Bow Basin Watershed

Water Quality Objectives & Indicators

March 14, 2008

Prepared by the Bow Basin Watershed Management Plan Technical Committee for the Steering Committee

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Comments from the Bow River Basin Council

The success of The Province of Alberta Water For Life Strategy depends upon collaborative partnerships developing a new vision of sustainable watersheds. In delivering these Water Quality Objectives, our Steering and Technical Committees have achieved an unprecedented breakthrough in shared-governance and shared-vision for our precious lifeline.

Albertans are the protectors of source waters to the Mackenzie Delta, Hudson's Bay and Gulf of Mexico. Millions of downstream neighbors and countless eco-systems rely, in part, on our vision and our commitment to collective interest. While we have always strived to do well, this Plan now articulates our desire to do even better.

Our team members overcame many barriers. The complexity of issues, depth of commitment and diversity of opinions can make it difficult to strike a balance between ecological integrity, economic prosperity and security of supply. Whereas much of the document is gleaned from standards and objectives from around the world, innovative approaches and original concepts were developed to address the breadth of qualities that constitute a healthy river system. The teams' scientific rigor combined with originality of thought has created a world-class product - from one of the most talented group of volunteers ever assembled.

For more than two years, stakeholders from across our watershed have worked tirelessly to develop a collaborative and community-led vision for our river. Their goal has been simple - to create a legacy for many generations to come that will benefit from our focus on the future. All they ask for in return, is for your help in achieving our vision of the best-managed watershed in the world.

We encourage you to join us as we now work to turn our objectives into reality.

Bill Berzins,
Chairman of the Bow River Basin Council

"If you want to move people, it has to be toward a vision that gets them something they desire. It has to be presented in a compelling way that they feel inspired to follow." (Martin Luther King)

Gloria Wilkinson,
Bow Basin Watershed Management Plan Steering Committee Chair

Executive Summary

Phase One of the Bow Basin Watershed Management Plan (BBWMP) identifies desired surface water quality outcomes for the Bow Basin and lists recommendations on how to achieve them. The plan is based on an environmental performance management system involving water quality outcomes, strategies for implementation and associated timelines for management actions, monitoring and evaluation. Specifically, it contains reach-specific water quality objectives, targets, warning levels, and baseline water quality data. The plan recommendations relate to monitoring and evaluation of the objectives or proposed management actions to achieve the overall desired water quality outcomes. Proposed leaders and timelines are identified for each recommendation.

Under the direction of the Steering Committee (SC), the Technical Committee (TC) created objectives for indicators within seven reaches and sub-basins of the Bow Basin. Reach-specific water quality objectives were established with the goal of maintaining or improving current water quality conditions in all reaches while considering their unique natural zonation features and user needs. Common biological, physical and chemical indicators of water quality were selected. Reach-specific water quality objectives, targets, and warning levels were developed by reviewing available guidelines or criteria relevant to the selected water quality indicators to protect the desired outcomes. Many factors were considered in deciding whether to modify or adopt available guidelines and criteria. Rationale are described for each of the recommended objectives.

Summary of Recommendations

- The recommendations work towards achieving the desired water quality outcomes and objectives. Recommendations are either performance indicators for future evaluation of the outcomes or actions necessary to achieving the desired water quality outcomes. These recommendations are grouped into the following management themes: water quantity, storm water and wastewater loading, pesticides, land use planning, riparian and wetland characterization and protection.
- The recommendations apply to the overall Bow Basin or to specific reaches in the Bow mainstem, Nose or Elbow River subwatershed.
- Proposed Leaders of Implementation have been identified for the recommendations and are responsible for:
    - developing an implementation plan for their specific recommendations shortly after the final plan is approved; and
    - preparing and submitting a summary progress report to the BRBC on an annual basis.

There are a number of important recommendations, some of the high priority short term recommendations include the following:

- monitoring and reporting of wastewater loadings from all licensed municipal and industrial sources throughout the Bow Basin and reporting these loadings for the various sub-basins;
- municipalities striving to use the best available wastewater and stormwater treatment technologies (and other methods to achieve similar means) whenever possible to protect the river;
- municipalities upholding the principle of minimizing the quantity and/or toxicity of active ingredients when applying pesticides on the land it manages;
- municipalities adopting environmental reserve setback as outlined in the approved City of Calgary setback policy for all new developments;
- education of municipalities and developers on the principles of low impact development and encourage developers to utilize these practices in their overall design;.
- further research on dissolved oxygen to determine: 1) What is causing low nocturnal dissolved oxygen levels in the Bow River downstream from Calgary in the spring and summer; 2) Whether nitrogen (N) and/or phosphorus (P) is the limiting nutrient for aquatic plant growth which contributes to low dissolved oxygen levels; 3) Additional monitoring, model refinement and research on total dissolved phosphorus (TDP) and dissolved oxygen (DO) in the Bow River

Central to ensure that 15 ug/L TDP is sufficient to prevent DO from falling below 5 mg/L; 4) Spawning success in relation to interstitial oxygen levels;

- coordinating a workshop to develop strategies for enhanced coordination of monitoring programs within the Bow Basin (including review of locations, standardization of methods and data, and enhanced provision of publicly-accessible real-time data);
- continued education of producers on manure application and setback distances with respect to water bodies as outlined by the Agriculture Operations Practices Act. Researching the effectiveness of different application techniques to reduce runoff of manure into receiving water bodies.
- implementation of significant stormwater quality upgrades / improvements within Calgary.
- Water conservation and efficiency targets should be developed for all municipalities and irrigation districts within the Bow Basin;
- continue to conduct the water quality monitoring program for the representative storm water outfalls in Calgary in support of the Total Loading Management Plan (Golder Associates 2007). Work on verifying and improving the storm water total suspended solid loading estimates. Expand the plan to estimate loadings from the pertinent storm outfalls in the Elbow Central reach;
- the land use on the alluvial aquifer in the Elbow River watershed should be carefully considered in the context of downstream river water uses with appropriate groundwater assessments done prior to development, if any. Groundwater assessments may lead to some additional monitoring.

It should be recognized that the BBWMP is a living document. Updates to the existing version of the BBWMP will be considered on a case-by-case basis by the BRBC Board of Directors.

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How to Use this Report

There are many acronyms and technical terms in this report therefore it is recommended that you first read the glossary and then read the document.

Chapter 1 and 2 describe the vision of the BBWMP, scope, background information, planning approach and the desired water quality outcomes.

Chapter 3 includes a table of reach-specific water quality objectives for the identified Bow mainstem reaches, Elbow Upper and Lower reaches and Nose Creek.

Chapter 4 includes recommendations on how to measure and achieve the desired water quality outcomes. These recommendations are summarized in a table which indicate proposed leaders of implementation and timelines.

Chapter 5 describes the engagement strategy used during the plan development and into the implementation.

Chapter 6 discusses future steps which includes: implementation and future updates to the plan

References and Appendices are included for further information.

A data summary has been prepared to accompany this report is available upon request.

1.0 INTRODUCTION

Managing and protecting the water supplies, water quality, and aquatic and riparian ecosystems within watersheds is a complex task. Multi-jurisdictional land development decisions (federal, provincial, municipal, First Nations) covering a multiplicity of uses (e.g., agricultural, residential, recreational, and industrial) add to this complexity. In 2005, recognizing this complexity and the need for a management tool that would align resource decisions across sectors and jurisdictions, the Bow River Basin Council (BRBC) initiated the development of a watershed management plan for the Bow Basin to be prepared in collaboration with partners and stakeholders.

1.1 Vision for the Bow Basin Watershed Management Plan

The vision for the plan as detailed in the approved terms of reference, is to:

- protect and enhance the watershed;
- recommend changes in education and awareness programs, public policy, practice and regulation; and
- serve as a catalyst for proactive action by land, water and resource managers.

1.2 Background

Based on the BRBC's assessment of desired outcomes and planning priorities, Phase One of the BBWMP focuses on issues related to surface water quality. However, because human activities influence water quality in a variety of ways, recommendations are grouped as either: 1) monitoring or evaluating the desired water quality outcomes or 2) management actions related to water quantity, land use, stormwater and wastewater loading, pesticides, source water areas, riparian wetland maintenance and protection.

The plan is based on a five step environmental performance management system involving outcomes, indicators, targets, thresholds, strategies for implementation, and associated timelines for management actions, monitoring, and evaluation (Figure 1).

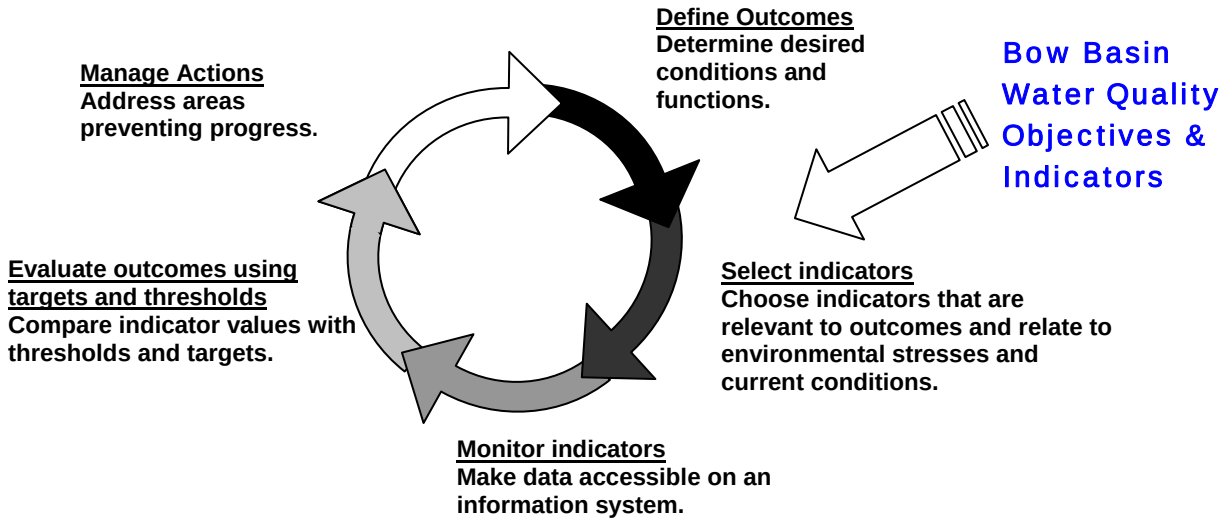


Figure 1. Environmental performance management system diagram.

1.3 Outcomes

For planning purposes, "outcomes" are the desired endpoints that should guide the development and implementation of the BBWMP's recommendations. The BBWMP contributes to the outcomes of the Province's Water for Life Strategy and a further seven desired outcomes of the Bow River Basin Council. The BBWMP (Phase One) identifies three overall goals.

1.3.1 Provincial Scale - Water for Life Outcomes

- Safe, secure, drinking water supply.
- Healthy aquatic ecosystems; and.
- Reliable, quality water supplies for a sustainable economy.

1.3.2 Bow Basin Desired Outcomes

- Surface water quality meets the requirements of the aquatic ecosystem and human uses.
- Riparian and wetlands systems are intact, restored, healthy and valued.
- Rivers and streams are free of "nuisance" growth of aquatic vegetation.
- Human influences are mitigated where these influences could negatively affect aquatic ecosystems;
- Aquatic and riparian ecosystems are protected during all flow periods but particularly during critical high and low flow periods.
- Source waters throughout the Bow watershed are protected for all uses.
- The public understands and values the Bow River Watershed for its ecological, economic, cultural and spiritual value.

1.3.3 Watershed Management Plan Outcomes and Goals

The Phase One BBWMP identifies desired water quality outcomes and related site-specific water quality objectives for the priority reaches within the Bow Basin. The plan also makes recommendations on a) monitoring and evaluation, and b) management actions needed to achieve the desired water quality objectives and outcomes.

The overall goals of the Phase One BBWMP are to:

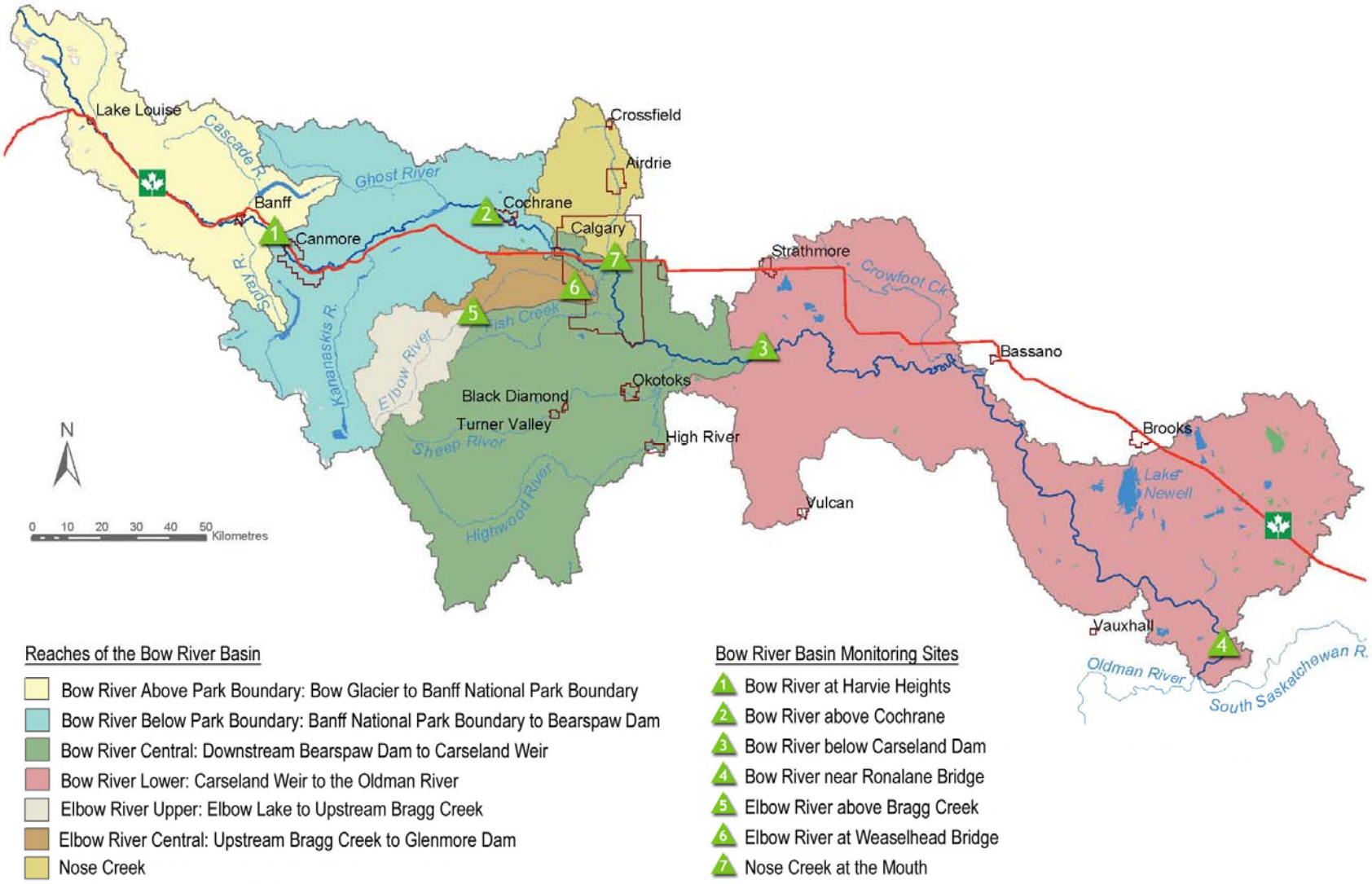
1) meet the water quality outcomes for the priority reaches within the Bow Basin;
2) monitor and evaluate whether the associated indicators are reaching the objectives; and
3) make some key recommendations for future management.

1.4 Geographic Area

Water quality desired outcomes were developed for four priority reaches within the Bow River mainstem (Figure 2) [1]. Specific attention was given to reaches within the City of Calgary (because of impacts downstream) and immediate area, and reaches below Bassano. Additionally, water quality desired outcomes were created for the Elbow River mainstem which was divided into two reaches and the Nose Creek. Figure 2 illustrates the location of the defined reaches along with monitoring sites used to represent the cumulative natural and anthropogenic impacts within each reach.

[1] BBWMP reaches can be compared to the reaches within the 2005 Report on the State of the Bow Basin. BBWMP reaches labelled as "Bow River Above Park Boundary" includes Reaches 1 & 2 in the State of the Basin report, "Bow River Below Park Boundary" is identical to Reach 3 in the report, "Bow River Central" includes Reaches 4, 5, & 6, and "Bow River Lower" includes Reaches 7 & 8 in the State of the Basin report.

Figure 2. Map of river and reach locations.



1.5 Defining Water Quality Objectives (WQOs)

WQOs are criteria adapted to protect the most sensitive designated water uses at a specific location with an adequate degree of safety, taking local circumstances and naturally occurring water quality fluctuations into account. Within a given waterbody, each objective may be based on the protection of a different water use depending on the water uses that are most sensitive to the characteristics of concern in that waterbody. (Province of British Columbia, 2001)

WQOs currently have no legal standing, but instead may be recognized and used as a guide for regulatory authorities, and as a means of supporting and maintaining designated water uses. While WQOs acknowledge that healthy aquatic ecosystems can tolerate some stress and can recover, it is accepted policy that degradation of existing water quality in important water bodies should be avoided (Saskatchewan Environment, 2006).

- Water Quality Guideline (WQG): Numerical concentration limit or narrative statement recommended to support and maintain a designated water use. (Canadian Council of Ministers of the Environment (CCME 1996). Example: Surface Water Guidelines for Use in Alberta 1999.
- Water Quality Objective (WQO): Numerical concentration limit or narrative statement which has been established to support and protect a designated water use at a specific site. (CCME 1996)
- WQOs are typically based on generic WQGs, which may be modified to account for local environmental conditions or other factors. In general, WQOs are prepared only for those water bodies and water quality variables that may be significantly affected by human activities, either now or in the future. (CCME 1996)

WQOs are important tools which, when used in a framework of municipal, provincial and federal environmental assessment, risk management, the application of best available treatment technology, support the management, protection and enhancement of the surface water resources of the province. Those charged with developing objectives (federal, provincial, territorial governments, and water management agencies such as the Prairie Provinces Water Board) must decide what uses are to be protected, gather the necessary information, formulate the objectives, and present them for approval to the appropriate jurisdiction (Saskatchewan Environment, 2006).

It is recognized that each reach in the Bow Basin will have differing natural/existing conditions. Therefore the WQOs are reach-specific to ensure that the objectives and targets are reasonably achievable to protect the natural or existing environment for each reach.

In order for the WQOs to be meaningful in the longer term, the WQOs need to be based on a sound understanding of:

1) current conditions and anticipated future conditions for a given reach or tributary, and
2) broader issues as they relate to potential effects on watershed quality (i.e., impacts from changes to other ecosystem components such as water quantity, riparian areas, etc.).

Phase One focuses on surface water quality including water connected through the alluvial aquifer. Reach-specific WQOs were developed along with targets (i.e. values to strive for in the longer-term), warning levels (i.e. planning trigger for certain management actions to occur) and associated timelines for implementing management actions, monitoring and evaluation. It is expected that these WQOs will also be used as 1) performance indicators for future watershed reporting, and 2) be considered by decision-makers for decisions that have the potential to impact water quality.

Ongoing, routine revisions to the surface WQOs are necessary to ensure that new scientific findings are incorporated and that emerging approaches to enhance environmental protection are considered. WQOs for Nose Creek will be considered by the Nose Creek Watershed Partnership[2] in their current and/or future planning initiatives. WQOs for the Elbow River mainstem will be considered as part of the Elbow River Water Management Plan, Phase One[3].

[2] The Nose Creek Watershed Partnership website is located at www.nosecreekpartnership.com.
[3] The Elbow River Watershed Partnership website is located at www.erwp.org/newsletter.html.

2.0 APPROACH

2.1. Formation and Structure of Technical Committee

Under the direction of the BRBC, the BBWMP Steering Committee developed the terms of reference and set up a BBWMP Technical Committee in March of 2006 with the goal of providing scientific and technical expertise leading to the development of WQOs and indicators for key reaches within the Bow River Basin.

