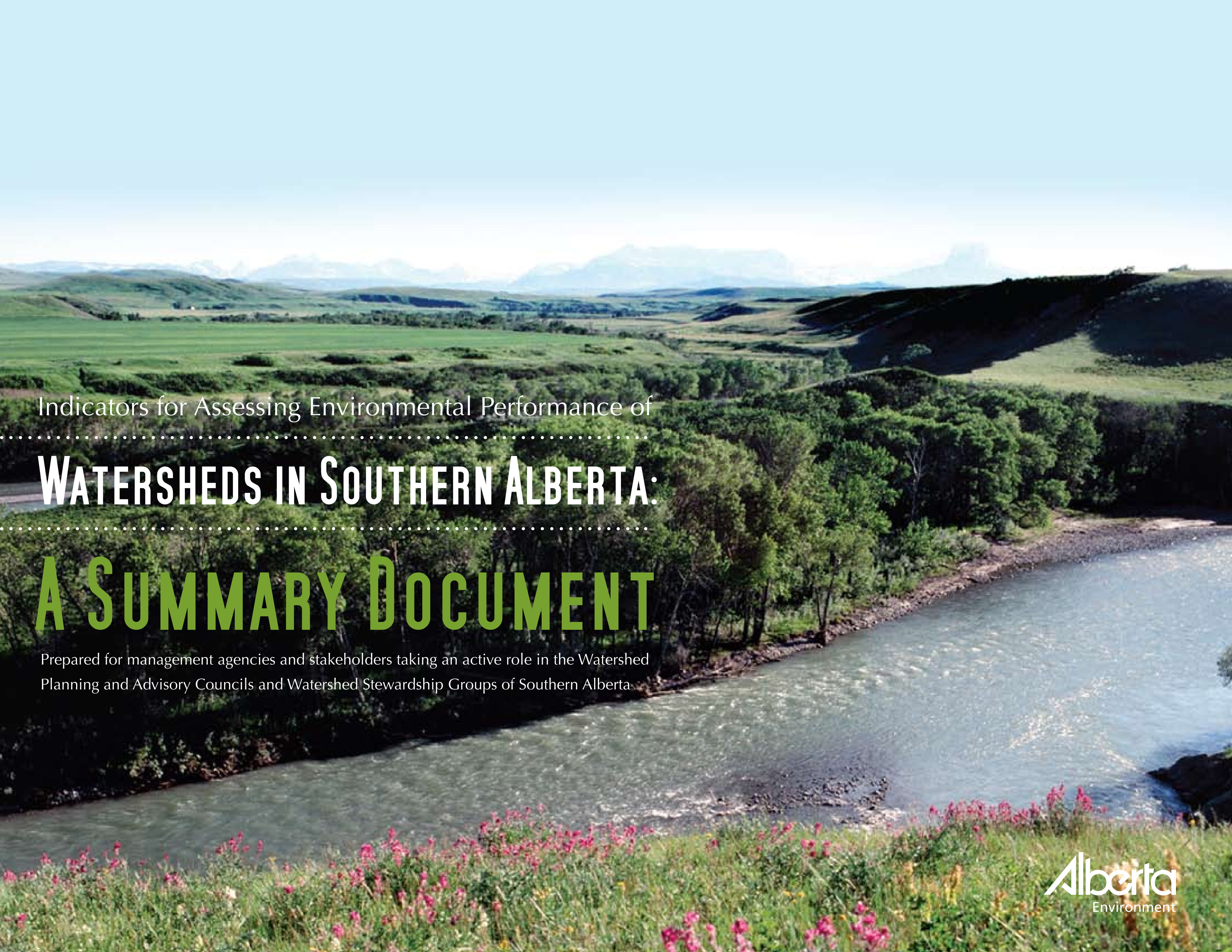


Indicators for Assessing Environmental Performance of

Watersheds in Southern Alberta:

A Summary Document

Prepared for management agencies and stakeholders taking an active role in the Watershed Planning and Advisory Councils and Watershed Stewardship Groups of Southern Alberta

Alberta
Environment


Drinking water


Irrigation pivot


Healthy aquatic ecosystem

This summary document is meant to provide guidance to WPACs and WSGs in terms of identifying environmental indicators to monitor the environmental state of watersheds and assess progress towards achieving environmental outcomes.

