Catchments as Freshwater Protection and Management Units

Brief Submitted April 15, 2021 by: Peter G. Lee (Affiliation: Salal Foundation)

To: House of Commons Standing Committee on Environment and Sustainable Development
Study on Freshwater in Canada

1. Introduction

I am a retired conservationist. My affiliation for this brief is Chairman, Salal Foundation (salalfoundation.ca[1]).

My career with Global Forest Watch Canada (affiliations with the World Resources Institute), World Wildlife Fund Canada, and the Alberta Government, and my involvement with regional and local conservation organizations and various ecological and freshwater scientists (especially Dr. David W. Schindler) leads me to make the following recommendation related to protecting and managing Canada's freshwaters:

> **Catchments as freshwater protection and management units – A catchment-based approach to data collection and to planning, protection and management decisions is needed that includes water and chemical mass-balances as a sensitive means of detecting early degradation of many ecosystem services in both catchments and their surface freshwaters.**

To protect and manage freshwaters, it is necessary to protect and manage the catchments that drain to them.

This recommendation and the following information are summarized, with some updated information, from the paper: *D.W. Schindler and P.G. Lee. 2010. Comprehensive conservation planning to protect biodiversity and ecosystem services in Canadian boreal regions under a warming climate and increasing exploitation. Biological Conservation 143, 1571-1586.*

Although this referenced paper focusses on the Canada's Boreal Biome, the idea of catchments as a key unifying framework is relevant to all of Canada when considering freshwater protection and management.

The recommendation addresses components of three topics in the groupings of questions provided by the House of Commons Standing Committee on Environment and Sustainable Development Study on Freshwater in Canada:

1. Federal water legislation, policies and regulations: Incorporating catchments as protection, management and planning units into federal legislation, policies and regulations would provide a unifying, science-based mechanism to address inter-jurisdictional freshwater issues and to assist in addressing intra-jurisdictional freshwater management decisions.
2. Collection of information and data: The federal government should play a major role in providing base data on the geographic distribution of catchments, as well as providing baseline data from the monitoring and analysis of the freshwater health of catchments.
3. International and business issues: Establishing catchments as protection, management and planning units would assist in dispute resolution on freshwater international boundary disputes by providing a science-based mechanism to address geographic extent of interest.

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[1] Salal Foundation (salalfoundation.org): Our mission is to research, test, and scale innovative strategies that nurture transparency, citizen engagement, democracy, and communities living within natural limits.

2. Background

2.1 Catchments

In North America, the area that drains to a water body is generally referred to as its watershed. The term catchment is used for the same designation in UK, where the term watershed customarily means the divide between adjacent catchments. The term catchment seems more descriptive of how the system operates.

It has been recognized for several decades (Likens et al., 1997) that to protect freshwaters, it is necessary to protect the catchments that drain to them. Yet until recently, conservation planning and land management has mostly ignored freshwater, focusing instead on protecting biodiversity or habitat of focal species or species groups of birds and mammals (Pringle, 2001).

2.2 Relevancy of Canada's Boreal Biome and the Schindler and Lee paper when considering protection and management of Canada's freshwaters

The intention of this submission is not to focus future freshwater protection and management efforts only or primarily on Canada's boreal biome, rather to apply the lessons learned and described in Schindler and Lee (2010) to all of Canada when considering freshwater protection and management.

Nevertheless, it is worth briefly summarizing the two major reasons why Canada's Boreal Biome is particularly relevant for Canada's freshwaters as a whole.

Firstly, it is Canada's largest biome at 58.5% of the country's area with disproportionately large freshwater resources. (Fig. 1 and 2). Freshwater protection and management must therefore have a significant focus on the boreal portions of Canada's jurisdictions as part of comprehensive freshwater protection and management efforts.

Secondly, as with most the more southern and more northern ecological regions, the Boreal is undergoing rapid change regarding climate warming and increasing exploitation (see Fig. 3 for the Boreal) (Vincent et al., 2019).