Meetings were open and democratic. Provision for votes involving one vote per agency was made before the process began. However, the committee was almost always able to reach consensus on key decisions. Some decisions were referred to sub-committees, which later reported back to the full Technical Committee. Observers were allowed to attend and speak where time allowed. Refer to Appendix C for committee members' expertise.

2.2. Reach-Specific Desired Outcomes

The Bow River experiences both natural and anthropogenic changes from the headwaters in the mountains to the confluence with the Old Man River in the grasslands. The Bow originates in the mountains and flows about 625 km through subalpine forests, aspen parkland, and mixed grass eco-regions. The variation in climate and vegetation leads to longitudinal zonation in the physical, chemical and biological characteristics of the river (Culp et al 1992). The Bow River Basin is the most highly populated river basin in Alberta. It supplies water to more than a million people. From its headwaters to its mouth, the Bow River also provides water for aquatic life, hydroelectric generation, irrigation, industrial, agricultural, wastewater assimilation and recreational purposes.

The upper Bow River (above the Banff National Park Boundary) and upper Elbow River (above Bragg Creek) typically are low in nutrients and is classified as oligotrophic. These headwater reaches are associated with coldwater aquatic life which is more sensitive to poor water quality than the aquatic life found further downstream. The upper reaches also provide outstanding raw water quality for a significant part of the basin's population. To some extent downstream enrichment of the river increases naturally, but it is also a consequence of municipal effluent discharges from Lake Louise, Banff and Canmore in the Upper Bow reaches. Overall the water quality is considered 'excellent' in the upper reaches of the Bow (North/South Consultants Inc. et al 2007).

The Bow central reach provides water for the Western Irrigation District and provides dilution for contaminants from urban runoff, municipal discharges from Calgary and tributary inputs. Water quality is summarized as 'good' with occasionally instances of dissolved oxygen levels dropping below provincial guidelines (North/South Consultants Inc. et al 2007). Just below Calgary, the Bow River supports a world-class sport fishery in a cold water aquatic ecosystem.

In the lower Bow reach, the river supplies water for the Bow River Irrigation District and Eastern Irrigation District, potable water for smaller municipalities, and supports a cool water aquatic ecosystem. Water quality in this reach is also currently considered 'good' with few exceedences of provincial guidelines (North/South Consultants Inc. et al 2007).

Table 1 summarizes the desired outcomes for each reach based on the Technical Committee's combined knowledge of the Bow River's natural zonation characteristics, along with the existing demands for human consumption, recreation, irrigation, livestock watering and healthy aquatic ecosystems. These factors were also considered in the desired outcomes for the Elbow River and Nose Creek watersheds of the Bow Basin.

Table 1. Summary of reach-specific desired outcomes.

Reach-Specific Outcomes	River and Reach						
	Bow River Above Park Boundary - Bow Glacier to Above Canmore	Bow River Below Park Boundary - Canmore to Upstream Bearspaw Dam	Bow River Central – Downstream Bearspaw Dam to Carseland Weir	Bow River Lower – Carseland Weir to Oldman River	Elbow River Upper – Elbow Lake to Upstream Bragg Creek	Elbow River Central – Upstream Bragg Creek to Glenmore Dam	Nose Creek
Maintain or enhance surface water quality (and linked alluvial aquifers) for **human consumption**. (SWQ)	☑	☑	☑	☑	☑	☑	
Surface water quality that is appropriate for **irrigation** of crops. (IRR)		☑	☑	☑		☑	☑
Surface water quality that is appropriate for **livestock** watering. (LIV)		☑	☑	☑	☑	☑	☑
Surface water quality where water withdrawal systems are protected from high levels of **algae and/or macrophytes**. (AQPT)		☑	☑	☑		☑	☑
Surface water quality that maintains the existing **cold-water aquatic ecosystem** fauna and abundance (e.g., healthy trout populations and benthic invertebrates). (CDWE)	☑	☑	☑		☑	☑	
Surface water quality that maintains the existing **cool-water aquatic ecosystem** fauna structure and abundance (e.g., healthy pike populations and benthic invertebrates). (CLWE)				☑			☑
Surface water quality where body contact **recreation** is safe. (REC)	☑	☑	☑	☑	☑	☑	

Reference sources are located in Appendix A along with a glossary of useful definitions.

2.3. Selected Indicator Outcomes for River and/or Reach

Seventeen physical, chemical and biological indicators were selected as appropriate direct or indirect indicators of water quality (refer to Appendix A for indicator descriptions). These indicators are important for assessing water quality for human consumption (SWQ), irrigation (IRR), and livestock watering (LIV), healthy aquatic ecosystems (AQPT, CDWE, CDWT), and recreational (REC) purposes. These indicators are linked back to the reach desired outcomes and summarized in Table 2. Other indicators were considered (e.g. benthic invertebrates) however it was decided that further research was needed prior to setting reach-specific objectives or targets.

Table 2. Indicator outcomes for river reaches.

Indicator	Outcomes by River and/or Reach						
	Bow River Above Park Boundary - Bow Glacier to Above Canmore	Bow River Below Park Boundary – Canmore to Upstream Bearspaw Dam	Bow River Central – Downstream Bearspaw Dam to Carseland Weir	Bow River Lower – Carseland Weir to Oldman River	Elbow River Upper – Elbow Lake to Upstream Bragg Creek	Elbow River Central – Upstream Bragg Creek to Glenmore Dam	Nose Creek
Attached algae (periphyton) biomass	CDWE,	CDWE, AQPT,	AQPT, CDWE, REC	AQPT, CLWE, REC	CDWE, [4]	AQPT	IRR
Dissolved oxygen	CDWE	CDWE	CDWE	CLWE	CDWE	CDWE	CLWE
Giardia	[5]	SWQ	SWQ	SWQ	SWQ	SWQ	[5]
Macrophytes	CDWE	AQPT, CDWE	AQPT, CDWE, REC	AQPT, CLWE, REC	[6]	[6]	[6]
Nitrate (nitrate + nitrite (as N))	CDWE, SWQ	AQPT, CDWE, LIV, SWQ	AQPT, CDWE, LIV, SWQ	AQPT, CLWE, LIV, SWQ	SWQ, CDWE, LIV	SWQ, CDWE, LIV	CLWE, LIV
Pathogens (as indicated by *E. coli)*	SWQ, REC	SWQ, IRR, REC	SWQ, IRR, REC	SWQ, IRR, REC	REC	REC, IRR	REC
Pathogens (as indicated by fecal coliforms)	[7]	IRR	LIV, IRR	LIV, IRR	LIV	LIV, IRR	LIV, IRR
Pathogens (as indicated by total coliforms)[8]	SWQ	SWQ	SWQ	SWQ	SWQ	SWQ	
Pesticides	CDWE, SWQ	CDWE, IRR, LIV, SWQ, REC	CDWE, IRR, LIV, SWQ, REC	CLWE, IRR, LIV, SWQ, REC	SWQ, CDWE, SWQ, REC	SWQ, CDWE, LIV, SWQ, REC	CLWE, IRR, LIV, SWQ, REC
Total ammonia	CDWE	AQPT, CDWE	AQPT, CDWE	AQPT, CLWE	SWQ, CDWE	SWQ, CDWE	CLWE
Total dissolved phosphorus	CDWE	AQPT, CDWE	AQPT, CDWE	AQPT, CLWE	SWQ, CDWE	SWQ, CDWE	CLWE
Total organic carbon	[9]	SWQ	SWQ	SWQ	SWQ	SWQ	[9]
Total phosphorus	CDWE	AQPT, CDWE	AQPT, CDWE	AQPT, CLWE	SWQ, CDWE	SWQ, CDWE	CLWE
Total suspended solids	CDWE	SWQ, CDWE	SWQ, CDWE	SWQ, CLWE	CDWE	CDWE	CLWE
Water temperature	CDWE	CDWE	CDWE	CLWE	CDWE	CDWE	CLWE
Riparian condition[10]	CDWE	CDWE	CDWE	CLWE	CDWE	CDWE	CLWE
Soil erosion[11]	CDWE	CDWE	CDWE	CLWE	CDWE	CDWE	CLWE, IRR

Indicator acronyms: human consumption (SWQ), irrigation (IRR), and livestock watering (LIV), aquatic plants (AQPT), cold water ecosystems (CDWE), cool-water ecosystems (CLWT), and recreational (REC) purposes.

[4] Attached algal biomass was generally low in historic sampling in the mainstem Elbow River upstream of Glenmore Reservoir (Beers and Sosiak 1993).
[5] Surface water is generally not used for drinking water purposes in these reaches (i.e. Bow River Above Park Boundary and Nose Creek)
[6] Macrophytes are uncommon in the Elbow River upstream of Glenmore Reservoir and Nose Creek (in the case of Nose Creek this may be due to high levels of suspended sediments which inhibit their growth) and therefore outcomes were not set at this time. However, there is an expectation that if macrophyte conditions change, outcomes would be revaluated and possibly created.
[7] There are no irrigation withdrawals in the Bow River above the park boundary.
[8] Total coliforms are only monitored by wastewater treatment plants in some reaches. Further is recommended to determine the reason for periodic increases in coliform counts (Table 4, recommendation 38).
[9] Total organic carbon was not included for these reaches because surface water is not typically used as a drinking water here.
[10] Associated indicator of water quality- healthy riparian conditions can filter nutrients, trap sediments and maintain cool water temperatures and therefore can serve as indirect indicators of water quality.
[11] Associated water quality indicator- water bodies adjacent to areas with high soil erosion tend to have higher total suspended sediments and therefore poorer water quality.

2.4. Development of Reach-Specific Objectives and Indicators

The Technical Committee developed reach-specific water quality objectives, targets, and warning levels by reviewing available guidelines or criteria relevant to the selected water quality indicators, to protect the desired outcomes. Water quality objectives were set with the goal of maintaining or improving current water quality conditions in the relatively pristine upper reaches and downstream reaches. Targets were created if objectives were typically exceeded but the intent was to eventually meet the desired outcomes of this reach but in the interim a short term target was created. Warning levels were created to act as a planning trigger for additional water quality management activities. Factors that were considered in deciding whether to modify or adopt the available guidelines and criteria included the following:

- quality and quantity of the existing monitoring data available to describe existing conditions at a specific site or in a specific reach;
- factors that modify toxicity or aquatic impacts;
- known aquatic organism thresholds (i.e., values not to be exceeded);
- committee experience with water quality in a given reach;
- impacts on the growth of aquatic plants, and consequent impacts on dissolved oxygen through plant respiration at night;
- aquatic species and uses at risk, along with fisheries management priorities, as determined by committee representatives from the Departments of Fisheries and Oceans Canada and Alberta Sustainable Resource Development;
- practicality of implementation and consequences of varying levels of protection; and
- level of uncertainty in the guideline or criterion under consideration, as reflected in the supporting documentation.

In some cases, available water quality guidelines and criteria were modified to account for site or reach-specific variations in water quality, uses and aquatic species in a given reach, and environmental conditions that could reduce toxicity (CCME 2003). For example, the only available surface water quality guideline for total phosphorus (0.05 mg/L, AENV 1999) was not considered sufficiently protective of the aquatic ecosystem, based on observed water quality. Accordingly, an alternative was recommended.

In other cases, after review of the available information, the committee decided that it was unable to recommend objectives, warning levels and/or targets for a specific variable. Recommendations for further research to allow development of these values were made where appropriate.

Where no appropriate guidelines or criteria were available (e.g. periphyton biomass), the Technical Committee reviewed the scientific literature for critical numerical limits, which were then used to set objectives, targets or warning levels. Since some important variables, such as phosphorus, are not typically toxicants at relevant environmental concentrations in the Bow River basin, the procedure outlined in CCME (2003; where literature review or a suite of bioassays is used), was not appropriate for such variables. Instead, the existing calibrated model developed by the City of Calgary to develop loading limits was used to determine critical values that would maintain dissolved oxygen above the Alberta guideline of 5.0 mg/L in the enriched reach below Calgary (Golder Associates 2004, 2007).

In the upstream relatively pristine reaches (i.e. Elbow Upper and Bow River above park boundary) it was decided that a high level of water quality protection was required to maintain current near-pristine conditions. This is consistent with the Banff Park mandate and the oligotrophic aquatic ecosystem needs. In these cases, values equal to the 90^{th} percentile of the most recently available representative time period were often recommended as the objective. This approach is a modification of the background concentration procedure method described in CCME (2003); however a higher percentile (90 percentile; Breidt et al 1991) of downstream reference site data was used in the Technical Committee's approach.

As mentioned, historical data from all reaches were reviewed and fully-mixed downstream monitoring locations are identified in Figure 2. Monitoring sites represent the cumulative natural and anthropogenic impacts within each reach. Data used for evaluating the water quality objectives came from Alberta Environment's provincial Water Data System (WDS) water quality data base and The City of Calgary Water Resources' Water Quality Database (unpublished). In addition, the Sosiak and Dixon (2004) and Sosiak and Beers (1993) reports were reviewed for Elbow River Upper and Central reaches water quality information. The year-round data in Glozier et al (2004) was reviewed for the Bow River above Park Boundary reach. Monitoring results from Bowman (2006, unpublished) were used to establish a periphyton objective for this reach. The Technical Committee also put forth recommendations.

3.0 Water Quality Objectives and Indicators

Water quality objectives were set with the goal of maintaining or improving current water quality conditions in all the Phase One BBWMP priority reaches. In an attempt to maintain or improve water quality in the downstream reaches, there are generally stricter water quality objectives in the headwater reaches relative to existing provincial and federal guidelines. These requirements in the headwaters were set because (a) the limited assimilative capacity of the river (b) greater contributing nutrient loads downstream and (c) cumulative effects.

The Upper Elbow River (above Bragg Creek) and Bow River (above the Banff National Park Boundary) are relatively pristine headwater reaches. These reaches are associated with coldwater aquatic life (e.g. ephemeroptera, plecoptera invertebrates and salmonids), which are more sensitive to poor water quality than the aquatic life found further downstream. As major sources of drinking water to all downstream users, the headwaters of the Elbow River and Bow River are considered areas of high importance from both a water quality and quantity perspective and need to be managed accordingly.

- This plan recommends that all agencies involved in the management of the Upper Elbow River and Bow River Above Park Boundary ensure that there is no degradation of water quality over the long-term in this portion of the watershed associated with human activities.
- The highest regard for water quality and quantity should be provided for these portions of the Elbow River and Bow River watershed.

Table 3 provides a list of water quality of the objectives, warning levels and targets for various indicators within defined river reaches of the Bow River, and reaches within the Elbow, and Nose Creek watersheds. The table also includes an estimate of baseline water quality conditions for each reach by providing a median and percentile value and the associated sampling information (Figure 3). Numbers in the last column correspond to the recommendations in Table 4. Refer to the Glossary for a definition of terms and acronyms and to Appendix B for a list of water quality indicators and guidelines or suggested limits.

Objectives were created for physical, biological and chemical water quality indicators (i.e. nutrients, attached algae) and they mainly apply to the open water season (defined as April to October) when there is associated algal productivity. Indicators that are typically monitored year-round by wastewater treatment plants have year-round objectives and targets (i.e. total ammonia, temperature, TSS, TOC, pathogens, DO, TSS and TP). In some cases, a provisional objective was set if data was lacking or a defined temporal influence needed more research (i.e. growing season versus winter values for the Lower Bow reach). In a few cases, a winter seasonal objective has been provided and is defined for the November to February time period. Monitoring should occur at sites that represent fully mixed conditions across the river channel.

Baseline water quality data is also provided for the identified monitoring sites (Figure 2). Where possible, data time periods correspond with water quality objective time periods and provide a general indication of the cumulative water quality conditions for that reach. Data periods for calculating baseline water quality values range from 4 to 30 years and use data that are considered to accurately reflect baseline reach-

specific conditions (e.g. Bow Central includes historical data following the 1982 wastewater upgrades at the Fish Creek and Bonnybrook wastewater Treatment Plants, and more recent enhanced phosphorus removal 2004-2005).

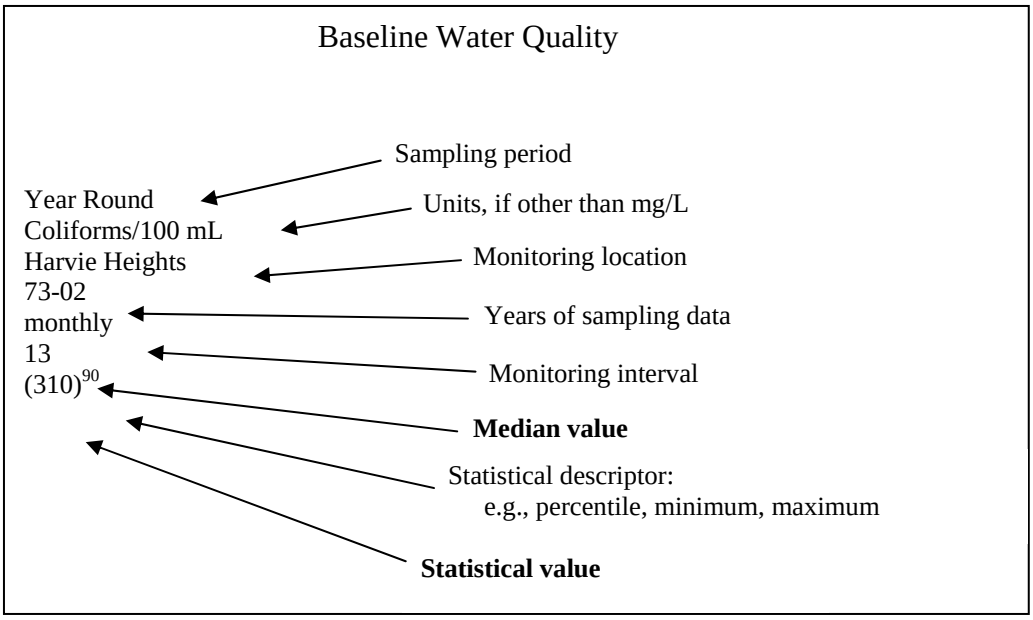


Figure 3. Definition of cell values for reach estimates of baseline Water Quality (column 4) in Table 3.

Table 3. Water quality objectives, warning levels and targets by reach.

Proposed Indicator or Topic Area	Reach or River	WQOs, Warning Levels and Targets	Baseline Water Quality (median, percentiles)[I]	Rationale	Related Recommendation Number in Table 4
Attached Algae (Periphyton) Biomass - defined as chlor *a*	Bow River Above Park Boundary	❑ WQO: 47 mg/m^2 maximum value during open water season	Harvie Heights Fall measurements (Sept – Oct) 1999-2006 30 (243)^{max} (197.6)^{90}- includes data prior to treatment plant upgrades 2002-2006 9 (44)^{max} (32.9)^{90}	❑ Objective supports the Park Canada mandate to maintain near pristine conditions in park areas. ❑ Objective is an experimentally derived value based on data from 1998-2006 upstream of the Banff town site (Bowman 2006). This is the value that represents the transition from good to fair rankings according to Parks Canada (Bowman 2003). ❑ Decline in algal growth with recent wastewater treatment upgrades. ❑ Objective may not be met in some locations due to recent occurrence of invasive strain of *Didymosphenia geminata*. Research recommended on reasons for its recent occurrence and growth.	**14, 15**
Dissolved Oxygen	Bow River Above Park Boundary	❑ WQO: CCME with protection of spawning and incubation. o 9.5 mg/L for spawning and incubation o 6.5 mg/L for acute daily minimum.	Year round Upstream Lake Louise 1973-2002 Monthly : 11.5 (9.5)^{10}	❑ CCME provides a high-level of protection for saturated conditions.	2
Macrophytes	Bow River Above Park Boundary	❑ WQO: No macrophyte biomass that adversely affects users.	Insufficient data, rare or absent	❑ Numerical relationships between biomass and DO are poorly understood and need to be established. For example, higher macrophytes biomass may naturally occur in standing or slower moving water.	14
Nitrate (nitrate + nitrite (as N))	Bow River Above Park Boundary	❑ WQO: 0.13 mg/L during growing season	Year round Harvie Heights 73-02 monthly 0.08 (0.13)^{90}	❑ 0.13 is based on 90th percentile from the 1983 to 2002 at the downstream monitoring station. ❑ Trying to maintain this reach at its current trophic state.	27, 35
Pathogens as indicated by *E. coli*	Bow River Above Park Boundary	❑ WQO: Not recommended at this time.	Insufficient data	❑ Not currently measured.	5, 28
Pathogens as indicated by Total Coliforms	Bow River Above Park Boundary	❑ WQO: Should not exceed 20,000 counts (total coliforms) per 100 mL at intake for drinking water treatment plant	Year Round Coliforms/100 mL Harvie Heights 73-02 monthly 13 per 100 mL (310)^{90}	❑ The instantaneous objective of <20,000 counts/100 mL is based on conventional water treatment plant's ability to remove contaminants if pre-disinfection is present (US EPA 1991). ❑ Protects human health by ensuring that municipal water treatment plants can remove pathogens (e.g., bacteria, protozoa, and viruses) from raw water.	28
Pathogens - *Giardia*	Bow River Above Park Boundary	❑ WQO: Not set for this reach. However, *Giardia* is an important issue, and agencies should continue to monitor for *Giardia* and attempt to identify sources.	Insufficient data	❑ Insufficient data to make an objective, as it is not currently monitored. ❑ Groundwater is currently being used as the drinking water source for this reach. ❑ Wildlife are the prime vectors of *Giardia* transmission in this reach.	3

[I] Units are mg/L unless otherwise noted.

