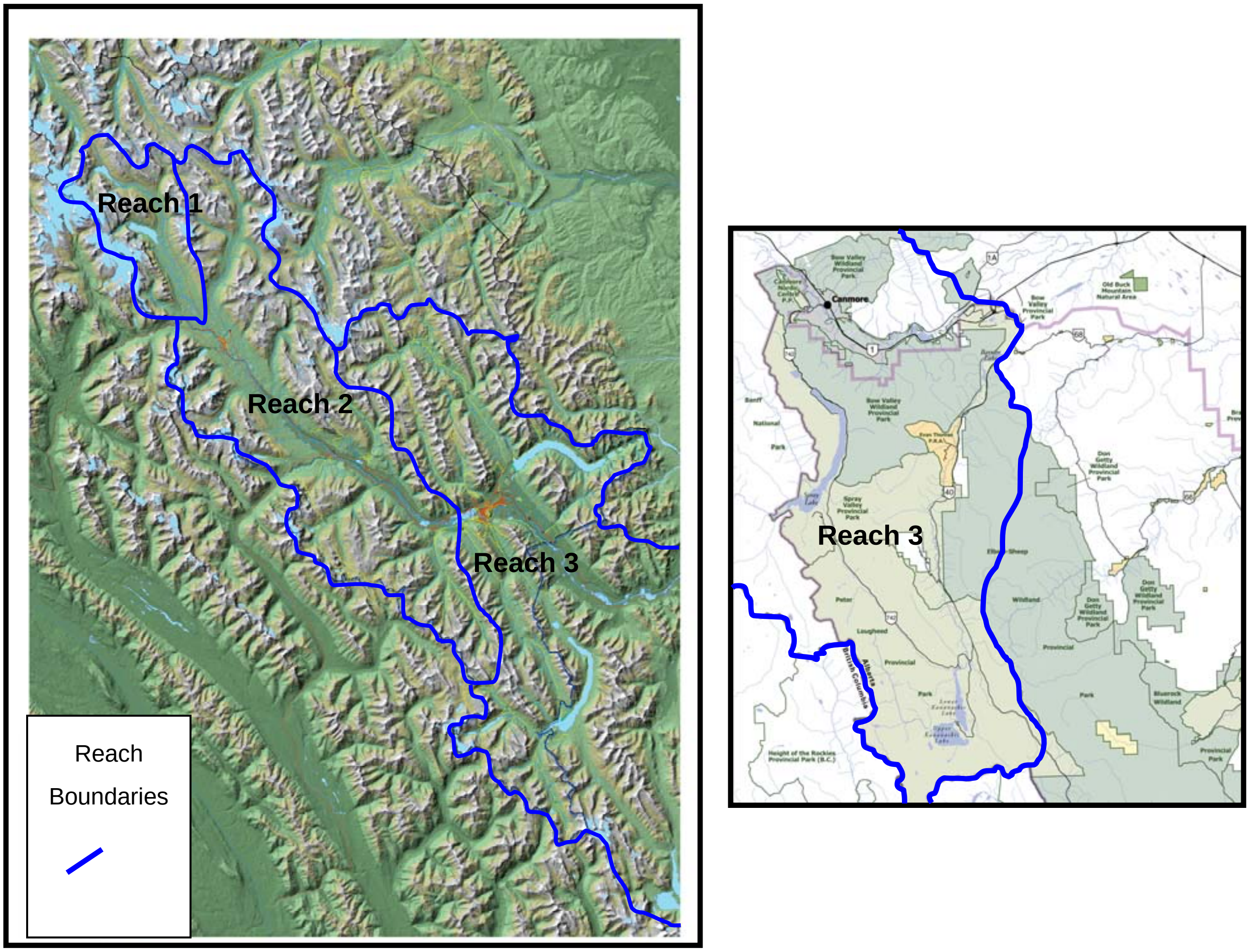

Figure 1: Boundaries for watersheds within each of the Reaches. Base maps provided by Parks Canada and the Province of Alberta.

The reach boundaries were located at significant ecological transitions to the river system. For instance, Bow Falls is thought to be a total barrier to the upstream movement of fish, thus representing an important change to the aquatic ecosystem.

1.2. Objectives

The objectives of this study include the following:

- Summarize the past and current status of bull trout and westslope cutthroat trout populations in the Bow River watershed upstream of Kananaskis Dam
- Identify the factors influencing the distribution and populations of bull trout and westslope cutthroat trout
- Identify existing data and data gaps
- Recommend research/data needs and restoration projects

2. METHODS/APPROACH

This project did not involve any new research; instead it gathered existing information, summarized it, and identified data gaps within that information. Nonetheless, in order to synthesize the best available information, stakeholder involvement was critical to all aspects of this study. Appendix A lists the stakeholders who participated in this effort.

The research approach consisted of two major components. The first involved site orientation and stakeholder meetings to identify the key factors affecting bull trout and westslope cutthroat trout in the Study Area. In June 2006, stakeholders met in Canmore to define Reach boundaries and to discuss their understanding of the factors that affect the Bow River. The outcome of that meeting was the identification and ranking of factors thought to affect populations of bull and westslope cutthroat trout within the Study Area. Factors were ranked according to their perceived severity, with 1 being the highest ranking (larger negative effects) and 2 being the lowest ranking (smaller negative effects).

The second component involved locating and reviewing existing reports and information and summarizing the information, with an emphasis on data gaps in the present state of knowledge. Researchers conducted a data-gathering effort through individual meetings between the Western Transportation Institute (WTI) and selected stakeholders. This effort focused on the identification of available resources and documents that provided the necessary information to perform the data summary.

The prioritization of further research and restoration opportunities that were identified during the data gathering and summarization efforts will be done by Y2Y and affected stakeholders in the near future. To assist with any prioritization efforts, projects were divided into two groups: (1) research/data needs and (2) restoration projects.

3. PAST AND CURRENT STATUS OF BULL AND WESTSLOPE CUTTHROAT TROUT IN STUDY WATERSHED

Native trout species in the Bow watershed study area include bull and westslope cutthroat trout. In addition, lake trout (*Salvelinus namaycush*) are native to Lake Minnewanka (Mayhood 1995). Although it is impossible to know the full extent of bull and westslope cutthroat trout distribution before human infrastructure development, there is evidence that most major drainages and lakes of this watershed supported at least one or both species (Mayhood 1995 and Cavender 1978, Haas and McPhail 1991, as cited in Mayhood 1995).

Although bull and westslope cutthroat trout still occupy portions of their original habitat, their distribution today is only a fraction of their historic distribution. Profound changes in habitat, in-stream flows and the aquatic ecosystem have occurred in the Bow River and its tributaries. One example of dramatic change is exemplified by the Spray River system which, until the construction of hydroelectric power generation plants with dams in the late 1940's, supported a thriving westslope cutthroat trout fishery (Schindler and Pacas 1996; TransAlta 2006). Now, the Spray River system is fragmented by numerous dams, and much of the original stream channel and riverine habitat has been lost to reservoir development. Pure populations of native westslope cutthroat trout exist today only in the uppermost tributaries of the Spray River system (Potvin et al. 2003; Alberta Sustainable Resource Development and Alberta Conservation Association 2006; Pacas 2006).

Several non-native trout species now inhabit the Bow River watershed: brown trout (*Salmo trutta*), brook trout (*Salvelinus fontinalis*), rainbow trout (*O. mykiss*), Yellowstone cutthroat trout (*O. clarki bouvieri*), lake trout (native to some parts and non-native to others) and several hybrid species (Mayhood 1995; Alberta Sustainable Resource Development and Alberta Conservation Association 2006; Post and Johnston 2002).

3.1. Bull Trout

Bull trout are recognized throughout most of their range as vulnerable and were listed as a *Threatened* species in the United States under the *Endangered Species Act* on June 10, 1998 (U.S. Fish and Wildlife Service 2007). Bull trout are ranked as *Sensitive* in the Province of Alberta (Alberta Sustainable Resource Development 2001). "*Sensitive*" is defined as

> *any species known to be, or believed to be, particularly sensitive to human activities or natural events* (Alberta Sustainable Resource Development 2001).

Within Canada and BNP, the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) has not evaluated bull trout yet (COSEWIC 2001).

3.1.1. General Description of Life Histories in the Bow River

Across their entire range, bull trout have three possible life histories including stream resident (or fluvial) populations, lacustrine (lake resident) populations and adfluvial (lives in lakes and spawns in streams) populations (Behnke 2002). The Bow River drainage has populations that exhibit each of these life histories (Mayhood 1995, Post and Johnston 2002, Mushens et al. 2001). Bull trout can have a variety of stream resident forms that include (1) populations that live their entire lives in small headwater streams, often isolated by natural barriers; and (2) populations that live in larger rivers and migrate to smaller tributary streams to spawn (Behnke 2002). The bull trout living in the main stem of the Bow River represent this second form. The bull trout population in lower Kananaskis Lake provides an excellent example of an adfluvial population. This population lives in the lake, and migrates into tributaries such as Smith-Dorrien Creek to spawn (Stelfox and Egan 1995).

3.1.2. Past and Present Distribution

The historic range of bull trout in the study area includes the entire main-stem of the Bow River, starting with tributaries to Bow Lake, as well as many of the major tributaries to the Bow River (Mayhood 1995). Figure 2 shows the historic distribution of bull trout in the study drainage.

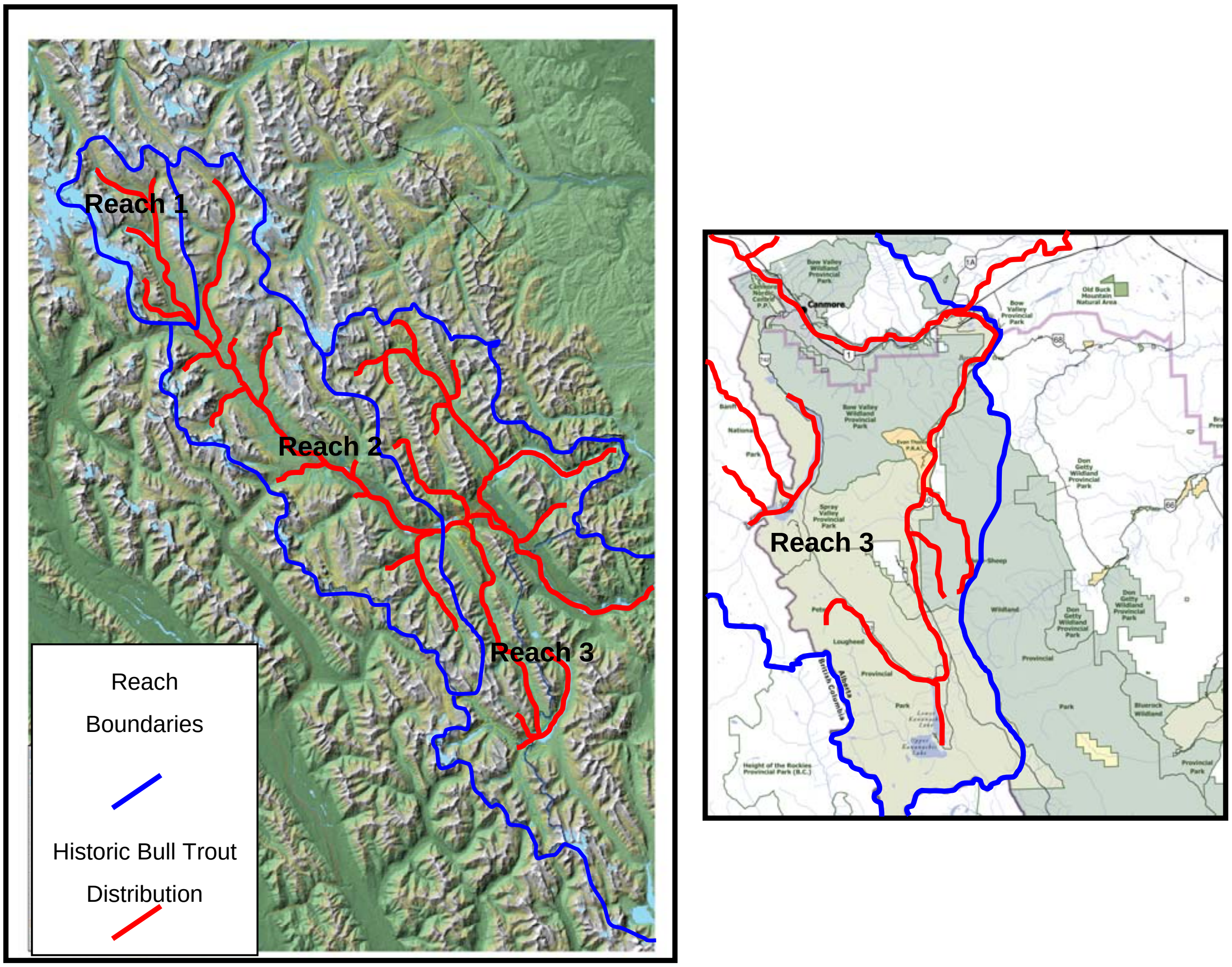

Figure 2: Historic distribution of bull trout in the Study Area. Base maps provided by Parks Canada and the Province of Alberta. Distribution data were modified from Mayhood 1995.