Alberta's *Water for Life* strategy sets three environmental outcomes as long-term objectives to work towards and maintain. These are:

- **safe, secure drinking water supplies**
- **reliable, quality water supplies for a sustainable economy**
- **healthy aquatic ecosystems**

Watershed Planning and Advisory Councils (WPACs) and Watershed Stewardship Groups (WSGs) will play a central role in achieving these outcomes. This summary document is meant to provide guidance to these groups in terms of identifying what environmental indicators they can use to monitor the environmental state of watersheds and assess progress towards achieving environmental outcomes. Condition indicators, measuring biotic or abiotic characteristics in the environment, and pressure indicators, measuring human activities that can influence the observed environmental conditions, are identified for four areas where there is increasing pressure on the environment: land, water quantity, water quality, and aquatic and riparian ecosystem health. A more thorough discussion of these indicators is available in a full-length report available from Alberta Environment www.environment.alberta.ca.

Land Indicators: Quality and Use

Watersheds act as a catchment for precipitation. All human activities occurring on the land within them ultimately affect the quantity and quality of surface water running off the land into waterbodies as well as the underlying groundwater. Land quality and land use indicators are proposed to assess the impact of these human activities.

Land Quality Indicators

1. Amount of land covered by natural vegetation

Natural vegetation plays a key role in the water-related functions of land. Non-native vegetation that performs the same functions as native vegetation should be included when measuring this indicator. More natural cover in a watershed results in a more natural flow regime, higher water quality, and healthier aquatic and riparian ecosystems.

- Riparian areas and wetlands should be evaluated separately from the broader watersheds as a whole.
- Vegetation acts as a natural biofilter, removing sediments, nutrients, and pathogens from water running off the land.
- Vegetation prevents soil erosion by stabilising the banks of waterbodies.

2. Model-predicted soil erosion rates

Erosion often leads to water quality contaminants running off the land into water bodies. Modelling and mapping erosion rates using soil and land cover data helps evaluate the location and intensity of various land use types that disturb the soil to determine whether they are occurring in appropriate areas.

3. Site-specific, on-the-ground measurements of rangeland health

- Species composition and presence of community structural layers (i.e., species varying in size, height, and root depth) should be measured to assess whether intact plant communities are present, which indicate low levels of human land disturbance.
- The amount of plant litter (i.e., fresh or decomposing dead material) should be measured to assess whether nutrient and water cycles are being supported.
- The amount of human-caused bare ground should be measured to assess the risk of erosion.

4. Site-specific, on-the-ground measurements of riparian health

- Regeneration of palatable woody riparian species, which stabilize banks and absorb nutrients in runoff, should be measured to assess the impact of livestock grazing and water flow reductions from dams and diversions.
- Measuring livestock browse on palatable woody riparian species should be used as an indicator of grazing intensity. Intense grazing leads to invasion by disturbance-caused plants, which do not perform riparian functions as well as native plants.
- The amount of riparian area covered in deep binding roots and human-caused bare ground should be measured, to assess the risk of erosion.

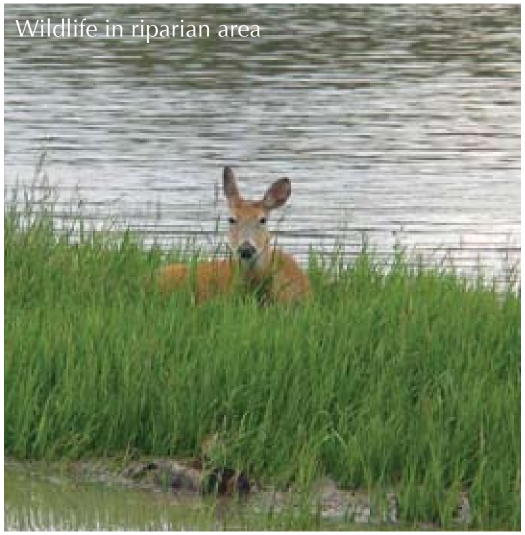

Wildlife in riparian area

Table 1. Summary of land quality indicators as well as potential thresholds or targets for these indicators.