Proposed Indicator or Topic Area	Reach or River	WQOs, Warning Levels and Targets	Baseline Water Quality (median, percentiles)[l]	Rationale	Related Recommendation Number in Table 4
Pesticides and Degradation Products	Bow River Above Park Boundary	❑ WQO: Should not exceed the lower of: o < 1/10 of federal drinking water guidelines or o < CCME guidelines for aquatic life in the river (provisional objective)	Insufficient data	❑ Provisional objective was set as there is currently no ongoing monitoring available at this time to set an objective. ❑ No current use of surface water for municipal water supplies however drinking objective included to consider to protect downstream users	37, 38, 39, 41, 42
Total Ammonia	Bow River Above Park Boundary	❑ WQO: Should not exceed CCME guideline for protection of aquatic life To apply outside mixing zone (AENV 1995).	Year Round Harvie Heights 87-02 monthly 0.011 $(0.044)^{90}$	❑ Designed to protect aquatic life and considers the influence of both temperature and pH on the toxicity of ammonia.	27, 28
Total Dissolved Phosphorus	Bow River Above Park Boundary	❑ WQO: 0.005 mg/L TDP	Year round Harvie Heights 73-02 monthly 0.006 $(0.016)^{90}$	❑ Based on trying to maintain or improve the existing water quality. ❑ Recent (2002 - 2003) water treatment improvements have decreased TDP concentrations at Harvie Height's site to below 0.005 mg/L (Humphries pers. comm.). ❑ It is expected that recent treatment plant upgrades will allow this water quality objective to be met.	27, 28
Total Phosphorus	Bow River Above Park Boundary	❑ WQO: 0.012 mg/L TP	Year round Harvie Heights 73-02 monthly 0.012 $(0.025)^{90}$	❑ Based on trying to maintain or improve the existing water quality in the mountain parks to a natural state, protected under federal legislation. ❑ Values may be exceeded during freshet conditions. ❑ Recent upgrades to the WWTPs (post 2002) have improved receiving water quality.	27, 28
Total Suspended Solids	Bow River Above Park Boundary	❑ WQO: CCME	Year Round Harvie Heights 73-02 monthly 2.0 $(11.2)^{90}$	❑ To maintain existing water quality for aquatic life.	27, 52, 54
Water Temperature	Bow River Above Park Boundary	❑ WQO: Should not exceed 18°C at any time or a 7-day mean of 15°C (added)	Year Round, °C Harvie Heights 73-02 monthly 5.0 $(11.0)^{90}$ $(16.3)^{max}$	❑ To protect most sensitive native fish, namely bull trout ❑ 7-day mean based on Taylor & Barton (1992).	2, 27
Riparian Condition[m]	Bow River Above Park Boundary	❑ TARGET: maintaining a "healthy" rating using Cows and Fish rating system.		❑ Based on the best available data, targets were set at one level higher than initial conditions measured using the Cows and Fish Riparian Health Inventory rating system (Fitch and Ambrose 2003) (e.g., "unhealthy" ➔ "healthy with problems" ➔ "healthy"). If the river and/or reach previously rated as "healthy", the target remained as "healthy". In all cases, the long-term goal is "healthy".	45, 47, 49, 57, 59

[m] Healthy riparian condition filters nutrients and minimizes the runoff of sediments into receiving water bodies.

Proposed Indicator or Topic Area	Reach or River	WQOs, Warning Levels and Targets	Baseline Water Quality (median, percentiles)[l]	Rationale	Related Recommendation Number in Table 4
Soil Erosion[n]	Bow River Above Park Boundary	❑ TARGET: The erosion and sediment control (ESC) plan should be designed with a T-value or maximum soil erosion rate target of 2t/ha/yr where disturbed land has direct connection to a water body (no buffer, no interception). Applies to all construction sites and endures for the life of the project (during and post construction phases).		❑ For new developments that are permitted within the defined boundaries, Operating Ground Rules are in place to minimize erosion and sedimentation (ASRD). ❑ An erosion and sediment control plan (ESC) must be developed, implemented and monitored for construction sites with any direct connection to surface water. ❑ An ESC plan should be prepared by a qualified professional (a professional certification that includes erosion and sediment control as a field of expertise). ❑ Based on methods described in Wall et al. (2002).	49, 50, 51
Attached Algae (Periphyton) Biomass - defined as chlor *a*	Bow River Below Park Boundary	❑ WQO: 150 mg/m^2 maximum value during open water season	Open Water Cochrane monthly 1995-2006 21 $(83)^{90}$ 154.3^{max}	❑ A literature review over many regions determined that periphyton concentrations above 150 mg/m^2 are associated with adverse impacts on users (Welch et al 1998).	**15**
Dissolved Oxygen	Bow River Below Park Boundary	❑ WQO: CCME with protection of spawning and incubation. o 9.5 mg/L for spawning and incubation o 6.5 mg/L for acute daily minimum.	Open Water Cochrane, 87-06 Monthly: 10.2 (8.95^{10}) 7.61^{min}	❑ CCME provides a high-level of protection for saturated conditions.	2, 27, 28
Macrophytes	Bow River Below Park Boundary	❑ WQO: No macrophyte biomass that adversely affects users.	Insufficient data	❑ Numerical relationships between biomass and DO are poorly understood and need to be established. For example, higher macrophytes biomass may naturally occur in standing or slower moving water.	14
Nitrate (nitrate + nitrite (as N))	Bow River Below Park Boundary	❑ WQO: 0.267 mg/L ❑ WARNING LEVEL: 0.163 mg/L ❑ WQOs, warning levels and targets for nitrate apply during the growing / open water season.	Open water Cochrane 87-06 monthly 0.067 $(0.112)^{90}$	❑ The value of 0.267 mg/L was obtained from Sosiak (2004) as the nitrate + nitrite level that corresponds to nuisance growth of periphyton in the Bow River basin. ❑ The warning level was developed based on the 90th percentile level for the period 1987 – 2006.	27, 28
Pathogens as indicated by *E. coli*	Bow River Below Park Boundary	❑ WQO: Meet recreational guideline - no single value to exceed 400 *E.coli*/100 mL or <200 *E. coli*/100 mL (geometric mean 5 samples/30 d).	Year Round coliforms/100 mL Cochrane 94-06 monthly 1 per 100 mL $(14)^{90}$	❑ 400 *E. coli*/100 mL is the CCME re-sampling guideline.	28
Pathogens as indicated by fecal coliforms	Bow River Below Park Boundary	❑ WQO: Meet 100 fecal coliforms/100 mL (no single value to exceed objective) at the point of withdrawal.	Year Round Coliforms/100 mL Cochrane 91-05 monthly 2 per 100 mL $(20)^{90}$	❑ Irrigation guidelines set by CCME. ❑ It is recognized, that the WQO values may be briefly exceeded for short periods of time during storm events. ❑ The intention though, is to maintain in-stream concentrations at or below current levels.	28

[n]Erosion is caused when soil particles are dislodged and transported by water falling on or running across bare soil or vegetated areas that are unable to resist the force of the flowing and falling water. If eroded material is transported to water bodies sedimentation occurs which reduces water quality after and during storm events.

Proposed Indicator or Topic Area	Reach or River	WQOs, Warning Levels and Targets	Baseline Water Quality (median, percentiles)[l]	Rationale	Related Recommendation Number in Table 4
Pathogens as indicated by Total Coliforms	Bow River Below Park Boundary	❑ WQO: Should not exceed 20,000 counts (total coliforms) per 100 mL at intake for drinking water treatment plant.	Year Round Cochrane 00-06 monthly 66 per 100 mL $(435)^{90}$	❑ The instantaneous objective of <20,000 counts/100 mL is based on conventional water treatment plant's ability to remove contaminants if pre-disinfection is present (US EPA 1991). ❑ Protects human health by ensuring that municipal water treatment plants can remove pathogens (e.g., bacteria, protozoa, and viruses) from raw water.	28
Pathogens - *Giardia*	Bow River Below Park Boundary	❑ WQO: Should not exceed 100 cysts per 100L (instantaneous) for the Bearspaw Water Treatment Plant.	Insufficient data	❑ This is the level above which will require in excess of 5-log reduction at the Bearspaw Water Treatment Plant (AENV, 2006). ❑ Higher levels of *Giardia* require new water treatment processes for small water supply systems in the Basin. Over time, as approvals come up for renewal, small water supply systems may be required to upgrade to treat higher levels of *Giardia*.	3
Pesticides and Degradation Products	Bow River Below Park Boundary	❑ WQO: Should not exceed the lower of: o < 1/10 of federal drinking water guidelines or o < CCME guidelines for aquatic life in the river.	Data not readily available	❑ Provisional objective as there is currently no ongoing monitoring available at this time to set an objective. ❑ Protects drinking water and aquatic ecosystems. ❑ <1/10 of federal drinking water guidelines used to provide a safety margin to protect against compounds for which there is no treatment.	37, 38, 39, 41, 42
Total Ammonia	Bow River Below Park Boundary	❑ WQO: Should not exceed 0.04 mg/L in the river for municipal water supply, and should not exceed CCME guideline for protection of aquatic life. To apply outside mixing zone (AENV 1995).	Open water Cochrane 87-06 monthly 0.010 $(0.020)^{90}$	❑ Protects municipal water supply from unacceptable chlorine demand. ❑ Based on experience at Glenmore Water Treatment Plant. ❑ This is more restrictive than the current CCME guideline. ❑ Designed to protect aquatic life and takes into account the influence of both temperature and pH on the toxicity of ammonia.	27, 28
Total Dissolved Phosphorus	Bow River Below Park Boundary	❑ WQO: 0.005 mg/L TDP during the growing season for aquatic plant	Open Water Cochrane 87-06 monthly 0.002 $(0.005)^{90}$	❑ Based on trying to maintain or improve the existing water quality. ❑ Objective is the 90 percentile (1987-2006) open water concentrations in the Bow River at Cochrane.	27, 28
Total Organic Carbon	Bow River Below Park Boundary	❑ WQO: Should not exceed 3.0 mg/L (instantaneous).	Year Round Cochrane 00-06 Monthly 0.82 $(1.51)^{90}$	❑ Value excludes periods of snowmelt runoff, mountain runoff, and significant precipitation events. ❑ TOC is generally lower in these upper reaches. ❑ Increasing TOC levels in the source water has affected the treatment process of water at many surface water treatment plans. TOC >3 mg/L result in increased coagulant and chlorine demands, and gets worse as TOC levels get higher. (UEWG 1999)	
Total Phosphorus	Bow River Below Park Boundary	❑ WQO: 0.014 mg/L TP	Open Water Cochrane 87-06 Monthly 0.004 $(0.014)^{90}$	❑ Based on trying to maintain or improve the existing water quality. ❑ Objective is the 90^{th} percentile (1987-2006) open water concentrations in the Bow River at Cochrane.	27, 28

Proposed Indicator or Topic Area	Reach or River	WQOs, Warning Levels and Targets	Baseline Water Quality (median, percentiles)[l]	Rationale	Related Recommendation Number in Table 4
Total Suspended Solids	Bow River Below Park Boundary	❑ WQO: CCME	Year Round Cochrane 87-06 monthly 1.0 $(6.0)^{90}$	❑ To maintain existing water quality for aquatic life.	27, 54, 50, 52
Water Temperature	Bow River Below Park Boundary	❑ WQO: Should not exceed 22°C at any time or a 7-day mean of 18°C.	Open Water Cochrane 87-06 monthly 10.4 $(15.07)^{90}$ $(18.02)^{max}$	❑ To protect most sensitive native fish, namely mountain whitefish. ❑ Maximum values are based on Taylor & Barton (1992).	2, 16, 27
Riparian Condition[m]	Bow River Below Park Boundary	❑ TARGET: Maintaining a "healthy" rating using Cows and Fish rating system.		❑ Based on the best available data, targets were set at one level higher than initial conditions measured using the Cows and Fish Riparian Health Inventory rating system (Fitch and Ambrose 2003) (e.g., "unhealthy" ➔ "healthy with problems" ➔ "healthy"). If the river and/or reach previously rated as "healthy", the target remained as "healthy". In all cases, the long-term goal is "healthy".	45, 47, 49, 57, 59
Soil Erosion[n]	Bow River Below Park Boundary	❑ TARGET: An erosion and sediment control (ESC) plan should be designed with a T-value or maximum soil erosion rate target of 2t/ha/yr where disturbed land has direct connection to a water body (no buffer, no interception). Applies to all construction sites and endures for the life of the project (during and post construction phases).		❑ For new developments that are permitted within the defined boundaries, Operating Ground Rules are in place to minimize erosion and sedimentation (ASRD). ❑ An erosion and sediment control plan (ESC) must be developed, implemented and monitored for construction sites with any direct connection to surface water. ❑ An ESC plan should be prepared by a qualified professional (a professional certification that includes erosion and sediment control as a field of expertise). ❑ Based on methods described in Wall et al. (2002).	45, 48, 50, 52, 51

Proposed Indicator or Topic Area	Reach or River	WQOs, Warning Levels and Targets	Baseline Water Quality (median, percentiles)[l]	Rationale	Related Recommendation Number in Table 4
Attached Algae (Periphyton) Biomass-defined as chlor *a*	Bow River Central	❑ WQO: No periphytic algal biomass that adversely affects users. ❑ Target: 150 mg/m^2 maximum value during open water season	Open Water Carseland 87-98 monthly 205 (469)^{90} (682)^{max} 99-06 monthly 121 (242)^{90} (432)^{max}	❑ A literature review over many regions determined that periphyton concentrations above 150 mg/m^2 are associated with adverse impacts on users (Welch et al 1998). ❑ Currently exceeded around Stier's ranch. ❑ Last 6 years there have been declines in periphyton biomass therefore this target was considered appropriate.	**14**
Dissolved Oxygen	Bow River Central	❑ WQO: 5.0 mg/L (acute daily minimum), 6.5 chronic (7 day running average) ❑ WARNING LEVEL: 5.5 mg/L (acute daily minimum) ❑ TARGET: 6.0 mg/L (acute daily minimum), 8.0 mg/L[o] (acute daily minimum) for spawning and incubation from October to end of May from WID Weir to Hwy 22, 9.5 mg/L upstream of WID Weir from Oct. to end of June.	Open Water Monthly Carseland 87-05: 10.1 (9.0)^{10} 7.7^{min} Hourly Above Highwood 2006: 8.49 (5.53)^{10} 4.08^{min}	❑ 5.0 mg/L is the Alberta guideline, which provides a threshold for aquatic effects and a margin of safety. ❑ 5.5 mg/L is the warning level used for the Highwood River. ❑ The Calgary Total Loading Management Plan (Golder Associates 2007) aadopted a trigger value of 340 kg/day for total phosphorus. It is based on maintaining the surface water quality guideline of 5.0 mg/L dissolved oxygen as a cross-sectional average across the Bow River just upstream of the confluence of the Highwood River at a frequency of compliance of 99.91%. ❑ 8.0 mg/L is to protect brown trout spawning in this reach [5 mg/L + 3 mg/L (safety margin; CCME, 1999)] ❑ 9.5 mg/L to protect rainbow trout spawning in this reach. ❑ During spawning periods, there is a recognized need to have a higher level of DO in the water column to ensure 5.0 mg/L within gravel for eggs and incubation.	2, 6, 7, 17, 24, 27, 28
Macrophytes	Bow River Central	❑ WQO: No macrophyte biomass that adversely affects users.	AENV Macrophyte sites, M1-M8, g/m^2 1979-1996: Median: 503 Range: 0-3897 2006: Median: 71.0 Range: 0-1273	❑ Numerical relationships between biomass and DO are poorly understood and need to be established. For example, higher macrophytes biomass may naturally occur in standing or slower moving water. ❑ Trying to relate measured macrophyte biomass in this reach to problems in irrigation district canals.	14

[m] Healthy riparian condition filters nutrients and minimizes the runoff of sediments into receiving water bodies.
[n] Erosion is caused when soil particles are dislodged by water falling on or running across bare soil or vegetated areas that are unable to handle the force of the flowing water. Receiving water bodies adjacent to eroded stream banks tend to have poor water quality after storm events.
[o] Based on brown trout population.

Proposed Indicator or Topic Area	Reach or River	WQOs, Warning Levels and Targets	Baseline Water Quality (median, percentiles)[l]	Rationale	Related Recommendation Number in Table 4
Nitrate (nitrate + nitrite (as N))	Bow River Central	❑ WQO: 1.5 mg/L ❑ WARNING LEVEL: Need to better understand the limiting factor for macrophytes and periphyton growth before assigning a warning limit. ❑ TARGET: Eliminate levels that cause nuisance aquatic plant growth. ❑ WQOs, warning levels and targets for nitrate apply during the growing / open water season.	Open Water Carseland 87-05 monthly 0.622 (1.146)^{90}	❑ WQO of 1.5 mg/L nitrate was the concentration in the City of Calgary Total Loading Management model (Golder Associates 2007) that corresponded to 5 mg/L DO for the period April to Sept 30. ❑ Nitrate + nitrite levels will be typically well below this objective except for occasional outliers during the open water season and levels may be exceeded during the winter. ❑ The model assumes that some form of nitrification is occurring at the Fish Creek WWTP. This objective may need to be revisited as improvements around the WWTP occur over time and as findings from related research recommendations become available.	6, 7, 24, 27, 28, 29, 31
Pathogens as indicated by *E. coli*	Bow River Central	❑ WQO: Further research required. ❑ TARGET: Meet recreational guideline (<200 *E. coli* per 100 mL (geometric mean 5 samples /30 d).	Year Round Carseland 94-05 monthly 23 per 100 mL (205)^{90}	❑ Pathogen indicator loads are significant. ❑ It is recognized that *E. coli* in the Bow Central can be above recreational guidelines following storm events. ❑ Further research required to establish warning level.	8, 28, 32
Pathogens as indicated by fecal coliforms	Bow River Central	❑ WQO: Meet 100 fecal coliforms per 100 mL (no single value to exceed objective) at the point of withdrawal	Year Round Carseland 87-05 monthly 91 per 100 mL (590)^{90}	❑ Irrigation guidelines set by CCME. ❑ The WQO values can be briefly exceeded for short periods of time during storm events. ❑ Fecal coliforms at this site have declined greatly (medians<62) since disinfection installed at both Calgary wastewater treatment plants in 1997.	8, 28
Pathogens as indicated by Total Coliforms	Bow River Central	❑ WQO: Should not exceed 20,000 counts (total coliforms) per 100 mL at intake for drinking water treatment plant.	Year Round Carseland 87-94 monthly 870 per 100 mL (2900)^{90}	❑ The instantaneous objective of <20,000 counts/100 mL is based on conventional water treatment plant's ability to remove contaminants if pre-disinfection is present (US EPA 1991). ❑ Protects human health by ensuring that municipal water treatment plants can remove pathogens (e.g., bacteria, protozoa, and viruses) from raw water. ❑ Total coliforms are not typically monitored here.	8, 28
Pathogens - *Giardia*	Bow River Central	❑ WQO: Should not exceed 100 cysts per 100L (instantaneous) for the Bearspaw Water Treatment Plant.	Insufficient data	❑ This is the level above which will require in excess of 5-log reduction at the Bearspaw Water Treatment Plant (AENV, 2006). ❑ Higher levels of *Giardia* require new water treatment processes for small water supply systems in the Basin. Over time, as approvals come up for renewal, small water supply systems may be required to upgrade to treat higher levels of *Giardia*.	8, 3, 28
Pesticides and Degradation Products	Bow River Central	❑ WQO: Should not exceed the lower of: o < 1/10 of federal drinking water guidelines or o < CCME guidelines for aquatic life in the river.	Breakdown of data by reach not available (Anderson A-M, 2005).[p]	❑ Protects drinking water and aquatic ecosystems. ❑ <1/10 of federal drinking water guidelines used to provide a safety margin to protect against compounds for which there is no treatment.	31, 37, 38, 39, 41, 43, 44

[p] Over entire Bow basin, Anderson (2005; Table 4c) found 180 of 406 samples exceeded irrigation guidelines (mainly Dicamba and MCPA), 12 of 406 samples (mainly, 2,4-D and chlorpyrifos-ethyl exceeded aquatic life guidelines, and no exceedance of guidelines for drinking water or livestock watering.