Largely due to anthropogenic factors, bull trout distribution has severely declined in the Bow River drainage (Schindler 2000). Areas that formerly supported bull trout, but which no longer do, include the Spray Lakes, the main-stem of the Bow River below Bow Falls and the main-stem of the Kananaskis River. There are reportedly a few remaining bull trout downstream of Bow Falls (Bell, 2006). Figure 3 shows the present distribution of bull trout in the Study Area.

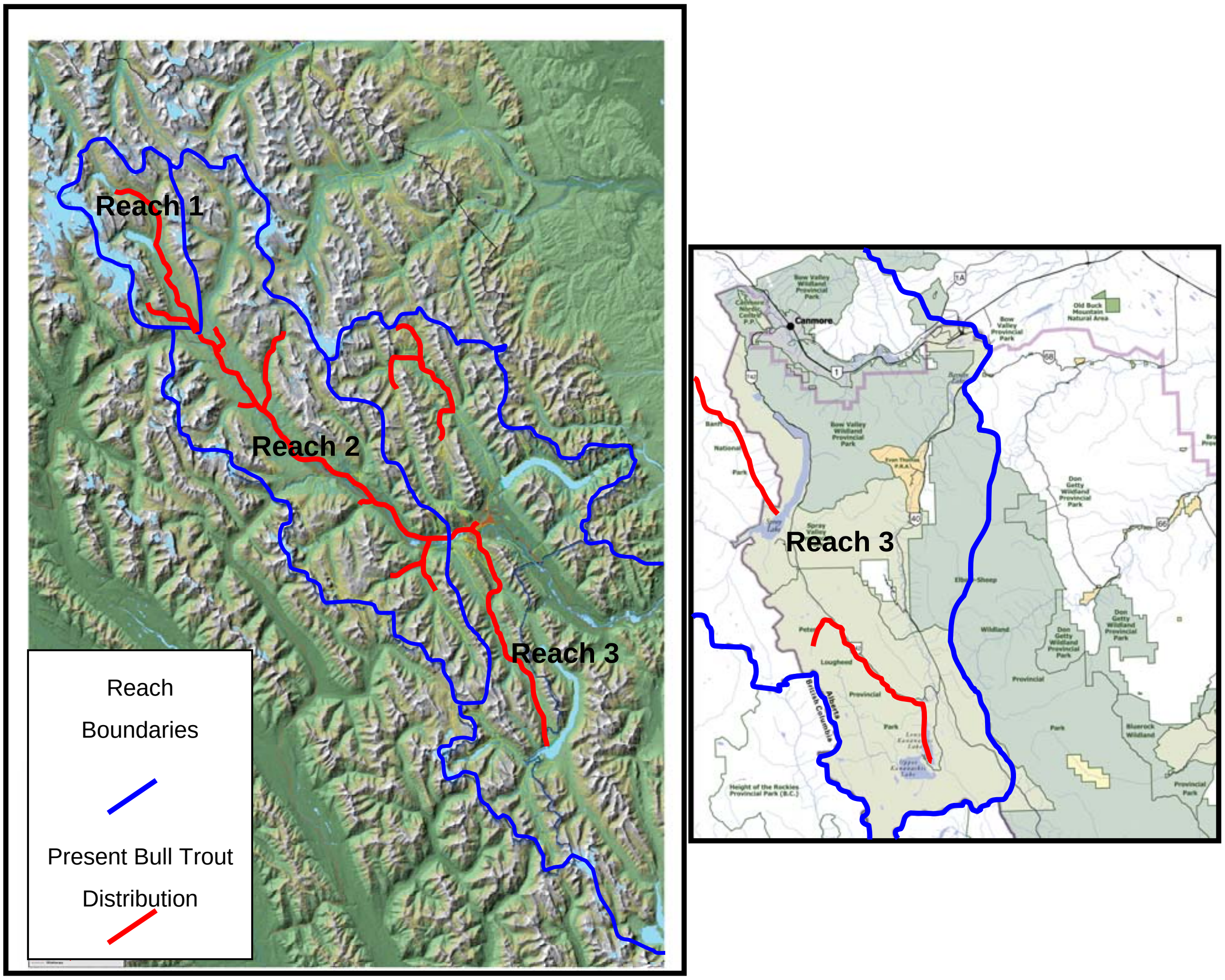

Figure 3: Present distribution of bull trout in the Study Area. Base maps provided by Parks Canada and the Province of Alberta. Distribution data were modified from Mayhood 1995.

3.1.3. Factors Known to Affect Bull Trout

There are several human related factors that have contributed to the decline of bull trout populations across their range and within the study watershed. Some of the more important factors include changes to aquatic habitat and flow regimes, loss of habitat connectivity, competition with non-native species, hybridization and susceptibility to over harvest (Post and Johnston 2002; Behnke 2002; Schindler and Pacas 1996; Bow River Council 2005). Human activities that affect bull trout and their habitat are well documented. Therefore, the following discussion will be brief and will focus on only a few examples that are relevant to the Study Area.

Human developments have degraded the aquatic habitat and connectivity in the Bow Watershed Study Area through damming, highway and railroad infrastructure, and residential and urban developments, to name just a few. Dams are one of the top five stressors in BNP (SOPHA 1999). These dams (Lake Minnewanka and Forty Mile Creek within BNP, and Spray Reservoir on the periphery of the park) have altered the flow regime in 41.5% of the flowing waters in the Bow watershed within BNP (Parks Canada 2004), have completely severed aquatic connectivity (creating barriers to chemical and biological processes) in portions of the study drainage and have dramatically altered downstream habitats by affecting the downstream flux of water and sediment.

Railroads and highways border the Bow River for much of its length both inside and outside the park. These linear features tend to channelize the river in many places, disrupting the natural connections between floodplain and channel, and watershed and floodplain. Woody debris provides important habitat features for bull trout (Muhlfeld and Marotz 2005, Rich et al. 2003). Habitat alterations by urban development and linear infrastructure can limit the supply of woody debris to aquatic systems (Brooks et al. 2003). Linear infrastructure also disrupts the flow of sediment and debris from dozens of alluvial fans that flow into the Bow River (deScally 1999). In addition, road crossings can impede or completely prevent the upstream movement of bull trout, both juveniles seeking rearing habitats and adults. Upstream passage may be even more difficult for adult bull trout during their fall spawning migration, because at that time many streams are at base flow with low water depths that can make upstream passage through culverts particularly difficult.

Over-harvest is a major factor in the decline of bull trout from various portions of their historic range and potentially from the study watershed. Bull trout are late to mature, slow growing and aggressive, making them susceptible to over-harvest and easy to catch (Post and Johnston 2002). Historically, they were considered a nuisance species, and efforts to eradicate them were common and are documented to have occurred as early as the 1920s in portions of their former range (Colpitts 1997).

An example of the effect of over-harvest and the subsequent positive effects of changes to fishing regulations is shown by the population dynamics of bull trout in the Lower Kananaskis Lake. Before 1992, Alberta’s sport fishing regulations allowed the harvest of bull trout over 40 cm in length. Many adults from the adfluvial population of bull trout in Lower Kananaskis Lake spawn in Smith-Dorrien creek, and in 1991, the spawning population was estimated at 60 adults. New regulations imposed in 1992 included a catch-and-release requirement, bait restrictions and the closure of angling in Smith-Dorrien Creek. Over the next several years, the number of spawning adults returning to Smith-Dorrien Creek clearly showed a dramatic increase (Mushens et al. 2001). Figure 4 shows the number of adult bull trout captured in a weir trap in Smith-Dorrien Creek before and after the regulation changes.

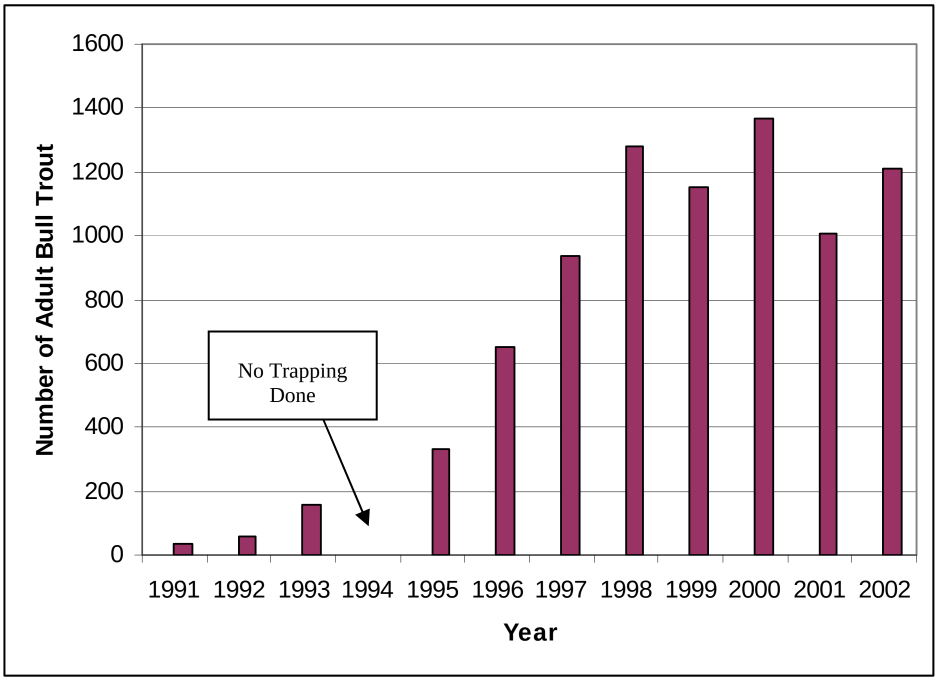

Figure 4: Number of bull trout captured in a weir trap in Smith-Dorrien Creek. Data from the Province of Alberta.

Bull trout populations have been protected from harvest in BNP since 1994.

Competition between and hybridization with non-native fish species is a major factor contributing to the decline of bull trout throughout much of their historic range and portions of the study watershed (Mayhood 1995, Schindler and Pacas 1996, Post and Johnston 2002, Brewin et al. 2001; Schindler 2000). Non-native species of the same genus, such as brook trout and lake trout, have particularly significant effects on bull trout populations. Brown trout can compete with bull trout for habitat and could potentially disturb bull trout redds, because they spawn later than bull trout (Rhude and Stelfox 1997).

3.2. Westslope Cutthroat Trout

In May 2005, COSEWIC designated all genetically pure populations of westslope cutthroat trout living within their native range in Alberta as *Threatened* (DFO 2007). The species is currently being considered for listing under the federal *Species at Risk Act* (SARA). In neighboring British Columbia, COSEWIC designated westslope cutthroat trout as *Special Concern*. *Threatened* is defined as “a species that is likely to become endangered if limiting factors are not reversed” (COSEWIC 2006). *Special Concern* is defined as “a species that may become threatened or endangered because of a combination of biological characteristics and identified threats” (COSEWIC 2006). Westslope cutthroat trout are not listed as a threatened or endangered species in the United States; however, they are a *Species of Special Concern* in Montana (Montana Natural Heritage Program and Montana Fish, Wildlife and Parks 2006).

3.2.1. General Description of Life Histories in Bow River

Westslope cutthroat trout exhibit a variety of life histories. However, two river-resident life forms are commonly observed: one that lives in small headwater streams and a second that moves between smaller tributary streams for spawning and larger main-stem rivers. Another potential life history form is lacustrine and lives in lakes (Behnke 2002). Mixed life history strategies are also common throughout its range (Alberta Sustainable Resource Development and Alberta Conservation Association 2006).

As an example of a westslope cutthroat trout population that exhibited mixed life histories, the Spray River system from the confluence with the Bow River upstream to the headwaters contained a variety of habitats before alterations by dam construction and dam operations. The lower to middle portions of the pre-dammed river contained two lakes: Upper and Lower Spray Lakes. An impassable natural falls divided the lower to middle portions of the watershed from the uppermost part. A study to document westslope cutthroat in the Spray River drainage before the dams were constructed describes four different populations: an upper Spray River population living upstream of the barrier falls, a second population living in the lake and spawning in Buller Creek and Woods Creek, a third population living from Spray falls downstream to within 15 miles of Banff, and a fourth inhabiting the Spray River from the confluence with the Bow River upstream about 15 miles (Miller and MacDonald 1949).

