ENVIRONMENTAL INDICATORS LITERATURE REVIEW

DEVELOPING THE COLUMBIA BASIN RURAL DEVELOPMENT INSTITUTE'S ENVIRONMENTAL RESEARCH PILLAR

Part of a series of research papers on indicator development for the State of the Basin project in the Columbia Basin Boundary Region

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The Columbia Basin Rural Development Institute, at Selkirk College, is a regional centre of excellence in applied research and information provision focused on strengthening rural communities in the Columbia Basin Boundary Region. Visit **www.cbrdi.ca** *for more information.*

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THE STATE OF THE BASIN INITIATIVE

The State of the Basin is an indicator and monitoring program originally developed by Columbia Basin Trust (CBT). Now a project of the Columbia Basin Rural Development Institute (RDI), the State of the Basin initiative involves collecting, analyzing and reporting on indicators in order to build an up-to-date and dynamic picture of the vitality of communities in the Basin Boundary region.

OBJECTIVES

When originally envisioning the State of the Basin, CBT developed the following four goals. These goals collectively define the purpose of the initiative:

- ***inform*** citizens and organizations about the people, natural environment, communities, and economy of the Basin by providing access to accurate, credible, and timely information,
- ***encourage*** understanding of complex issues and trends over time, including into the future when possible,
- ***signal*** whether conditions are similar or different within the Basin, and in comparison to other areas to highlight and celebrate areas of achievement, and to identify significant issues, ideally before they become critical, and
- ***motivate*** discussion, information sharing, strategic evidence-based decisions and collective action.

HISTORY

In 2006, CBT responded to long-standing requests for information on social, economic, environmental and other trends in the Basin by launching the State of the Basin initiative. Resulting from the work of project consultants, a volunteer working group, CBT staff and more than 50 expert advisors, the first State of the Basin report was released in 2008. This report was accompanied by a website that provided access to updated trend analyses and raw data. In order to support the application of available information, the State of the Basin initiative also provided support to individuals and communities interested in understanding and using the data. The purpose of the 2008 State of the Basin Initiative was to test the concept of indicator reporting in the region by presenting a sample of credible, locally relevant information.

Response to the 2008 project indicated that the State of the Basin initiative addressed an important need for information in the region, and that future iterations would be of benefit to local communities and organizations. Acknowledging the links between the objectives of the State of the Basin project and the mandate of the RDI, CBT transferred responsibility for the project to the RDI in 2011. Because the RDI's service area includes the entire Basin Boundary region of BC, the geographic scope of the State of the Basin has expanded beyond the area defined by CBT as "the Basin" to include a portion of the Regional District of Kootenay Boundary referred to as "the Boundary region" (figure 1).

Figure 1: The Basin Boundary Region

In 2012, the RDI developed an updated State of the Basin report using the same, or similar, indicators that were used in the 2008 version. However, the 2013 State of the Basin project will incorporate a significant revision to the suite of indicators monitored through the initiative. The future focus of the State of the Basin will be on researching and reporting on information that is of the highest value to Basin Boundary communities. In order to ensure the State of the Basin achieves maximum relevance and utility, consultation with key stakeholders and user groups will be an important component of the indicator development and reporting process.

Indicator Model

The State of the Basin uses an indicator model to report on the status of well-being in the Basin Boundary region. Indicator reporting is a growing trend among organizations that operate at various geographic scales (from global to neighbourhood-specific) and with varying scopes of interest (from those as broad as well-being to those as specific as financial performance). By distilling complex information into easily understandable measures, indicators help diverse audiences, with widely ranging backgrounds, to understand important trends.

As part of the 2013 State of the Basin update, the RDI completed research on best practices in indicator reporting and on lessons learned from the 2008 report development process. This literature review adds context-specific discussion to that research.

Research Framework

The RDI has developed a new State of the Basin research framework which, similar to the 2008 framework, is centred on the concepts of well-being and sustainable development. The new framework organizes research efforts into four "pillars" – society, culture, the environment, and the economy—each of which have several defined sub-themes (figure 2).

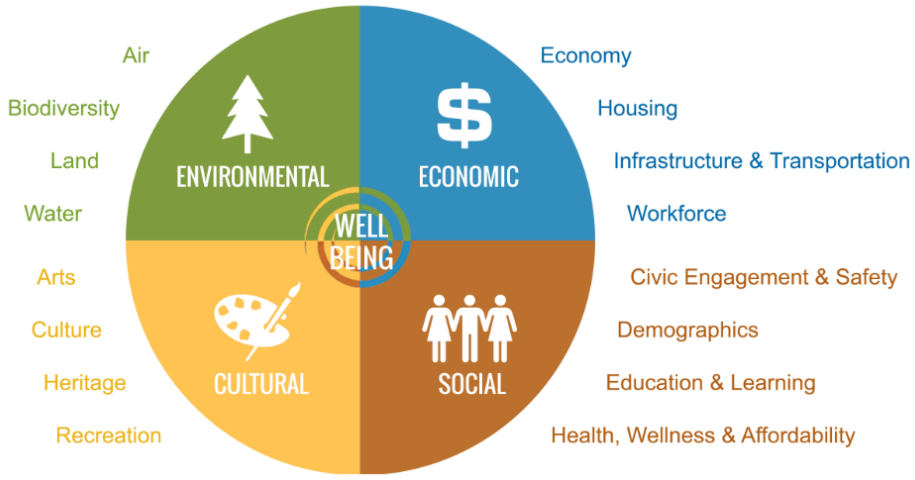

Figure 2: Revised State of the Basin research framework

Many indicator projects adopt a similar approach to research, understanding that "well-being" or "sustainability" are difficult concepts to measure in themselves. Instead, progress toward achieving those goals can be measured through an assessment of conditions in more narrowly-defined realms of influence.

In the literature on indicator reporting, a strong case is made for linking environmental, economic, social, and cultural indicators through a common lens such as well-being or sustainability. By adopting this approach, the State of the Basin initiative explicitly acknowledges that community vitality is dependent on the strength of all four pillars and that the environment, the economy, culture and social systems are very much interconnected. A change in conditions in one pillar or sub-theme not only affects the overall measure of well-being, but it can also affect the status of other pillars or sub-themes. Exploring these inter-pillar relationships will be a priority for State of the Basin research.