Proposed Indicator or Topic Area	Reach or River	WQOs, Warning Levels and Targets	Baseline Water Quality (median, percentiles)[l]	Rationale	Related Recommendation Number in Table 4
Total Ammonia	Bow River Central	❑ WQO: The lower of US EPA or 0.2 mg/L ammonia during the growing season for growth of aquatic vegetation. To apply outside mixing zone (AENV 1995). ❑ TARGET: CCME	Open Water Carseland 87-05 monthly 0.040 $(0.160)^{90}$	❑ 0.2 mg/L total ammonia was a fully-mixed concentration in the City of Calgary Total Loading Management model (Golder Associates 2007) that corresponded to 5 mg/L DO. ❑ The model assumes that some form of nitrification is occurring at the Fish Creek WWTP. This objective may need to be revisited as improvements around the WWTP occur over time and as findings from related research recommendations become available. ❑ Objectives are based on toxicity thresholds and aquatic plant growth.	7, 24, 27, 28, 31
Total Dissolved Phosphorus	Bow River Central	❑ WQO: 0.015 mg/L TDP during the growing season for aquatic plants ❑ Provisional objective: 0.054 mg/L for winter season	Open Water Carseland 83-05 monthly 0.016 mg/L $(0.037)^{90}$ With Enhanced P Removal monthly 2004 0.008 2005 0.006 Winter season 84-06 0.032 $(0.054)^{90}$	❑ Objective based on protecting DO and nuisance aquatic plants. ❑ Cross-sectional average TDP concentration that maintained DO levels above 5.0 mg/L in City of Calgary Total Loading Management model (Golder Associates 2007) using data from the April to Sept time period. ❑ Provisional objective is the 90^{th} percentile based on historical data. ❑ Lower [TDP] have been observed with recent wastewater treatment upgrades.	7, 24, 27, 28, 31
Total Organic Carbon	Bow River Central	❑ WQO: Should not exceed 5.0 mg/L (instantaneous) ❑ TARGET: Should not exceed 3.0 mg/L (instantaneous).	Year Round Carseland 87-05 monthly 1.90 $(3.11)^{90}$	❑ Increasing TOC levels in the source water has affected the treatment process of water at many surface water treatment plans. TOC >3 mg/L result in increased coagulant and chlorine demands, and gets worse as TOC levels get higher (UEWG 1999). ❑ Values exclude periods of snowmelt runoff, mountain runoff, and significant precipitation events.	9

Proposed Indicator or Topic Area	Reach or River	WQOs, Warning Levels and Targets	Baseline Water Quality (median, percentiles)[l]	Rationale	Related Recommendation Number in Table 4
Total Phosphorus	Bow River Central	❑ WQO: 0.028 mg/L ❑ TARGET: Eliminate levels that cause nuisance aquatic plant growth. ❑ Provisional WQO: 0.075 mg/L during winter season	Open Water Carseland 83-05 monthly 0.038 $(0.095)^{90}$ With Enhanced P Removal monthly 2004 0.023 2005 0.021 Winter season Carseland 84-06 0.052 $(0.075)^{90}$	❑ Objective is based on protecting DO and the target relates to controlling the growth of aquatic plant growth. The TP objective was inferred from the TDP objective using observed TP:TDP ratios. ❑ Based on TLM model (Golder & Assoc. 2007) using an average TDP concentration during Apr. to Sept. that maintained DO above 5.0 mg/L and a TDP:TP ratio of approx. 55%. ❑ Although there is currently no CCME guideline for phosphorus, the Bow River water quality objective is in the middle of the "trigger range" of TP concentration (0.020-0.035 mg/L) that CCME (2004) recommends for mesotrophic rivers (those with moderate levels of productivity), above which management action and investigation is required. It is also within the range of TP levels (0.018 - 0.030 mg/L) that corresponded to nuisance growth of periphyton in studies reviewed in Sosiak (2004). ❑ The WQO may be exceeded during storm events due to particulate phosphorus. ❑ With the addition of alum treatment, concentrations have declined in the last couple of years. ❑ Provisional objective is the 90th percentile based on historical data	7, 24, 27, 28, 31
Total Suspended Solids	Bow River Central	WQO: If the background[q] concentration is: < 25 mg/L conditions must not exceed an SEV value of 6 > 25 mg/L conditions must not exceed an SEV value of 7-(CCME 2002, Caux et al 1997) >250 mg/L CCME (2002) applies (conditions should not increase more than 10% above background levels when background is >250 mg/L) ❑ Calculation of the SEV value must be taken from fully mixed zone. ❑ WARNING LEVEL: Visible plume entering river during base river flow. ❑ TARGET: CCME, increase compliance frequency with objectives	Year Round Carseland 87-05 monthly 5.0 $(26.9)^{90}$	❑ There are different objectives to consider natural and anthropogenic TSS variation along the river. ❑ When the background is less than <250 mg/L, the objectives are based on SEV values derived from Newcombe and Jensen (1996). The approach relates the biological fish response to duration of exposure and suspended sediment concentration. The SEV values selected ensures that only a moderate level of physiological stress is endured by fish in this reach during 1 and 7 day exposure periods. ❑ SEV objectives are based on ASRD and DFOs' mandates which strive to ensure that fish and their habitats support success in all life stages. SEV exposure periods for 1 and 7 days were used to protect fish during storm events. ❑ It is recognized that the objectives may be temporarily exceeded during spring freshet and storm events. ❑ Warning narrative similar to what is used by the City of Calgary.	18, 27, 28, 31, 33, 30, 50, 52, 53

[q] Two general approaches are considered acceptable to define background concentrations of water quality variables which involve (CCME 2002 pg20- Site-specific guidance):
-Utilization of historically-collected water quality data for site (i.e., prior to the commencement of activities that coud have substantially altered water quality conditions); or -Monitoring contemporary water quality conditions at one or more stations located upstream of contaminant sources.

Proposed Indicator or Topic Area	Reach or River	WQOs, Warning Levels and Targets	Baseline Water Quality (median, percentiles)[l]	Rationale	Related Recommendation Number in Table 4
Water Temperature	Bow River Central	❑ WQO: Should not exceed 24°C at any time.	Open Water Carseland Above 87-05: Highwood Monthly 2006: hourly 12.4 17.37 $(17.1)^{90}$ $(19.81)^{90}$ $(20.2)^{max}$ 22.49^{max}	❑ 24°C was used in the Highwood Water Management Plan. ❑ Temperatures above 26°C can be lethal to rainbow trout (Hokanson et al, 1977). ❑ Need to also consider the interplay between oxygen & temperature.	2, 7, 17, 24, 27
Riparian Condition[m]	Bow River Central	❑ TARGET: a "healthy" rating using Cows and Fish rating system	❑	❑ Based on the best available data, targets were set at one level higher than initial conditions measured using the Cows and Fish Riparian Health Inventory rating system (Fitch and Ambrose 2003) (e.g., "unhealthy" ➔ "healthy with problems" ➔ "healthy"). If the river and/or reach previously rated as "healthy", the target remained as "healthy". In all cases, the long-term goal is "healthy".	45, 47, 49, 57, 59
Soil Erosion[n]	Bow River Central	❑ TARGET: An erosion and sediment control (ESC) plan should be designed with a T-value or maximum soil erosion rate target of 2t/ha/yr where disturbed land has direct connection to a water body (no buffer, no interception). Applies to all construction sites and endures for the life of the project (during and post construction phases).	❑	❑ An erosion and sediment control plan (ESC) must be developed, implemented and monitored for construction sites with any direct connection to surface water. ❑ An ESC plan should be prepared by a qualified professional (a professional certification that includes erosion and sediment control as a field of expertise). ❑ Based on methods described in Wall et al. (2002).	30, 31, 45, 47, 50, 51, 52
Attached Algae (Periphyton) Biomass-defined as chlor *a*	Bow River Lower	❑ WQO: No periphytic algal biomass that adversely affects users. ❑ Target: 150 mg/m^2 maximum value during open water season	Open Water Ronalane 87-05 monthly 53 $(109)^{90}$ $(493)^{max}$ last exceeded 150 mg/m^2 in 1987	❑ A literature review over many regions determined that periphyton concentrations above 150 mg/m^2 are associated with adverse impacts on users (Welch et al 1998).	**14**
Dissolved Oxygen	Bow River Lower	❑ WQO 5.0 mg/L (acute daily minimum), 6.5 chronic (7 day running average)	Open Water Ronalane 87-05 2000 monthly hourly 10.1 8.79 $(8.0)^{10}$ $(6.93)^{10}$ 3.7^{min} 5.75^{min}	❑ These values support the species of concern (e.g., sturgeon) and the main sport fish (e.g. Walleye, Northern pike).	2, 24, 27, 28
Macrophytes	Bow River Lower	❑ WQO: No macrophyte biomass that adversely affects users.	Peak macrophyte biomass of 105 g/m^2 below Bassano Dam during 1994-97 synopic surveys (Western Resource Solutions 2004)	❑ Numerical relationships between biomass and DO are poorly understood and need to be established. For example, higher macrophytes biomass may naturally occur in standing or slower moving water. ❑ Trying to relate measured macrophyte biomass in this reach to problems in irrigation district canals.	14

Proposed Indicator or Topic Area	Reach or River	WQOs, Warning Levels and Targets	Baseline Water Quality (median, percentiles)[l]	Rationale	Related Recommendation Number in Table 4
Nitrate (nitrate + nitrite (as N))	Bow River Lower	❑ WQO: 1.5 mg/L ❑ WARNING LEVEL: Need to better understand the limiting factor for macrophytes and periphyton growth before assigning a warning limit. ❑ TARGET: Eliminate levels that cause nuisance aquatic plant growth. ❑ WQOs, warning levels and targets for nitrate apply during the growing / open water season.	Open Water Ronalane 87-05 monthly 0.166 $(0.596)^{90}$	❑ WQO of 1.5 mg/L nitrate was the concentration in the City of Calgary Total Loading Management model (Golder Associates 2007) that corresponded to 5 mg/L DO for the period April to Sept 30. ❑ Although the City of Calgary model was not designed for this reach, it is assumed that the model's predicted limit is appropriate and it has been applied to this reach as well. ❑ Nitrate + nitrite levels will be typically well below this objective except for occasional outliers during the open water season and levels may be exceeded during the winter. ❑ The model assumes that some form of nitrification is occurring at the Fish Creek WWTP. This objective may need to be revisited as improvements around the WWTP occur over time and as findings from related research recommendations become available.	24, 27, 28
Pathogens as indicated by *E. coli*	Bow River Lower	❑ WQO: Meet recreational guideline - no single value to exceed 400 *E.coli*/ per 100 mL or (<200 *E. coli* per 100 mL (geometric mean 5 samples /30 d).	Year Round Ronalane 94-05 monthly 6 per 100 mL $(43)^{90}$	❑ 400 *E. coli*/100 mL is the CCME re-sampling guideline.	28
Pathogens as indicated by fecal coliforms	Bow River Lower	❑ WQO: Meet 100 fecal coliforms per 100 mL (no single value to exceed objective) at the point of withdrawal.	Year Round Ronalane 87-05 monthly 10 per 100 mL $(109)^{90}$	❑ Irrigation guidelines set by CCME. ❑ The WQO values can be briefly exceeded for short periods of time during storm events.	28
Pathogens as indicated by Total Coliforms	Bow River Lower	❑ WQO: Should not exceed 20,000 counts (total coliforms) per 100 mL at intake for drinking water treatment plant.	Year Round Ronalane 87-94 monthly 66 per 100 mL $(580)^{90}$	❑ The instantaneous objective of <20,000 counts/100 mL is based on conventional water treatment plant's ability to remove contaminants if pre-disinfection is present (US EPA 1991). ❑ Protects human health by ensuring that municipal water treatment plants can remove pathogens (e.g., bacteria, protozoa, and viruses) from raw water. ❑ Total coliforms are not typically monitored here.	28
Pathogens - *Giardia*	Bow River Lower	❑ WQO: Not set for this reach. However, *Giardia* is an important issue, and agencies should continue to monitor for *Giardia* and attempt to identify and reduce sources.	Insufficient data	❑ Insufficient data to make recommendation. We need to first determine *Giardia* counts in surface water reaches that can be effectively treated by different methods. ❑ Higher levels of *Giardia* require new water treatment processes for small water supply systems in the Basin. Over time, as approvals come up for renewal, small water supply systems may be required to upgrade to treat higher levels of *Giardia*.	3

Proposed Indicator or Topic Area	Reach or River	WQOs, Warning Levels and Targets	Baseline Water Quality (median, percentiles)[l]	Rationale	Related Recommendation Number in Table 4
Pesticides and Degradation Products	Bow River Lower	❑ WQO: Should not exceed the lower of: o < 1/10 of federal drinking water guidelines or o < CCME guidelines for aquatic life in the river.	Breakdown of data by reach not available (Anderson, 2005)[r].	❑ Protects drinking water and aquatic ecosystems. ❑ <1/10 of federal drinking water guidelines used to provide a safety margin to protect against compounds for which there is no treatment.	37, 38, 39, 41, 42
Total Ammonia	Bow River Lower	❑ WQO: The lower of US EPA or 0.2 mg/L ammonia during the growing season for growth of aquatic vegetation. To apply outside mixing zones (AENV 1995). ❑ TARGET: CCME	Open Water Ronalane 87-05 monthly 0.010 $(0.072)^{90}$	❑ 0.2 mg/L total ammonia was a fully-mixed concentration in the City of Calgary Total Loading Management model (Golder Associates 2007) that corresponded to 5 mg/L DO. ❑ Although the City of Calgary model was not designed for this reach, the model predicted limit is appropriate and has been applied to this reach as well. ❑ The model assumes that some form of nitrification is occurring at the Fish Creek WWTP. This objective may need to be revisited as improvements around the WWTP occur over time and as findings from related research recommendations become available. ❑ Objectives are based on toxicity thresholds and aquatic plant growth.	24, 27, 28
Total Dissolved Phosphorus	Bow River Lower	❑ WQO: 0.015 mg/L TDP during the growing season for aquatic plants ❑ Provisional objective: 0.025 mg/L for winter season	Open Water Ronalane 83-05 monthly 0.007 mg/L $(0.017)^{90}$ Winter season 84-05 0.007 $(0.025)^{90}$	❑ Objective is based on protecting DO and reducing nuisance aquatic plant growth. ❑ Although the City of Calgary model (Golder Assoc. 2007) was not designed for this reach, the model's predicted limit is appropriate and has been applied to this reach as well using ave. conc. during Apr. to Sept. ❑ Based on TLM model (Golder Assoc. 2007) using an average TDP concentration during Apr. to Sept. that maintained DO above 5.0 mg/L and a TDP:TP ratio of approx. 55%. ❑ Provisional objective is the 90th percentile based on historical data.	24, 27, 28
Total Organic Carbon	Bow River Lower	❑ WQO: Should not exceed 5.0 mg/L (instantaneous) ❑ TARGET: Should not exceed 3.0 mg/L (instantaneous).	Year Round Ronalane 87-05 monthly 2.55 $(4.20)^{90}$	❑ Increasing TOC levels in the source water has affected the treatment process of water at many surface water treatment plans. TOC >3 mg/L result in increased coagulant and chlorine demands, and gets worse as TOC levels get higher. (UEWG 1999) ❑ Values exclude periods of snowmelt runoff, mountain runoff, and significant precipitation events.	

[r] Over entire Bow basin, Anderson (2005; Table 4c) found 180 of 406 samples exceeded irrigation guidelines (mainly Dicamba and MCPA), 12 of 406 samples (mainly 2,4-D and chlorpyrifos-ethyl exceeded aquatic life guidelines, and no exceedance of guidelines for drinking water or livestock watering.

Proposed Indicator or Topic Area	Reach or River	WQOs, Warning Levels and Targets	Baseline Water Quality (median, percentiles)[l]	Rationale	Related Recommendation Number in Table 4
Total Phosphorus	Bow River Lower	❑ WQO: No recommendation for TP. TDP is believed to be the better WQO for this reach. ❑ TARGET: Eliminate levels that cause nuisance aquatic plant growth.	Open Water Ronalane 83-05 monthly 0.027 $(0.095)^{90}$ With Enhanced P Removal monthly 2004 0.031 2005 0.019 Winter season 1984-2006 0.020 $(0.041)^{90}$	❑ Total phosphorus in this reach is predominantly particulate phosphorus which can increase above this level with concurrent algae production. For this reason, total dissolved phosphorus is the better indicator for this reach.	24, 27, 28
Total Suspended Solids	Bow River Lower	WQO: If the background[s] concentration is: < 25 mg/L conditions must not exceed an SEV value of 6 > 25 mg/L conditions must not exceed an SEV value of 7-(CCME 2002, Caux et al 1997) >250 mg/L CCME (2002) applies (conditions should not increase more than 10% above background levels when background is >250 mg/L) ❑ Calculation of the SEV value must be taken from fully mixed zone. ❑ WARNING LEVEL: Visible plume entering river during base river flow. ❑ TARGET: CCME, increase compliance frequency with objectives	Year Round Ronalane 87-05 monthly 9.6 $(80.0)^{90}$	❑ There are different objectives to consider natural and anthropogenic TSS variation along the river. ❑ When the background is less than <250 mg/L, the objectives are based on SEV values derived from Newcombe and Jensen (1996). The approach relates the biological fish response to duration of exposure and suspended sediment concentration. The SEV values selected ensures that only a moderate level of physiological stress is endured by fish in this reach during 1 and 7 day exposure periods. ❑ SEV objectives are based on ASRD and DFOs' mandates which strive to ensure that fish and their habitats support success in all life stages. SEV exposure periods for 1 and 7 days were used to protect fish during storm events. ❑ It is recognized that the objectives may be temporarily exceeded during spring freshet and storm events. ❑ Warning narrative similar to what is used by the City of Calgary.	27, 50
Water Temperature	Bow River Lower	❑ WQO: Should not exceed 29°C at any time or a 7-day mean of 24°C. ❑ WARNING LEVEL: ABOVE BASSANO DAM: A warning level of 24°C should be used as a signal to stop all angling until such time as temperatures fall below 24°C for a period of 2 consecutive days.	Open Water Ronalane Bow City 87-05 1998 Monthly Hourly 15.7 20.38 $(20.9)^{90}$ $(23.97)^{90}$ $(25.9)^{max}$ $(28.8)^{max}$	❑ Lake Sturgeon occur in this reach and are considered a species of concern in Alberta. ❑ Objective is based on Taylor and Barton (1992).	2, 24, 27

[s] Two general approaches are considered acceptable to define background concentrations of water quality variables which involve (CCME 2002 pg20- Site-specific guidance):
-Utilization of historically-collected water quality data for site (i.e., prior to the commencement of activities that could have substantially altered water quality conditions); or -Monitoring contemporary water quality conditions at one or more stations located upstream of contaminant sources.