3.2.2. Past and Present Distribution

Prior to the 1900s and the dramatic increase of human activities in the Bow River drainage, westslope cutthroat trout inhabited the drainage from the headwater streams, through the main-stem rivers downstream to the prairie (Mayhood 1999, Mayhood 1995, Alberta Sustainable Resource Development and Alberta Conservation Association 2006). This range was dramatically reduced over the past hundred years to today's present distribution, which occurs mainly in headwater streams where westslope cutthroat trout seem to have a competitive advantage over non-native trout species (Alberta Sustainable Resource Development and Alberta Conservation Association 2006). Figure 5 shows the historic distribution of westslope cutthroat trout in the study area.

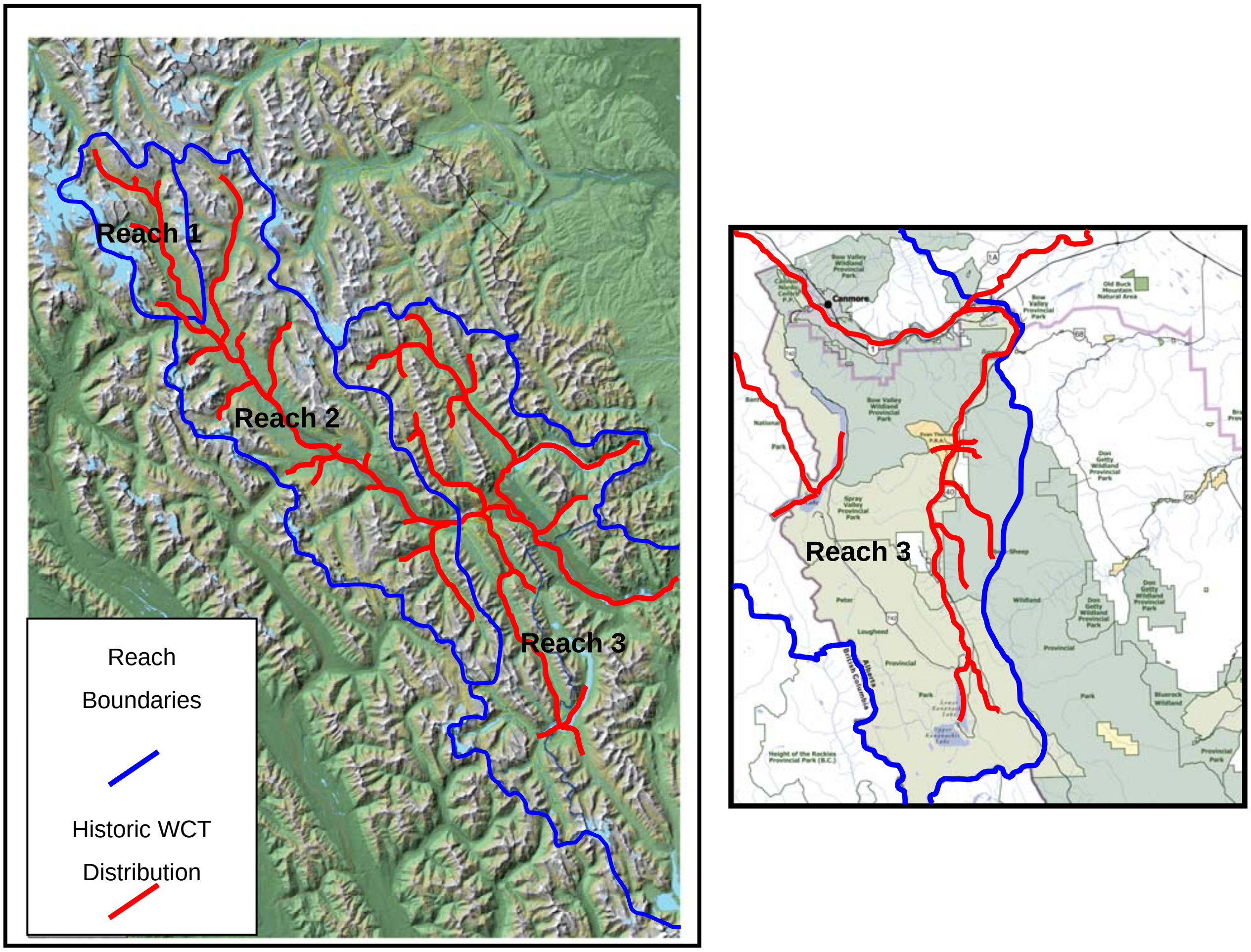

Figure 5: Historic distribution of westslope cutthroat trout in the Study Area. Base maps provided by Parks Canada and the Province of Alberta. Distribution data were modified from Mayhood, 1995.

The present distribution map shows all populations of westslope cutthroat trout including native, introduced and hybridized (Figure 6). (Maps were modified from distribution maps produced by Mayhood for Y2Y in 1995.)

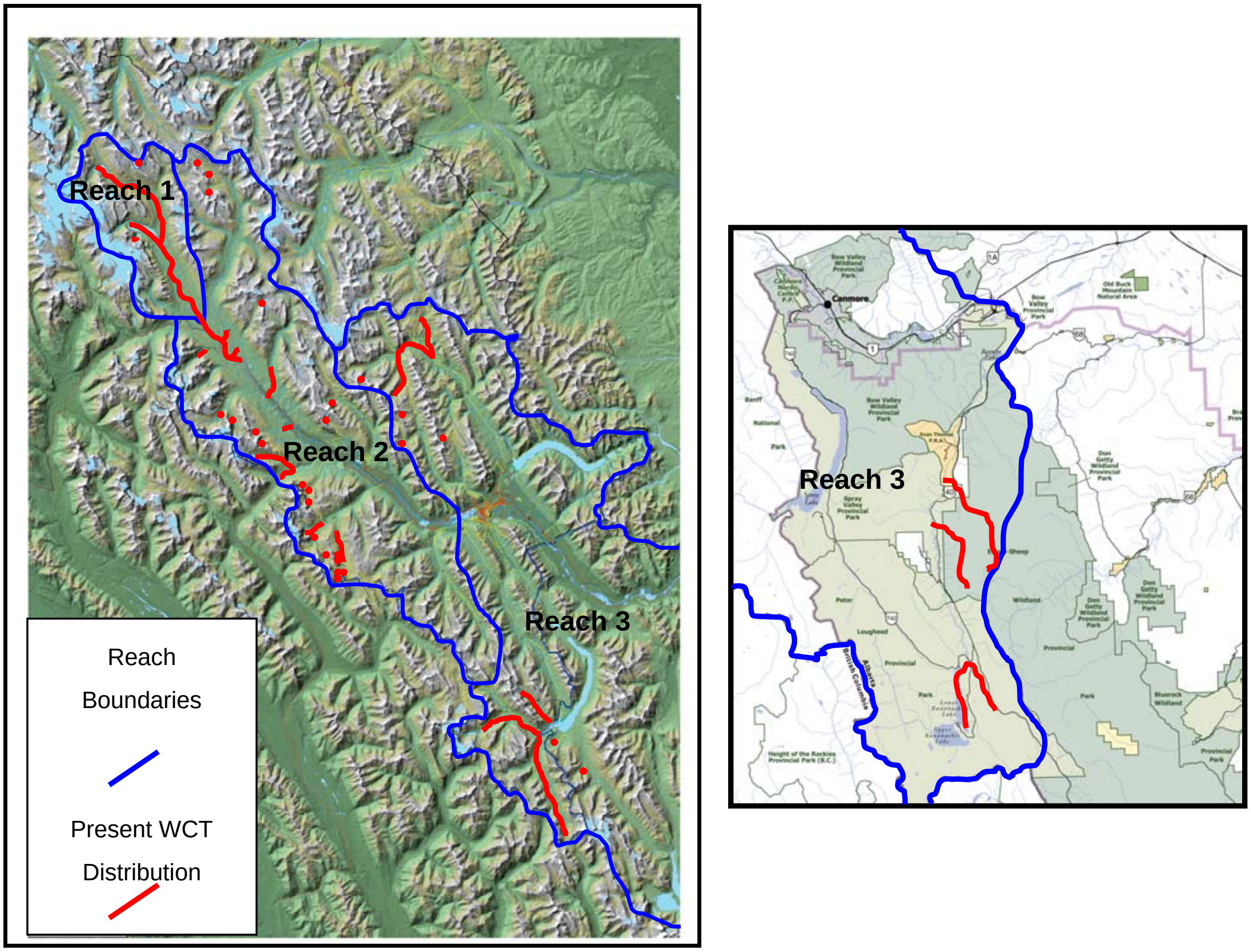

Figure 6: Present distribution of westslope cutthroat trout in the Study Area. Base maps provided by Parks Canada and the Province of Alberta. Distribution data were modified from Mayhood, 1995.

3.2.3. Factors Known to Affect Westslope Cutthroat Trout

Similar to bull trout, factors that negatively affect westslope cutthroat trout include competition from non-native species, especially brook trout, hybridization with non-native species and habitat alteration and degradation (McIntyre and Rieman 1995).

Habitat alteration, such as changes in flow regimes by dam operations and loss of aquatic connectivity through barrier culverts, has negatively affected westslope cutthroat trout. Dam operations change the annual and daily flow patterns in streams and rivers, thus altering available habitat and temperatures. Westslope cutthroat trout typically inhabit cold streams with limited productivity (Behnke 2002). Barrier culverts prevent the movement of westslope cutthroat trout and limit the amount of available habitat. This lack of connectivity could have drastic effects on a westslope cutthroat trout population by eliminating access to upstream spawning areas or juvenile rearing habitats.

Non-native trout such as brook trout compete with westslope cutthroat trout. Brook trout mature more quickly than cutthroat trout and can out-compete juvenile cutthroat trout for food. Other non-native trout like brown trout and lake trout prey on cutthroat trout (Novinger, D.C. and F.J. Rahel 1999). Westslope cutthroat trout are often displaced by non-native trout. In some areas like Yellowstone National Park, the occurrence of brook trout has almost always resulted in the disappearance of Yellowstone cutthroat trout (Varly and Gresswell 1995). Whether this same result applies to the displacement of westslope cutthroat trout by brook trout in the Bow Study Area could be questioned; however, it is a possibility. Schindler and Pacas (1996) indicated that in streams within the Bow River system of BNP where there are sufficient data, rainbow trout occupy 36% of original westslope cutthroat habitat.

Hybridization between westslope cutthroat trout and non-native fish species such as rainbow trout and Yellowstone cutthroat trout is arguably the greatest threat to native cutthroat trout (Allendorf and Leary 1988). The maintenance of genetic diversity is important for the long-term viability of a species (Potvin et al. 2003, Behnke, 2002). Recent studies of the genetic population structure of westslope cutthroat trout in BNP found low within-population genetic diversity; however, the populations were genetically diverse. The study recommended maintaining the independence of each population and minimizing the potential for mixing of populations (Potvin et al. 2003).

4. RANKING OF FACTORS AND EXISTING DATA

The data gathering effort identified many documents with a variety of information related to the factors affecting bull trout and westslope cutthroat trout populations in the Bow River and its tributaries. This part of the report is divided into sections by Reach and provides a summary of the factors affecting the ecological integrity of the watershed along with their perceived rank. The factors are identified relative to their impacts on bull and westslope cutthroat trout, because those species were identified as indicator species for the health of the watershed. To avoid redundancy, some discussions of factors will refer to a discussion of that same factor in another Reach (many factors affect all Reaches).

There are very good previous studies that summarize the factors affecting the Bow River watershed and describe the cumulative impacts to the aquatic ecosystem, in particular, a paper by Schindler entitled “Aquatic problems caused by human activities in Banff National Park, Alberta, Canada” (Schindler 2000) and a report by Schindler and Pacas entitled “Cumulative effects of human activity on aquatic ecosystems in the Bow Valley of Banff National Park” (Schindler and Pacas 1996). Another excellent study is the *State of the Bow River Report* by the Bow River Council (Bow River Council 2005). As an introduction, information from Schindler (2000) and Schindler and Pacas (1996), and related research is summarized in the following paragraphs.

In these two documents, Schindler and Pacas identify several human impacts to surface water systems within BNP. From stocking programs, 10 species of non-native fish are now found in the Park. Between 1901 and 1972, more than 17 million fish were stocked to improve recreational fishing. In many places, this has resulted in reductions (including local extirpations) of native fish populations, including the extinction of one endemic subspecies, the Banff Longnose Dace (*Rhinichthys cataractae smithi*).