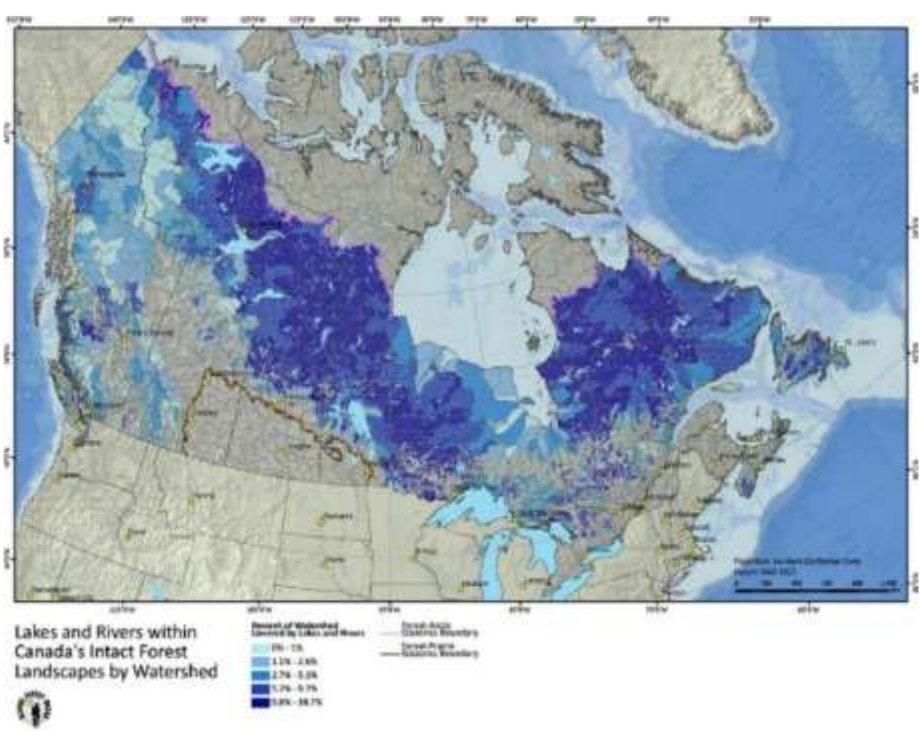

Fig. 1. Lakes >10 km^2 in Canada's boreal region. The area contains over 2 million lakes, most of them small. Some parts of the Boreal have as much as 40% of their surface area covered by water. Figure from Global Forest Watch Canada.