Information Products, Tools, and Support

State of the Basin research will be made available to Basin Boundary communities in a variety of formats:

1. A snapshot report will provide an overview of the project and quick, interesting research findings in a format that will be accessible to a wide audience.
2. A full report will provide in-depth discussion of each indicator, including its relevance, current status and an analysis of regional trends.
3. The "Digital Basin" will provide web-based data tools, including:

a. an interactive and customizable map displaying spatial features of all relevant indicators, as well as environmental, economic, social and cultural assets in the region,
b. a customizable data viewer that allows for analysis and comparison of indicator data over time and space, and
c. a resource library that will allow users to download supporting documents (plans, reports by other organizations, etc.) for independent analysis.

In addition, the RDI will support development and use of State of the Basin research in Basin Boundary communities by:

- liaising with key economic, social, cultural and environmental stakeholders to better understand their information needs and research capacity (such as the ability to collect and use related information),
- identifying opportunities for local data collection by key stakeholder groups,
- providing direct research support, standardized data templates, training and support materials focused on the collection and use of indicator data,
- promoting and facilitating the sharing of information and best practices across key stakeholder groups, and
- exploring opportunities to link the State of the Basin initiative with K-12 and post-secondary student learning.

ENVIRONMENTAL INDICATORS

Environmental indicators condense detailed environmental information into easily understandable trends and measures that help track the state of the environment (Environment Canada, 2003; UNEP, 2006; EEA, 2012). There are several types of indicators including direct measurement indicators, representative indicators, performance indicators, comparative indicators and aggregated indicators. Where there is data available from multiple time periods, any of these indicators can then be used to show trends over time.

Direct measurement indicators are the simplest type of indicator and can be used to demonstrate the state of an environmental issue. For example, the area of forest impacted by mountain pine beetle within a given area can be measured based on ground surveys, aerial flights or satellite imagery. This direct measurement can then be compared to historical trends to produce an indicator that shows if the mountain pine beetle epidemic is increasing or decreasing over time.

Representative indicators are measures that are surrogates for the larger system. For example, species such as caribou can be used as a representative indicator because they rely on healthy and intact old growth forest at high elevations and are sensitive to change in their habitat (Wittmer et al., 2005). Therefore, if mountain caribou numbers are in decline, it indicates that old growth forests at high elevations may also be in decline.

Performance indicators compare environmental conditions to stated goals (SOE, 2011). Specific targets are identified, and the distance between the current state of the indicator and the target are reported upon. For example, the stated goal of the Canadian Government in the Kyoto

Protocol was to reduce greenhouse gas emissions by 6% by 2012 based on emissions in 1990 (UN, 1998). A performance indicator would report that in 2012 the actual greenhouse gas emissions were 24% above the 1990 levels, demonstrating that the emissions performance of Canadians are well below the stated goal (Conference Board of Canada, 2011).

Comparative indicators rank jurisdictions against each other. For example, the Conference Board of Canada ranks Canada last out of 17 countries for municipal waste generation. They compare the 777 kg per capita waste in Canada to the best performer, Japan, which produces half as much waste (Conference Board of Canada, 2011).

When using the same indicator to show both trends and comparisons, the information may be conflicting. The emissions of sulphur dioxide in Canada shows an improving trend over time, but other countries are reducing their sulphur dioxide emissions faster, so while the trend is improving, the comparison is not (Boyd, 2001; Conference Board of Canada, 2011). When conflicts such as this arise, it is especially important to provide context for the indicator; sulphur emissions have decreased dramatically worldwide, but other countries are doing more to reduce emissions than Canada.

Aggregated indicators such as the Living Planet Index and the concept of Ecological Footprints combine several parameters to produce a single numerical value (Wilson and Anielski, 2005; WWF, 2012). These aggregated indicators can then be used in several ways. They may be used as comparative indicators to measure overall environmental performance of different jurisdictions (Boyd, 2001); as performance indicators comparing results to stated goals (Esty et al., 2008); or to monitor overall environmental performance over time (WWF, 2012). For example, the Environmental Performance Index developed at Yale University uses 25 indicators to gauge performance against two overarching environmental objectives (reducing environmental stresses to human health; and promoting ecosystem vitality and sound natural resource management) to create a final score (Esty et al., 2008).

HOW ARE INDICATORS USED?

Environmental indicators used most often are reported in State of the Environment (SOE) reports which provide a summary of environmental conditions within a given region. Indicators and SOE reports can demonstrate a wide variety of information. In addition to revealing trends over time, measuring performance, or comparing jurisdictions, they can be used to:

- describe current environmental conditions,
- identify environmental risks,
- predict future trends,
- provide an early warning signal for emerging environmental problems,
- inform policy decisions,
- inform the efforts of environmental stakeholders in the region,
- provide feedback on management actions in an adaptive management cycle,
- demonstrate relationships between environmental issues,
- compare policy decisions,

- prompt governments to take action and set priorities,
- identify where limited resources should be allocated,
- identify underperformers to help inspire action, and
- identify knowledge gaps.

List compiled from: Holt et al., 2004; Wilson and Anielski, 2005; Esty et al., 2008; UNEP, 2006; Cullington et al., 2010; FPTGC, 2010; Conference Board of Canada, 2011; SOE committee, 2011; EEA, 2013; Pinter, 2013.

Most SOE reports were developed specifically for one or more of the reasons listed above, while some reports explicitly state that their role is only to report on identified indicators (Austin et al., 2008).

Target audiences include the general public (especially where SOE reports are intended to draw attention to important environmental problems) (UNEP, 2006; WWF, 2012), as well as educators, researchers, policy experts and decision makers (Holt et al., 2004). Some SOE reports include suggestions for solutions to the problems identified by environmental indicators (WWF, 2012), while others simply report scientifically sound information, trends and comparisons without comment (EPA, 2008).

Reports may explicitly state that they are created to measure progress towards a particular set of policy goals, such as progress towards "healthy and diverse ecosystems" (FPTGC, 2010) or "environmental sustainability" (FBC, 2010). For example, the European Environment Agency uses indicators to present information to improve environmental policy and management processes in their move towards developing a "green economy" (EEA, 2010).

In 1972, the UN Conference on the Human Environment first identified the need to periodically report on the state of the environment at international, regional and sub-regional scales (UNEP, 2006). Early SOE reports described current environmental conditions of air, water, and, marine resources, forests etc. (UNEP, 2006). The reports used indicators that their producers thought were important, and typically used a large amount of information. While some jurisdictions continue to produce very comprehensive and detailed reports every five years (SOE committee, 2011), many SOE reports have evolved away from this model.