The introduction of non-native species of fish and stocking of lakes where fish previously did not occur has negatively impacted other vertebrate and invertebrate life. Numerous small alpine lakes in BNP were stocked with non-native trout species earlier this century in an effort to increase backcountry angling opportunities for park visitors. Unfortunately, the introduced trout frequently severely damaged the native invertebrate communities of the stocked lakes while providing only marginal fisheries (Parker and Schindler 1995). With a change in parks policy, trout stocking ceased and the lake communities were left to evolve without further management influence. A number of stocked lakes have failed to return to their pre-stocked condition, either because the introduced trout populations naturalized or, if the introductions failed, native species of invertebrates had been extirpated.

To assess whether previously fishless, then stocked, lakes can be returned to their pre-stocked conditions, the University of Alberta (Dr. David Schindler and his students) conducted experimental restoration of lakes damaged by fish stocking. In one example, introduced fish species caused the extirpation of the large calanoid copepod *Hesperodiaptomus arcticus* in Snowflake Lake, BNP. In 1992, *H. arcticus* was re-introduced to Snowflake Lake. By 1994, the *H. arcticus* population was beginning to suppress populations of zooplankton that had exploded in its absence (McNaught et al. 1999).

Bighorn Lake, an originally fishless 2.1 hectare (ha), 9 m deep alpine cirque lake with no surface inflows or outflows, was stocked with 2,000 fingerling brook trout and an unreported number of rainbow trout in each of 1965 and 1966. In 1977, stunted brook trout were abundant (mean length of 248 mm) in Bighorn Lake. All of the trout captured during test-netting were either 13 or 14 years old and thus were survivors of the original stocking (Anderson and Donald 1978). Resurveys of Bighorn Lake between 1991 and 1996 revealed that numerous brook trout, including juveniles, were present. After 12 to 15 years, the brook trout population had become self-sustaining.

The University commenced an experimental gill net removal of the introduced brook trout from Bighorn Lake in July 1997 and eliminated brook trout within 3-years. Research on the removal of non-native brook trout from Bighorn Lake indicated the partial recovery of the pre-stocking aquatic invertebrate community (Parker et al. 1996). While *Diacyclops* and *Daphnia* quickly returned to Bighorn Lake following commencement of fish removal, *Hesperodiaptomus* did not. The introduction of 269,000 *Hesperodiaptomus arcticus* to Bighorn Lake in August 2001 is expected to assist in the recovery of the planktonic invertebrate community.

Approximately 41.5% of running waters of the Bow watershed within BNP have been regulated, obstructed, impounded or altered either for generating hydroelectric power, providing water supply or recreation, or building and maintenance of transportation infrastructure. Some of the effects documented from these changes include alteration or obstruction of migration of native fishes, reduced diversity and biomass of bottom living invertebrates, loss of important littoral feeding and spawning areas, and reductions in reach length and available habitat on dammed rivers.

Highly significant reductions in available phosphorous and nitrogen from wastewater discharge have been reported following plant upgrades, despite ever-growing numbers of visitors and the nearly doubling of residents within the Park since 1970 (Pacas 1996). Prior to tertiary upgrades in 1998 (including phosphorus removal), the Lake Louise sewage treatment plant contributed 75% more available phosphorus in the downstream section of the Bow River when compared to that available upstream from the plant. Similarly, using the same calculations, the Banff sewage treatment plant contributed 58% more available phosphorus than that available upstream. The authors recommended basing guidelines regulating nutrient inputs on growth of attached algae instead of concentration of nutrients in the water (e.g., British Columbia: mg of algal chlorophyll per m^2 of bottom area).

Increased phosphorus levels were connected to increased abundance in *Dipteran* larvae at the sewage outfall for Lake Louise (prior to tertiary treatment) and reduced numbers of *Plecoptera* larvae downstream from the sewage outfall for Banff. In addition, increased proportions of larval deformities were documented at the Banff site as well as below sewage and industrial outflows in the Bow River outside the Park. Above the town site and in other pristine areas, the occurrence of such deformities was low. Deformities like these have been linked to agricultural and industrial toxins, suggesting that other substances of concern may be contained in Banff wastewater.

The authors reported sodium and chloride concentrations (within the Bow River) at the eastern Park Boundary 2.4- and 4.1- fold greater, respectively than that found above Lake Louise. They identified two primary sources of sodium and chloride: sewage and road runoff of de-icing agents (e.g., $NaCl$, $CaCl_2$). The annual application of road salt in the Park ranges from 1,500 to 3,500 tonnes and has increased over time since 1983 (based on available information). Road salt is highly soluble and much of it can be expected to reach the Bow River.

Lastly, the authors discuss long-range transport of airborne contaminants. Substances such as mercury and other metals and organochlorines such as toxaphene, DDT, PCBs and the like reach mountain parks via precipitation from polluted air masses and also from melt-water when stored in glacial ice. Though concentrations of these materials in Banff are low, biomagnification in food chains is a concern. An example of this was shown with lake trout from Bow Lake that contained as much as 300 parts per trillion of toxaphene (three times above the Health Canada guideline). Since humans do not rely heavily on lake trout, no restrictions have been initiated regarding consumption. However, there are no efforts to monitor the potential effect on fish-eating birds or mammals.

4.1. Reach 1 - Bow Glacier to Bath Creek

Reach 1 includes the portion of the Bow River watershed from Bow Glacier downstream to its confluence with Bath Creek. The nature of the Bow River downstream of this confluence changes from a high-gradient, fast-flowing stream to a medium-gradient river that is less incised, more sinuous, and more braided. The Pipestone River enters the Bow River just downstream from here and increases the flow of the Bow River by a third. Major lakes in this Reach include Bow Lake and Hector Lake.

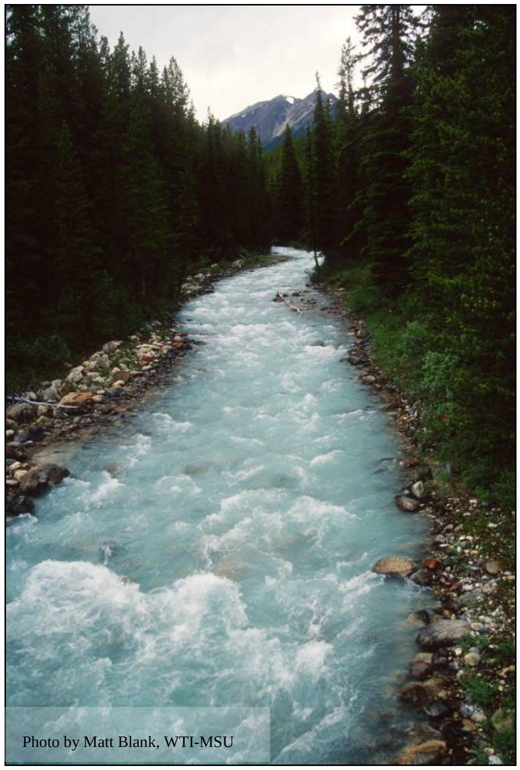

Figure 7: Bath Creek, upstream of the confluence with the Bow River, which marks the downstream boundary for Reach 1.

There are no major towns in this Reach. Transportation infrastructure is light with the railroad cutting along a small portion of the southern edge of the Reach, and only two major park roads.

Table 1 provides a summary of the major factors influencing native populations of bull and westslope cutthroat trout in Reach 1. Non-native fish, climate change and transportation infrastructure were identified as primary factors; water quality and angling as secondary and tertiary factors, respectively.

Table 1: Summary of factors affecting Reach 1

Reach 1 – Bow Glacier to Bath Creek	
Factors Affecting the Ecological Integrity	**Rank**
Non-native Species	1
Climate Change	1
Transportation Infrastructure	1
Water Quality Lodge effluent and day use Atmospheric pollutants	2
Angling	3

4.1.1. Primary Factors

Non-native Species

The Bow River and its tributaries in Reach 1 run clear, cold and relatively nutrient poor. Because of the low productivity, fish populations in this Reach are smaller than in downstream Reaches (Bow River Basin Council 2005). Historically, native fish included bull trout, westslope cutthroat trout and mountain whitefish (*Prosopium williamsoni*). This Reach contains the only known remaining population of westslope cutthroat trout in the main stem of the Bow River (Bow River Basin Council 2005).

Presently, non-native salmonids in this Reach include brook trout, rainbow trout, Yellowstone cutthroat trout, and lake trout. Lake trout were introduced into Bow and Hector Lakes (Mayhood 1995). Brook trout, which hybridize with bull trout and out-compete westslope cutthroat trout, occupy 100% of historic bull trout habitat in this Reach (Schindler and Pacas 1996). During the initial meetings, stakeholders also indicated that white suckers, a fish not native to this Reach, may be present as well.

Climate Change

Climate change is occurring and these changes likely will affect aquatic systems like the Bow River. Globally, temperatures rose 0.6º C during the 20^{th} century (Houghton et al. 2001); however, in Canada changes in climate differed regionally and seasonally during this period (Taylor 2004). The western and southern portions of the country experienced warmer temperatures over the past 50 years, with most of the increase occurring during the colder months of the year and reflected as a rise in minimum nighttime temperatures. Temperatures were actually cooler during this same period for the area around the Labrador Sea (Taylor 2004).

Predictions of the effects of global warming on aquatic habitat in western Canada include rising water temperatures, altered hydrologic regimes and changes in aquatic productivity. These changes likely will affect the abundance and distribution of freshwater fish (Tyedmers and Ward 2001, Chu et al. 2005). One model that predicted the distribution of freshwater fish in Canada, using climate forecasts for 2020 and 2050, predicts that coldwater species may be extirpated and that more warm water species will expand into what was formerly cold water habitat (Chu et al. 2005). This model predicted a 49% decrease in brook trout distribution by 2050, and conversely, that walleye and smallmouth bass may expand throughout much of their present range (Chu et al. 2005). Similar predictions include an estimated 50% loss of coldwater habitat in the Rocky Mountains of the United States for a 3º C rise in mean July air temperatures (Rahel 2002).

The cumulative effects of climate change on cold freshwater habitats are expected to be severe (Schindler 2001). One possible scenario for the upper Bow River includes less storage and volume of water as the Bow Glacier and other headwater glaciers recede, changed timing of severity and occurrence of peak flows, and increased water temperatures. Under this scenario, the aquatic habitat will change because the river will have less energy and scouring flows to build quality habitat, increased temperatures will further stress temperature sensitive species, and water quality will change in part due to a reduced ability to dilute pollutant loads with less flow input to the river.

Transportation Infrastructure

Transportation infrastructure affects aquatic ecosystems in a variety of ways including water quality impacts, hydrologic and geomorphic impacts, and loss or reduction in aquatic connectivity. A thorough discussion of Transportation Infrastructure is included for Reach 2, below. Most of the discussion about Transportation Infrastructure for Reach 2 is relevant to Reach 1. However, Reach 1 has far fewer roads and highways than the other Reaches, and the roads are, on average, much further from the river.

4.1.2. Secondary Factors

Water Quality

Activities in this portion of the watershed that affect water quality include lodge and day use facility effluents, atmospheric pollutants in glaciers and runoff from transportation system activities. A thorough discussion of water quality issues is included for Reach 2.

Reach 1 does not include any towns or major Park facilities; therefore, the amount of wastewater effluent is low in this portion of the watershed.

The release of atmospheric pollutants by receding glaciers is of particular importance to the water quality in this Reach. As previously mentioned, substances such as mercury, organochlorines such as toxaphene, DDT, and PCBs reach the upper Bow watershed via precipitation from polluted air masses and from glacial meltwater. Although concentrations of these materials in Banff are low, biomagnification in food chains is a concern. An example of this was shown in lake trout from Bow Lake, which contained as much as 300 parts per trillion of toxaphene (three times the Health Canada guideline).

4.2. Reach 2 – Bath Creek to Bow Falls

Reach 2 contains the portion of the Bow River watershed from the confluence of the Bow River and Bath Creek downstream to Bow Falls. Bow Falls is thought to be a total barrier to the upstream movement of all fish presently inhabiting the Bow River (Pacas 2006). Developments within this Reach include the Hamlet of Lake Louise and the town site of Banff (which is at the downstream end of the Reach). Three ski areas are located here: Lake Louise Mountain Resort, Sunshine Village Resort and Ski Norquay. Dams on Lake Minnewanka and Forty Mile Creek are located in this Reach. (However, water flows from Lake Minnewanka are directed to the lower Cascade River in Reach 3.)