Proposed Indicator or Topic Area	Reach or River	WQOs, Warning Levels and Targets	Baseline Water Quality (median, percentiles)[l]	Rationale	Related Recommendation Number in Table 4
Riparian Condition[m]	Bow River Lower	❑ TARGET ABOVE BASSANO DAM: a "healthy" rating using the Cows and Fish rating system ❑ TARGET BELOW BASSANO DAM: a "healthy with problems" rating using the Cows and Fish rating system		❑ Based on the best available data, targets were set at one level higher than initial conditions measured using the Cows and Fish Riparian Health Inventory rating system (Fitch and Ambrose 2003) (e.g., "unhealthy" ➔ "healthy with problems" ➔ "healthy"). If the river and/or reach previously rated as "healthy", the target remained as "healthy". In all cases, the long-term goal is "healthy".	45, 47, 49, 57, 59
Soil Erosion[n]	Bow River Lower	❑ TARGET: An erosion and sediment control (ESC) plan should be designed with a T-value or maximum soil erosion rate target of 2t/ha/yr where disturbed land has direct connection to a water body (no buffer, no interception). Applies to all construction sites and endures for the life of the project (during and post construction phases).		❑ An erosion and sediment control plan (ESC) must be developed, implemented and monitored for construction sites with any direct connection to surface water. ❑ An ESC plan should be prepared by a qualified professional (a professional certification that includes erosion and sediment control as a field of expertise). ❑ Based on methods described in Wall et al. (2002).	45, 48, 50, 51
Attached Algae (Periphyton) Biomass-defined as chlor *a*	Elbow River Central	❑ WQO: 150 mg/m^2 maximum value during open water season	Open Water Sarcee Bridge 88-89 monthly 105.1 (143.1)^{75} (174.4)^{max} Not currently monitored	❑ A literature review over many regions determined that periphyton concentrations above 150 mg/m^2 are associated with adverse impacts on users (Welch et al 1998).	**14**
Dissolved Oxygen	Elbow River Central	❑ WQO: CCME with protection of spawning and incubation. o 9.5 mg/L for spawning and incubation o 6.5 mg/L for acute daily minimum.	Open Water Weaselhead 00-06 monthly 9.7 (8.5)^{10} 7.0^{min}	❑ CCME minimum for adult and juvenile cold-water fish ❑ Requires fishery inventory to determine spawning areas.	2, 28
Nitrate (nitrate + nitrite (as N))	Elbow River Central	❑ WQO: 0.267 mg/L ❑ WARNING LEVEL: 0.132 mg/L ❑ WQOs, warning levels and targets for nitrate apply during the growing / open water season.	Open Water Weaselhead 97-06 monthly 0.065 (0.129)^{90}	❑ Protects against stimulation of excessive algal growth to protect municipal water supplies. ❑ Nitrogen may be entering the reach as a result of long-range transport. ❑ The value of 0.267 mg/L was obtained from Sosiak (2004) as the nitrate + nitrite level that corresponds to nuisance growth of periphyton. ❑ The warning level was developed based on the 90th percentile level for the period 1992 – 2006.	27, 28, 35
Pathogens as indicated by *E. coli*	Elbow River Central	❑ WQO: Meet recreational guideline - no single value to exceed 400 *E.coli* per 100 mL or (<200 *E. coli* per 100 mL (geometric mean 5 samples /30 d).	Open water[t] Weaselhead 94-06 monthly 28 per 100 mL (167)^{90}	❑ 400 *E. coli*/100 mL is the CCME re-sampling guideline.	28, 32

[t] Most available data from April-September, although some years include March, October and November data

Proposed Indicator or Topic Area	Reach or River	WQOs, Warning Levels and Targets	Baseline Water Quality (median, percentiles)[t]	Rationale	Related Recommendation Number in Table 4
Pathogens as indicated by fecal coliforms	Elbow River Central	❑ WQO: Meet 100 fecal coliforms per 100 mL (no single value to exceed objective) at the point of withdrawal.	No baseline data currently available	❑ Irrigation guidelines set by CCME. ❑ The WQO values can be briefly exceeded for short periods of time during storm events.	28
Pathogens as indicated by Total Coliforms	Elbow River Central	❑ WQO: Should not exceed 20,000 counts (total coliforms) per 100 mL at intake for drinking water treatment plant.	Open water[u] Weaselhead 93-06 monthly 444 per 100 mL (2420)^{90}	❑ The instantaneous objective of <20,000 counts/100 mL is based on conventional water treatment plant's ability to remove contaminants if pre-disinfection is present (US EPA 1991). ❑ Protects human health by ensuring that municipal water treatment plants can remove pathogens (e.g., bacteria, protozoa, and viruses) from raw water.	28, 34
Pathogens - *Giardia*	Elbow River Central	❑ WQO: Should not exceed 100 cysts per 100 L (instantaneous) at the intake for Glenmore Water Treatment Plant.	Year Round cysts/100 L Weaselhead 97-05 24 (172)^{90}	❑ This is the level above which will require in excess of 5-log reduction at the Glenmore Water Treatment Plant (AENV, 2006). ❑ *Giardia* is more of a concern on the Elbow than the Bow, as levels are typically higher on the Elbow River. For this reason, the treatment facility has a clearwell to increase the chlorine contact time. ❑ Higher levels of *Giardia* require new water treatment processes for small water supply systems in the Basin. Over time, as approvals come up for renewal, small water supply systems may be required to upgrade to treat higher levels of *Giardia*.	3, 28
Pesticides and Degradation Products	Elbow River Central	❑ WQO: Should not exceed the lower of: o < 1/10 of federal drinking water guidelines or o < CCME guidelines for aquatic life in the river.	Insufficient data	❑ Provisional objective as there is currently no ongoing monitoring available at this time to set an objective. ❑ Protects drinking water and aquatic ecosystems. ❑ <1/10 of federal drinking water guidelines used to provide a safety margin to protect against compounds for which there is no treatment.	31, 37, 38, 39, 41, 42, 44
Total Ammonia	Elbow River Central	❑ WQO: Should not exceed 0.04 mg/L in the river for municipal water supply, and should not exceed CCME guideline for protection of aquatic life. To apply outside mixing zones.	Open Water Weaselhead 97-06 monthly 0.010 (0.020)^{90}	❑ Protects municipal water supply from unacceptable chlorine demand. ❑ Based on experience at Glenmore Water Treatment Plant. ❑ This is more restrictive than the current CCME guideline. ❑ Designed to protect aquatic life and takes into account the influence of both temperature and pH on the toxicity of ammonia. ❑ This objective does not represent a value to protect the river against excessive growth of aquatic plants.	27, 28

[u] Mostly April-September, although some years include March, October and November dates

Proposed Indicator or Topic Area	Reach or River	WQOs, Warning Levels and Targets	Baseline Water Quality (median, percentiles)[l]	Rationale	Related Recommendation Number in Table 4
Total Dissolved Phosphorus	Elbow River Central	❑ WQO: 0.009 mg/L TDP ❑ TARGET: Eliminate levels that cause nuisance aquatic plant growth.	Open Water Weaselhead 93-06 monthly 0.002 $(0.009)^{90}$	❑ Based on 90th percentile (1993-2006) for all available data from March to November at the Elbow River at Weaselhead.	27, 28
Total Organic Carbon	Elbow River Central	❑ WQO: Should not exceed 5.0 mg/L (instantaneous). ❑ TARGET: Should not exceed 3.0 mg/L (instantaneous).	Open Water[v] Weaselhead 93-06 monthly 1.41 $(3.97)^{90}$	❑ Values exclude periods of snowmelt runoff, mountain runoff, and significant precipitation events.	9
Total Phosphorus	Elbow River Central	❑ WQO: No recommendation for TP. TDP is believed to be the better WQO for this reach. ❑ TARGET: Eliminate levels that cause nuisance aquatic plant growth.	Open Water Weaselhead 93-06 monthly 0.011 $(0.089)^{90}$	❑ Total phosphorus in this reach is predominantly particulate phosphorus which can increase above this level without concurrent algae production. For this reason, total dissolved phosphorus is the better indicator for this reach.	27, 28
Total Suspended Solids	Elbow River Central	WQO: If the background[w] concentration is: < 25 mg/L conditions must not exceed an SEV value of 6 > 25 mg/L conditions must not exceed an SEV value of 7- (CCME 2002, Caux et al. 1997) >250 mg/L CCME (2002) applies (conditions should not increase more than 10% above background levels when background is >250 mg/L) ❑ Calculation of the SEV value must be taken from fully mixed zone. ❑ WARNING LEVEL: Visible plume entering river during base river flow. ❑ TARGET: CCME, increase compliance frequency with objectives	Open water[x] Weaselhead 98-06 monthly 8.1 $(62.0)^{90}$	❑ Trend analysis has indicated that levels of suspended solids are increasing. ❑ There are different objectives to consider natural and anthropogenic TSS variation along the river. ❑ When the background is less than <250 mg/L, the objectives are based on SEV values derived from Newcombe and Jensen (1996). The approach relates the biological fish response to duration of exposure and suspended sediment concentration. The SEV values selected ensures that only a moderate level of physiological stress is endured by fish in this reach during 1 and 7 day exposure periods. ❑ SEV objectives are based on ASRD and DFOs' mandates which strive to ensure that fish and their habitats support success in all life stages. SEV exposure periods for 1 and 7 days were used to protect fish during storm events. ❑ It is recognized that the objectives may be temporarily exceeded during spring freshet and storm events.	27, 28, 31, 33, 53, 50
Water Temperature	Elbow River Central	❑ WQO: Should not exceed 18°C at any time or a 7-day mean of 18°C.	Open Water Weaselhead 98-06 monthly 9.9 $(14.5)^{90}$ $(17.2)^{max}$	❑ 18°C is above the recorded maximum ❑ To protect most sensitive native fish, namely white fish. ❑ Chronic maximum based on Taylor & Barton.	2, 27

[v] Include some March and November data

[w] Two general approaches are considered acceptable to define background concentrations of water quality variables which involve (CCME 2002 pg20- Site-specific guidance):
-Utilization of historically-collected water quality data for site (i.e., prior to the commencement of activities that coud have substantially altered water quality conditions); or -Monitoring contemporary water quality conditions at one or more stations located upstream of contaminant sources.

[x] Available data is mostly from April-Sept, although some years include March, October and November dates

Proposed Indicator or Topic Area	Reach or River	WQOs, Warning Levels and Targets	Baseline Water Quality (median, percentiles)[l]	Rationale	Related Recommendation Number in Table 4
Riparian Condition[m]	Elbow River Central	❑ TARGET: maintaining a "healthy" rating using Cows and Fish rating system.	❑	❑ Based on the best available data, targets were set at one level higher than initial conditions measured using the Cows and Fish Riparian Health Inventory rating system (Fitch and Ambrose 2003) (e.g., "unhealthy" ➔ "healthy with problems" ➔ "healthy"). If the river and/or reach previously rated as "healthy", the target remained as "healthy". In all cases, the long-term goal is "healthy".	45, 47, 49, 56, 57, 59
Soil Erosion[n]	Elbow River Central	❑ TARGET: An erosion and sediment control (ESC) plan should be designed with a T-value or maximum soil erosion rate target of 2t/ha/yr where disturbed land has direct connection to a water body (no buffer, no interception). Applies to all construction sites and endures for the life of the project (during and post construction phases).	❑	❑ An erosion and sediment control plan (ESC) must be developed, implemented and monitored for construction sites with any direct connection to surface water. ❑ An ESC plan should be prepared by a qualified professional (a professional certification that includes erosion and sediment control as a field of expertise). ❑ Based on methods described in Wall et al. (2002).	27, 28, 29, 45, 48, 50, 51
Attached Algae (Periphyton) Biomass-defined as chlor *a*	Elbow River Upper	❑ WQO: 150 mg/m^2 maximum value during open water season ❑ Target: 47 mg/m^2 maximum	Open Water Downstream Bragg Creek 88-89 monthly 14.8 (21.5)^{75} (61.1)^{max}	❑ Target is an experimentally derived value based on 10 years of monitoring data for the Bow River near the Town of Banff. It is the value that represents the transition from good to fair rankings. In the absence of reach specific data for the Elbow, the upper Bow objective was considered a reasonable target. ❑ A literature review over many regions determined that periphyton concentrations above 150 mg/m^2 are associated with adverse impacts on users (Welch et al 1998). ❑ Not currently monitored and no historic data in this reach, very sparse.	**14**
Dissolved Oxygen	Elbow River Upper	❑ WQO: CCME with protection of spawning and incubation. o 9.5 mg/L for spawning and incubation o 6.5 mg/L for acute daily minimum.	Open Water Above Bragg Ck. 00-06 monthly 10.6 (9.4)^{10} 8.1^{min}	❑ CCME provides a high-level of protection for saturated conditions.	2
Nitrate (nitrate + nitrite (as N))	Elbow River Upper	❑ WQO: 0.13 mg/L during the open water season	Open Water Above Bragg Ck 99-06 monthly 0.083 (0.118)^{90}	❑ Trying to maintain this reach at its current trophic state. ❑ 90th percentile for Elbow River above Bragg Creek = 0.125 mg/L (1999 -2006).	27, 35
Pathogens as indicated by *E. coli*	Elbow River Upper	❑ WQO: Meet recreational guideline - no single value to exceed 400 *E.coli* per 100 mL or (<200 *E. coli* per 100 mL (geometric mean 5 samples /30 d).	Year Round[y] Above Bragg Ck. 98-06 monthly 4 per 100 mL (22)^{90}	❑ 400 *E. coli*/100 mL is the CCME re-sampling guideline.	28

[y] Not entirely year round historical data, year round data for 2004-2006

Proposed Indicator or Topic Area	Reach or River	WQOs, Warning Levels and Targets	Baseline Water Quality (median, percentiles)[l]	Rationale	Related Recommendation Number in Table 4
Pathogens as indicated by Total Coliforms	Elbow River Upper	❑ WQO: Should not exceed 20,000 total coliforms per 100 mL at intake for drinking water treatment plant.	Year Round[z] Above Bragg Ck. 98-06 monthly 68 per 100 mL (249)^{90}	❑ The instantaneous objective of <20,000 counts/100 mL is based on conventional water treatment plant's ability to remove contaminants if pre-disinfection is present (US EPA 1991). ❑ Protects human health by ensuring that municipal water treatment plants can remove pathogens (e.g., bacteria, protozoa, and viruses) from raw water.	28, 34
Pathogens - *Giardia*	Elbow River Upper	❑ WQO: Not set for this reach. However, *Giardia* is an important issue, and agencies should continue to monitor for *Giardia* and attempt to identify and reduce sources.	Insufficient data	❑ Insufficient data to make recommendation. We need to first determine *Giardia* counts in surface water reaches that can be effectively treated by different methods. ❑ Wildlife are the prime vectors of *Giardia* transmission in this reach.	3
Pesticides and Degradation Products	Elbow River Upper	❑ WQO: Should not exceed the lower of: o < 1/10 of federal drinking water guidelines or o < CCME guidelines for aquatic life in the river. (provisional objective)	Insufficient data	❑ Provisional objective as there is currently no ongoing monitoring available at this time to set an objective. ❑ <1/10 of federal drinking water guidelines used to provide a safety margin to protect against compounds for which there is no treatment. ❑ Protects drinking water and aquatic ecosystems.	37, 38, 39, 41, 42
Total Ammonia	Elbow River Upper	❑ WQO: Should not exceed CCME guideline for protection of aquatic life. To apply outside mixing zone (AENV 1995).	Open Water Above Bragg Ck. 00-06 monthly 0.010 (0.020)^{90}	❑ Designed to protect aquatic life and takes into account the influence of both temperature and pH on the toxicity of ammonia. ❑ Historical total ammonia values have not exceeded 0.02 mg/L in 7 years of data.	27, 28
Total Dissolved Phosphorus	Elbow River Upper	❑ WQO:0.006 mg/L TDP	Open Water Above Bragg Ck. 00-06 monthly 0.001 (0.006)^{90}	❑ Based on year-round historical data at Elbow River above Bragg Creek using 90th percentile (2000-2006).	28
Total Organic Carbon	Elbow River Upper	❑ WQO: Should not exceed 5.0 mg/L (instantaneous). ❑ TARGET: Should not exceed 3.0 mg/L (instantaneous).	Open Water[aa] Above Bragg Ck. 00-06 monthly 0.960 (3.76)^{90}	❑ Values exclude periods of snowmelt runoff, mountain runoff, and significant precipitation events.	
Total Phosphorus	Elbow River Upper	❑ WQO: 0.019 mg/L TP	Open Water Above Bragg Ck. 99-06 monthly 0.003 (0.019)^{90}	❑ Based on historical data at Elbow River above Bragg Creek using 90th percentile.	28
Total Suspended Solids	Elbow River Upper	❑ WQO: CCME	Year Round[bb] Above Bragg Ck. 01-06 monthly 1.0 (16.7)^{90}	❑ To maintain existing water quality for the protection of aquatic life.	27, 50, 52, 54

[z] Not entirely year round for all years in the period of record (2004-2006)
[m] Healthy riparian condition filters nutrients and minimizes the runoff of sediments into receiving water bodies.
[aa] Include some March and November data

Proposed Indicator or Topic Area	Reach or River	WQOs, Warning Levels and Targets	Baseline Water Quality (median, percentiles)[l]	Rationale	Related Recommendation Number in Table 4
Water Temperature	Elbow River Upper	❑ WQO: Should not exceed 18°C at any time or a 7-day mean of 15°C.	Open Water Above Bragg Ck 98-06 monthly 8.8 $(11.3)^{90}$ $(14.0)^{max}$	❑ 14°C is the recorded maximum in the Elbow River above Bragg Creek. ❑ To protect most sensitive native fish, namely bull trout ❑ Chronic maximum based on Taylor & Barton (1992).	2, 27
Riparian Condition[m]	Elbow River Upper	❑ TARGET: maintaining a "healthy" rating using Cows and Fish rating system.		❑ Based on the best available data, targets were set at one level higher than initial conditions measured using the Cows and Fish Riparian Health Inventory rating system (Fitch and Ambrose 2003) (e.g., "unhealthy" ➔ "healthy with problems" ➔ "healthy"). If the river and/or reach previously rated as "healthy", the target remained as "healthy". In all cases, the long-term goal is "healthy".	45, 47, 49, 57, 59
Soil Erosion[n]	Elbow River Upper	❑ TARGET: An erosion and sediment control (ESC) plan should be designed with a T-value or maximum soil erosion rate target of 2t/ha/yr where disturbed land has direct connection to a water body (no buffer, no interception). Applies to all construction sites and endures for the life of the project (during and post construction phases).		❑ For new developments that are permitted within the defined boundaries, Operating Ground Rules are in place to minimize erosion and sedimentation (ASRD). ❑ An erosion and sediment control plan (ESC) must be developed, implemented and monitored for construction sites with any direct connection to surface water. ❑ An ESC plan should be prepared by a qualified professional (a professional certification that includes erosion and sediment control as a field of expertise). ❑ Based on methods described in Wall et al. (2002).	45, 50, 51, 52, 54
Attached Algae (Periphyton) Biomass-defined as chlor *a*	Nose Creek	❑ WQO: No periphytic algal biomass that adversely affects users. ❑ Target: 150 mg/m^2 maximum value during open water season	Open Water Downstream Airdrie 99-01 monthly 48 $(136)^{90}$ $(257.2)^{max}$	❑ Creeks may be light-limited so the amount of periphyton is highly variable depending on location. ❑ A literature review over many regions determined that periphyton concentrations above 150 mg/m^2 are associated with adverse impacts on users (Welch et al 1998). ❑ Not currently monitored.	**19**
Dissolved Oxygen	Nose Creek	❑ WQO: Not recommended at this time. ❑ TARGET: 5.0 mg/L (acute daily minimum), 6.5 chronic (7-day running average).	Open Water At Mouth 95-06 7.1 $(4.8)^{10}$ 2.3^{min} Open Water At Mouth 2004 6.6 $(4.52)^{10}$ 2.21^{min}	❑ Action and more research is required before setting a WQO. ❑ DO is currently going well below 5.0, at both the mouth and the City of Calgary limit (can go as low as 3.0 mg/L).	2, 11, 27, 28
Nitrate (nitrate + nitrite (as N)	Nose Creek	❑ WQO: 1.5 mg/L ❑ TARGET: Eliminate levels that cause nuisance aquatic plant growth. ❑ WARNING LEVEL: Need to better understand the limiting factor for macrophytes and periphyton growth before assigning a warning level. ❑ All apply during the growing season.	Open water At the Mouth 95-06 monthly 0.500 as nitrate $(1.408)^{90}$ as nitrate	❑ Although exceeded at times, the WQO is reasonable and will be a catalyst for action. ❑ WQO of 1.5 mg/L nitrate was the concentration in the City of Calgary Total Loading Management that corresponded to 5 mg/L DO for the period April to Sept 30 (Golder Associates 2007). ❑ Although the City of Calgary model was not designed for Nose Creek, the model's predicted limit is appropriate and has been applied to this reach as well.	27, 28