Trends in State of the Environment (SOE) reporting

The trend has been to move away from producing voluminous periodic updates on SOE and towards continually updating more focused indicators online. As evidence of this trend:

- The US EPA last produced a written ROE report in 2008 (EPA, 2008), and now produces updated reports available for download.
- Natural Resources Canada provides updated information online while continuing to provide annual reports on the state of the environment (NRC, 2012).
- The Vancouver Foundation produced a brief report on a range of demographic, economic, environmental, and social indicators (Vancouver Foundation, 2010), but the bulk of the details as well as additional indicators are available only on their website.

- The Conference Board of Canada produced a brief summary report, with the full report complete with source information available online (Conference Board of Canada, 2011).

These new approaches are moving away from providing only one level of detailed information and towards a layered approach where the user can access the level of detail that is desired (Holt et al., 2004). Through a variety of platforms, a brief introduction to the indicator is provided, and if the user would like more details, additional information is made available. The more detailed information is provided through additional reports, maps or links, sometimes to the detail of including the raw data for independent analysis (Conference Board of Canada, 2011).

Other emerging trends include:

- adopting GIS technologies and the internet to access a wider audience and interactive reporting,
- consulting with the public and stakeholders during the design of indicators and reports,
- using only selected indicators that help translate complex data into comprehensible information
- showing the interconnections among environmental, economic, social and institutional issues,
- producing shorter, more focussed reports for specific audiences and reducing the number of indicators for better communication,
- measuring progress towards achieving targets and objectives (often using report-card style assessments),
- discussing solutions as well as trends,
- using aggregated indicators for reporting (e.g. Ecological Footprint, Environmental Sustainability Index, Living Planet Index, Canadian index of wellbeing), and
- developing indicators that are useful specifically to decision-makers and practitioners.

WHAT ORGANIZATIONS DEVELOP ENVIRONMENTAL INDICATORS?

Any type of organization that has an interest in the environment may produce environmental indicator reports. Governments of all levels produce SOE reports including the United Nations (e.g. UNEP, 2006), federal governments (e.g. Government of Canada, 2007), provinces (e.g. Austin et al., 2008), regional districts (e.g. Cullington, 2010) and cities (e.g. Vancouver Foundation, 2010). Often SOE reports are the result of partnerships between government organizations and NGOs (e.g. Austin et al., 2008) or partnerships between governmental departments and organizations at different levels (e.g. Wilson and Anielski, 2005; Government of Canada, 2007; FPTGC, 2010).

Academic institutions and think tanks produce SOE reports that can be developed at arm's length from governments and NGOs allowing them to produce unbiased reports free of vested interests (Boyd, 2001; Esty et al., 2008). For example, in the United States, the Heinz Center for Science, Economics and the Environment brings together representatives from business, government, academia, and the environmental community to produce reports such as the *State of the Nation's Ecosystems* (Heinz Center, 2008). They receive funding from public and private sources allowing them to operate in an unbiased environment capable of producing environmental policy

recommendations and science-based solutions to environmental issues (Heinz Center, 2008). Independent committees may be formed by governments to function without political pressures and in order to maintain credibility; the Australian Government forms an independent committee that produces a very comprehensive SOE report every 5 years (SOE committee, 2011).

Some organizations produce SOE reports specific to their area of interest that focus on a particular issue such as indicators of climate change (CCME, 2003). Examples include the Canadian Council of Forest Ministers (CCFM) which developed a set of indicators to measure the sustainability of forest management (CCFM, 2004) and the Heinz Center which developed indicators of the ecological effects of air quality (Heinz Center, 2009). Environmental groups with explicit agendas may develop SOE reports to bring attention to issues that they feel are important. For example, the World Wildlife Federation produces Living Planet Reports to highlight the cumulative pressure humans are placing on the planet, and also provide solutions to identified problems (WWF, 2012).

WHAT ARE THE SOURCES OF DATA FOR INDICATOR DEVELOPMENT?

Each indicator may have a different data source. Data might be collected only once and is then used as a baseline for measuring trends in the future, while other indicators have years of data available (EPA, 2008). Data sources may be from large centralized databases where the pertinent information is extracted, or they may be very specialized targeted studies with a limited geographic scope. Data collection also is extremely varied, ranging from permanent monitoring stations, to aerial surveys, to on-the-ground field sampling (Parks Canada, 2011; Westfall and Ebata, 2012). An increasingly powerful tool involving remote sensing using satellite imagery is being used to measure a growing number of indicators (WWF, 2012).

LINKAGES BETWEEN SOCIAL, CULTURAL AND ECONOMIC INDICATORS

Environmental indicators are usually a part of broader indicator initiatives that include measures on economic, social, cultural and institutional aspects of a given region (UNEP, 2006). SOE reports that include economic and social indicators often draw direct links between the health of the environment and economic and social well-being (NTREE, 2003; CCFM, 2004; UNEP, 2006; Government of Canada, 2007; FPTGC, 2010).

When sets of indicators are developed specifically to measure environmental performance, at a minimum, linkages are made between environmental health and human health (Environment Canada, 2002; EPA, 2008; WWF, 2012). The main objective of the Millennium Ecosystem Assessment was to "assess the consequences of ecosystem change for human well-being, and to establish the scientific basis for actions needed to enhance the conservation and sustainable use of ecosystems and their contributions to human well-being" (MEM, 2005, p.ii). Environment Canada (2002) draws the link between the release of toxic substances into the environment and the human health impacts of these releases.

Economic and social activities are often discussed in relation to their impacts on environmental issues (Austin et al., 2008). For example, at the very beginning of the Government of Canada 2007 report on Canadian environmental sustainability indicators they state that "the health of Canadians and the country's social and economic progress are highly dependent on the quality of

their environment" (Government of Canada, 2007, p.1). The Frasier Basin Council reported on environmental indicators through the lens of social and economic health and sustainability to elevate the importance of environmental health (FBC, 2010).

As an example, the Cowichan Valley Regional District 2010 SOE report (Cullington et al., 2010) draws the following links:

- air quality indicators to hospital admission rates (human health),
- air quality to open burning and woodstove use (cultural issues),
- habitat fragmentation to suburban sprawl, car-dependency and climate change (social issues and other environmental issues),
- aquifer levels to water availability (social issues),
- water quality to leaking septic fields (cultural and social issues),
- health of fish stocks to local food security (social and economic issues),
- water quality to the closure of shellfish fisheries and `fish kills` events (economic issues), and
- invasive plants to agriculture production, clean water, and flood control (economic issues).