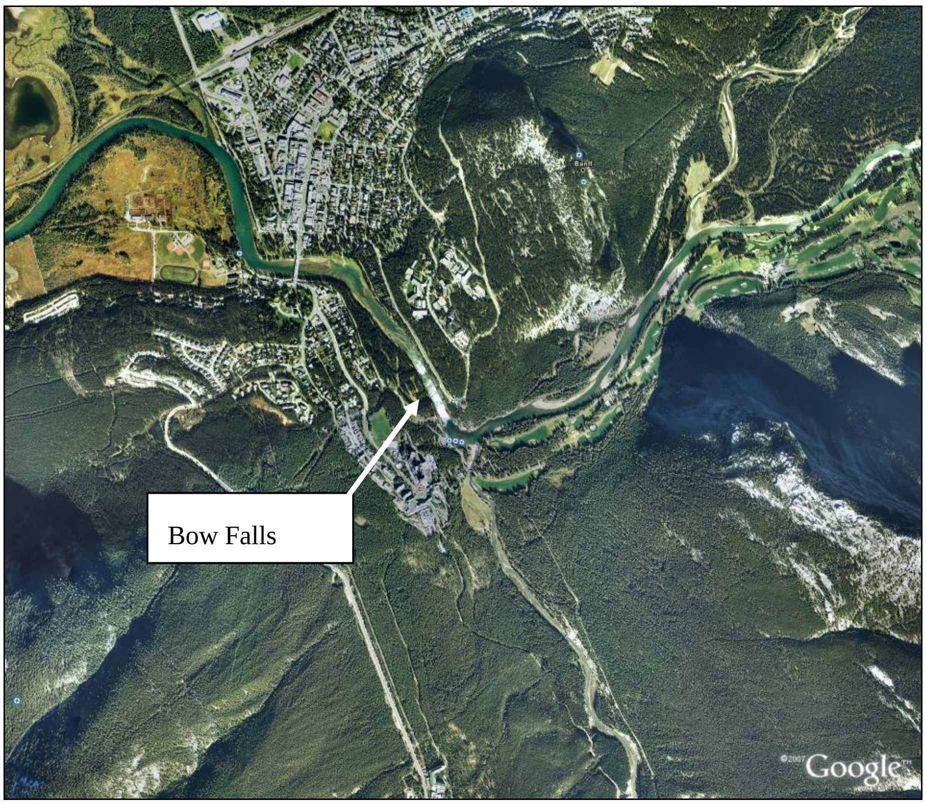

Figure 8: Bow Falls and town of Banff, at the downstream end of Reach 2.

Table 2 provides a summary of the factors affecting Reach 2. Non-native fish, water quantity and transportation infrastructure were identified as primary factors; water quality is a secondary factor; and angling was identified as a tertiary factor. Previously, water quality was identified as a major impact to the aquatic system in this portion of the watershed. Recent upgrades to the wastewater treatment facilities in Lake Louise have improved significantly the water quality in this Reach (Bow River Basin Council 2005; Pacas 2006). Therefore, there now is less concern related to water quality issues in the Bow downstream of the hamlet.

Table 2: Summary of factors affecting Reach 2

Reach 2 – Bath Creek to Bow Falls	
Factors Affecting the Ecological Integrity	**Rank**
Non-native Species	1
Water Quantity	1
Transportation Infrastructure	1
Water Quality	2
Angling	3

4.2.1. Primary Factors

Non-native species

Native salmonids in Reach 2 include bull trout and westslope cutthroat trout as well as mountain whitefish (Bow River Basin Council 2005). Non-native salmonids within this Reach include brown, brook, Yellowstone cutthroat, rainbow trout, and lake whitefish (*Coregonus clupeaformis*), typically introduced to attract anglers, with documented introductions starting as early as 1940 (Schindler and Pacas 1996). White suckers are a non-native fish that also now inhabit this section of the Bow River. There is no evidence that stocked Yellowstone cutthroat trout remain in this portion of the watershed.

Water Quantity

Stream flows have been altered in this Reach by the construction of dams and ski resort activities. The dams are those on Lake Minnewanka, Forty Mile Creek and McNair Pond. The discussion of the Lake Minnewanka dams is included under Reach 3, because their water flows are directed to the lower Cascade River (which is in the adjacent Reach) by these structures. These dams have altered the aquatic habitat and are migration barriers. Ski resorts withdraw water from surface waters for snow-making activities and day use. The amount of withdrawal and the timing of the withdrawals affect stream flows and habitat in creeks with bull trout.

Dams

The original dam at Forty Mile creek was constructed in 1911 to create a water supply source. It was enlarged twice, once in 1913 and a second time in 1949. The dam has not been modified since 1949 and it no longer provides Banff's source of drinking water. The present structure is aging and needs to be either restored or removed in the not too distant future. The structure is presently owned by the town of Banff.

Forty Mile creek has populations of bull trout that may benefit from re-establishing connectivity between the Bow River main stem and the upper reaches of the watershed. Over the past several years there have been proposals to remove the structure and restore the ecological integrity of the watershed. For various reasons, the previous efforts have stalled or been postponed (Pacas 2007).

McNair Pond is an earthen structure that was constructed in the 1960's or 1970's to prevent water from filling a construction borrow pit. The structure is owned by Parks Canada. Prior to damming, the creek was probably fishless; now the impoundment contains non-native brook trout (Pacas 2007).

Ski Resort Water Withdrawals

Ski resorts in this Reach draw water from surface water sources to make snow and to supply other resort needs such as water for day use lodges. The effect of these water withdrawals on bull and westslope cutthroat trout and their winter habitat has been studied in this area. In specific, Skiing Louise, which operates the Lake Louise Mountain Resort, withdraws water from the Pipestone River for snow-making and use at three day lodges. Prior to 1998, it also withdrew water from Corral Creek.

The present agreement between Parks Canada and Skiing Louise allows water for snowmaking between October 15th and April 15th, and water for domestic use is allowed year-round. Water withdrawals for snowmaking operations are allowed only when the discharge in Pipestone River exceeds the 90% exceedence flow[1] (Eagleson 2002). Only the volume of water exceeding the 90% exceedence flow is available for removal, and the amount of water withdrawn cannot exceed 10% of the natural flow in the river. This rule is often referred to as the 10/90 rule which was developed to ensure the water withdrawal would have minimum impacts on aquatic habitats.

Eagleson performed a study to assess the effects of these winter withdrawals on the habitat of the Pipestone River. The approach included detailed measurements of hydraulic, hydrologic and habitat characteristics with modeling using RHABSIM (Riverine HABitat SIMulation).

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[1] "Exceedence" is a way to describe the percentage of time for which an observed stream-flow is greater than or equal to a defined stream-flow. Exceedence is used when stream-flow data are not normally distributed (i.e., on a bell-shaped curve). Most streams flows are not normally distributed because high flow events can skew the data making the mean flow greater than the median flow. Low-flow events have a high exceedence percentage because most of the time, observed flows exceed the low flow. Similarly, high-flow events have low exceedence percentages because most observed flows are lower than the high-flow levels. (Source: http://www.idwr.idaho.gov/nezperce/exceedence_flows.htm)

RHABSIM is a computer program that combines hydrologic, hydraulic and biological criteria and information to estimate the weighted usable area in a river reach. The Pipestone River naturally creates challenging conditions to aquatic life in winter due to the formation of frazil and anchor ice. The study found an overall decrease in available habitat in early winter, the same time period when snowmaking operations are needed most (Eagleson 2002).

Ski Norquay withdraws water following the 10/90 rule from Forty Mile Creek for snow-making activities. A study was recently conducted to assess whether snow-making affects bull trout behavior and habitat. Based on radio telemetry tracking of the movements of bull trout during the winter of 2003/2004, bull trout moved upstream of the water withdrawal intake, suggesting that the withdrawal activities affect bull trout behavior (Bartlett, 2004).

Sunshine Village withdraws water from Healy Creek. The author is not aware of any studies that have been undertaken to examine the effect of these withdrawals on aquatic habitat or species.

Transportation Infrastructure

Roads affect aquatic ecosystems in a variety of ways, including water quality impacts, hydrologic and geomorphic impacts and loss or reduction in aquatic connectivity. Reach 2 contains many roads and rail lines, with major highways on both sides of the Bow River in places.

Water Quality

Road maintenance activities, including the application of sand, salt and other de-icing or anti-icing chemicals to the road surface, can cause detrimental effects to aquatic ecosystems (Marsalek 2003). During winter 1989/1990, about 4,300 tonnes of salt (NaCl) were applied directly (or together with an abrasive substance) onto roads in Banff National Park to provide safe, dry pavement for vehicular travel. The cumulative effect of the application of de-icing salts in Banff is suspected of creating widespread localized damage to conifers adjacent to major highways and secondary roads (Banff Warden Service 1991).

A study of sodium and chloride concentrations in sample plots along rights-of-way was conducted in 1989 and 1990. Tests revealed critical (toxic) levels of sodium in 6 of 8 plots and chloride in 3 of 8 plots. From soil and foliage analysis, salt contamination was extensive at sites along the TCH corridor. At Tunnel Mountain Drive, where de-icing was discontinued, 1990 test results showed that sodium and chloride ions were quickly leached from soil samples (Banff Warden Service 1991).

Trans-Canada Highway road salt contamination of wetlands is suspected in the decline of amphibian populations (Wendeborn 2001). Road salt (at the time writing) used on the TCH is about 97% NaCl with small amounts of other ions. Ten sample sites, including one control, were analyzed chemically and isotopically in 2000. Most sites exhibited no unusual values. However, at least two sites appeared to be impacted by road salt: East Vermilion Lake and the Sunshine Marl Ponds. The amount of road salt runoff that reaches groundwater is a function of the amount of road salts applied, soil permeability, vegetation cover and roadside drainage. These two sites are at or near the bottom of steep, unvegetated or sparsely vegetated slopes. Salt concentrations are negatively correlated with distance from the highway, and depth below the surface. Sodium and chloride ions present in the soils bordering major highways move laterally up to 60 ft and downward at least 45 cm.

Two contributing and possibly confounding factors to estimating the contribution of anthropogenically generated sodium and chloride are evaporation of shallow surface waters and ion exchange caused by weathering processes and groundwater flow. An analysis that accounted for precipitation/evapotranspiration and ion exchange indicates that these two sites are influenced by anthropogenic inputs of sodium and chloride rather than just natural sources. Despite these results, it was concluded that the calcareous nature of the study sites and high rainfall levels and snowmelt may offset the potential for bio-accumulation of road salts (Wendeborn 2001).

A variety of other chemicals originating from road use by cars and trucks may have negative effects on the aquatic ecosystem. Examples of the origin of these pollutants include fuel and exhaust; brake-lining and tire wear; leakage of oil, lubricants and hydraulic fluids; and hazardous material spills (National Research Council 2005). These pollutants are washed from the road surface into the nearby environment during precipitation or snow-melt events.

Hydrologic and Geomorphic

Highway infrastructure changes the natural flow of sediment, water and debris across the landscape (Jones et al. 2000). A study performed in the late 1990s identified 80 alluvial fans between East Gate and Castle Junction (de Scally 1999). Of these 80 fans, 55 extended across transportation corridors, 36 of which possessed active water and sediment transport mechanisms that had been altered to various degrees. Of the remaining nineteen fans that extended across transportation corridors, seven had been altered notably by excavation of fan sediments.

The Five Mile Creek drainage illustrates the magnitude and importance of these changes on aquatic systems. A significant debris flow in 1999 covered almost 200 m of the TCH. Over 40,000 cubic meters of debris, including boulders and trees, had to be removed before normal traffic could be resumed. Current estimates indicate that another 40,000 m^3 are available for transport down the channel and could result in a similar event if conditions were appropriate. To various degrees, transportation infrastructure blocks this material from building alluvial fans or reaching the river. Remedies to the alteration of alluvial fan functions by transportation systems include the construction of larger bridges across the active channel margins of the fans. This type of remedy is expensive and typically occurs when sections of the transportation system are being upgraded.

As previously mentioned, the road system along many sections of the Reach confines the lateral movement of the Bow River. Typically, the riparian area adjacent to roads is confined by large rock (riprap) to stabilize the bank and protect the road from encroachment by the river. Lateral confinement can disrupt the natural movement of the river channel, destroy critical riparian habitat, and change the hydrological flow paths near and in the river channel. Riparian habitat provides several critical functions to a river system including bank stabilization by roots and woody debris, temperature regulation by vegetation, and maintenance of complex habitat that is critically important to a variety of species including fish. Riprap areas are also favoured holding habitat for non-native fish species such as brook trout (Pacas personal communication).