Land quality indicators	Potential or existing targets and thresholds
Proportional and absolute areal amount of watersheds covered by key types of natural vegetation, including ecologically similar, non-native vegetation. 1. Native/natural grassland cover types • riparian areas • grasslands • wetlands 2. Native/natural forested cover types • burnt, regenerating and mature forests with age and size class • naturally non-forested vegetated land	Percent of watershed area that must be covered in natural vegetation could be set using watershed scale soil erosion and runoff models as well as using studies evaluating aquatic and riparian ecosystem health in relation to land use intensity.
Model-predicted soil erosion rates	Thresholds could be set using soil erosion rates that would exist under natural land cover as a benchmark.
Site-specific, on-the-ground measurements of rangeland health on public and private native grassland and forest and tame pasture • plant species composition • presence of plant community structural layers • amount of plant litter • amount of human-caused bare ground	Thresholds could be set with respect to requirements for land to be able to perform its basic water-related functions of resisting erosion, filtering runoff, regulating the storage and discharge of runoff, and allowing for groundwater recharge.
Site-specific, on-the-ground measurements of riparian health on public and private land • regeneration of palatable woody riparian species • livestock browse intensity on palatable woody riparian species • amount of riparian area covered in deep binding roots • amount of human-caused bare ground	Alberta's Cows and Fish program suggests the lower two levels of their classification system for these measurements are sufficiently unhealthy that they can be considered as below a threshold for a sustainable, functioning riparian ecosystem.

Land use indicators

1. Human population and dwelling unit density

These are the most basic measures of land use.

2. Human-altered land and constructed features on the landscape

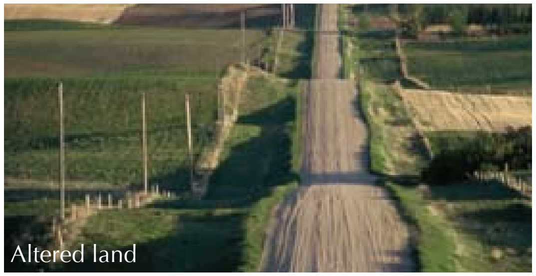
Any human land use that alters the land from its natural state. Measures of land use can be expressed in terms of:

- the percentage of area they cover
- densities over a particular area
- densities over a given shoreline distance or length of stream

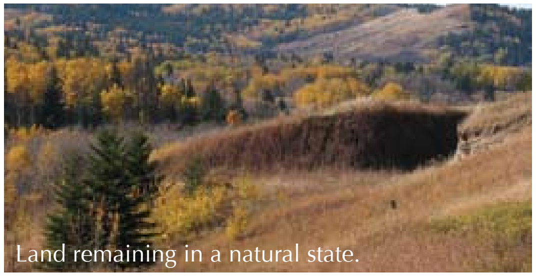
Land use activities can have a higher level of impact in riparian and wetland areas, so these indicators should be reported separately for areas near waterbodies (e.g., within 500 m) and areas where wetlands exist or used to exist.

3. Amounts of agricultural and non-agricultural fertilizers and pesticides applied to the land

The amount of these key contaminants applied to the land measures the risk of contaminating water with nutrients, pathogens, and pesticides.



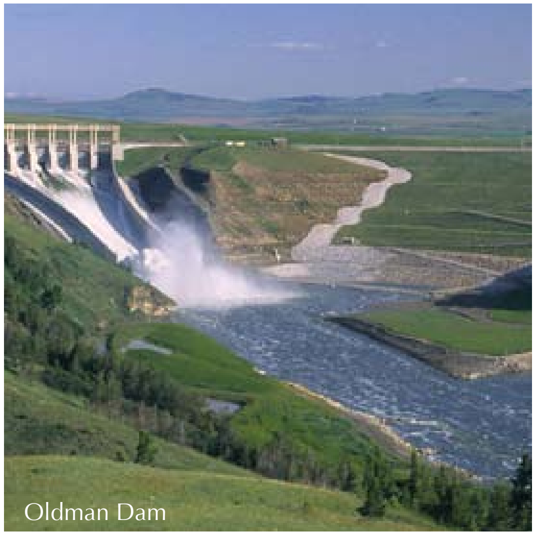
Altered land



Land remaining in a natural state.