Even sets of indicators on a specific subject rarely are limited to environmental issues. When describing the state of Canada's forests, most indicators relate to biodiversity, water, productivity and other environmental issues, but economic benefits and social equity measures are also included to highlight the importance of healthy forest systems (CCFM, 2004; NRC, 2012). The BC Lung Association produces annual State of the Air reports which focuses on the impacts of air quality on human health (BC Lung Association, 2012).

Economic and social indicators may be measured in the context of how they drive environmental change (SOE committee, 2011) or environmental indicators may be measured with the understanding that long term economic development is dependent on a healthy environment (EEA, 2012). Regardless of how it is viewed, there is a widespread recognition that social, cultural, economic and environmental indicators are intrinsically linked, and that no indicators act in isolation from larger global systems.

LIMITATIONS TO INDICATORS

It is important to recognize the limits of environmental indicators:

- there is danger in oversimplifying complex systems,
- they may be misinterpreted by the reader,
- if there is a correlation between indicators, it may not equal causation,
- indicators may be developed to serve the interests of the organization that develops them,
- indicators may be chosen based on the availability of data rather than the usefulness or appropriateness of the indicator, and
- indicators are often developed to report on environmental issues within political boundaries (usually Federal or Provincial) rather than ecological units (UNEP, 2006).

For all these reasons above, it is important to provide context for each indicator presented. Gaps in knowledge should be discussed, indicators can be interpreted, linkages can be highlighted, conflicts of interest must be disclosed, and the purposes of the reports should be outlined.

Environmental indicators can be reported on multiple scales including global (MEM, 2005; Esty et al., 2008; WWF, 2012), continental (EEA, 2012), country-wide (Environment Canada, 2003; EPA, 2008), provincial (Austin et al., 2008), bioregional (Cullington et al., 2010), municipal (Vancouver Foundation, 2010) or organizational (Gray, 2012). One of the challenges when developing environmental indicators for areas without defined political boundaries such as the Columbia Basin Boundary Region is that data sources tend to report on either larger geographic or political boundaries (BC, Canada, or North America) or smaller areas (site specific or by municipality).

For data sets from larger jurisdictions, substantial analysis will be required to make the data relevant to the Columbia Basin Boundary Region. Where data is only available for a portion of the basin (e.g. a single municipality), the indicator can be developed as a 'pilot project'. These pilot projects can show the value of the information thereby prompting the collection of similarly useful data elsewhere in the region and expanding the indicator.

Developing Environmental Indicators for the Columbia Basin Boundary Region

RDI should follow several steps when developing a set of environmental indicators:

1. Clearly identify the goals and objectives of the reporting initiative.
2. Identify the target audience.
3. Develop a list of criteria for indicator selection.
4. Propose an initial set of candidate indicators.
5. Engage with stakeholders, the environmental advisory committee and researchers for advice and feedback to help evaluate indicators according to criteria.
6. Start to identify data sources and data gaps with the help of the advisory committee and community engagement.
7. Define a core set of indicators for development.
8. Create a work plan to develop each indicator.
9. Gather data and populate the indicators; standardize measurement wherever possible
10. Analyze the data by comparing indicator values to targets, thresholds, and policy goals (if applicable).
11. Interpret the data and, if applicable, create map layers for each indicator.
12. Disseminate results by updating the online portal and publishing reports.
13. Request feedback from users to assess strengths and weaknesses of the indicator set.
14. Continue development of superior indicators and update indicators whenever new data becomes available.

The first step where the goals and objectives are identified has been completed. The goal of this project is to support informed decision-making, including land use planning in the Columbia Basin Boundary Region through the provision of timely and relevant information. A web-based geospatial portal will be developed to provide easy access to information to support information sharing and collaboration. The initiative will build capacity of environmental stakeholders, support data collection efforts, and link research to sustainability planning and implementation efforts.

The target audience has also already been identified to include local governments and First Nations, community and non-governmental organizations, businesses and the private sector, educators and the general public. In addition to annual short and long reports, a web-based geospatial portal has been selected for reporting to this diverse audience. A geospatial portal is an ideal tool for a layered approach that will be useful to all audiences, and can be updated on an ongoing basis. An overview map that displays the basic information will be presented, while more information and links to other websites or data sources are just a click away if more detailed analysis is required.

The remainder of this paper is devoted to steps three, four and six. The criteria for indicator selection is outlined (step 3), then an initial set of candidate indicators is proposed (step 4). In some cases, the discussion of individual indicators may also include sources of available data (step 6).

CRITERIA FOR INDICATOR SELECTION

If there is one commonality with the selection of environmental indicators, it is that each organization chooses different sets of indicators. Regardless of which environmental indicators are selected, they aim to provide timely, targeted, relevant and reliable information (EEA, 2013). Questions that should be asked about candidate indicators include:

- Is the information relevant?
- Will the information be understandable?
- Will it lead to action?
- Are they measureable and valid?
- Is the source data neutral and legitimate?
- Are they comparable to other indicators?
- Are they affordable, cost-effective and feasible?
- Are there benchmarks or thresholds for comparison?
- Do they provide a representative picture of environmental conditions?
- Were they developed with the participation of stakeholders?
- Are they sensitive to change?
- Do they show trends over time?

List compiled from: (Jackson et al. 2000; Holt et al. 2004; UNEP 2006; EPA 2008; SOE committee 2011; Pinter 2013)

The answers to these questions will be different for each agency or region based on different goals, objectives, target audience, and environment, which explains why different indicators are

selected for each report. The goals, objectives, and target audience for this project have already been identified in the Columbia Basin Boundary Region, so selection of indicators can begin.

A notable omission to the list is the question of whether or not this information is available. If only available information is used in developing indicators, then the list will be inherently biased towards what is already being measured. An important role of SOE reports is to identify gaps in knowledge and highlight areas that need to be investigated (Heinz Centre, 2008).

Aggregated indices are not recommended for development by the RDI. The direction of this initiative is to provide users with the ability to choose those indicators that they feel are important via the web-based mapping portal. Aggregated indices are more appropriate for snapshots and do not lend themselves well to web-based mapping tools.

Candidate Indicators

A short list of over 30 candidate indicators for the Columbia Basin Boundary Region is presented below, with additional candidate indicators listed in Appendix 1. They are split into four broad categories: air, biodiversity, land, and water.