[bb] Data record is not entirely year round for all years is for 2004-2006 data

Proposed Indicator or Topic Area	Reach or River	WQOs, Warning Levels and Targets	Baseline Water Quality (median, percentiles)[I]	Rationale	Related Recommendation Number in Table 4
Pathogens as indicated by fecal coliforms	Nose Creek	❑ TARGET: Meet 100 fecal coliforms per100 mL (no single value to exceed objective) at the point of withdrawal	Year Round At the Mouth 95-06 monthly 350 per 100 mL $(2540)^{90}$	❑ Irrigation guidelines set by CCME. ❑ The WQO values can be briefly exceeded for short periods of time during storm events. ❑ The challenge for Nose Creek is to determine what pathogen levels will be indicative of negative impacts to human health, stock health and pet health.	28
Pesticides and Degradation Products	Nose Creek	❑ WQO: Not recommended at this time. ❑ TARGET: Should not exceed CCME guidelines for aquatic life in the river.	1999-2001 (Cross 2002): samples exceeding CCME irrigation MCPA: 35% Dicamba: 59% (sensitive crops)	❑ Guidelines are currently being exceeded.	37, 38, 39, 41, 42, 44
Total Ammonia	Nose Creek	❑ WQO: US EPA during the growing season for growth of aquatic vegetation. To apply outside mixing zone (AENV 1995). ❑ TARGET: CCME	Open Water At the Mouth 95-06 monthly 0.250 $(0.500)^{90}$	❑ Currently both the WQO and target are exceeded at times. ❑ Ammonia can be toxic to fish and other aquatic species.	27, 28
Total Dissolved Phosphorus	Nose Creek	❑ WQO: To be developed.	Open Water At the Mouth 99-06 (as DRP) monthly 0.020 $(0.070)^{90}$	❑ Values fluctuate widely throughout the basin. See recommendation. ❑ Sources are likely urban storm water and agricultural runoff adjacent to the stream.	27, 28, 36
Total Phosphorus	Nose Creek	❑ WQO: To be developed. ❑ TARGET: Reduction in number of exceedences of the SWQG.	Open water At the Mouth 95-06 monthly 0.170 $(0.500)^{90}$	❑ The provincial guideline is frequently exceeded, with values fluctuating widely throughout the basin. ❑ West Nose is in better condition but is still two times higher than the SWQG. ❑ Sources are urban storm water and agricultural runoff adjacent to the stream.	27, 28, 36
Total Suspended Solids	Nose Creek	❑ WQO: To be developed. ❑ TARGET: Maintain and then reduce TSS loadings from current levels.	Year Round At the Mouth 95-06 monthly 19.0 $(62.1)^{90}$	❑ Highest levels are at the mouth and downstream of Airdrie probably resulting from urban runoff and urban flow alteration (higher flows). ❑ Nose Creek is a very turbid system with a mixture of natural sediments and those that result from human activities. ❑ Further work is required to determine what is natural and achievable.	10, 27, 50, 55
Water Temperature	Nose Creek	❑ WQO: Should not exceed 29°C at any time or a 7-day mean of 24°C.	Open Water At Mouth At Mouth 95-06 2004 Monthly hourly 13.10 16.57 $(18.91)^{90}$ $(20.94)^{90}$ $(20.50)^{max}$ $(26.2)^{max}$	❑ Objective is derived from Taylor and Barton (1992).	2, 11, 27

Proposed Indicator or Topic Area	Reach or River	WQOs, Warning Levels and Targets	Baseline Water Quality (median, percentiles)[l]	Rationale	Related Recommendation Number in Table 4
Riparian Condition[m]	Nose Creek	❑ TARGET FOR WEST NOSE CREEK: a "healthy" rating using the Cows and Fish rating system. ❑ TARGET FOR NOSE CREEK: a "healthy with problems" rating using the Cows and Fish rating system.	❑	❑ Based on the best available data, targets were set at one level higher than initial conditions measured using the Cows and Fish Riparian Health Inventory rating system (Fitch and Ambrose 2003) (e.g., "unhealthy" ➔ "healthy with problems" ➔ "healthy"). If the river and/or reach previously rated as "healthy", the target remained as "healthy". In all cases, the long-term goal is "healthy". ❑ Also to follow riparian protection recommendations outlined in the Nose Creek Watershed Management Plan (Nose Creek Watershed Partnership, 2006).	45, 47, 49, 57, 59
Runoff, soil erosion and impervious areas[n]	Nose Creek	❑ TARGET: Impervious and runoff recommendations as detailed in the Nose Creek Watershed Water Management Plan[cc].		❑ To preserve the natural hydrological runoff volume to pre-development conditions (i.e., natural conditions). ❑ Based on the overall goal of trying to achieve pre-development rates & volumes entering the streams or rivers. ❑ An erosion and sediment control plan is required (encourage retrofitting where possible). ❑ Erosion control plan applies to any new development or construction site during and post construction.	10, 26, 40, 45, 48, 50, 51, 55

[n] Although these indicators are not direct measures of water quality, they have been shown to influence water quality conditions and therefore are included in the document.
[cc] The Nose Creek Watershed Partnership website is located at www.nosecreekpartnership.com.

4.0 Recommendations

The Technical Committee put forward a number of recommendations with the purpose to either evaluate progress or suggest actions to help meet the reach-specific objectives and associated water quality outcomes. The recommendations are grouped as (1) performance indicators, necessary for the evaluation of the water quality outcomes or (2) management actions, suggested actions to meet the water quality outcomes. Specifically, there are water quality and aquatic ecosystem health performance indicators. Water quality management recommendations are related to water quantity, storm water and wastewater loading, pesticide use, land use planning, riparian and wetland characterization, and riparian and wetland protection. Recommendations are then categorized by the type of activity (i.e. research, education, planning, monitoring and evaluation, indicator/objective or target development, practice change, modelling and reporting). The recommendations apply to the overall Bow Basin, or a specific reach within the Bow Basin, Nose or Elbow River subwatersheds. Recommendations are numbered and relate back to Table 3 Water quality objective and indicator table. In some cases, recommendations listed below are for projects that are either in progress or are planned subject to budgetary approval. These recommendations are identified with an asterix (*). Suggested leaders of implementation and proposed timelines have been assigned to each of the recommendations.

All proposed Leaders of Implementation are expected to adopt the reach-specific water quality objectives and indicators identified in Table 1 and are responsible for:

1) developing an implementation plan for their specific recommendations shortly after the final plan is approved; and
2) preparing and submitting a summary progress report to the BRBC on an annual basis.

Table 4. Associated water quality recommendations.

Theme	Activity	Proposed Indicator or Topic Area	River or Reach	Recommendations	Proposed Leaders for Implementation*	Implementation Timeline	Recommendation # relate back to WQO's in Table 3
1a) water quality performance indicators	Monitoring and evaluation	Coordinated Monitoring	Overall Bow Basin	Coordinate a workshop to develop strategies for enhanced coordination of monitoring programs within the Bow Basin (including review of locations, standardization of methods and data, and enhanced provision of publicly-accessible real-time data).	BRBC	Short-Term (2008-2010)	1
1a) water quality performance indicators	Reporting	Real-Time Monitoring	Overall Bow Basin	Expand real-time monitoring for both flow and water quality in reaches where water quality is likely to be limiting for water management purposes. Agencies should move toward making all monitoring data "publicly accessible". Data assurance and quality control issues would also need to be addressed.	City of Calgary*, AENV, Environment Canada, BRBC	Medium-Term (2011-2012)	2
1a) water quality performance indicators	Research	*Giardia* Research	Overall Bow Basin	Further research and monitoring is needed to develop a long-term target for *Giardia*, and to determine natural and anthropogenic sources.	Research communities	Long-Term (2013-2014)	3

Theme	Activity	Proposed Indicator or Topic Area	River or Reach	Recommendations	Proposed Leaders for Implementation*	Implementation Timeline	Recommendation # relate back to WQO's in Table 3
1a) water quality performance indicators	Indicator development	*Cryptosporidium*	Overall Bow Basin	A report should be developed for the Bow Basin that will: 1) review *Cryptosporidium* data (to determine current levels, trends and potential threats) and 2) review *Cryptosporidium* monitoring methodologies (to help determine the most appropriate monitoring methods).	Research communities, City of Calgary	Medium-Term (2011-2012)	4
1a) water quality performance indicators	Monitoring and target development	*E. coli*	Bow above park boundary	include *E. coli* in surface water quality monitoring program to determine an appropriate target	Parks Canada and Environment Canada	Medium-Term (2011-2012)	5
1a) water quality performance indicators	Monitoring and evaluation	Spawning and Dissolved Oxygen Levels	Bow River Central	The City of Calgary needs to evaluate wastewater treatment methods and/or other options to improve river DO levels particularly during trout spawning and incubation.	City of Calgary	Medium-Term (2011-2012)	6
1a) water quality performance indicators	Research and monitoring	Research and monitoring on Dissolved Oxygen	Bow River Central	Further research on dissolved oxygen is required to determine the following: -What is causing low nocturnal dissolved oxygen levels in the Bow River downstream from Calgary in the spring and summer; -Whether N and/or P is the limiting nutrient for aquatic plant growth which contributes to low dissolved oxygen levels; -Additional monitoring, model refinement and research is required to ensure that 0.015 mg/L TDP is sufficient to prevent DO from falling below 5 mg/L; -Spawning success in relation to interstitial oxygen levels.	Research communities, City of Calgary, AENV, ASRD, City of Calgary	Short-Term (2008-2010)	7
1a) water quality performance indicators	Education	Pathogens (*E. coli*) and Education	Bow River Central	Additional education programs about risks associated with body contact recreation are recommended for this section of the Bow River (program already exists for the Lower Elbow below Glenmore).	City of Calgary*, Calgary Health Region	Short Term (2008-2010)	8
1a) water quality performance indicators	Research	Total Organic Carbon Thresholds and Exceedence Options	Bow River Central and Elbow River Central	Further research is needed to better define thresholds for total organic carbon. If WQOs are exceeded, treatment and source control options need to be investigated.	City of Calgary	Medium-Term (2011-2012)	9
1a) water quality performance indicators	Indicator development and research	Total Suspended Solids WQO and research	Nose Creek	A total suspended solids WQO should be developed for Nose Creek. Research is required to identify the anthropogenic causes of total suspended solids in Nose Creek and how it compares in quantity to natural causes.	Nose Creek Watershed Partnership	Long-term (2013-2014)	10
1a) water quality performance indicators	Monitoring and evaluation	Dissolved Oxygen Monitoring	Nose Creek	Enhanced monitoring of DO is required to better characterize and understand low nocturnal DO concentrations.	AENV, City of Calgary	Short-Term (2008-2010)	11

Theme	Activity	Proposed Indicator or Topic Area	River or Reach	Recommendations	Proposed Leaders for Implementation*	Implementation Timeline	Recommendation # relate back to WQO's in Table 3
1b) Aquatic ecosystem performance indicators	Indicator development	Benthic Invertebrate Research and Index of Biotic Integrity	Overall Bow Basin	Complete benthic invertebrate study for sites upstream and downstream of Calgary. Develop an index to assess benthic invertebrate response to water quality and assess overall aquatic ecosystem health.	City of Calgary*, Environment Canada, AENV, ASRD, ACA, Parks Canada & Research communities	Short-Term (2008-2010)	12
1b) Aquatic ecosystem performance indicators	Indicator development	Fish community Index	Overall Bow Basin	Fisheries Management will continue to refine the fish IBI (Index of biotic integrity) for use as an index to assess fish community response to water quality. The IBI will be designed for specific application to all portions of the overall Bow River Basin.	ASRD*	Medium-Term (2011-2012)	13
1b) Aquatic ecosystem performance indicators	Research	Macrophyte, Periphyton and Fish Research	Overall Bow Basin	Further research is required to link adverse human use impacts to macrophyte growth. Research is needed to determine periphyton levels that are acceptable with respect to water quality and still provide benefits for fish growth.	Research communities	Medium-Term (2011-2012)	14
1b) Aquatic ecosystem performance indicators	Research	*Didymosphenia* Research	Bow River Above Park Boundary, Bow River Below Park Boundary	Research is required to determine how *Didymosphenia geminata* is proliferating and what can be done to contain its growth.	Research communities, Environment Canada	Short-Term (2008-2010)	15
1b) Aquatic ecosystem performance indicators	Research	Water Temperature & Cutthroat Trout	Bow River Below Park Boundary	Research is required in this reach to help determine if water temperatures are sufficiently warm for cutthroat trout spawning in the spring.	Parks Canada, ASRD, Trout Unlimited	Short-Term (2008-2010)	16
1b) Aquatic ecosystem performance indicators	Monitoring and evaluation	Water Temperature and Dissolved Oxygen & Mountain Whitefish	Bow River Central	The thresholds for acute and chronic temperature and dissolved oxygen effects on mountain whitefish need to be established.	Research communities, ASRD	Short-Term (2008-2010)	17
1b) Aquatic ecosystem performance indicators	Research	Total Suspended Solids - Particle Size & Fish	Bow River Central	Further research on the effects of smaller particle size (e.g., in stormwater) on fish health and spawning is required.	Research communities, other academic agencies	Long-Term (2013-2014)	18
1b) Aquatic ecosystem performance indicators	Monitoring and evaluation	Periphyton Biomass	Nose Creek	Future water quality monitoring should include the collection of periphyton biomass (as chlorophyll *a*).	AENV	Short-Term (2008-2010)	19

Theme	Activity	Proposed Indicator or Topic Area	River or Reach	Recommendations	Proposed Leaders for Implementation*	Implementation Timeline	Recommendation # relate back to WQO's in Table 3
2a) Water quantity management in relation to water quality	Modelling and research	Water Balance Schematics	Overall Bow Basin	Water balance schematics should be developed for the Bow Basin and all key reaches defined in this document. Enhanced groundwater research will be required to help ensure completion of this task.	AENV, ASRD	Medium-Term (2011-2012)	20
2a) Water quantity management in relation to water quality	Indicator development	Flow Deviations	Overall Bow Basin	Further work is needed to develop an appropriate method to evaluate the deviation of recorded flows from naturalized flow regimes and three flow regime benchmarks[30] that have been set in the Bow Basin to meet the needs of the aquatic environment and consumptive water users. The method should quantify deviations over the historical period of record as well as on an ongoing annual basis at monitoring stations throughout the basin. It should allow consequences of proposed water license transfers within the basin to be evaluated and allow performance and progress with respect to meeting and reaching the flow regime benchmarks within the basin to be monitored over time. This recommendation will require the weekly natural flow database maintained by Alberta Environment to be updated with subsequent updates ideally occurring on an annual basis.	AENV, SRD, EC*	Short-term (2008-2010)	21
2a) Water quantity management in relation to water quality	BMP Implementation & Indicator development	Water Conservation	Overall Bow Basin	Water conservation, efficiency, productivity targets and programs to meet targets should be developed for all municipalities and irrigation districts within the Bow Basin.	Bow Municipalities	Short-Term (2008-2010)	22
2a) Water quantity management in relation to water quality	Reporting	Water Use Data	Overall Bow Basin	AENV to provide readily, accessible water use data for all major licensed water users in the Bow Basin (i.e. IDs, municipalities, and industry) and strive for enhanced recording of use for all other licence users.	AENV	Medium-Term (2011-2012)	23
2a) Water quantity management in relation to water quality	Modelling	Coupled-water quantity and quality modelling	Bow River Central, Bow River Lower	Modelling is needed to quantify how water quality on these reaches is affected by the high degree of flow regulation. Upstream hydroelectric dams as well as irrigation diversions within these reaches result in altered flow regimes. Modelling work is required to understand the effects of this alteration on assimilation capacity of the river to wastewater loadings and on ambient water quality.	Research communities	Medium-Term (2011-2012)	24

[30] The three flow benchmarks that have been set for the Bow Basin are: i) the Instream Flow Need values determined using the Instream Flow Incremental Methodology, ii) the Water Conservation Objectives established under the approved Water Management Plan for the South Saskatchewan River, and (iii) the Instream Objectives established under the Water Act and used as regulatory restrictions on existing water licences for dams and diversions.

Theme	Activity	Proposed Indicator or Topic Area	River or Reach	Recommendations	Proposed Leaders for Implementation*	Implementation Timeline	Recommendation # relate back to WQO's in Table 3
2a) Water quantity management in relation to water quality	Modelling	Headwater runoff modelling	Bow River Upper, Bow River Below Park Boundary, Elbow River Upper	Evaluate potential landcover scenarios in the headwaters of the Bow Basin using existing runoff models in response to different levels of forest disturbance (e.g. forestry, fire and mountain pine beetle). Results should be expressed in terms of the relative risks of various scenarios (e.g. more extreme peak and base flow events, changes to annual water supplies, erosion and sediment loading). Information will be helpful for land management decisions.	ASRD, University of Alberta	Medium-Term (2011-2012)	25
2a) Water quantity management in relation to water quality	Research	Peak and Base Flows	Nose Creek	Further research is needed to compare the frequency and magnitude of base and peak flows. Storm events should remain within the range of pre-developments conditions (pre-1970).	Nose Creek Watershed Partnership	Short-Term (2008-2010)	26
2b) Storm water and wastewater management	Modelling	Water Quality Modelling	Overall Bow Basin	An expanded water quality modelling program for both NPS and PS pollution entering the Bow River and key tributaries should be established for the Calgary region and other parts of the basin. Additional long-term water quality modelling expertise is required for the Bow Basin to help model targets for rivers and reaches outside of the existing City of Calgary model (Golder Associates 2007).	City of Calgary, Research communities Alliance, Alberta Agriculture & Food, & AENV*	Medium-Term (2010-2011)	27
2b) Storm water and wastewater management	Monitoring and reporting	Wastewater Monitoring and Reporting	Overall Bow Basin	Wastewater loadings from all licensed municipal and industrial sources throughout the Bow Basin should be monitored and reported for the various sub-basins.	AENV, municipalities and industries with discharges to the river	Short-Term (2008-2010)	28
2b) Storm water and wastewater management	BMP implementation	Wastewater and Stormwater Treatment	Overall Bow Basin	Municipalities must evaluate and implement the best available wastewater and stormwater options or technologies prior to protect the river water quality.	Bow Municipalities AENV (lead)	Short-Term (2008-2010)	29
2b) Storm water and wastewater management	BMP implementation	Total Suspended Sediments and Source Control Practices	Bow River Central	Develop design guidelines for source control practices (i.e., BMPs).	City of Calgary*	Medium-Term (2011-2012)	30
2b) Storm water and wastewater management	Monitoring and modelling	Storm water Monitoring	Bow River Central, Elbow River Central	Continue to conduct the water quality monitoring program for the representative storm water outfalls in Calgary in support of the Total Loading Management Plan (Golder Associates 2007). Work on verifying and improving the storm water total suspended solid loading estimates. Expand the model to estimate loadings from the pertinent storm outfalls in the Elbow Central reach (both Elbow and Glenmore outfalls).	City of Calgary*	Short-Term (2008-2010)	31
2b) Storm water and wastewater management	Objective development	Pathogen (*E. coli*) Source Tracking	Bow River Central, Elbow River Central	Further source tracking within the City of Calgary (including evaluation of risks) is required prior to setting WQOs and warning levels.	City of Calgary	Medium Term (2011-2012)	32