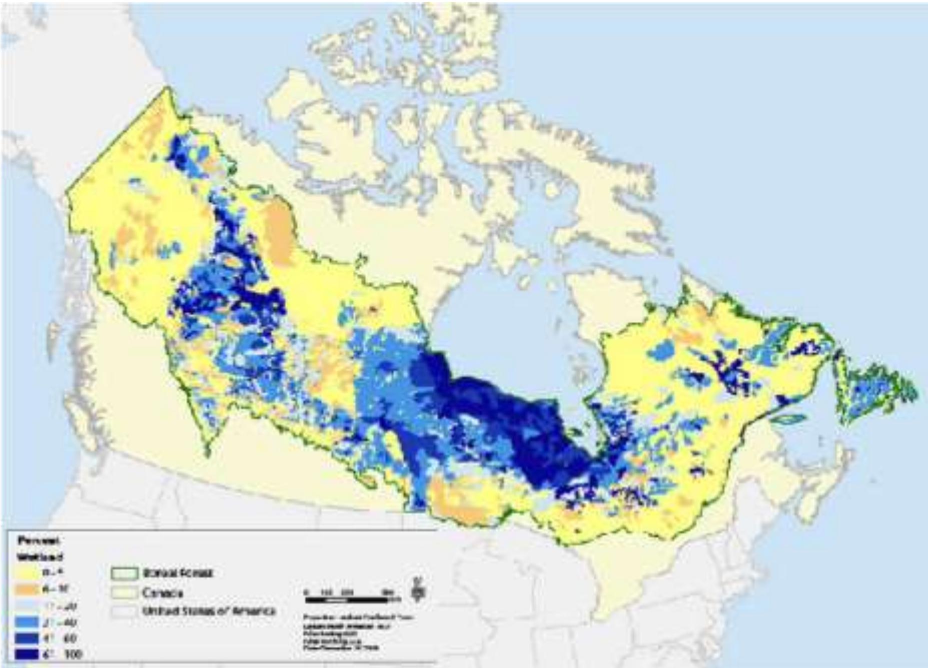

Fig. 2. The proportion of surface area covered by wetlands in boreal Canada. Figure from Canadian Boreal Initiative originally produced by Global Forest Watch Canada

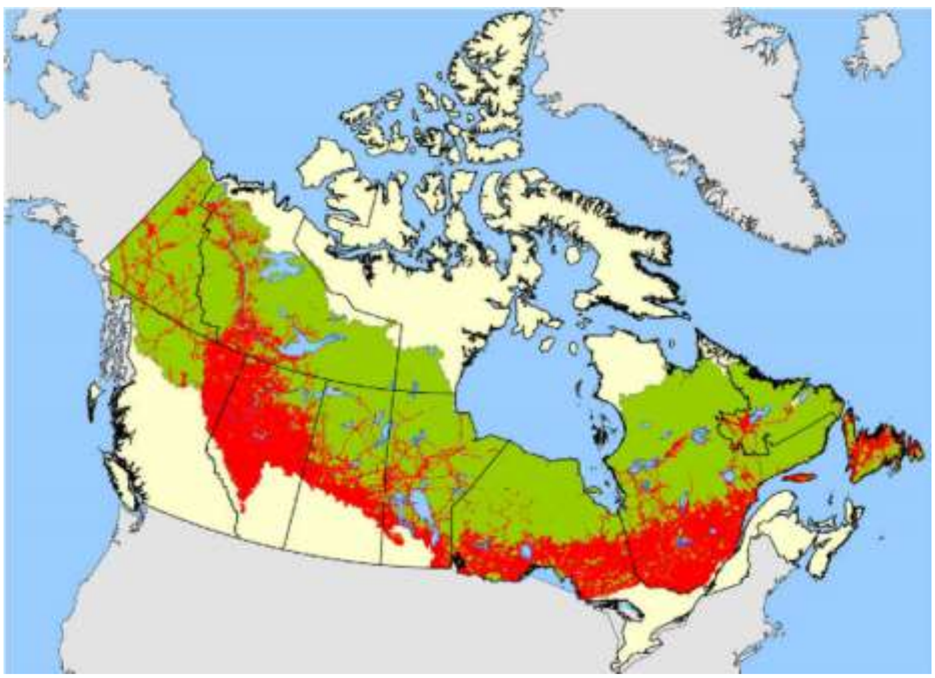

Fig. 3. A map of Canada showing fragmentation of the boreal forest (in red). Map from Global Forest Watch.

2.3 Examples of threats to Canada's catchments where hydrology and hydrochemistry are useful diagnostic tools

2.3.1 Climate change

Much of Canada, including the Prairies, the boreal and far north are among the regions of Earth being most rapidly affected by climate change (Schindler, 1998a,b; Chapin et al., 2006; Ruckstuhl et al., 2008, Vincent et al.,

2019). The potential positive feedback cycles to the global carbon cycle would cause great changes to the character of much of Canada.