Table 2. Summary of land use indicators as well as potential thresholds or targets for these indicators.

Land use indicators	Potential or existing targets and thresholds
Total human footprint classified by: 1. Land cover types, for example: • irrigated and non-irrigated crops and cultivated pasture • forest clear-cuts • pits and mines • industrial as well as urban and rural residential development • all types of constructed impervious surfaces 2. Landscape features, for example: • confined feeding operations and large dairies • oil and gas batteries • compressors or refineries • industrial processing plants • oil, gas, and groundwater wells 3. Linear disturbance and stream crossing types, for example: • all types of roads • dams, weirs, bridges, culverts, and fords • rail, transmission, seismic, and pipe lines	Thresholds could be set with respect to levels of land use resulting in unsustainable increases in runoff volume, erosion, and pollutant loadings as well as degradation of aquatic ecosystem health.
Human population • population density • dwelling unit density	Town of Okotoks provides an example: a limit has been set on its maximum population size based on capacity of the Sheep River to supply municipal drinking water.
Agricultural manure and fertilizer application rates Agricultural and non-agricultural pesticide use	Thresholds for manure and fertilizer application rates could be set using models that predict erosion and runoff rates and volumes together with watershed scale water quality models. For pesticides, provincial regulations and municipal bylaws banning the sale of certain types of products may be more appropriate than setting thresholds and targets.



Oldman Dam

High and low river flows and when these flows occur are important for:

- **water quality**
- **aquatic and riparian ecosystem health**
- **physical river channel**

Prairie river channel features

Water Quantity Indicators: Flow, Runoff, and Use

Water quality, aquatic and riparian ecosystem health, and the physical river channel all depend on natural variability in the quantity and timing of river flows.

- High flows can improve water quality by diluting contaminants, buffering against human-caused water temperature increases, and increasing dissolved oxygen levels.
- High flows can also degrade water quality when a large amount of water runs off the land carrying contaminants with it.
- Fish, benthic invertebrates, and riparian vegetation are adapted to the natural flow regime, and their abundance and distribution matches the availability of physical habitats, the range of water quality, and the supply of food from upstream sources that high and low-flow periods provide.
- Low flows resulting from dams and diversions can reduce the amount of spawning and refugia habitat as well as diminish groundwater levels critical to supporting these habitats and the riparian vegetation.
- Minimum flushing flows are required to prevent sediment from building up, while higher flows form new river channels and keep existing channels from becoming too narrow and prone to flooding.

Flow Indicators

1. Deviation of recorded flows from naturalized flows

- Comparing existing recorded flows to estimates of the flows without the dams and diversions in place indicates the absolute amount by which flows have been altered.

2. Deviation of recorded flows from three flow regime benchmarks intended to protect water quality and aquatic and riparian ecosystem health:

- Instream Flow Needs (IFNs) are scientifically determined flow requirements thought to be necessary to sustain the health of various components of river ecosystems. They are not legislated flows and cannot be enforced under Alberta's Water Act.
- Water Conservation Objectives (WCOs) are flow benchmarks based on public input and the government's decision in terms of what is deemed a reasonable and socially acceptable trade-off between environmental protection and socio-economic needs for water.
- Instream Objectives are used as operational numbers setting restrictions on existing water licences based on Alberta's Water Act. These objectives define minimum regulated flows that must remain in rivers downstream of dams and licensed water diversions.

Flow regime benchmarks that preserve some of the natural flow variability provide better protection than those that allow the variability in flows to be removed as flows are kept at a constant minimum value.

Erosion and runoff from a forestry road

Calgary street flooding

Low flows below Oldman River Dam

Table 3. Summary of flow indicators as well the assessment role of these indicators.

Flow indicators	Assessment role of the indicator
Deviation of recorded flows from naturalized flows	Identify reaches under greatest stress from water management
Deviation of recorded flows from IFNs	Focus water conservation efforts and best management practices on locations and times when IFNs are achievable
Deviation of recorded flows from WCOs	Determine where and when WCOs are and are not being achieved
Deviation of recorded flows from Instream Objectives	Ensure these minimum regulated flows are being achieved

Runoff and water use indicators

1. Changes to annual runoff rates and volumes modelled at the watershed scale

- In unregulated watersheds, changes to land cover will impact flow regimes rather than dams and diversions, and changes to runoff from all areas where natural land cover has been altered should be estimated using models.
- Land use effects on flow regimes are poorly understood, and as land use intensifies, it is important to have accurate models predicting runoff rates and volumes under changing land cover.