Aquatic Connectivity

Aquatic connectivity is critical for bull and westslope cutthroat trout as well as many other aquatic organisms. Bridges and culverts are used to convey water underneath roads and rail lines. Often these structures are too small to allow the passage of sediment and woody debris, and over time conditions develop that create barriers to the movement of aquatic organisms. Common physical impediments at road and rail crossings include excessive water velocity, insufficient water depth, excessive outlet drop, and debris blockage or damming (Baker and Votapka 1990, Fitch 1995).

Parks Canada has completed an inventory of road culverts within the Bow River watershed within Banff National Park. The inventory measured physical characteristics of the culvert and near-stream reach, such as outlet drop or "hang height", water velocity and water depth. A total of 613 culvert crossings were inventoried within the Park's Bow River watershed (Pacas 2007). In terms of aquatic connectivity, a total of 75 sub-watersheds within the Bow River watershed of BNP are affected by road culvert crossings that are either partial or total barriers to the upstream movement of trout. At the time this report was prepared, the culverts and bridges on the rail lines of this Reach had not been inventoried (Pacas and Humphries 2007). Therefore, the number of sub-watersheds affected by connectivity issues may be higher than the documented 75.

4.2.2. Secondary Factors

Water Quality

The Bow River historically has been an oligotrophic (nutrient poor) river. Water quality in Reach 2 has been affected by human developments for years. Anthropogenic input of nutrients and other changes to water quality in oligotrophic systems like the Bow River can adversely impact their ecological integrity (Bowman 2004).

Wastewater effluent from wastewater treatment facilities in Lake Louise and Banff historically has caused significant negative impacts to water quality. Recent upgrades to treatment facilities in the two communities have proven effective at improving the water quality in the effluents and thus to the Bow River. Sewage treatment facilities that discharge to the Bow River include the Town of Banff, the Hamlet of Lake Louise and Sunshine Village. The treatment plant at Banff has included secondary treatment processes and UV disinfection since 1989 and was upgraded to tertiary treatment in 2003 (including phosphorus removal). At Lake Louise, secondary treatment occurred prior to 2003, when the plant was upgraded to tertiary level (including phosphorus removal). The Sunshine Village ski area includes an effluent aeration plant that has the capability for groundwater injection or discharge to Sunshine Creek (a tributary of the Bow River).

The history of water quality relative to the wastewater treatment plants and their upgrading is quite interesting. An early study, conducted in 1975-6, indicated that the water quality of the Bow and Spray Rivers, and Louise, Sunshine and Forty Mile Creeks in Banff National Park was degraded by human activities. Sample sites located on tributaries of the Bow River downstream of Lake Louise on Louise Creek, Baker Creek and Spray River exhibited elevated levels of total and fecal coliform (likely influenced by discharges from human developments) when compared to the control site located on the Bow River upstream of Lake Louise. Concentrations of total nitrogen and phosphorus exhibited similar spatial trends to the bacteriological parameters – with the highest levels downstream of Lake Louise and Banff town sites and the lowest levels on the Bow River upstream of Lake Louise (Block and Gummer 1979). Effluent from inadequate wastewater treatment was identified as likely being responsible for these spatial patterns.

A group of researchers led by Glozier studied water quality in Banff and Jasper National Parks (Glozier et al. 2004). A consistent result identified in their analysis was the significant improvements to water quality as a result of improvements to wastewater treatment since 1989. This study determined that the existing long-term water quality monitoring program was valuable and sufficient to evaluate water chemistry; however, it was recommended that the program be expanded to include monitoring of biotic densities and community composition (especially periphyton, benthic invertebrates and fish). Additionally, it recommended that contaminant levels in fish should be evaluated on a five-year return frequency.

Bowman has monitored nutrients, algal communities and benthic macroinvertebrates for over 10 years in the Bow River. Data from her work shows the treatment plant at Banff has improved the water quality downstream of the plant to resemble the water quality upstream of the plant. The monitoring data for the wastewater treatment plant upgrade at Lake Louise shows that nutrient levels between the upstream and downstream sampling locations are comparable and stable; however, the other water quality indicators have not shown much improvement in the downstream sampling location at Lake Louise (Bowman 2007).

4.2.3. Tertiary Factors

Angling

Anglers have fished the upper Bow River system since the creation of the Park (Quinn 2002). Today, anglers represent a significant user group for the park, with an estimated 9,000 park fishing licenses sold in 1998 (Quinn 2002). More recent estimates place the number of licenses at ~ 6,000 (Pacas 2007). The Bow River was identified by 57% of respondents to a recent survey of anglers as the most commonly fished water inside the park (Quinn 2002). Lake Minnewanka may see the largest amount of fishing pressure recently (Pacas 2007).

National Parks Policy states that "where fish populations can sustain some harvest without impairing resources, angling may be permitted in designated areas. Regulations will be conservatively based on continuing stock assessments and will conform to the principle that angling is part of an overall aquatics program involving public education, recreation and ecosystem protection" (Canadian Heritage 1994).

Bull trout and westslope cutthroat trout have been protected from harvest in BNP since 1994, and present regulations do not allow the harvest of bull trout in the province of Alberta (Brewin 1999). Harvest restrictions can clearly benefit native species like bull trout, as seen by the dramatic increase in spawning adults in Smith-Dorrien Creek in the Kananaskis system (Stelfox 1995). There is a zero possession limit for bull trout and cutthroat trout in Banff National Park.

4.3. Reach 3 – Bow Falls to Kananaskis Dam

Reach 3 includes the portion of the Bow River watershed from Bow Falls downstream to the Kananaskis Dam. This Reach includes the Kananaskis, Spray, and Cascade River drainages. Anthropogenic factors influencing the watershed increase in this Reach, because of dams on all three rivers and the location of the community of Canmore within it.

Figure 9: Canyon Dam located on the Spray River System, a major tributary watershed to the Bow River in Reach 3. Prior to construction, the Spray River flowed through the channel outlined in the foreground. Currently, 75% of the water is directed toward Canmore.

Table 3 provides a summary of the factors affecting Reach 3. The primary factors include the presence of non-native fish species, water quantity, transportation infrastructure and the Lac Des Arcs dike. This Reach includes several large dams on tributary streams, as well as the first major dam on the main stem of the Bow River. These facilities have drastically altered the natural hydrologic flow regime (Bow River Basin Council 2005). Secondary factors include water quality and surface water-groundwater interaction. Angling is a tertiary concern. Recent upgrades to wastewater treatment facilities in Banff have improved the water quality in this Reach (Bow River Basin Council 2005).

Table 3: Summary of factors affecting Reach 3

Reach 3 – Bow Falls to Kananaskis Dam	
Factors Affecting the Ecological Integrity	**Rank**
Non-native species	1
Water Quantity	1
Transportation Infrastructure and Dike	1
Water Quality	2
Surface Water-Groundwater Interaction	2
Angling	3

4.3.1. Primary Factors

Non-native species

Native fish species within Reach 3 include bull trout, lake trout and westslope cutthroat trout, mountain whitefish, white suckers (*Catostomus commersonii*), longnose suckers (*Catostomus catostomus*), longnose dace (*Rhinichthys cataractae*), brook stickleback (*Culaea inconstans*), burbot (*Lota lota*) and lake chub (*Couesius plumbeus*) (Bow River Basin Council 2005). Non-native salmonids now present in this Reach include brown, brook, and rainbow trout. Yellowstone cutthroat trout were stocked into portions of the watershed within Banff National Park; however, they no longer exist. Provincial records show no stocking of Yellowstone cutthroat trout in provincial waters within the Bow River watershed.

Water Quantity

There are several dams on major tributaries of the Bow River in this section, as well as the Horseshoe hydroelectric plant located on the main stem of the Bow River at the downstream end of this Reach. These structures and their operation have profoundly changed the natural flow regime and aquatic habitat in this Reach (Bow River Basin Council 2005, Schindler 2000, Schindler and Pacas 1996).

The Minnewanka (Cascade River) dam was constructed for hydroelectric power generation in 1942. Three dams were constructed on the Spray River system (commissioned in 1951): Rundle, Spray and Three Sisters. The Kananaskis River system has three dams: the Interlakes Plant, commissioned in 1955, is the uppermost facility; the Pocaterra Plant, commissioned in 1955, sits downstream of Lower Kananaskis Lake; and the Barrier Plant, commissioned in 1947, is located approximately 10 km upstream of the confluence between the Kananaskis River and Bow River (TransAlta 2006).

Damming of rivers has significant negative effects on aquatic systems (Williams 2006). Some obvious, but severe, effects include conversion of moving water habitats to still-water habitats (reservoirs), changes to the flow regime downstream of the dams, reduction in the transport of sediment, woody debris and other important nutrients to downstream reaches, blockage of migration routes (Williams, 2006) and changes in temperature downstream of reservoirs.

Studies to assess the effect of changes to flow releases and dam operations have been conducted on the Cascade River, the lower Spray River, Goat Creek (Spray River system) and the Kananaskis River. The findings from these studies and their recommendations for restoration potential are summarized in the next few paragraphs.

McCleary, and subsequently Godman, investigated the feasibility of restoring aquatic habitat for bull and westslope cutthroat trout by increasing flows in the Cascade River downstream of the main dam on Lake Minnewanka (McCleary 1996, Godman 1999). McCleary studied the effect of increasing the dam release discharge from 1% of the historic flow to 3%. His study showed that this relatively small increase in discharge would not be sufficient to improve the aquatic habitat in the river (McCleary 1996).

As recommended by McCleary, a subsequent study was undertaken by Godman to define minimum in-stream flows that would improve aquatic habitat in the Cascade River. Godman utilized PHABSIM (Physical Habitat Simulation Model) to identify the amount of flow needed to maximize fish habitat. PHABSIM combines an estimation of the hydraulic environment in a river, including water depths and depth-averaged velocities, with habitat preferences for fish. His study found that a steady flow of 1.75 m^3/s would maximize fish habitat in the Cascade River and provide habitat for all age classes of bull trout and cutthroat trout. Benefits to habitat could be achieved by even a modest increase in discharge from 0.2 m^3/s (baseflow) to 0.5 m^3/s. This study also recommends implementing a flushing flow, which simulates flood flows, to scour the river channel, create habitat and improve the riparian environment. The recommended scour flow is 3.5 m^3/s to 5 m^3/s (Godman 1999).

Goat Creek is a tributary of the Spray River that historically supported both bull and westslope cutthroat trout. Presently, it supports a population of non-native brook trout and lake trout. Hydroelectric development drastically changed the flow regime in Goat Creek. In addition, two structural failures on a dike created to divert water at Goat Canal released very large flows (up to 181 m^3/s compared to historic base flows of 4.5 m^3/s) that further degraded the aquatic habitat. A study completed in the late 1990s investigated the potential for restoring Goat Creek. The study recommends removal of non-native fish species and addressing the effects of the unnatural flows created by upstream impoundments. Restoration efforts should focus on restoring natural processes at the watershed scale with an emphasis on structure and function (Tough 2000).

Studies have been completed to assess the feasibility of improving the fishery and aquatic habitat in the Kananaskis River system. Historic dam operations create dramatic daily fluctuations in the river, making recreation difficult and damaging the aquatic resource. Stabilizing the lake level was proposed as a means of improving both the recreation and fisheries in Lower Kananaskis Lake and the Kananaskis River (FREWG, 2007).

There are a couple of small dams in Reach 3 on Johnston Lake. The lake area was most likely a wetland complex before damming. These structures were built to create a lake for recreation purposes. Recreational use of the lake is quite popular today. One structure is entirely built from earth and a second is a combination of earth and concrete. The west end structure failed in the 1980s and was repaired by Parks Canada. The structures are owned by Parks Canada (Pacas 2007).

Transportation Infrastructure

Impacts to the watershed in this Reach from transportation infrastructure include changes to natural geomorphic and hydrologic processes, reduced aquatic connectivity through barrier culverts, and changes to water quality from highway and railway runoff. A specific example that shows the effect of a road on geomorphic and hydrologic processes is Cougar Creek (Figure 10). The road crossing at Cougar Creek is too small and interrupts the natural flow of sediment, debris and water from upstream to downstream across the highway. This disruption starves the downstream aquatic habitat of necessary and important inputs from upstream.

Figure 10: An alluvial fan interruption by Highway 1A and CP Railway

Parks Canada has inventoried most of the road culvert crossings in Reach 3 that are within Park boundaries (Pacas 2007). A complete inventory of crossings in the portion of the watershed outside the Park boundaries has not been completed (Lajeunesse 2007). In addition, there has not been an inventory of the culverts or bridges on the rail lines inside and outside the Park.

The discussion of Transportation Infrastructure for Reach 2 provides further descriptions of its general impacts.