2.3.2 Examples of threats to Canada's catchments that are likely to be amplified by changing climate, or vice versa

Many of the current threats to Canada's catchments are viewed in isolation. In reality, climate change can amplify the effects of many threats. In other cases, the threat can amplify the effects of climate change, as has been the case for permafrost melting and forest fire. The following are some examples for the Boreal of threats to catchments that are likely to be amplified by changing climate, or vice versa:

- Insect outbreaks and forest fire
- Acid rain

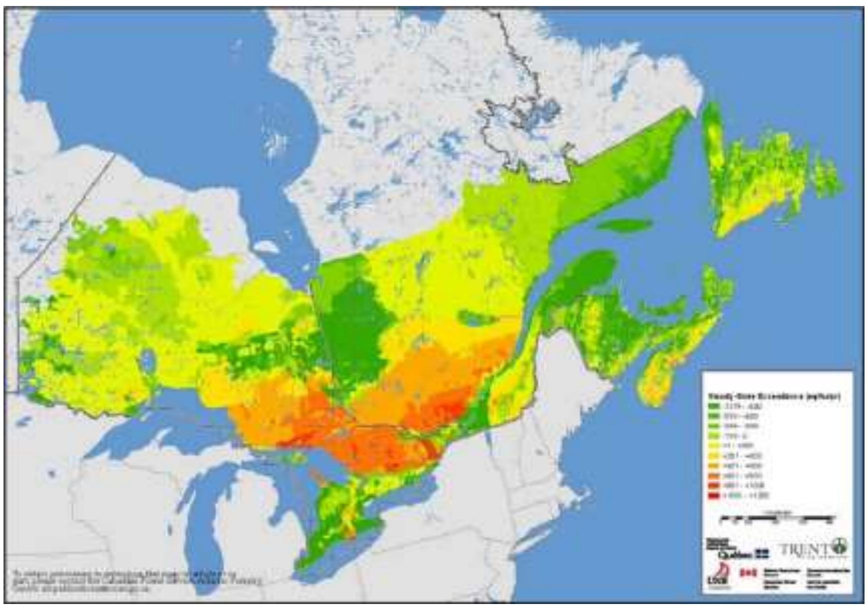

Fig. 4. A map of calculated exceedances of critical loads of sulphur and nitrogen for upland forest soils of Canada, based on preliminary estimates of 2002 deposition from the AURAMS model. The map is based on a base cation/aluminum ratio of 10, which was estimated to maintain base cation saturation in soils >20%. Areas in red and orange are areas where forest soils and lakes are particularly damaged. The additional effects of forest harvesting are not shown. From Carou et al. (2008).

- Logging
- Dams and diversions
- Eutrophication
- Agriculture clearing and runoff
- Declines in fisheries
- Oil sands and other oil and gas developments
- Mines and other toxic discharges

3. <u>Advantages of integrating freshwater catchments into conservation planning and management</u>

In the past few years, some have recognized the importance of including freshwater in conservation planning from the standpoint of protecting biodiversity and habitat. Catchments have been proposed as the fundamental unit of conservation for linking fisheries to their habitats (Collares-Pereira and Cowx, 2004; Naiman and Latterell, 2005). Other fairly recent conservation plans for freshwater have considered biodiversity as the major issue (Higgins et al., 2005; Moilanen et al., 2008). Amis et al. (2009) found that integrated terrestrial-freshwater conservation plans were more successful at protecting freshwater biodiversity. Pringle (2001) proposed hydrologic connectivity as essential in managing biological reserves. Leroux et al. (2007) included wetlands and water in a balanced approach for protection However, all of the

above studies are focused on aquatic objectives. Schindler and Lee (2010) proposed that the approach be modified to combine chemical–biological–hydrological factors in both catchments and freshwaters, with the multiple objectives of protecting freshwater supplies, detecting changes to ecosystem services in catchments, and preserving biodiversity at catchment scales, as described below.