2. The actual amount of water being diverted from and returned to streams and rivers

- All licensed water diversions and any associated return flows should be monitored to provide accurate, sector-specific measurements of water use.
- This information could be used to determine whether provincial targets for water conservation, efficiency, and productivity are being met.

Table 4. Summary of runoff and water use indicators, their assessment role, and potential thresholds or targets.

Runoff and water use indicators	Assessment role of the indicator	Potential or existing targets and thresholds
Water used by • irrigation districts • private irrigators • industry • cities, towns, and municipalities	Provides basic information for monitoring volume, rate, and timing of water removed and returned to rivers. Reach-specific water balancing can be used to compare relative contribution of various users to overall use as well as the flow deviations described in Table 3	Water users should set targets to reduce their overall water use if they are not experiencing growth in production or demand. If they are experiencing growth, targets should be set to reduce water use at least on a per capita or per unit basis.
Change in annual runoff rates and volumes as well as the magnitude and frequency of base and peak flow events.	Observed or model predicted estimates can be compared to predevelopment records or estimates to determine whether existing or proposed land use has or will alter runoff patterns to be outside the natural range of variability. Predevelopment estimates could be based on a natural land cover scenario.	Urban areas, especially areas of new development, should maintain and restore pre-development runoff patterns by reducing impervious area and increasing infiltration of runoff.

Angler with a Trout

Water quality is determined by what the water is used for. Water quality can be degraded by point sources that release effluent from a single source as well as by diffuse, non-point sources.

Water Quality Indicators: Ambient and Point Source

Water quality provides a cumulative assessment of the state of the environment because it is affected by all human activities occurring in a watershed. However, water cannot simply be 'good' or 'bad' quality; it depends on what the water will be used for. Humans can use water for:

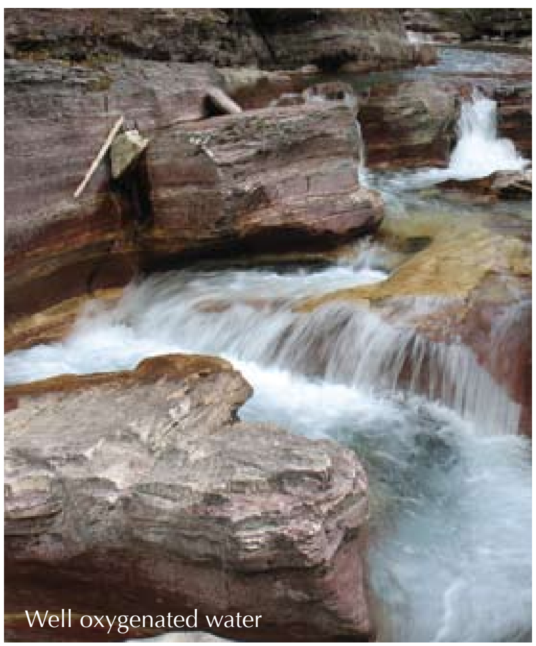
- agriculture to irrigate crops and water livestock
- recreational activities like swimming and boating
- supporting components of aquatic ecosystems such as sport fish
- commercial and industrial processing
- as a source of drinking water

All these uses have different water quality requirements, and water that is suitable for one use may not be suitable for another.

Water quality can be degraded by point and non-point sources of contamination. Non-point sources include:

- atmospheric deposition
- surface runoff
- contaminated sediments and groundwater

Point sources are effluent released from single sources such as municipal wastewater treatment plants and industrial facilities. Most of the improvements in water quality that have been achieved to date are the result of the reduction of point source pollution because these sources are easy to identify and regulate. In some watersheds loadings of suspended sediments and nutrients are greater from non-point sources than from point sources. Unlike point sources, non-point sources are diffuse so it can be difficult to identify which of the sources is causing the most water quality degradation and to know how these sources can be controlled.