Theme	Activity	Proposed Indicator or Topic Area	River or Reach	Recommendations	Proposed Leaders for Implementation*	Implementation Timeline	Recommendation # relate back to WQO's in Table 3
2b) Storm water and wastewater management	BMP implementation	Stormwater Improvements	Bow River Central, Elbow River Central	Implement significant stormwater quality upgrades / improvements within Calgary.	City of Calgary*	Short to Long-Term (2008–2014)	33
2b) Storm water and wastewater management	Research	Pathogenic Speciation and WQOs (Total Coliforms)	Elbow River Central	Need to determine the species composition of pathogens and other organisms if counts are seen above 20,000 coliforms/100 mL at the intake for Glenmore Water Treatment Plant. Once the pathogenic speciation work has been completed, further work will be required to refine the WQO.	City of Calgary, BRBC	Medium-Term (2011-2012)	34
2b) Storm water and wastewater management	Research	Nitrate Research	Elbow River Central, Elbow River Upper, Bow River Above Park Boundary	Further research is needed to determine if increased nitrate in the headwaters and foothills is from natural sources, or the result of local anthropogenic changes or long-range transport.	Research communities	Medium-Term (2011-2012)	35
2b) Storm water and wastewater management	Research	Total Phosphorus Reductions	Nose Creek	Responsible for working to reduce total phosphorus and total dissolved phosphorus. Conduct research into the primary productivity of Nose Creek.	Nose Creek Watershed Partnership (lead), Research communities	Medium-Term (2011-2012)	36
2c) Pesticide management	Education	Pesticide Use and Education	Overall Bow Basin	Enhanced education programs should be developed to encourage a reduction in urban pesticide applications.	Bow Municipalities	Medium-Term (2011-2012)	37
2c) Pesticide management	Indicator development	Pesticide Index	Overall Bow Basin	Once completed, the new 1) Alberta pesticide index (based on thresholds of observable effects limits developed by Anne-Marie Anderson, AENV) and the new 2) European Union Water Framework Directive pesticide index should be reviewed as alternatives to the existing recommended WQO.	BRBC's Knowledge Data and Research team	Short-Term (2008-2010)	38
2c) Pesticide management	Monitoring and evaluation	Pesticide Monitoring	Overall Bow Basin	Monitoring agencies must ensure that pesticide concentrations continue to be part of all long-term monitoring programs. Parks Canada will consider adding pesticide monitoring to their existing agreement with Environment Canada. The monitoring program should be coordinated and consistent with the sampling methodologies utilized by AENV (e.g., frequency, variables tested, etc.)	AENV*, City of Calgary, Environment Canada, Parks Canada	Long-Term (2013-2014)	39
2c). Pesticide management	BMP implementation	Topsoil Thickness in New Developments	Overall Bow Basin	Require developers to provide thicker topsoil layers for all landscaped areas within new developments. This will help minimize the use and resulting impacts of urban pesticide applications and increase water retention.	Bow Municipalities, Urban Development Institute Calgary	Medium-Term (2011-2012)	40
2c) Pesticide management	BMP implementation	Pesticide Use	Overall Bow Basin	Municipalities will uphold the principle of minimizing the quantity and/or toxicity of active ingredients when applying pesticides on the land they manage.	Bow Municipalities	Short-Term (2008-2010)	41

Theme	Activity	Proposed Indicator or Topic Area	River or Reach	Recommendations	Proposed Leaders for Implementation*	Implementation Timeline	Recommendation # relate back to WQO's in Table 3
2c) Pesticide management	Reporting and evaluation	Pesticide Surveys for Bow Basin	Overall Bow Basin	Continue to survey pesticide sales every five years and break information down by major river basins including the Bow Basin. Data on pesticide sales can contribute important information for a variety of monitoring and research needs, such as the relationship between pesticide use and their persistence in the environment.	AENV*	Short-Term (2008-2010)	42
2c) Pesticide management	Education	Pesticide Applications and Buffer Areas	Bow River Central & Elbow River Central	Continue to support pesticide use education programs and BMP extension materials. Producers and commercial applicators must continue to follow product label application specifications if spraying on cultivated land. If no specifications are provided on the label, the provisions contained in the fact sheet "Pesticide Use In or Near Water" should be followed. (http://environment.gov.ab.ca/info/library/7459.pdf	Alberta Agriculture and Food, BRBC Legislation & Policy Committee, Bow Municipalities	Short-Term (2008-2010)	43
2c) Pesticide management	Reporting	Pesticide Use and Sales in Calgary	Bow River Central & Elbow River Central, Nose Creek	Continue to prepare annual surveys of urban domestic pesticide sales and actual use by golf course and landscape companies beyond 2008.	City of Calgary*	Short-Term (2008-2010)	44
2d) Landuse management in relation to water quality	Education	Low Impact Development Education	Overall Bow Basin	Take a lead role in helping to educate municipalities and developers on the basic principles of low impact development and encourage developers to utilize these practices in the overall design.	Urban Development Institute Calgary, Alberta Low Impact Development Partnership	Short-Term (2008-2010)	45
2d) Landuse management in relation to water quality	Education	Manure Application & Setbacks	Overall Bow Basin	Continue to educate producers on manure application and setback distances with respect to water bodies as outlined by the Agriculture Operations Practices Act. Research the effectiveness of different application techniques to reduce runoff of manure into receiving water bodies.	Alberta Agriculture & Food*, Natural Resource and Conservation Board*	Short-Term (2008-2010)	46
2d) Landuse management in relation to water quality	BMP implementation	Cattle Grazing in Riparian Areas	Overall Bow Basin	Implement grazing strategies to reduce the degree and impact of cattle grazing on riparian habitat along rivers and creeks (for grasslands, forested areas and protected areas).	ASRD, Alberta Environmental Farm Plan Company, Alberta Agriculture & Food, Cows & Fish*, Bow Municipalities	Short-Term (2008-2010)	47
2d) Landuse management in relation to water quality	BMP implementation	Low Impact Development and Municipal Approvals	Overall Bow Basin	All new residential and commercial developments should incorporate elements of low impact development beneficial management practices into the overall design. Whenever possible, the benefits of these changes should be monitored and assessed to see whether the changes are having an actual effect (i.e., performance monitoring). Municipalities need to ensure timely responses when dealing with approval requests from developers wishing to incorporate low impact development methodologies.	Bow Municipalities, Urban Development Institute Calgary	Short-Term (2008-2010)	48

Theme	Activity	Proposed Indicator or Topic Area	River or Reach	Recommendations	Proposed Leaders for Implementation*	Implementation Timeline	Recommendation # relate back to WQO's in Table 3
2d) Landuse management in relation to water quality	BMP implementation	Urban Riparian Buffer Zone Protection	Overall Bow Basin	Municipalities should adopt riparian setbacks within urban areas as outlined in the approved City of Calgary setback policy (2007) for all new developments (6 m for 1st order small streams, 30 m for 2nd order medium size creeks and rivers, and 50 m for 3rd and 4th order larger creeks and rivers, including modifications for slope, cover type and hydraulic connectivity). More protective setbacks are encouraged in areas where water quality needs improvement (e.g. Nose Creek Watershed Management plan, 2006)	Bow Municipalities	Short-Term (2008-2010)	49
2d) Landuse management in relation to water quality	BMP implementation	Soil Erosion	Overall Bow Basin	Include erosion and sediment control measures for construction sites in all development plans submitted to municipalities or management agency (e.g. Alberta Transportation). The City of Calgary's "erosion and sediment control manuals" can provide some guidance. A requirement for an inspection of the development site during and post construction by a qualified professional should be included.	Bow Municipalities	Short-Term (2008-2010)	50
2d) Landuse management in relation to water quality	Target development	Runoff, Erosion & Effective Impervious Areas	Overall Bow Basin	Review the City of Calgary's and MD of Rocky View's 1) effective impervious area targets, 2) reach-specific runoff volume targets, and 3) erosion control targets for all new developments with the potential adoption of these targets (or modified version of the targets to reflect sub-regional differences) for all new developments within the respective municipality.	Bow Municipalities	Medium-Term (2011-2012)	51
2d) Landuse management in relation to water quality	Target development	Runoff and Soil Erosion	Bow River Upper, Bow River Below Park Boundary and Elbow River Upper	Review the effectiveness of existing forestry guidelines (e.g., stream crossings, riparian protection, road maintenance) on water quality. Erosion control targets should be developed for reaches without a target and implemented.	ASRD	Short-Term (2008-2010)	52
2d) Landuse management in relation to water quality	Indicator development	Effective Impervious Areas	Bow River Central & Elbow River Central	Develop effective impervious area targets for all new developments based on the overall goal of trying to achieve pre-development rates & volumes entering the streams or rivers. -	City of Calgary and Municipal District of Rocky View, City of Airdrie, Town of Strathmore	Short-Term (2008-2010)	53
2d) Landuse management in relation to water quality	BMP implementation	Soil Erosion	Elbow River Upper, Bow River Upper	Efforts should continue to reduce erosion from trails, recreation sites or other recreational activities.	Alberta Tourism, Parks, Recreation & Culture*, ASRD*	Short-Term (2008-2010)	54
2d) Landuse management in relation to water quality	Target development	Runoff, Erosion & Effective Impervious Areas	Nose Creek	Enhanced stream and stormwater flow monitoring at various points throughout the system is needed to assist in the identification of the impervious and runoff targets.	City of Calgary	Short-Term (2008-2010)	55

Theme	Activity	Proposed Indicator or Topic Area	River or Reach	Recommendations	Proposed Leaders for Implementation*	Implementation Timeline	Recommendation # relate back to WQO's in Table 3
2e) Source water protection	Planning	Alluvial Aquifer	Elbow River Central	Land use on alluvial aquifer lands overlying groundwater under the direct influence of surface water (GUDI) has the potential to affect both groundwater and surface water quality. The land use should thus be carefully considered in the context of downstream river water uses with appropriate groundwater assessments done prior to development, if any. Groundwater assessments may lead to some additional monitoring.	MD of Rocky View, Tsuu T'ina First Nation, City of Calgary	Short-Term (2008-2010)	56
2f) Wetland & riparian characterization and protection	Objective and indicator development	Wetland and Riparian Health Inventory & Classification	Overall Bow Basin	A comprehensive wetland and riparian inventory which includes drained and altered wetland and developed and degraded riparian areas is critical for source water protection. The inventories should classify wetland and riparian areas at appropriate resolution/scale and according to their existing vegetation, the vegetation potential and the type and intensity of landuse occurring within them. Priorization by geographic area should be considered (e.g., White/Settled area vs. Green/ Forested area, heavily populated versus lightly populated areas). Objectives and indicators to assess wetland and riparian health that relate to water quality should be reassessed when this is complete.	AENV, Ducks Unlimited, ASRD Cows and Fish*	Short-Term (2008-2010)	57
2f) Wetland & riparian characterization and protection	Objective & Indicator development	Wetland Coverage	Overall Bow Basin	Using the enhanced wetland inventory, the percentage of land-base covered by wetlands should be used as an indicator for future state of watershed reporting and planning. The comprehensive wetland inventory capturing historic wetland loss and alteration should be used as an indicator for future state of watershed reporting and planning and the setting of wetland conservation and restoration goals.	BRBC AENV, DUC	Medium-Term (2011-2012)	58
2f) Wetland & riparian characterization and protection	Planning	Wetland and Riparian Restoration & Planning	Overall Bow Basin	Based on the findings of the comprehensive riparian and wetland inventories, a wetland management plan and riparian management plan should be developed and implemented as part of the BBWMP planning process.	Ducks Unlimited, AENV, Bow Municipalities, BRBC, ASRD	Medium-Term (2011-2012)	59

Theme	Activity	Proposed Indicator or Topic Area	River or Reach	Recommendations	Proposed Leaders for Implementation*	Implementation Timeline	Recommendation # relate back to WQO's in Table 3
2f) Wetland & riparian characterization and protection	Research	Wetlands and Storm water	Overall Bow Basin	Further research is required to determine the practicality of using existing undisturbed wetlands for storm water treatment purposes.	University of Calgary*	Long-Term (2013-2014)	60
2f) Wetland & riparian characterization and protection	Research	Wetlands and Water Quality	Overall Bow Basin	Further research into wetland restoration and its relationship with water quality is required.	Ducks Unlimited*	Medium-Term (2011-2012)	61

5.0 Next Steps

5.1 Tracking of Implementation Progress

The BBWMP is a basin-level decision-support tool that will provide decision makers with the relevant, Bow Basin-specific information essential for effective protection, restoration, and/or maintenance of the Bow Basin. The process of identifying water quality objectives and other key indicators allows stakeholders to work out mutually acceptable objectives and targets for the protection, restoration, and/or maintenance of the Bow Basin. Regulators can be confident that the objectives for phase 1 of the BBWMP are achievable since they are based on a consensus among stakeholders developed through an open process using credible scientific information.

The use of a consensus-based and collaborative process involving all agencies noted as "potential leaders for implementation" were essential in obtaining support of the plan. To the best of their ability, it is expected that the "potential leaders for implementation" will:

- Use the water quality objectives and indicators in all decision-making processes when their decision could impact the protection, restoration, and/or maintenance of the water quality in the Bow Basin;
- Consider the social and economic implications and benefits of the plan as part of their overall review and discussion regarding implementation of the recommendations.
- although each "potential leader for implementation" will be responsible for implementing the recommendations to the best of their ability, the BRBC will be responsible for tracking the overall implementation of the BBWMP through the annual progress report back.
- To assist in this regard, each "proposed leader for implementation" will be requested to: (1) develop an implementation plan for their specific recommendations shortly after final plan approval (2) prepare a summary of progress report for submission to the BRBC on an annual basis.
- To assist reporting agencies, the BRBC will prepare a standard reporting template for both the implementation plan and progress report. The template will be developed in an expedient manner.

5.2 BBWMP Updates

- Future phases of the BBWMP are currently under consideration by the BRBC Board of Directors. Please contact the BRBC for opportunities to get involved with future phases of the BBWMP.
- The BBWMP is a living document. As new information becomes available, updates to the existing version of the BBWMP will be considered on a case-by-case basis by the BRBC Board of Directors. Subsequent phases of the BBWMP will be inclusive and incorporate the key components of all earlier phases, thereby providing future opportunities to update the BBWMP as new information becomes available.
- Water quality data for each reach should be reported and reviewed on a regular basis and used as performance measurements of implementation for recommendations in this phase of the watershed management plan. A Technical Committee of predominantly fisheries and water quality specialists should continue to meet bi-annually to review the water quality objectives to: add or modify indicators, objectives, targets; warning levels based on their monitoring performance or research developments, adapt to future potential challenges (e.g. climate change, population growth), and maintain communication direct resource expenditure; and share knowledge among monitoring groups.

6.0 GLOSSARY

Term	Abbreviation	Description or Definition
Alluvial aquifer		Subsurface geological unit along a river or stream that is hydraulically connected to the surface water body. This is an unconfined aquifer but not all unconfined aquifers are in alluvial deposits.
Alberta Environment	AENV	Alberta Environment's mission is to assure the effective stewardship of Alberta's environmental systems to sustain a high quality of life.
Alberta Sustainable Resource Development	ASRD	ASRD encourages balanced and responsible use of Alberta's natural resources through the application of leading practices in management, science, and stewardship.
Aquatic plants outcome	AQPT	Aquatic plants reach specific desired outcome - Surface water quality where water withdrawal systems are protected from high levels of algal and macrophyte biomass
Bow Basin Watershed Council	BRBC	The Bow River Basin Council is a multi-stakeholder, charitable organization dedicated to conducting activities for the improvement and protection of the waters of the Bow River Basin**.**
Buffer		A transitional area between two different land types or uses (e.g., a riparian buffer zone provides a transition between the river and the upland area.)
Canadian Environmental Quality Guidelines, Canadian Council of Ministers of the Environment	CCME	A document that compiles surface water quality guidelines for use in Canada.
Cold Water Ecosystem Outcome	CDWE	Cold water ecosystem reach specific desired outcome - Surface water quality that maintains the existing cold-water aquatic ecosystem fauna structure and abundance (e.g., healthy trout populations and benthic invertebrates).
Cool water ecosystem outcome	CLWE	Cool water ecosystem reach specific desired outcome - Surface water quality that maintains the existing cool-water aquatic ecosystem fauna structure and abundance (e.g., healthy walleye populations and benthic invertebrates).
Irrigation Outcome	IRR	Irrigation reach specific desired outcome - Surface water quality that is appropriate for the irrigation of crops.
Livestock outcome	LIV	Livestock reach specific desired outcome - Surface water quality that is appropriate for livestock watering.
Mixing zone		The regulatory mixing zone is rectangular in shape. It has a width equal to half the river width, and a length equal to 10 x the river width. The definition originates from Alberta Environment's Water Quality Effluent Procedures Manual (AENV 1995).
National Recommended Water Quality Criteria, United States Environmental Protection Agency	US EPA	A document that compiles surface water quality criteria (equivalent to Canadian guidelines) for use in the United States.
Nuisance Growth		The biomass of native or non-native aquatic plant species that threatens the diversity or abundance of native aquatic species; commercial, agricultural, aquacultural or recreational activity; or the ecological stability of impacted waters.
Provisional objective		Objective used when there is not enough data or understanding of the data to set an objective.
Rate of soil erosion		The rate of soil erosion is expressed in terms or tonnes per hectare per year (t/ha/yr). A rate of 1 t/ha/yr is approximately a layer of soil 0.1 mm thick or the thickness of 1 sheet of 20 lb paper.
Recreation Outcome	REC	Recreation reach specific desired outcome - Surface water quality where total body contact recreation is safe (e.g., high coliforms from storm events).
Riparian areas		The lands adjacent to streams, rivers, lakes and wetlands where the vegetation, soils and alluvial aquifers are strongly influenced by the presence of surface water. They are part of healthy, functioning landscapes and form part of the extensive drainage network within every watershed.
Severity of ill effects	SEV	Index score provided by Newcombe and Jensen (1996) that relates suspended sediment to fish stress and habitat degradation.
Surface Water Quality outcome	SWQ	Reach specific desired outcome- Maintain or enhance surface water quality (and linked alluvial aquifers) for human consumption.
Surface Water Quality Guidelines for Use in Alberta	SWQG	A document that compiles surface water quality guidelines for use in Alberta.

Term	Abbreviation	Description or Definition
T- value or soil loss tolerance		A concept of human-induced erosion that is widely used throughout the world for conservation planning. The goal is to maintain the rate of soil loss at a level approximately the same as soil formation. To address the problem of erosion degrading receiving water bodies, erosion and sediment control specialists may use soil loss prediction models as an aid in selecting effective methods appropriate for site-specific conditions. The T-value applies to erosion on disturbed land up to where there is concentrated flow of runoff water. If this point is a waterbody, then the soil loss rate equals the sediment delivery rate and water quality may be affected if the quantity is high.
Target		A target is a numerically defined desired condition for a given indicator.
Threshold		Values not to be exceeded.
Trophic state		The total weight of living biological material (*biomass*) in a waterbody at a specific location and time. Trophic state includes the biological response to forcing factors such as nutrient additions along with the modifying factors such as season, grazing, mixing depth, etc. The trophic state indices can use algal biomass as the basis for trophic state classification. Three variables, chlorophyll pigments, Secchi depth, and total phosphorus, independently estimate algal biomass (Carlson and Simpson 1996).
Warning Level		Warning levels act as a planning trigger for certain management actions to occur.
Water Quality Objectives	WQO	Water quality objectives are minimum or maximum values adapted to protect the most sensitive designated water uses at a specific location with an adequate degree of safety, taking local circumstances and naturally occurring water quality fluctuations into account.
Wetlands		Land having water at, near, or above the land surface or which is saturated with water long enough to promote wetland or aquatic processes as indicated by poorly drained (hydric) soils, hydrophytic vegetation, and various kinds of biological activity that are adapted to the wet environment. Degraded wetlands may not show all of these characteristics, but remain important.