Air

Indicators relating to air can be placed in three broad categories: climate, emissions and air quality. Climate change is an important issue for people and ecosystems throughout the Columbia Basin Boundary Region, and should be closely monitored over time. Emissions look at sources of air quality problems, while direct air quality measurements illustrate the impacts of these emissions. Which set of indicators are chosen depends on the goals and objectives of the reporting agency. If the goal is to describe where the emissions are coming from with the objective of reducing their negative impacts, then reporting on emissions is the better set of indicators. If the goal is simply to describe and report on the general quality of the air without any attempt at identifying or curbing sources of emissions, then using air quality monitoring station data is recommended. Since the goal of the Columbia Basin Boundary State of the Basin project is to report on issues that are relevant to a diverse audience, it is recommended that RDI and stakeholders mutually agree on a set of indicators that relate to both emissions and air quality.

Emissions

Air pollutants can come from either point source or non-point sources. Point source pollutants are far easier to track because they tend to be released from industrial facilities that must report the data. Non-point emissions can come from many sources. For example, fine particulate matter ($PM_{2.5}$) can be created from road dust, or it can be emitted directly from a pulp mill. The pulp mill is required by law to report their emissions, while dust from a logging road is not reported.

Industrial emissions are reported and made publically available by Environment Canada via a searchable database at http://www.ec.gc.ca/pdb/websol/emissions/ap/ap_query_e.cfm. There are 16 different substances that are tracked by this database, each with emissions data by facility. For example, if an indicator is developed to track mercury emissions into the air, the database can

be queried, and it will show that there are 37 facilities that emit mercury, nine of which are in the Basin Boundary region. Data goes back to 1994, and includes spatial coordinates, so an indicator could track the point source emissions over time, and could be updated annually.

Which substances are tracked will depend on the concerns over human health and the objectives of the indicator. For example, Environment Canada specifically tracks and reports sulphur oxides (SOx), nitrogen oxides (NO_X), volatile organic compounds (VOC), ammonia (NH_3), carbon monoxide (CO), total particulate matter (TPM), repairable particulate matter (PM_{10}), fine particulate matter ($PM_{2.5}$), Mercury (Hg) and Hexavalent chromium (CR(VI)). Only raw emissions data is available for all the other substances.

CO_2/GREENHOUSE GAS EMISSIONS

The stated goal of the BC government is to reduce greenhouse gas emissions (GHGs) by 6% below 2007 levels by 2012; by 18% by 2016; by 33% by 2020; and by 80% by 2050 (Government of BC, 2010). A performance indicator could be developed to measure the contribution that the Columbia Basin Boundary Region makes towards this goal.

Emissions reporting data from large emitters is publically available through the federal government websites, and includes several industrial sources within the region. The data starts in 2004, with reports being updated annually. This data could be tracked over time to help identify trends and companies with improving records.

The BC Climate Action Charter signed by the province of BC and almost every local government in BC represented a commitment by local governments to become carbon neutral in their corporate operations by 2012. There is a standardized reporting procedure (MOE, 2012a), so an indicator could be developed that assesses the progress of all local governments in the Basin Boundary region towards meeting this goal.

CARBON CAPTURE AND STORAGE

An exciting new area of research is looking at ecosystems as natural carbon sinks that can reduce CO_2 levels in the atmosphere. It is a challenging research question to quantify due to a variety of factors. Forests and grasslands soak up and store CO_2 as they grow, and release it as they burn or decay. A healthy forest or grassland can be a net sink of carbon by storing this carbon in the soil and in the live portions of woody materials.

Carbon storage may also be a source of income for large landowners because they may be able to sell carbon credits on the open carbon market if they manage their land in a way that promotes carbon capture and storage. For example, the Nature Conservancy of Canada has sold carbon credits for drastically reducing the area of land harvested on the newly purchased Darkwoods Conservation property between Nelson and Creston.

An indicator that tracks carbon storage in Basin Boundary ecosystems would be a fascinating research problem that would encourage much thought and discussion. This indicator could be combined with the GHG emissions indicator to provide a net GHG indicator.

AIR QUALITY

There is a strong link between air quality and several human health issues, particularly asthma, lung function, and possibly cardiovascular issues, low birth weights (associated with exposure to NO, NO_2 and $PM_{2.5}$) and lung cancer (Brauer et al. 2012). There are 16 air quality monitoring stations within the Columbia Basin Boundary Region, with data available from http://www.bcairquality.ca/readings/index.html, but the measures that they record are not consistent. Some only report meteorological readings, while others include hourly averages of carbon monoxide, hydrogen sulphide, ozone, nitrogen dioxide, sulphur dioxide, $PM_{2.5}$, and PM_{10}. The challenge will be to determine which indicators are most important, and to balance this need with available data sets.

Air quality objectives and standards for PM_{10}, $PM_{2.5}$, ozone, sulphur dioxide, nitrogen dioxide and carbon monoxide and standards in BC are established by the Ministry of Health, and monitored by the Ministry of Environment. Performance indicators could therefore be developed for each of these measures where current readings are compared to government standards. This information could be tracked and reported on over time.

The Air Quality Health Index (AQHI) is an aggregate indicator of ozone, NO_2, $PM_{2.5}$, and PM_{10}, which were chosen due to their impacts on human health (www.airhealthbc.ca). In this region, the AQHI is only available for Castlegar, so this indicator could be adopted as a pilot project. The value of this index for this project may be that it suggests which indicators we should consider reporting on if we are concerned with the impacts on human health.

Fine particulate matter (PM 2.5)

Fine particulate matter ($PM_{2.5}$) is the only air quality indicator reported on in the 2012 SOTB report (RDI 2013). These are the smallest particles (2.5 micrometres or smaller) that are closely linked to health issues and come from combustion of wood and diesel, industrial processes, agriculture, unpaved roads and atmospheric reactions involving other pollutants. The BC Ministry of Environment reports hourly averages of $PM_{2.5}$ levels in Castlegar, Creston, Grand Forks, Golden and Nelson so this indicator should be transformed from an annual average to a real-time report in the near future.

An hour-by-hour forecast of $PM_{2.5}$ from wildfires is provided at http://www.env.gov.bc.ca/epd/bcairquality/bluesky/index.html and is updated once a day during the fire season.

Ground level ozone (O3)

Ozone (O_3) is a secondary pollutant that is formed from primary pollutants through chemical reactions that occur when nitrogen oxides and VOCs mix in the atmosphere (Brauer et al., 2012). O_3 is also closely linked to respiratory and cardiovascular diseases and other health issues. It also has a negative impact on vegetation resulting in reduced tree growth and crop yields. Ground level ozone can therefore be a representative indicator of primary air pollutants. The BC Ministry of Environment reports hourly averages of O_3 levels in Castlegar and Nelson.