Well oxygenated water

Water quality condition indicators

Condition indicators are measured anywhere in the drainage system of a watershed. Natural water quality parameters are essential for aquatic ecosystems, but can still result in poor water quality if they become out of balance. Four natural parameters often leading to problems can be used as condition indicators:

1. Total suspended solids (sediment)

Sediment can carry excess nutrients into waterbodies as well as harmful pathogens. It can also reduce the productivity of aquatic ecosystems by blocking sunlight necessary for photosynthesis and interfering with the respiration, feeding, and reproduction of benthic invertebrates and fish.

2. Nitrogen and phosphorus (nutrients)

Excess nutrients in water increase aquatic plant abundance and lower dissolved oxygen levels as a result of high levels of respiration from plants at night and decaying organic material.

3. Dissolved oxygen

Dissolved oxygen integrates the cumulative effects of all nutrient inputs and is essential for aquatic life. Low dissolved oxygen levels can harm or kill fish and can lead to the loss of desirable fish species such as trout.

4. Water temperature

High and low water temperatures resulting from dams and diversions can harm aquatic life. A lack of shade from the loss or removal of riparian vegetation can also raise temperatures.

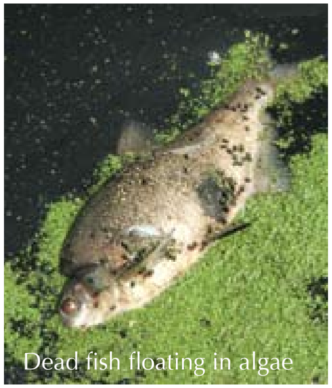

Recreational water use, floating down the Oldman River in Lethbridge

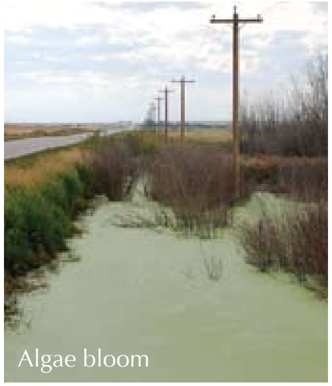
A fifth parameter associated with natural and human sources can also be used as a condition indicator:

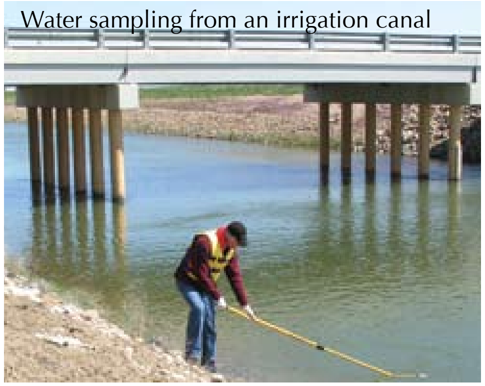
5. Pathogens
Pathogens pose a risk to human health when water is used for irrigation, recreation, and drinking. Agricultural runoff is a significant source of pathogens, and can exceed loadings from wastewater treatment plants with enhanced treatment. Faecal coliforms and E. coli are two types of bacteria that are commonly monitored to assess risk to human health.

Water quality varies naturally in Alberta from cold, clear, nutrient-poor water in the mountains to warm, cloudy, nutrient-rich water on the prairies. For some water quality condition indicators, more conservative and protective thresholds than are currently set by provincial guidelines are needed in the headwaters to protect aquatic life and drinking water supplies. For other condition indicators, more lenient and permissive thresholds could be used in the prairies because current guideline values can be exceeded under natural conditions. Ultimately, reach-specific thresholds need to be developed for water quality condition indicators.


Anhydrous ammonia fertilizing


Dead fish floating in algae


Algae bloom


Water sampling from an irrigation canal


Algae growth in glacial lake

Water quality pressure indicators

Unlike water quality condition indicators, pressure indicators are only measured in effluent released by point sources. The indicators are municipal and industrial wastewater loadings of:

- **Total suspended solids (sediment)**
- **Nitrogen and phosphorus (nutrients)**
- **Pathogens**

These measurements can be used to determine the cumulative effect of point sources relative to non-point sources, on ambient water quality. Some wastewater facilities have licensed limits on the concentration of certain contaminants that can exist in their effluent, and wastewater loadings should be reported with respect to these licensed limits.