4.3.2. Secondary Factors

Water quality in Reach 3 is affected by discharge from the wastewater treatment plants in the towns of Banff and Canmore, and transportation infrastructure. These factors as they relate to water quality are discussed in the Water Quality discussion for Reach 2.

Didymosphenia geminata

Another potential factor related to water quality is the recent increase in abundance of *Didymosphenia geminata* (commonly referred to as “rock snot”), a diatom native to northern lakes and streams including the Bow River. The diatom can create large mats that cover substrate and affect stream macroinvertebrate and freshwater fish (Elwell 2007). Effects to salmonids include covering spawning habitat, which results in fish seeking other suitable spawning habitat or spawning in marginal habitat. Other fisheries concerns include possible effect of mats on habitats used for rearing by juvenile salmonids (B.C. Ministry of Environment 2007).

Kilroy investigated the diatom in New Zealand. She found that these diatoms occur in oligotrophic (nutrient poor), clear water, in montane or northern boreal streams, and grow attached to stones and plant substrates. *D. geminata* has expanded its range since the mid 1980s, often forming large mats. Little research has been performed to determine the potential impacts of the recent proliferation of this species; however, some work exists from British Columbia and Europe (Kilroy 2004).

Based on studies in British Columbia, benthic macroinvertebrate populations may shift from a diverse community to one dominated by chironimids (the reduced composition of macroinvertebrate species favoured by native fish species to those less favored). These algal mats can prevent the growth of other diatoms favoured by various macroinvertebrates. Where biomass of the diatom was extensive, salmonid parrs were generally absent from normal rearing areas. Possible reasons include gill irritation or clogging from diatom sloughing or changes in food availability. The potential for significant diurnal dissolved oxygen fluctuations exists where large algal mats are present.

Based on studies in the United States, in some streams, the algal mats can cover as much as 90% of available substrates and may extend for several kilometers of stream length. As a result, declines in macro-invertebrate populations cause a decrease in food availability for fish. In some western states, reports of declines in fish populations in some streams have reached 90% (Kilroy 2004).

In general, the effect of this organism on fish and habitat is not very well understood. However, concern is warranted as it seems this diatom could have drastic consequences on habitat and the food web. Also, the conditions that promote the growth of *D. geminata* and the causes for the recent explosion of its occurrence and extent are not very well understood. At present, increased sunlight and low, stable flows are thought to contribute to the proliferation of the diatom (Kilroy 2004).

5. IDENTIFICATION OF RESEARCH AND ACTION NEEDS

The goal of restoration of disturbed ecosystems is to reestablish “pre-disturbance functions and related physical, chemical and biological characteristics” (NRC 1992). Part of the approach includes defining ecological integrity for the degraded system and identifying target species that provide the focus of restoration efforts. In the case of this study, bull trout and westslope cutthroat trout are the target species; therefore, future research and restoration project efforts should focus on quantifying and understanding the factors affecting their populations and the actions necessary to restore healthy populations of these species within the watershed.

Tables 4, 5 and 6 provide a summary of the factors that are affecting each Reach, a brief description of the available data for each factor, research/data needs and restoration project recommendations. Information in these three tables was used to create a summary list of research/data needs and restoration projects (Table 7). Table 7 also includes research/data needs and restoration projects suggested by stakeholders in a meeting held in Banff on October 26, 2007. Table 7 may be helpful for future prioritization efforts. The order of projects in Table 7 is random.

The primary factors affecting the ecological integrity of all three Reaches are similar, with non-native fish species and highway infrastructure identified as primary factors in each. In addition, alteration of habitat and hydrologic regimes by dams affects habitat and bull and westslope cutthroat populations in Reaches 2 and 3. Several research themes that could be implemented across all three Reaches are provided in section 6.

Table 4: Factors, Research/Data Needs and Restoration Projects for Reach 1

Factor	Data	Research/Data Need	Restoration Project
Non-native Fish Species	There is present data on the distribution of native and non-native fish in this Reach.	Continue to document the distribution of native and non-native fish in this Reach, and investigate the genetic structure of both native and non-native fish populations. Continue to research and experiment with restoration techniques aimed at re-establishing the original aquatic communities in lakes and streams in this Reach.	Depending on the distribution of native and non-native fish species, the setting (both physical and biological) and management considerations, implement restoration of native populations. Restoration efforts may require the removal of existing populations using piscicides (a pesticide targeted to fish) or other means and/or the construction of barriers to ensure the preservation of native fish populations.
Climate Change	There is limited data that specifically addresses the present and future effect of climate change on aquatic resources.	Develop climate change scenarios that are specific to upper Bow River and important tributaries. Monitor biophysical indicators of change within the upper Bow River and important tributaries. These indicators should include thermodynamic characteristics, biological indicators, water quality characteristics and flow regime changes. Develop models of the distribution of the freshwater fish in the upper Bow River and anticipated changes.	
Transportation Infrastructure	Aquatic Connectivity – an inventory of road crossings began in 2006 and a culvert working group has been created.	Inventory all railroad crossings on aquatic systems. Continue to inventory all road crossings in this Reach. Characterize the degree to which each structure allows or obstructs fish passage. Develop a prioritization model to identify and rank crossings that should be replaced, retrofitted or allowed to remain. Monitor the effectiveness of new crossings and improved crossings.	Depending on the results of the prioritization and management considerations, remove and replace barrier culverts and retrofit structures to improve passage.
Transportation Infrastructure	Geomorphic Impacts – not much specific information is available about the geomorphic impacts of transportation infrastructure in this Reach.	Quantify the effect of transportation on geomorphology in this Reach. What is the linear extent of road/stream interactions? What types of bank stabilization have been employed? What methods are available to provide both aquatic habitat and protection for the road in this climate and setting? What alternatives are there for rip-rap and hard bank stabilization techniques? How well do they work?	

Factor	Data	Research/Data Need	Restoration Project
Transportation Infrastructure	Water Quality – not much is known of the effect of winter maintenance activities (sanding, salting, snow removal, etc.) on aquatic habitat in this Reach. In addition, little is known about the effect of highway runoff on the aquatic system.	Perform a study to assess the effects of winter maintenance activities on different types of aquatic habitat and organisms in this Reach. Perform a study to assess the effect of highway runoff on the aquatic habitat and organisms in this Reach. Monitor the effectiveness of Best Management Practices at treating highway and storm water runoff.	
Transportation Infrastructure	Hydrologic Effects – not much specific information is available on the effect of roads on hydrologic connectivity, especially subsurface flows and surface-groundwater interactions.	Perform a study to assess the effect of roads on all levels of hydrologic connectivity.	

Table 5: Factors, Research/Data Needs and Restoration Projects for Reach 2

Factor	Data	Research/Data Need	Restoration Project
Non-native Fish Species	There is present data on the distribution of native and non-native fish in this Reach.	Continue to document the distribution of native and non-native fish in this Reach, and investigate the genetic structure of both native and non-native fish populations. Continue to research and experiment with restoration techniques aimed at re-establishing the original aquatic communities in lakes and streams in this Reach.	Depending on the distribution of native and non-native fish species, the setting (both physical and biological) and management considerations, implement restoration of native populations. Restoration efforts may require removal of existing populations using piscicides or other means and/or the construction of barriers to ensure the preservation of native fish populations.
Water Quantity	Studies of water withdrawals for snow making activities show potential detrimental effects to aquatic habitat and behavior of key indicator species.	Additional study on the effect of winter water withdrawals on aquatic habitat and fish behavior may be necessary; however, the present data suggest the withdrawal activities are causing changes to winter habitat and behaviour.	Change water withdrawals from surface water sources to groundwater sources. Try to ensure that the selected groundwater source does not have a zone of influence that intersects critical surface water habitat.
	Past studies suggest removal of the dam at Forty Mile creek to restore natural flows, increase aquatic connectivity and improve aquatic habitat.		The effort to remove the dam on Forty Mile creek and rehabilitate the stream should be pursued.
Transportation Infrastructure	Aquatic Connectivity – an inventory of road crossings began in 2006 and a culvert working group has been created.	Inventory all railroad crossings in this Reach. Continue to inventory all road crossings in this Reach. Characterize the degree to which each structure allows or obstructs fish passage. Develop a prioritization model to identify and rank crossings that should be replaced, retrofitted and allowed to remain. Monitor the effectiveness of new crossings and improved crossings.	Depending on the results of the prioritization and management considerations, remove and replace barrier culverts; and retrofit structures to improve passage.
Transportation Infrastructure	Geomorphic Impacts – not much specific information is available on the geomorphic impacts of transportation infrastructure on the stream channel in this Reach. The effect of the transportation system on alluvial fans in this Reach is fairly well documented.	Quantify the effect of transportation on geomorphology in this Reach. What is the linear extent of road/stream interactions? What types of bank stabilization have been employed? What methods are available that provide both aquatic habitat and protection for the road in this climate and setting? What alternatives are there for rip-rap and hard bank stabilization techniques? How well do they work?	Work with Parks Canada and Transport Canada to provide natural function for alluvial fan movements across the transportation network. Work with Canadian Pacific to provide natural function for alluvial fan movements across the transportation network.

Factor	Data	Research/Data Need	Restoration Project
Transportation Infrastructure	Water Quality – not much is known about the effect of winter maintenance activities (sanding, salting, snow removal, etc.) on aquatic habitat in this Reach. In addition, little is known about the effect of highway runoff on aquatic system.	Perform a study to assess the effects of winter maintenance activities on different types of aquatic habitat and organisms in this Reach. Perform a study to assess the effect of highway runoff on the aquatic habitat and organisms in this Reach. Monitor the effectiveness of Best Management Practices at treating highway and storm water runoff.	
Transportation Infrastructure	Hydrologic Effects – not much specific information is available about the effect of roads on hydrologic connectivity, especially subsurface flows and surface-groundwater interactions.	Perform a study to assess the effect of roads on all levels of hydrologic connectivity, not just flowing surface waters.	
Water Quality	Presently, there is very little information related to the effects of *Didymosphenia geminata* ("rock snot") on the Bow River aquatic ecosystem.	A study to determine the effect of *D. geminata* on the aquatic ecosystem should be completed. A second study should be undertaken to understand the factors that promote the growth of this diatom in this watershed.	

Table 6: Factors, Research/Data Needs and Restoration Projects for Reach 3

Factor	Data	Research/Data Needs	Restoration Projects
Non-native Fish Species	There is present data on the distribution of native and non-native fish in this Reach.	Continue to document the distribution of native and non-native fish in this Reach, and to investigate the genetic structure of both native and non-native fish populations. Continue to research and experiment with restoration techniques aimed at re-establishing the original aquatic communities in lakes and streams in this Reach.	Depending on the distribution of native and non-native fish species, the setting (both physical and biological) and management considerations, implement restoration of native populations. Restoration efforts may require removal of existing populations using piscicides or other means and/or the construction of barriers to ensure the preservation of native fish populations.
Water Quantity	Several studies have identified measures that could be taken to improve the aquatic habitat of the tributaries with dams.	There is a lot of research that could be completed with regards to the effect of the dams and their operations on aquatic habitat; however, the existing studies provide good recommendations for improving the conditions.	Work with TransAlta to identify the proposed changes to their dam operations that are acceptable and that would provide the greatest benefit to the aquatic ecosystem.
Transportation Infrastructure	Aquatic Connectivity – an inventory of road crossings began in 2006 and a culvert working group has been created.	Continue to inventory all road crossings in this Reach. Characterize the degree to which each structure allows or obstructs fish passage. Develop a prioritization model to identify and rank crossings that should be replaced, retrofitted and allowed to remain. Monitor the effectiveness of new crossings and improved crossings.	Depending on the results of the prioritization and management considerations, remove and replace barrier culverts; and retrofit structures to improve passage.
Transportation Infrastructure	Geomorphic Impacts – not much specific information is available on the geomorphic impacts of transportation infrastructure to the stream channel in this Reach. The effect of the transportation system on the alluvial fans in this Reach is fairly well documented.	Quantify the effect of transportation on geomorphology in this Reach. What is the linear extent of road/stream interactions? What types of bank stabilization have been employed? What methods are available that provide aquatic habitat and protection for the road for streams in this climate and setting? What alternatives are there for rip-rap and hard bank stabilization techniques? How well do they work?	Work with TCH to provide natural function for alluvial fan movements across the transportation network. Work with the railroad to provide natural function for alluvial fan movements across the transportation network.
Transportation Infrastructure	Water Quality – not much is known on the effect of winter maintenance activities (sanding, salting, snow removal, etc.) on aquatic habitat in this Reach. In addition, little is known about the effect of highway runoff on the aquatic system.	Perform a study to assess the effects of winter maintenance activities on different types of aquatic habitat and organisms in this Reach. Perform a study to assess the effect of highway runoff on the aquatic habitat and organisms in this Reach. Monitor the effectiveness of Best Management Practices at treating highway and storm-water runoff.	