Sulphur dioxide (SO2)

Sulphur dioxides come from burning of sulphur containing fossil fuels and industrial processes. It aggravates respiratory problems and contributes to acidification of soil and water, which can negatively impact ecosystems. The BC Ministry of Environment reports hourly averages of SO2 levels in Castlegar and Trail (http://envistaweb.env.gov.bc.ca/).

Nitrogen dioxide (NO2)

Nitrogen dioxides are secondary pollutants that are formed from nitrogen oxides (NO) in the atmosphere through chemical reactions and physical conversions. Therefore, NO_2 concentrations is a representative indicator of NO emissions, and have a direct impact on human health (Brauer et al. 2012). The BC Ministry of Environment reports hourly averages of NO_2 levels in Castlegar (http://envistaweb.env.gov.bc.ca/).

Volatile organic compounds (VOC)

Volatile organic compounds are compounds containing carbon, emitted by forest fires, solvents and industrial activities, that easily evaporate into the atmosphere. Many VOCs are toxic air pollutants that are a major component of urban smog and negatively affect human health. There is data available nationally and provincially from 1996 to 2010, but the provincial data is from only two monitoring stations and is based on expensive manual monitoring.

CLIMATE - DIRECT MEASURES

Temperature

The mean annual temperature at four weather stations with data since at least 1914 were reported in the 2012 SOTB report (RDI, 2013). This indicator provides a partial understanding of how the climate has changed over time. Climate change models in the region suggest that in addition to projected average annual temperature increases, there will be more pronounced seasonal variations (Utzig, 2011). These seasonal variations will have wide ranging impacts on ecosystems and the services they provide. Environment Canada reports average temperatures by month (http://www.climate.weatheroffice.gc.ca) so future SOTB reports could refine this indicator to include average seasonal variations, and can continue to provide annual averages.

Precipitation

Another important indicator of climate change is the amount, timing and type (rain or snow) of precipitation. Climate change models in the region suggest that seasonal precipitation may change over time with summers becoming drier and with more rain in the winters (Utzig, 2011). Monthly rain and snowfall averages are also available from Environment Canada (http://www.climate.weatheroffice.gc.ca). Future SOTB reports could report on the overall amount as well as by season and form of precipitation.

CLIMATE - INDIRECT MEASURES

In addition to directly measuring changing climates, indirect measures can also be monitored. A slight increase in temperature or a change in precipitation might go unnoticed in an urban environment, but these changes can have a far more profound impact on natural environments. A few examples include: birds migrating at different times or altering their distribution, plants

flowering earlier, cedar dieback, glaciers melting, and snow cover is reduced in the springtime. Any of these would make good representative indicators, but data availability would be an issue.

Glacier cover

With recent developments in GIS and remote sensing technologies, the extent of glacier cover can be measured. Historical imagery can be compared to recent images, and the extent and rate of glacier cover retreat can be quantified. The melting of glaciers is one of the most visually effective means of demonstrating that climate change is upon us, and would make an excellent indicator that would attract attention from the public.

May snow cover

Similar to glacier cover measures, the snow cover in May can be measured using new GIS technologies. This would provide an indicator of the timing of snow melt change over time, which has repercussions for ecosystem function, stream flow, the agriculture industry, ski hill developments and more.

BIODIVERSITY

INDICATOR SPECIES

Indicator species are used as a proxy for environmental change. They may be a keystone species, an umbrella species, dispersal limited species, resource limited species or a flagship species (Cariganan and Villard 2002).

- A keystone species is critical to the functioning of the environment in which it is found because it generates an effect that is large relative to their abundance due to strong interactions with other species and their environment.
- An umbrella species requires large areas of suitable habitat and have habitat requirements that are similar to a wide variety of associated species.
- Dispersal limited species are unable or unwilling to move from habitat patch to habitat patch due to high risk of mortality.
- Resource limited species are sensitive to changes in ecological processes and require specific resources for survival
- A flagship species can attract public support for conservation.

Ideally a chosen indicator species will have more than one of these characteristics.

Mountain Caribou

Mountain Caribou populations were included in the 2012 State of the Basin (SOTB) report (RDI, 2013). They are an excellent indicator species because they are an umbrella species, resource limited species, a flagship species and a dispersal limited species which rely on healthy and intact old growth forest at high elevations and are sensitive to change in their habitat (Wittmer et al. 2005). Mountain Caribou populations in the Columbia Basin Boundary Region are red listed in BC, and listed as threatened by the Committee On the Status of Endangered Wildlife In Canada (COSEWIC). Therefore, if mountain caribou numbers are in decline, it indicates that old growth forests at high elevations are also in decline. Population estimates for each herd in the basin are

available online at http://webmaps.gov.bc.ca/imfx/imf.jsp?site=imapbc. This data is updated annually by provincial wildlife biologists who do regular aerial population surveys. This indicator should continue to be updated annually whenever new estimates are available.

White Sturgeon

White sturgeon populations were included in the 2012 SOTB report (RDI, 2013). They are listed as endangered by COSEWIC, and are a dispersal limited species, a resource limited species and an umbrella species for other species of fish that are negatively impacted by altered flow regimes and habitat fragmentation in the Columbia river system due to dams. They are a flagship species as evidenced by the successful and ongoing program of releasing juvenile sturgeon with extensive public support and involvement with school-aged children. They are the subject of extensive research efforts so populations will continue to be monitored over time, and should continue to be used as an indicator species in future SOTB reports.

Grizzly Bear

Grizzly bears are a good indicator species because they are an umbrella, dispersal limited and flagship species that are sensitive to cumulative effects of human development including settlements, agriculture, utility corridors, roads, and habitat degradation.

They have become extirpated from large portions of their range, including most of the US, the Okanagan Valley, the lower mainland and the Sunshine Coast. They are still found throughout the Columbia Basin Boundary Region, but the Kettle-Granby population and the Yahk population are both listed as threatened by the provincial government (MOE, 2012a), and other populations are in danger of becoming threatened (Michael Proctor pers. comm., 2013). Historical population estimates are available as are estimates from 2012, and will continue to be tracked over time.

Birds

Changing bird populations reflect changing land use patterns. For example, declining grassland birds indicate that the quality or extent of grasslands are declining. There have been several recent efforts to establish baseline data for bird populations across Canada including the breeding bird atlas and several others. A recent report on the State of Canada's Birds looks at trends for hundreds of bird species across Canada since 1971, and data is available from this study (NABCIC 2012). There are huge databases of raw data from various monitoring projects available from http://www.birdscanada.org/ which could be accessed to develop an indicator. Alternatively, a few bird species that are sensitive to change could be selected for specific indicators, such as Lewis's woodpecker which relies on recently burned areas or the Northern goshawk which relies on larger patches of mature forest.