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8.0 Appendices

8.1 Appendix A. Description of Indicators

Indicator	Description
Attached algae (periphyton) biomass	Periphyton are benthic algae that grow attached to surfaces such as rocks or larger plants. Periphyton are primary producers and sensitive indicators of environmental change such as physical and chemical disturbances in both flowing and standing waters. High biomass typically corresponds to high nutrient concentrations.
Benthic invertebrates	Benthic invertebrates are aquatic invertebrates living in the bottom of our lakes and rivers. Benthic invertebrates make good indicators of watershed health because they are abundant, easy to collect and identify to genus level in a laboratory, and have specific tolerances to the amount and types of pollution (US EPA, 2007).
Organic carbon	Organic carbon is composed of both dissolved and particulate forms; total organic carbon (TOC) incorporates both forms. Organic contaminants (e.g. natural organic substances, waste water treatment plant effluent, agricultural chemicals) can enter water bodies in runoff. High organic concentrations can increase the growth of microorganisms and therefore decrease oxygen supplies. TOC is important from a water treatment perspective because it increases coagulant and chlorine demand and is a source of organic precursors to potentially harmful disinfection by-products.
Dissolved oxygen	Sufficient dissolved oxygen (DO) concentrations are essential for the survival of most aquatic life forms. With increasing water temperature, the solubility of oxygen decreases. At the same time, however, the respiratory requirements of aquatic organisms increase. Decomposition of excessive organic material and respiration of aquatic plants can also decrease DO concentrations to the point where fish die.
Erosion	Erosion is caused when soil particles are dislodged and transported by water falling on or running across bare soil or vegetated areas that are unable to resist the force of the flowing and falling water. If eroded material is transported to water bodies sedimentation occurs which reduces water quality after and during storm events. Erosion problems can be made worse by the increased volumes of stormwater runoff generated by the impervious (non-porous) surfaces we create, such as rooftops, decks, driveways, and paved walkways (Meyer and Tesarik, 2003). Rate of soil erosion is expressed in terms or tonnes per hectare per year (t/ha/yr). A rate of 1 t/ha/yr is approximately a layer of soil 0.1 mm thick or the thickness of 1 sheet of 20 lb paper.
Giardia	*Giardia lamblia* is a flagellated protozoan parasite that infects the gastrointestinal tract of many animals, including humans. It causes giardiasis (also known as beaver fever. *Giardia* can be transferred from contact with animal or human feces and infection can occur from consuming contaminated food or water. Chlorine and ultraviolet light are common means of water treatment for *Giardia*.
Macrophytes	Macrophytes are aquatic plants, growing in or near water that are either emergent, submergent, or floating. Macrophytes are beneficial to lakes and rivers because they provide cover for fish and substrate for aquatic invertebrates. They also produce oxygen, which assists with overall lake and river functioning, and provide food for some fish and other wildlife. However, an overabundance of macrophytes can result from high nutrient levels and may interfere with river processes, recreational activities (e.g., swimming, fishing, and boating), and detract from the aesthetic appeal of the system.
Nitrate + nitrite	Nitrate is the principal and most stable form of inorganic nitrogen in aquatic systems. Nitrite is an intermediate form in the nitrification/denitrification pathway, and can be toxic, but is usually found in negligible quantities because of its instability in the presence of oxygen. Because of this instability, nitrate and nitrite are often reported as a combined variable. Natural sources of nitrogen to surface water bodies can include atmospheric deposition. Human sources include municipal and industrial wastewaters, septic tanks and runoff or leaching from agricultural practices. Nitrate is a nutrient necessary for plant growth. High concentrations of nitrate can pose a toxic risk for livestock watering, and infants. Elevated concentrations can also result in the excessive growth of algae and aquatic plants.
Pathogens (as indicated by fecal coliforms)	Fecal coliform bacteria are found in the guts of mammals and birds. They can enter surface waters through fecal contamination by wildlife and domestic animals. They can also enter surface waters through wastewater discharges or surface water runoff. Fecal coliform bacteria are not necessarily harmful to human health, but they indicate fecal contamination and the possible presence of other pathogenic organisms, including *E. coli, Salmonella, Giardia* and *Cryptosporidium*, which can have serious health implications.
Pathogens (as indicated by *E. coli)*	*E. coli* is a type of fecal coliform bacteria. Most *E. coli* are harmless but several strains (including the 0157;H7 strain) can be toxic and cause severe gastrointestinal illness if contaminated water is ingested.
Pesticides and herbicides	Pesticides can be toxic to aquatic organisms and watered livestock. Conventional drinking water treatment plants are not designed to treat pesticides so they must be controlled at the source. Pesticides can enter surface waters via runoff from municipal or agricultural land applications. Pesticides leaching through soils can contaminate groundwater.
Riparian condition	Healthy, functioning riparian areas offer resiliency (the ability to bounce back from floods, droughts and human-caused problems); ecological services (such as trapping and storing sediment, building and maintaining banks and shorelines, recharging aquifers, filtering and buffering water, etc.); and stability (landscapes that maintain themselves, persist and are sustainable) (Fitch and Ambrose, 2003). Water bodies receiving runoff from areas with poor riparian condition generally have poorer water quality than those with healthy riparian condition.

Indicator	Description
Runoff	Runoff is water from precipitation, rain or melting snow, which flows across the surface of the land. It composes a fraction of the total volume of precipitation that lands on the ground; the remainder seeps into the ground through the soil or evaporates back into the atmosphere with the help of the sun and vegetation. Runoff, often called stormwater runoff when used to refer to the unnaturally large volumes of runoff we create by paving roads and driveways and building structures such as our homes and other buildings, can cause flooding, erosion, water pollution, and property damage, and it can ultimately cause the loss of fish and wildlife habitat and reduced water quality in our lakes and streams.
Total ammonia	Total ammonia is the most reduced form of inorganic nitrogen in water, and includes both the ionized (NH_4^+) and unionized forms (NH_3). Unionized ammonia is the toxic form and its prevalence depends on a combination of pH and temperature. In most well-oxygenated waters, ammonia is converted quickly to nitrate. Ammonia is produced by the decomposition of organic material. Ammonia can be found in municipal and industrial wastewater effluents and in runoff downstream of fields with intensive manure/fertilizer application.
Total coliforms	The total coliform group is composed of various bacteria genera with similar characteristics. The natural niches for members of this group range from being faecal specific, such as *E. coli*, to being widely distributed in the water, soil, and vegetation (Leclerc et al, 2001; Rompré et al, 2002). This lack of specificity is why many monitoring agencies are moving away from testing for total coliforms and moving towards more specific tests. Never the less, total coliform tests have been around the longest and unusual deviations from baseline concentrations are still a good cause for closer investigation.
Total phosphorus and total dissolved phosphorus	Phosphorus is another nutrient essential for aquatic plant growth. Total phosphorus includes particulate as well as dissolved phosphorus, however, it is the latter form that is most readily bio-available for plant growth. Phosphorus enters surface waters naturally through runoff, or through human activities such as wastewater discharges and agricultural practices. Elevated concentrations can result in excessive growth of algae and aquatic plants.
Total suspended solids	Total suspended solids are solid materials, including organic and inorganic, that are suspended in the water, including silt, plankton and industrial wastes. High concentrations of suspended solids can lower water quality by absorbing light. Waters then become warmer and lessen the ability of the water to hold oxygen necessary for aquatic life. Because aquatic plants also receive less light, photosynthesis decreases and less oxygen is produced. The combination of warmer water, less light and less oxygen makes it impossible for some forms of life to exist. Suspended solids affect life in other ways. They can clog fish gills, reduce growth rates, decrease resistance to disease, and prevent egg and larval development. Suspended solids can result from erosion from urban runoff and agricultural land, industrial wastes, bank erosion, bottom feeders (such as suckers), algal growth or wastewater discharges (North Dakota, 2007). Suspended solids can also be a carrier of adsorbed toxic substances such as pesticides, heavy metals and pathogens.
Water quantity	Water quantity and quality are inextricably linked. River flow is also affected by natural changes in climate and seasonal weather patterns. As well, dams and other structures have affected many Alberta rivers. Large volumes of water may be withdrawn or stored for human use at certain times of year with surplus water being returned at other times of the year. This human influence can significantly alter the seasonal flows from natural patterns.
Water quantity balance	Water balance schematics will provide a summary of where water resources are located for a given basin or sub-basin. By showing where water is located, this information can be used to assist in the decision-making processes for the development of plans, programs and policies.
Water temperature	Water temperature has direct and indirect effects on nearly all aspects of stream ecology. For example, the amount of oxygen that can be dissolved in water is partly governed by temperature. As cold water can hold more oxygen than warm water, certain species of aquatic invertebrates and fish with high oxygen demands (including popular sport fish such as some trout) are found only in these waters. Temperature also influences the rate of photosynthesis by algae and aquatic plants. As water temperature rises, the rate of photosynthesis increases providing there are adequate amounts of nutrients. Furthermore, as most aquatic animals are cold-blooded, their metabolic rate is faster in warm water. Therefore, they need more food and oxygen in warm water and release more wastes.
Wetland loss and restoration	Wetlands and their associated riparian areas contribute significantly to watershed function beyond the mainstem and tributaries and they are a significant indicator of watershed health and function. Their role in groundwater recharge, waste and nutrient assimilation, flood attenuation and storage in the watershed are well recognized.

******* Additional information on the various indicators can be found in the Canadian Environmental Quality Guidelines (CCME 1999) at http://www.ec.gc.ca/CEQG-RCQE/English/default.cfm.

8.2 Appendix B: Existing Water Quality and Indicator Guidelines

Proposed Indicator or Topic Area	Existing Water Quality and Indicator Guidelines
Attached Algae (Periphyton) Biomass	❑ SWQG: Not available. ❑ CCME: Not available. ❑ US EPA: Not available. ❑ LITERATURE: 150 mg/m^2 maximum (Welch et al,1998)
Dissolved Oxygen	❑ SWQG: 5.0 mg/L (1 d minimum acute), 6.5 mg/L (7d mean) ❑ CCME: 5.5 to 9.5 mg/L (5.5 relates to the protection of other life stages in warm water ecosystems and 9.5 relates to the protection of early life stages of aquatic life in cold water ecosystems). ❑ US EPA: 3.0 to 9.5 mg/L (3.0, 1 d minimum, for the protection of aquatic life in other stages of warm water ecosystems; 9.5 relates, 7 d mean to protect the early life stages of aquatic life in cold water ecosystems).
Giardia	❑ There are currently no Alberta, CCME, or US EPA guidelines for *Giardia* in raw water supplies.
Macrophytes	❑ SWQG: Not available. ❑ CCME: Narrative. Swimmers should avoid areas with rooted or floating plants; very dense growths could affect other activities such as boating and fishing. ❑ US EPA: Not available. ❑ BRBWQC Task Force Report (Bow River Water Quality Council, 1994) 75 g/m$^{2.}$.
Nitrate (nitrate + nitrite, as N))	❑ SWQG: Not available. ❑ CCME: 2.94 mg/L plus narrative - concentrations that stimulate weed growth should be avoided. ❑ US EPA: Not available. ❑ STUDY RESULTS: Previous work found 0.267 mg/L nitrate + nitrite sufficient for maximum growth of periphyton in Bow (Sosiak, A., 2002).
Pathogens as indicated by *E. coli*	❑ SWQG: Not available. ❑ CCME: <200 *E. coli*/100 mL (geometric mean 5/30 d) ❑ US EPA: 126 *E. coli*/100 mL; 33 enterococci/100 mL (geometric means)
Pathogens as indicated by fecal coliforms	❑ CCME: 100 coliforms/100 mL.
Pathogens as indicated by Total Coliforms	❑ There are currently no Alberta, CCME, or US EPA guidelines for raw water supplies. ❑ The current guidelines for finished drinking water are 0 total coliforms and 0 *E. coli*.
Pesticides and Degradation Products	❑ Canadian Drinking Water Guidelines ❑ CCME
Riparian Condition	❑ No current guidelines.
Rural Runoff and Erosion Targets	❑ Thresholds can be set at 5 tonnes/hectare/year using a 100-year return storm for agricultural areas (Wall et al, 2002)
Runoff, Erosion & Effective Impervious Areas	❑ City of Calgary has accepted Imagine Calgary's target to reduce impervious areas to 30% by 2036. ❑ Thresholds can be set at 2 tonnes/hectare/year using a 100-year return storm for forested and urban areas (Wall et al, 2002) ❑ Thresholds can be set at 5 tonnes/hectare/year using a 100-year return storm for agricultural areas (H. Sinton pers. comm.)
Total Ammonia	❑ SWQG: Not available. ❑ CCME: 0.343-32.4 mg/L. Exact guideline depends on pH and temperature. Range given as example only for 10 C, pH 6.5 to 8.5 (lowest at 8.5), based on 2000 revision. Calculator available. Chronic guidelines. ❑ US EPA: Tables - Refer to page 10 of the Alberta Surface Water Quality Guidelines (AENV1999) for the complete table. Acute and chronic guidelines.
Total Dissolved Phosphorus	❑ SWQG: Not available. ❑ CCME: Not available. ❑ US EPA: Not available. ❑ LITERATURE: 6.4 ug/L – point of nuisance algae growth (Sosiak 2002).
Total Organic Carbon	❑ No current guidelines. More research recommended to better define limits.
Total Phosphorus	❑ SWQG: 50 ug/L ❑ CCME: Not available. ❑ US EPA: Not available. ❑ LITERATURE: 18 – 30 ug/L (scientific literature, including study on Bow River aquatic plants) (Sosiak, A., 2002; Dodds, W.K. et al, 1997; Chételat, J. et al, 1999).
Total Suspended Solids	❑ SWQG: Not increased by more than 10 mg/L over background. ❑ CCME: For clear flow - Maximum increase of 25 mg/L from background levels for any short-term exposure (e.g., 24-h period). Maximum increase of 5 mg/L from background levels for any long-term exposure (e.g., inputs lasting between 24 h and 30 d). For high flow - Maximum increase of 25 mg/L from background levels at any time when background levels are between 25 and 250 mg/L. Should not increase more than 10% of background levels when background is >250 mg/L. ❑ US EPA: Settleable and suspended solids should not reduce the depth of the compensation point for photosynthetic activity by more than 10% from the seasonally established norm for aquatic life (for solids –

Proposed Indicator or Topic Area	Existing Water Quality and Indicator Guidelines
	suspended, settleable, and turbidity).
Water Quantity Indicator	❑ No readily available indicators used to date.
Water Temperature	❑ SWQG: Not to be increased by more than 3°C above ambient temperature. ❑ CCME: As narrative. Thermal additions should not alter thermal stratification or turnover dates, exceed maximum weekly average temperatures, nor exceed maximum short-term temperatures. ❑ US EPA: Not available. A narrative is available in the US EPA Gold Book (1986), but depends on detailed knowledge of the temperature tolerance of fish species, and is complex.

In Alberta, water quality monitoring agencies generally take guidance from either the Alberta Surface Water Quality Guidelines, the Canadian Council of Minister of the Environment Canadian Environmental Quality Guidelines, or United States Environmental Protection Agency National Water Quality Criteria.

8.3 Appendix C. Technical Committee Biographies

Al Sosiak, M.Sc. Biol. Senior Limnologist, Al has a B.Sc., from Brock University and a M.Sc. from the University of New Brunswick. Al has worked on lake and watershed restoration programs, water quality monitoring, fisheries management, and impact assessment studies throughout the South Saskatchewan basin with the Alberta government since 1982. He is currently the limnologist responsible for water quality programs in the Bow and the South Saskatchewan basin downstream of the confluence of the Bow and Oldman River. He is the chair of the BBWMP Technical Committee.

Cathy Ryan, PhD, P. Eng, P. Geol., Associate Professor, Dept of Geoscience and BSc Environmental Science Program, University of Calgary. Cathy has been a University of Calgary faculty member since 1997. Her research program is focused on ground- and surface-water quality.

Earl Wilson, P.Eng. General Manager of Eastern Irrigation District. Earl received undergraduate degree from the University of Saskatchewan in 1979 and has over 25 years of water resources experience.

Fay Westcott, M.Sc., P.Biol., Aquatic Biologist, Clearwater Environmental Consultants Inc.
Fay received her B.Sc. (1994) and M.Sc. (1997) in Ecology from the University of Calgary. She is a partner at Clearwater Environmental Consultants where she conducts environmental assessments, with a focus on water quality and aquatic resources.

Francine Forrest, M.Sc., P. Biol. Water Quality Specialist, Alberta Agriculture and Food, Edmonton, AB. Francine has a B.Sc. from the University of Victoria and a M.Sc. (limnology) from Queen's University in Ontario. She has been employed with Alberta Agriculture and Food since 2001. As Acting Head of the Water Quality Unit she was overseeing the surface water monitoring program of the Alberta Environmentally Sustainable Agriculture program and has over the years been involved in several research projects that evaluate agricultural impacts on receiving water bodies. She has an additional 2.5 years of experience on water quality projects with an environmental consulting company.

Gerald R. Ontkean, M.Sc., PAg., Soil and Water Specialist, Alberta Agriculture and Food, Lethbridge, AB. Completed a BSc. (Agriculture, Soil Science Major) at the University of Alberta in 1982 and a M.Sc. (Land and Water Resources) from the University of Alberta in 2000. Employed by Alberta Agriculture and Food since 1982. Current projects are concerned with the examination of relationships between the agricultural landbase and surface water quality in Alberta

Jamie Dixon, M.Sc., P.Biol., Watershed Biologist, The City of Calgary Water Resources, Water Quality Services. As the watershed biologist for the City of Calgary since 1990, Jamie coordinates surface water quality monitoring in the Bow and Elbow watersheds through the Calgary region. A graduate of the University of Calgary, he received a B.Sc. in Environmental Biology in 1983, and a M.Sc. in Aquatic Ecology in 1988. He is an active member of the American Water Works Association, the Western Canada Water and Wastewater Association, and the Alberta Society of Professional Biologists.

Jean-Philippe (J.P.) Bechtold, M.A.Sc., P.Biol., Senior Water Quality Specialist, Golder Associates Ltd. J.P. holds a B.Sc. in Biology from the University of Western Ontario and an M.A.Sc. in Environmental Engineering from the University of British Columbia. He has over 10 years of consulting experience in the field of water quality. As a specialist in computer modelling of aquatic systems, J.P. has applied numerical models to streams, rivers, lakes and wetlands with the objective of assessing how various activities may affect water quality and aquatic life in the receiving environment. His project experience includes the successful completion of baseline sampling programs, environmental impact assessments and environmental effects monitoring programs. J.P. has also developed total loading management targets for both the City of Calgary and the City of Edmonton, all with a focus on protecting aquatic life in the receiving environment.

John Jagorinec, B.Sc., P.Chem. The City of Calgary, Water Resources, Strategic Services. As the Senior Water Quality and Regulatory Analyst for the City of Calgary Water Resources, John looks after the regulatory and water quality issues associated with Calgary's wastewater and drinking water treatment plants. John is the Chairman of the Ghost Stewardship Monitoring Group and Vice Chairman of the Elbow River Watershed Partnership. He received his B.Sc. in Chemistry from the University of Calgary in 1993 and has been with The City for 11 years. He is an active member of the American Water Works Association, the Western Canada Water and Wastewater Association, and the Association of the Chemical Profession of Alberta.

Joanne Little, M.Sc., Joanne received her B.Sc. (Honours) in Environmental Science and her M.Sc. in limnology from Queen's University in Kingston, Ontario. Since 1999, she has researched agricultural water quality and evaluated Beneficial Management Practices with Agriculture and Agri-Food Canada and then Alberta Agriculture and Food. She is currently on maternity leave from her position as Head of the Water Quality Unit with her newborn twins.

Matthew Coombs, M.Sc., Environmental Indicators Specialist, Southern Region, Alberta Environment. Matthew received a B.Sc. (Hon) in Biology from Queen's University in 2002 and a M.Sc. from Trent University's Watershed Ecosystems Graduate Program in 2005. He has identified indicators to monitor and manage cumulative environmental effects on land, water quantity and quality, in aquatic and riparian ecosystems in southern Alberta. These indicators will be used to monitor broad-scale environmental performance of watersheds and will be part of a new adaptive approach to environmental management in Alberta.

Richard Barss, MEDes, Land use Planner. He has a B.Sc in geology (from the University of Calgary), a BSc. in Zoology (from the University of Alberta) and a Master Env. Design (from the University of Calgary). Richard currently is a land use planner for the Municipal District of Rocky View.

Sheena Majewski, M.Sc. Fish Habitat Biologist, Department of Fisheries and Oceans

Shelley Humphries, M.Sc. Aquatic Specialist, Lake Louise, Yoho and Kootenay Field Unit, Parks Canada Agency
Received undergraduate B.Sc. (Honors Zoology) from the University of Alberta in 1991 and completed a M.Sc. (Environmental Biology and Ecology) in 1998 at the University of Alberta. She has been employed with Parks Canada since 1999, as the aquatic specialist since 2005. Area of responsibility includes water quality, benthic bio-monitoring, fish populations and aquatic species at risk for the western and northern portions of Banff National Park.

Travis Ripley, M.Sc., P. Biol., Fish and Wildlife Program Manager, SRD, Southern Rockies Area - Received undergrad B.Sc. from University of Lethbridge in 1996 and completed M.Sc. (Environmental Biology and Ecology) in 2003 at the University of Alberta. Travis has been employed with the Alberta Government as a Fisheries Biologist since 1992 assessing fish biology, fisheries assessment techniques, impacts of water quality and quantity on fish population and structure including fish population modelling.