Castle River

Cattle grazing in riparian area

Indicators of Aquatic and Riparian Ecosystem Health

Biological indicators are important because they provide a cumulative assessment of the state of the environment by integrating the effects of environmental conditions over a longer time period than individual water quality measurements. Benthic invertebrates and fish are often used for these types of measurements, but other groups of organisms can also be used if they have varying tolerances to environmental stress and are representative of the larger ecosystem as a whole.

Measurements of individual indicator species

Indicator species show a known response (either positive or negative) to environmental stress. Their response is similar to that of other species with similar ecological requirements and may be indicative of broader environmental conditions within an area, the presence and extent of human impacts, or the diversity of other species. Common measurements used to evaluate indicator species include:

- **Presence/absence**
- **Abundance or biomass**
- **Spatial distribution**
- **Size and age distribution**
- **Condition factor**
- **Survival or harvest rates**
- **Reproductive effort and success**

Integrated multi-species measures of diversity

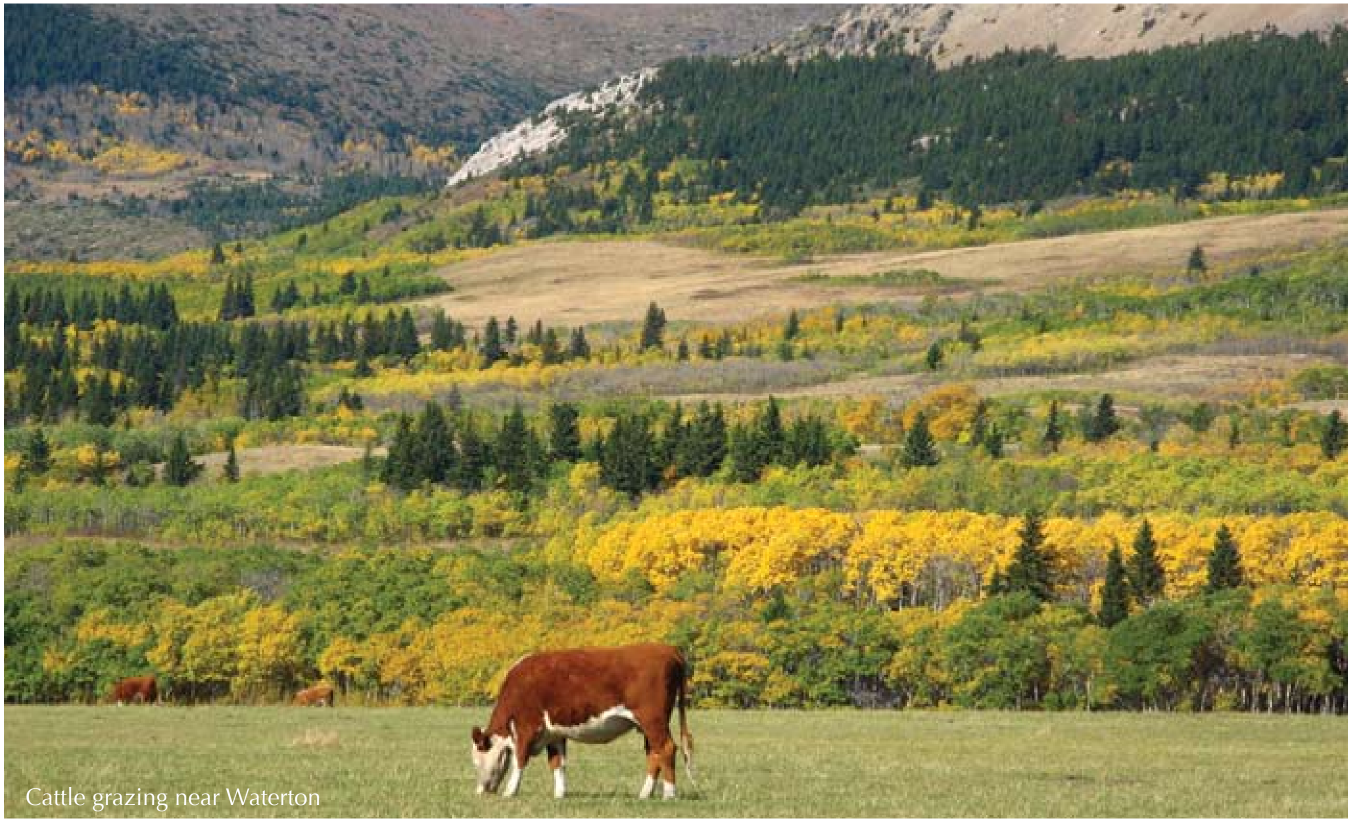
Biological communities are the basic building blocks of ecosystems, and diversity within communities is an indicator of overall ecosystem health. Diversity can be measured as:

- **Number of species or families present**
- **Abundance and condition of these organisms**
- **Number of organisms tolerant or sensitive to environmental stress**

Healthy ecosystems generally have a high number of species or families present, an even distribution of individuals among these groups, and a moderate to high overall abundance of organisms. In aquatic environments stressed by excess nutrient inputs, communities generally respond with a decrease in diversity as sensitive organisms are lost, an increase in abundance as the tolerant organisms flourish on the enriched food source, and an overall decrease in how evenly individuals are distributed among the different groups of organisms. A similar loss of diversity and increase in abundance of non-native plant species is also expected in riparian areas subject to human land use disturbances (e.g., grazing, stream crossings, development).

Table 5. Examples of condition and stressor indicators of aquatic and riparian ecosystem health.

Ecosystem health indicators	Individual indicator species	Integrated multi-species measures
Condition indicators	• Presence, absence, and condition of umbrella species (species that share the same habitat requirements and spatial distribution as other species) • Presence, absence, and condition of species with limited dispersal • Presence, absence, and condition of species that depend on environmental processes to reproduce (e.g., cottonwoods and floods)	• Single-metric measures of community diversity (e.g., number of species or families) • Multi-metric indices (e.g., biotic indices, Index of Biotic Integrity)
Stressor indicators	• Presence, absence, and distribution of non-native, invasive species that thrive in disturbed ecosystems • Harvest rates from angling and hunting of indicator species	• Single-metric measures of community evenness (i.e., an evenness index) • Number of species present that are tolerant to environmental stress



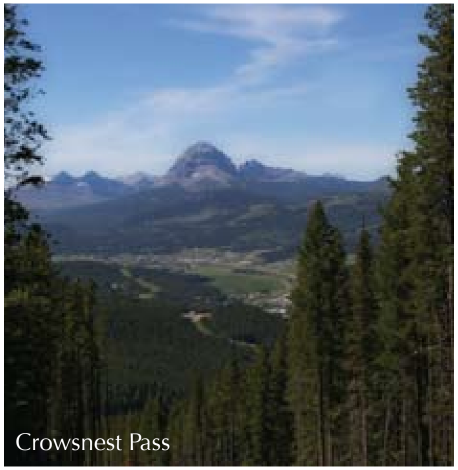
Cattle grazing near Waterton

Conclusion

The WPACs and WSGs have the opportunity to link values or trends they observe in the water quantity, water quality, and aquatic and riparian ecosystem indicators they monitor to corresponding patterns observed in land use and land quality. Based on the relationships they observe, they can then make specific actions and recommendations to address priority issues.

Bow River Valley

Bow River through Calgary



Crowsnest Pass

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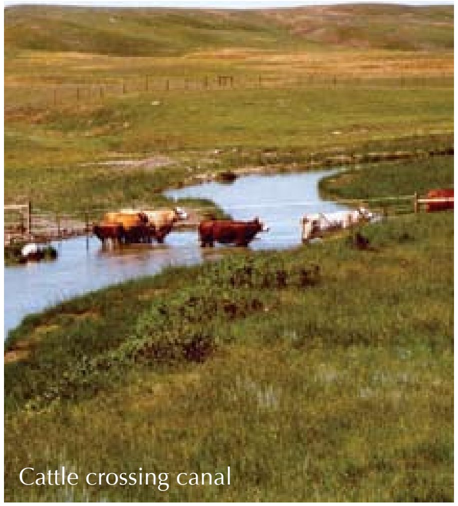

Cattle crossing canal

Alberta foothills

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