THREATENED ECOSYSTEMS

Sensitive ecosystems

Several lakes in the Basin Boundary region have had sensitive ecosystems mapped in Foreshore Inventory and Mapping projects (FIM). There are standardized FIM standards which will allow for trends to be tracked over time, and lakes can be compared to each other. These FIM projects are valuable because they can identify sensitive ecosystems and provide an assessment of the current

condition, threats, and recommendations for Best Management Practices for development (McPherson et al., 2010).

Sensitive Ecosystem Inventories (SEI) identify and map rare, at-risk and fragile ecosystems for a given area (Haney and Iverson 2009). These inventories have been published in several areas of British Columbia including the Okanagan, Vancouver Island and the Sunshine Coast, but not yet in the Columbia Basin Boundary Region. A SEI project was ongoing for the Slocan Valley in 2012, but the final report is not yet publically available. Identifying sensitive ecosystems would be a valuable tool for land conservation initiatives as well as smart urban and industrial development. Filling this information gap with a region-wide SEI inventory would be a valuable tool.

The BC Wildlife Federation has initiated a BC Wetlands Atlas that aims to encourage citizen scientists to take part in mapping wetlands in BC: http://www.shim.bc.ca/wetland/main.htm.

Invasive species

Invasive species are non-native organisms that cause environmental or economic harm. Typically they can spread to new areas and compete with native species and negatively impact the ecology of the ecosystem they invade. They continue to spread into new areas, but information is often lacking on their distribution and management options.

Invasive plants

There are several active invasive species organizations including the Invasive Alien Plant Program (IAPP) that has an online mapping tool which provides information on invasive plant inventory and treatment information (http://webmaps.gov.bc.ca/imf5/imf.jsp?site=mofr_iapp). The Central Kootenay Invasive Plant Committee works with IAPP, and has expressed an interest in sharing data and collaborating on the development of an invasive plant indicator.

Invasive fish

There are between eight and 10 invasive fish species in the lakes, rivers and streams throughout the Basin Boundary region. Some species such as brook trout were intentionally stocked for recreational fisheries, while others such as pumpkinseed were introduced by unauthorised release and are negatively impacting some local aquatic ecosystems. Tracking the spread and/or control of these species (and the introduction of new ones) may be a useful indicator in management of invasive fish.

Human-wildlife interactions

Bear attractants and conflicts

Each year, black bears and grizzly bears are killed by residents or conservation officers because they come into conflict with humans throughout the region. They are attracted to garbage, fruit trees, pets, chicken coops and other livestock and then become habituated to these food sources, lose their fear of humans, and become dangerous bears. SGRC has partnered with several Bear Aware coordinators to help reduce this conflict by identifying bear attractants and recording where conservation officers are called to deal with problem bears. Several pilot projects are underway in communities such as Rossland, Trail, and Castlegar where attractants are mapped and compared to locations of conservation officer bear calls. These maps will then be used to aid

in publicizing the importance of mitigating or eliminating bear attractants and aiding in the identification of where limited resources should be allocated for conflict reduction.

Urban ungulates

Ungulates including deer, elk and sheep are found in many urban centres in the region. They cause damage to gardens, landscaping and community forests as well as causing vehicle collisions and problems with aggressive behaviour (Badry, 2010). These interactions often result in complaints to city officials and conservation officers, and several communities are employing various techniques to reduce populations and/or conflicts. The volume of complaints could be tracked over time to monitor the impacts of various urban ungulate management decisions.

LAND

CONTAMINATION

Pollution release - water and land

The National Pollutant Release Inventory is a legislated inventory of pollutant releases, disposals and transfers available at http://www.ec.gc.ca/inrp-npri/ where an access database can be downloaded and queried. More than 300 pollutants have been tracked since 1993, and come complete with spatial data that would make mapping the sources in the basin region relatively easy. The database includes transfers of these pollutants to air, water, or land, injected underground, or transferred off-site for treatment, disposal or recycling.

Contaminated sites

Contaminates sites are areas of land where the soil, groundwater or sediment contains a hazardous waste or substance that exceeds provincial standards. They may pose a threat to human health, the environment or safety. The BC government has a Contaminated Sites Registry of over 9000 locations across the province that are on provincial land. There are also over 2000 contaminated sites on federal lands in BC, and an unknown number of sites on municipal land. An indicator that tracks contaminated site identification and remediation could be an important tool for land developers, local governments, planners, managers and citizens. Alternatively, if an indicator that tracks contaminated sites is politically unpalatable, an indicator that tracks successful cleanups of contaminated sites in the region could be developed. This would provide a positive indicator of what actions are being taken to clean up contaminated sites.

FORESTS

Forest health and diseases

The mountain pine beetle epidemic over the past decade has increased the profile of forest health issues for the public and government officials. Forest pests and diseases can have a dramatic impact on forest ecosystems, the forest industry and on the communities that rely on forestry. The BC Forest Service produces an annual report on forest health conditions in BC, which includes areas of damaged forests for dozens of forest health agents, including mountain pine beetle (Westfall and Ebata, 2012). A valuable indicator would track these health agents over time to help identify emerging issues which will help prioritize action plans.

Ratio of old to young forests

Logging has had a large impact on forested habitats throughout the region. Remote sensing can measure the areas covered by young and old forests, which can then be compared to historical imagery. This can provide an indicator of the current character of forests in the region, including how that character compares to the historic range of variability for forest types.

Wildfires

Fire suppression activities over the past century have increased fire hazards due to fuel buildups in forests throughout the basin, and climate change analysts predict that summers will be hotter and dryer in the future. These two factors are expected to result in increased numbers of large, high severity fires. An indicator could be developed that tracks the area of burns each year. This data is available from the Wildfire Protection Branch of the Ministry of Forests Lands and Natural Resource Operations.

LAND USE

Parks and tree cover in urban environments

Trees and green spaces within urban environments improve urban liveability and help improve air quality by absorbing certain pollutants (Brauer et al., 2012). They also help regulate the micro-climate, stream flows and groundwater levels (Molnar, 2011). Remote sensing allows for the measurement of green spaces in urban environments, and could track trends over time and across space.