Factor	Data	Research/Data Needs	Restoration Projects
Transportation Infrastructure	Hydrologic Effects – not much specific information is available on the effect of roads on hydrologic connectivity, especially subsurface flows and surface-groundwater interactions.	Perform a study to assess the effect of roads on all levels of hydrologic connectivity, not just flowing surface waters.	
Lac Des Arcs Dike	Little data exists that quantifies the effect of the dike on the aquatic ecosystem.	Perform a study to assess the effect of the dike on the aquatic ecosystem.	
Water Quality	Presently, there is very little information related to the effects of *Didymosphenia geminata* ("rock snot") on the Bow River aquatic ecosystem.	A study to determine the effect of *D. geminata* on the aquatic ecosystem should be completed. A second study should be performed to understand the factors that contribute to the growth of this diatom.	
	The concrete plants in this Reach create a large amount of dust that potentially could have detrimental effects on aquatic habitat in this Reach.	Perform a study to quantify the amount of dust that is affecting the aquatic ecosystem in this Reach and characterize its effect on the organisms and habitat.	Work with the concrete plants to curb the amount and extent of dust pollution.

Research/Data Needs	Restoration Projects
Continue to document the distribution of native species and their genetic purity in all Reaches.	Remove, replace or retrofit culverts as appropriate.
Continue to monitor water quality and biotic indicators to assess changes in watershed health.	Implement bank restoration/stabilization projects that maintain quality riparian habitat.
Perform social/education/cultural needs assessment and outreach.	Remove the dam on Forty Mile Creek, restore habitat and provide aquatic connectivity to the Bow River.
Study the effect of dam operations on the thermographs in the Cascade, Kananaskis and Spray River systems.	Implement restoration of native populations by removal of non-native species.
Monitor the effectiveness of any restoration project thoroughly using a BACI ("before-after-control-impact") type study design.	Modify dam operations in the Spray River system to restore habitat in Goat Creek.
Identify bank restoration/stabilization techniques that maintain quality riparian habitat and protect linear infrastructure.	Modify dam operations in the Lower Spray River System to restore habitat.
Study the effect of dams and dam removal on upstream habitat and fish populations.	Remove McNair Pond and restore aquatic habitat.
Inventory all rail crossings in all Reaches and any road crossings that have not been inventoried to date.	Modify dam operations on the Kananaskis River system to restore habitat.
Study the interactions of bull trout, westslope cutthroat trout, brook trout, rainbow trout (and other species?). Identify habitat features in areas where healthy populations of bull and westslope cutthroat trout have been maintained despite the presence of non-native fish species.	Modify dam operations on the Cascade River (Lake Minnewanka) to restore habitat.
Study the effect of highway runoff on a variety of aquatic habitats and life stages of bull and westslope cutthroat trout at various times of the year.	
Develop a prioritization scheme for removal and replacement of barrier crossings.	
Quantify the effect of bank stabilization and channelization by transportation infrastructure on river morphology.	
Improve the understanding of angling effects.	
Gather information on the Lac Des Arc Dike and its potential effect on the river.	
Develop climate change scenarios that are specific to the Bow River watershed. Develop models to estimate fish distributions based on predicted climate change scenarios.	

Table 7: Summary of research needs and restoration projects

6. SUGGESTED RESEARCH DIRECTIONS

The following list contains research ideas that could be implemented across all three Reaches, rather than in individual Reaches. The benefit of large-scale research is that it provides a big picture analysis and investigation, rather than research directed towards small segments of the watershed, which addresses only a portion of the problem. Many of the suggested research directions would benefit from GIS-based analyses. An added benefit to large-scale projects is that, typically, more funding sources are available when the project scope is larger and encompasses a bigger geographic area.

1. Perform a stream/river integrity assessment of the study watershed to identify areas for protection, and areas for restoration. Previous work to investigate and classify river integrity in Western Montana has used the following metrics: connectivity, fish assemblage structure, floodplain condition and headwater conditions (Hitt and Broberg, 2002). Other researchers used a similar GIS based approach to identify the best remaining sub-watersheds of a larger watershed (the Upper Yellowstone River Basin) using the following metrics: human impacts measured by the proportion of non-roaded land in a watershed, the fish stocking history, native/non-native fish ratio, and the presence of threatened or endangered species and species of special concern (Oechsli and Frissell, 2003) These approaches could be customized to include additional factors thought to impact the study area such as water quality, and to prioritize for protection **and restoration**.

2. Quantify all aquatic barriers, both man-made (i.e., culverts and dams) and natural, throughout the watershed and synthesize with the present state of knowledge regarding native and non-native fish species. This analysis should not only have a spatial component (GIS analyses), but also an important temporal component. The temporal component will provide the amount of passage that is occurring relative to the flow rates in the streams and rivers, thus quantifying the dynamic nature of the barriers. This study could use predictive models of fish distribution relative to barriers and identify the critical barriers that may be limiting access to certain habitat types that are determined to be more critical in the future under predicted climate scenarios. The metrics for the model could include change in aquatic connectivity and fish distributions. This research might develop a tool that could be used to better understand management strategies that involve aquatic connectivity, native and non-native fish distributions and effects such as climate change.

3. Climate change will affect the coldwater fisheries in all portions of the Bow River watershed. Future research should assess the effect of climate change on water quality, hydrologic regimes, and coldwater aquatic habitat. The research should use existing information gathered by a study in progress by Alberta Environment on glaciers in the South Saskatchewan River Basin and data from other climate change research. Research should develop climate change scenarios that are specific to the upper Bow River and

important tributaries as well as to bull and westlope cutthroat trout within those habitats. Future research should focus on monitoring biophysical indicators of change within the upper Bow River and tributaries. These indicators should include thermodynamic characteristics, biological indicators, water quality characteristics and flow regime changes. Also, models of fish distribution should be developed (as stated earlier) for the upper Bow River. These models should incorporate anticipated changes from climate change.

A potential outcome of this study might be a focus on preserving ecologically significant portions of the watershed that are likely to come under increasing ecological demands due to climate change.

4. Perform a feasibility study on modifying existing dams and operations to provide more natural flow regimes and habitat connectivity. Several studies (McCleary 1996, Godman 1999, Tough 2000, FREWG, 2000) have been done to quantify the impacts of changed flow regimes on individual dams and streams within the study watershed and to identify changes to dam operations to reduce these impacts. This study should first synthesize all of the existing studies to provide a big picture analysis of the potential for improving the watershed flow regime as a whole. The study will need support from TransAlta and other key stakeholders prior to implementation; otherwise it will not have much potential for success.

5. Conduct a basin-wide study to identify geomorphic restoration projects and methods that would improve the function of the Bow River in terms of access to its floodplain and natural sediment and woody debris inputs. Geomorphic studies (deScally 1999) have shown the importance of alluvial fan functions for providing sediment and woody debris to the Bow river system and the magnitude to which these functions are interrupted by the transportation corridors. The focus of this study should be on re-establishing natural geomorphic processes within the present constraints of rail and highway infrastructure and the climate of the region.

6. Assess the impact of winter highway maintenance activities (i.e., sanding and salting) on a variety of aquatic habitats throughout the watershed. Earlier studies focused on specific aquatic habitat, such as the East Vermillion Wetlands and Sunshine Marl Ponds (Wendeborn 2001). Future studies should investigate other types of aquatic habitats that intersect road and rail corridors. In addition, studies that target specific periods of the year relative to the life histories of bull and westslope cutthroat trout (and other aquatic organisms) would be useful. Even if winter maintenance substances are diluted and flushed during spring snow-melt, how do they affect the aquatic system before that melt occurs?

   A second component of this study might be to identify Best Management Practices (both structural and non-structural) that limit the impact to the environment, yet provide safety to the public using the highways. Research should focus on improving existing methods that have already shown success in treating runoff in the watershed and in similar cold region climates.

7. CONCLUSION

The upper Bow River watershed is a significant ecosystem within the Yellowstone to Yukon region. It is a source of one of the major watercourses in western Canada. The headwater streams and lakes of the Bow River are protected within the boundaries of Banff National Park; downstream reaches flow through lands managed by the Province of Alberta. Many factors have altered or affected stream flows and the health of native westslope cutthroat and bull trout populations in this watershed. As such, it provides a unique opportunity to examine the impacts of previous management decisions and to propose potential restoration opportunities.

The Yellowstone to Yukon Conservation Initiative commissioned a review of existing information about the status and factors affecting the distribution of native westslope cutthroat and bull trout populations in the upper Bow River watershed. As this report documents, many past management decisions with respect to stocking with non-native fish species, highway and railroad design and infrastructure, the construction and operation of hydroelectric dams, water pollution, water withdrawals, angling pressure and climate change are all having negative impacts of varying degrees on the health of native fish in the upper Bow.

This report suggests a significant number of opportunities for further research and potential restoration projects that could improve significantly the conditions under which weststlope cutthroat and bull trout populations could recover to some degree. Y2Y encourages scholars, researchers and managers to undertake and implement the suggested projects. Y2Y will work with national park and provincial fish and wildlife managers to prioritize and seek funding to support the most important and beneficial of the suggested initiatives.

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9. APPENDIX A

Rob Buffler, Y2Y
rob@y2y.net
Unit 200, 1240 Railway Ave
Canmore, Alberta T1W 1P4
Phone: 1-403-609-2666
Toll- free: 1-800-966-7920
Fax: 1-403-609-2667

Wendy Francis, Y2Y
wendy@y2y.net
P.O. Box 1477
Banff, Alberta T1L 1B4
Phone: 1-403-763-8633
Toll- free: 1-800-966-7920
Fax: 1-403-762-0351

John Olyslager, Parks Canada
john.olyslager@pc.gc.ca
13th Floor, 635 8th Avenue S.W.
Calgary, Alberta T2P 3M3
Phone: 1-403-292-4775
Fax: 1-403-292-4404

Kathy Rettie, Parks Canada
kathy.rettie@pc.gc.ca
Box 900
Banff, Alberta T1L 1K2
1-403-762-1492

Charlie Pacas, Parks Canada
charlie.pacas@pc.gc.ca
Box 900
Banff, Alberta T1L 1K2
1-403-762-1418

Shelley Humphries, Parks Canada
Shelley.humphries@pc.gc.ca
1-250-343-6108

Brian Lajeunesse, Province of Alberta
Brian.lajeunesse@gov.ab.ca
Southwest Region
201, 800 Railway Ave.
Canmore, Alberta T1W 1P1
Phone: 1-403-678-5500
Fax: 1-403-678-5505
Cell: 1-403-678-1032

Dan Bell
Upper Bow Fly Fishing Company
Trout Unlimited Canada
ubff@telusplanet.net
P.O. Box 2772
Banff, Alberta T1L 1C4
Phone: 1-403-760-7668
Fax: 1-403-762-8263

Tony Clevenger, WTI
tony.clevenger@pc.gc.ca
138 Birch Avenue
Harvie Heights, Alberta T1W 2W2
Phone: 1-403-609-2127

Matt Blank, WTI
mblank@coe.montana.edu
P.O. Box 174250
Bozeman, MT 59717-4250
Phone: 1-406-994-7120
Fax: 1-406-994-1697

10. APPENDIX B

Yellowstone to Yukon Conservation Initiative

The Yellowstone to Yukon Conservation Initiative (Y2Y) is a Transboundary effort to maintain and restore the unique natural heritage of the mountain landscape extending from the southern extent of the Greater Yellowstone Ecosystem to the Arctic Circle in the Yukon. Based out of its headquarters in Canmore, Alberta, with an office in Bozeman, Montana, and staff in Calgary and Banff, Alberta, Armstrong, British Columbia, and Ketchum, Idaho, Y2Y promotes collaborative efforts to maintain viable and interconnected populations of native carnivores, fish and birds throughout the region. Hundreds of organizations representing over a million citizens have endorsed the Y2Y vision. Y2Y envisions a day when residents, visitors, communities, land use managers and aboriginal groups throughout the region understand and appreciate their location within the world's last, fully functioning mountain ecosystem and undertake or support actions that foster its conservation.

Y2Y is developing an aquatics conservation strategy for the region based on the habitat needs of a suite of focal fish species. A preliminary step was an assessment of the *Fishes of the Yellowstone to Yukon Region* completed by Dave Mayhood in 2007 and downloadable from www.y2y.net.

To learn more about the Yellowstone to Yukon Conservation Initiative, please visit www.y2y.net.

Big Sky Conservation Institute GIS