3.1 Catchment mass-balance approaches to detecting changes to ecosystem services and biodiversity loss

There are many good reasons for terrestrial and wetland protection, management and planning to include freshwaters. They are sentinels of change for both terrestrial and aquatic ecosystems (Schindler, 2009; Williamson et al., 2009). Changes in the water balance and disruptions to the biogeochemical cycles of terrestrial, wetland and aquatic ecosystems are often most easily detected by monitoring inputs and outputs of water and the chemicals dissolved or suspended in it. Water budgets and biogeochemical mass-balance budgets can provide an early warning of impending problems of ecosystem processes in catchments. Accurate measurements of precipitation, surface water levels, surface water flows, and input–output budgets of dissolved chemicals to catchments are well developed sciences. Most chemical substances are now detectable at concentrations of parts per billion or even parts per trillion. Groundwater measurements are less precise, but a number of isotopic, GIS, or remote-sensing based diagnostic tools have improved our abilities to gauge underground flows and the sources of chemical constituents (Krabbenhoft et al., 1994; Webster et al., 1996; Hinton et al., 1997; Buttle et al., 2009).

Changes to the water balance of catchments can be used to predict impending changes to community types in the catchment. For example, lower precipitation or higher evaporation can be reflected in lower streamflows and groundwater levels, heralding the transition of mesic to xeric communities, from minerotrophic to ombrotrophic wetlands, of higher outputs of hydrogen ion and sulphate from wetlands (Bayley et al., 1992a; Lazerte, 1993) or of more frequent or more intense forest fires.

There are also numerous examples of where chemical mass-balances have shown that the ecosystem services of terrestrial or aquatic ecosystem services are being compromised. Examples include acid rain, insect outbreaks, disruption of biogeochemical cycles, fire, and eutrophication.

3.2 Using paleoecology to evaluate past changes to catchments

Another good reason to include lakes in catchment-scale protection, management and planning is that they assist in interpreting changes that occurred to catchments before contemporary monitoring began. Lake sediments contain records of past changes to all ecosystems within the catchment, in the fossil remains and geochemical indices that are deposited chronologically. Using these biological and geochemical signals, it is possible to deduce in some detail how communities and ecosystems reacted to and recovered from past stresses (Smol, 2008). For example, it has been possible to predict the frequency and duration of past droughts and associated changes in algal communities (Fritz et al., 2000; Laird et al., 2003), and of forest fires and the terrestrial species succession that followed them (Campbell and Campbell, 2000; Weir et al., 2000). In some cases, records span several millennia. This knowledge of how an ecosystem has responded to, or recovered from past stresses is useful for evaluating the likelihood that future stresses will cause catastrophic ecosystem shifts, or estimating the time required for a community to recover after stress.

In summary, in order to fully utilize the unique hydrological, chemical and paleoecological properties of aquatic ecosystems in freshwater protection, management, it is necessary to include catchments as basic units of planning.

4. Planning a catchment conservation approach

The numerous examples presented above and detailed in Schindler and Lee (2010) are evidence that a catchment-based approach to freshwater protection and management is urgently needed, and that including water will provide many advantages for interpreting threats to both terrestrial and aquatic ecosystems. There is also clear evidence that the threats posed by direct perturbations to ecosystems are compounded by climate warming, and in the southern ecological regions by continued acid deposition. It is the cumulative effects of a cascade of direct and indirect insults, including airborne stresses, stresses to catchment ecosystems, and direct stressors to aquatic ecosystems that are of concern. It is thus essential that planning be broadly enough based to allow a true assessment of cumulative effects. Schneider et al. (2003) have already advocated the need for such a plan for northeastern Alberta, based on the cumulative effects of oil and gas exploration and development plus forestry. The ALCES model that they use is well suited for including aquatic criteria. Such an approach would in most cases require little modification to existing plans. Here are some of the criteria that need to be considered:

- If catchments designated for deliberate protection and management are to include all desired features, including far-ranging terrestrial species such as bears, woodland caribou, and wolverines, scales of thousands of square kilometres might be needed. This is probably still possible in northern boreal, subarctic and arctic regions of Canada, where relatively little industrial development has taken place. The Northwest Territories government had earlier initiated proactive planning to protect aquatic resources and has considered an approach that includes many of the necessary features for catchment-scale protection and management.
- In many catchments, protection and management at large catchment scales is hindered by geopolitical boundaries. In this respect, Canada has a great advantage, with several large catchments contained entirely within the country, although interprovincial politics have often been a hindrance to progress.
- However, many of the stresses common in southern ecological regions occur at smaller scales, affecting the catchments of first or second order streams. To detect these, it may be more advantageous to perform monitoring at the scale of multiple small catchments, rather than one large one. This will be necessary in any case in the more southerly ecological regions, where development has proceeded piecemeal with little thought to cumulative effects or ecosystem services, and it is no longer possible to protect such large catchments. Small catchments are usually the most sensitive biogeochemical units, where many of the early signs of problems with ecosystem services can usually be detected hydrologically or biogeochemically, as clearly shown by studies at Hubbard Brook and at three boreal sites in Ontario: Dorset, Turkey Lakes, and the Experimental Lakes Area (reviewed by Parker et al. (2009)).
- Extrapolating results to larger areas, or to hydrologically-difficult areas such as those described by Devito et al. (2005) poses some difficulties. In this regard, recent advances in understanding subsurface water movement using geographical information systems, remote sensing and modelled hydrological patterns show considerable promise for estimating water and geochemical budgets for large forested areas (reviewed by Buttle et al. (2009)).
- To incorporate aquatic studies that can detect both direct and indirect changes to ecosystem processes with the required accuracy will require some serious upgrading of the monitoring of meteorology, hydrology and water chemistry. There are a number of useful models in boreal or near-boreal regions, at the Experimental Lakes Area (Schindler et al., 1996a; Parker et al., 2009), Dorset (Watmough and Dillon, 2003), at Turkey Lakes (Spoelstra et al., 2001), all in Ontario, and at Trout Lake, Wisconsin (Magnuson et al., 2006). Depending on site location and air mass movement, these have already revealed long-term problems caused by climate change and other stresses, for example, long-term increases in ammonium input, decreases in

calcium input (Parker et al., 2009), increased calcium loss (Watmough et al., 2004) and increased nitrogen losses (Spoelstra et al., 2001).

- It would be useful to a catchment-scale program if changes in water quality could be linked to standards that designate thresholds and concentrations of substances that are detrimental to biodiversity and ecosystem health services. At present, both the Canadian federal government and provinces have only water quality guidelines, which are not legally enforceable and are often exceeded. With respect to terrestrial ecosystems, it would make sense to have ‘‘loading” similar to the ‘‘critical load” problem developed in Europe for managing the effects of acidifying emissions on both terrestrial catchments and receiving waters. The critical load approach has been successfully applied in some systems in Canada (for example Watmough et al., 2006), but it is not in widespread use in formulating protection, management policies.
- Measuring water and biogeochemical balances in many catchments in the Precambrian Shield, including those of several thousand square kilometres, is relatively easy, because most areas have little groundwater flow and are underlain by unfractured bedrock. In most areas, water and biogeochemical balances are dominated by surface flows, because aquifers are generally shallow and well-defined.
- In contrast, at many sites in the prairie provinces, lack of relief, limited sites for accurate streamflow and lake level monitoring, thick overburden containing important aquifers, and large areas of wetlands make determining water balances for catchments very difficult.

In summary, a few simple changes to freshwater protection and management to employ input–output budgets of water and chemicals would allow many advantages in protecting the health of aquatic and terrestrial ecosystems and evaluating stresses to ecosystem services and natural capital.

5. Conclusion

The Salal Foundation proposes that the freshwater protection and management combine chemical–biological–hydrological factors in both catchments and freshwaters, with the multiple objectives of protecting freshwater supplies, detecting changes to ecosystem services in catchments, and preserving biodiversity at catchment scales. I make the following recommendation related to protecting and managing Canada’s freshwaters:

Catchments as freshwater protection and management units – A catchment-based approach to data collection and to planning, protection and management decisions is needed that includes water and chemical mass-balances as a sensitive means of detecting early degradation of many ecosystem services in both catchments and their surface freshwaters.

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