Food security

As the global population grows and land use pressures consequently intensify, many regions are becoming concerned with the sustainability of their food supply. The Basin Boundary region is no exception to this trend. An indicator measuring food security could address any number of issues, including land tenure (e.g., extent of tenured rangeland), the nature of farms (organic vs. conventional), planning issues (e.g., changes to, or use of, the Agricultural Land Reserve), or levels of local food production.

PARKS AND PROTECTED AREAS

Federal/Provincial parks

This measure is included in the 2012 SOTB report (RDI, 2013). It measures the percentage of land that is classified as a national park or is managed by BC Parks, and assesses the degree to which ecosystems are protected based on the Biogeoclimatic Ecosystem Classification (BEC) system. It can be used as a performance indicator comparing the actual level of protection to the stated goal of the BC government in protecting 12% of land in BC. The evaluation of levels of protection by BEC zones allows for the identification of ecosystems that are underrepresented in protected areas which can then be used to plan for future land conservation.

Private land conservation

BEC zones that are underrepresented in the parks system tend to be the low elevation zones where human populations reside and the highest levels of private land exist. There are several private land conservation organizations including the Nature Conservancy of Canada (NCC), the

Nature Trust of BC (TNT) and The Land Conservancy of BC (TLC) that recognize the need for protection of these low elevation zones. Over the past several decades these organizations have worked with many partners to purchase and protect large areas of private land. Publically available maps of these areas are available (e.g. http://www.natureconservancy.ca; www.naturetrust.bc.ca) and can be compiled and used in conjunction with the public protected areas indicator to produce a more comprehensive picture of land conservation in the Columbia Basin Boundary Region.

Ecosystem restoration

Ecosystem Restoration is the process of assisting the recovery of an ecosystem that has been degraded, damaged or destroyed (Society for Ecological Restoration International, 2004). Throughout the region, ecosystem restoration activities are taking place on all scales, by many groups, individuals and large organizations. Restoration activities include prescribed burning, invasive weed removal, thinning dense forest stands, riparian restoration, fish habitat restoration, reclaiming old mine sites and abandoned agricultural fields.

The Rocky Mountain Trench Ecosystem Restoration Program is a coalition of forest and range licensees, naturalists, hunting, fishing and environmental organizations and is co-ordinated by the Ministry of Forests, Lands and Natural Resource Operations. They work together to restore fire-maintained ecosystems in the East Kootenays, and have an extensive database of past restoration activities.

An indicator could be developed that tracks areas of ecological restoration in the region. It is an ideal indicator to use the layered approach where the most basic level is area of land restored, with more details available for each project. This would provide restoration practitioners with the ability to learn about other restoration activities going on in the region, to learn new techniques, and make contacts with other organizations. It would improve the efficiency of restoration planning, reduce overlap, and raise the profile of important restoration activities.

Urban / wildfire interface hazards

Fire suppression over the past century has resulted in forest in-growth and an increased risk of high severity, stand replacing fires that threaten many communities in the Basin Boundary region. Several communities are producing wildfire protection plans which include hazard assessments for fires in their surrounding forests. A valuable indicator would look at communities with plans in place, and map areas where hazards are high. This indicator could highlight successful plans including details on communities that have taken effective action to reduce fire hazards in the wildland urban interface.

Water

There are several organizations and individuals that collect water quality sampling data in the lakes, streams and rivers of the Columbia Basin Boundary region. An indicator could be developed to track the changes in water quality using the data from these groups. Initial contacts have been made with several of these groups and there is a willingness to share data. The challenge will be to standardize data collection from different water bodies to make the

information more useful and relevant. Some work on this has already been initiated by the Columbia Basin Watershed Network (www.cbwn.ca). RDI should explore opportunities to collaborate with these organizations in developing indicators and promoting information exchange and dissemination.

Water quality index - lakes and rivers

The water quality index is an aggregate indicator that synthesizes multiple measures of the quality of a water body in relation to relevant guidelines. The index helps distil complex water quality information, and is an important communication tool for many water monitoring programs. RDI could either report on individual indicators, or use the water quality index aggregate indicator.

Stream flow timing

The peak flow dates of 17 rivers in the Columbia Basin Boundary Region were reported in the 2012 SOTB report (RDI, 2013). This indicator is a proxy for the timing of snow melt, and shows a trend towards earlier snow melt. Earlier snow melt suggests longer periods of low flows in the late summer and fall and higher water temperatures. Higher water temperatures will have an impact on cold-water dependent fishes such as cutthroat trout, and longer periods of low flows could negatively impact water availability for human use. Stream flow timing data is readily available and this indicator should continue to be reported in future SOTB reports.

Conclusion

The next step is to present this candidate list to the environmental advisory committee, stakeholders, the local scientific community and potential end users for input. Please provide us with feedback on how we could better monitor the vitality of our region by sending an email to cbrdi@selkirk.ca.

Additional candidate indicators that may be developed are listed in Appendix 1. The questions listed in the section outlining indicator selection criteria should be answered by these groups for each potential indicator. Particular focus should be on determining if the indicator is technically sound, understandable, relevant, measureable, reliable and feasible, and if the indicator will show trends over time. RDI currently has access to a highly variable amount of information on each indicator, and once the list is shortened and finalized, work can begin on locating additional relevant information.

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APPENDIX A: ADDITIONAL CANDIDATE INDICATORS

Air

Radon levels in homes (a health threat in the basin)

Extreme weather events (frequency of flooding, snow on rain events, etc.)

Biodiversity

Roadkill (numbers of animals killed on highways in the basin)

Invasive animals (similar to invasive fish and plants)

Whitebark pine habitat (endangered species, keystone species in threatened habitat)

Recreational fisheries (number of fishing licences, fishermen, and fish harvested)

Hunting (number of hunting licences, hunters, and wildlife harvested)

Fish barriers (locations of culverts that do not allow fish to pass on fish bearing streams)

Kokanee (response of Kokanee populations to lake fertilization programs)

Land

Extent of watershed integrity (road densities and functioning ecosystems by watershed)

Area affected by dams (area flooded or agricultural land lost)

Areas of soil degradation (reduced ecosystem productivity)

Landslides (locations and areas of mass wasting events)

Pesticide Use (volume of pesticide use in agriculture/forestry/urban settings)

Area of impermeable surfaces around municipalities

Use of forest resources (harvested area per year)

Water

Well water levels (aquifers)

Water coverage at spring freshet (indicates extent of natural flow regimes)

Water temperatures (lake and river temperatures affect aquatic ecosystem function)