Public Policy Assessment and Advancing Science-Based Freshwater Protection

BACKGROUND PAPER

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International Institute for Sustainable Development

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Table of Contents

1. Introduction

1.1 Purpose and Focus Question

Achieving the United Nations Development Program's Sustainable Development Goals will require adept water management—changes to the world's climate are being observed, along with changes in the water cycle at local through global scales, and significant additional climate-induced changes are anticipated through the coming decades. The times demand comprehensive freshwater management approaches. As a skilled and resourceful nation, is Canada well positioned to manage its water resources and protect aquatic biodiversity in the face of changing climate, shifting population demographics, development pressures and other factors?

This backgrounder provides information to inform discussion at a workshop hosted by the International Institute for Sustainable Development (IISD) on questions pertaining to comprehensive, science-informed management of Canadian fresh waters and in support of a pan-Canadian approach to freshwater management:

- What are the main principles embedded in Canadian freshwater policies and regulations?
- Is there a clear process to track changing risks to Canada's fresh water and link risks to threats?
- Are there clear approaches to align water science and water policy? How do we know if there are gaps, and is there a systematic way of updating policy and research priorities?

The broader goal, toward which the workshop is an initial step, is *to develop a systematic science-informed approach to assess regulatory and policy regimes and prioritize freshwater science needs*. This goal is relevant to federal, provincial, territorial and aboriginal government organizations, academic institutions, business and civil society and international jurisdictions engaged in managing and protecting fresh waters. Such an approach could inform budget and human resource-allocation decisions and guide the development and use of management interventions to protect aquatic ecosystems and water resources.

The workshop specifically focuses around a typology to align water science, risks, threats and policies. The focus question for the workshop is:

Does the current public policy regime (laws, regulations, policies, agreements and guidelines) adequately address threats to Canada's fresh waters (and how do we know)?

An assessment of the "adequacy" of public policy to address threats requires both science- and values-based thresholds to serve as benchmarks. Specific to our purposes for the workshop, to answer this question, we can consider:

1) Gaps in scientific understanding of threats. Science gaps exist where threats are not assessed, or are poorly characterized, at one or more relevant spatial or temporal scales (e.g., short-term/acute and long-term/chronic). For instance, when a new substance is introduced to the marketplace (e.g., nanosilver), the causal mechanism(s) for potential threats to fresh waters may not be known, including long-term effects on various biota, pathways of exposure (e.g., magnification through a food web), concentrations triggering effects and other factors.

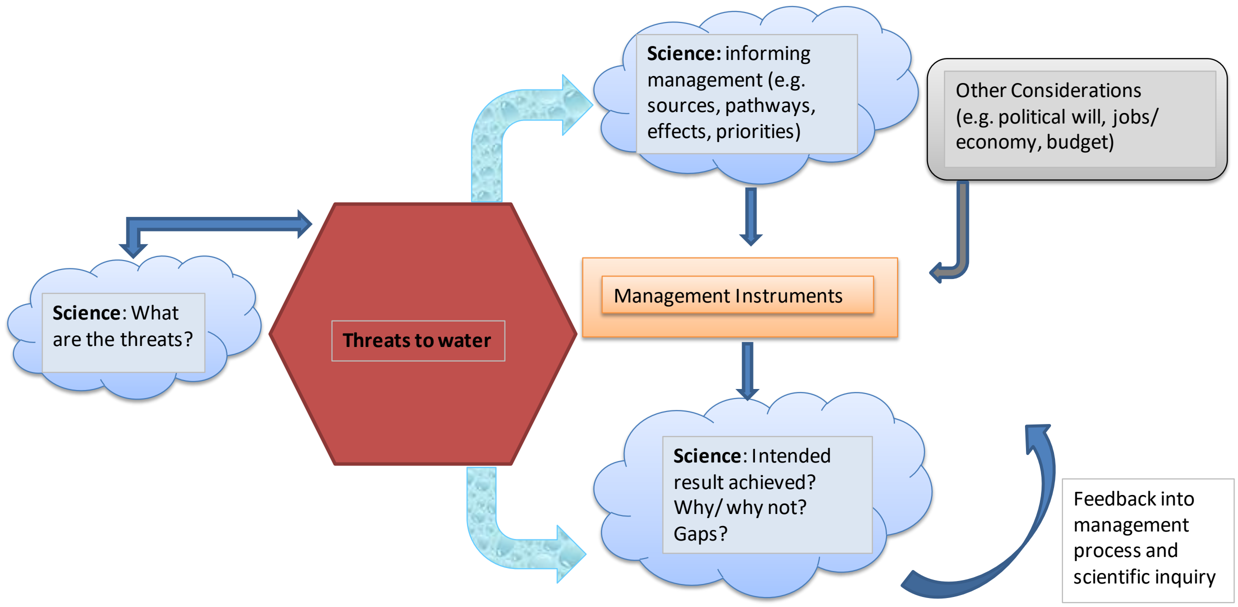
2) Gaps in the public policy suite to address threats to water. A policy gap exists where an activity or condition poses a threat to water resources or habitat, but no management instrument exists to mitigate (or compensate for) the threat, or where a policy has not been fully implemented or enforced as intended.

3) *Gaps in scientific understanding pertaining to the effectiveness of public policy to address threats*. A science gap also exists where there is no evidence, or weak evidence, to assess the extent to which a threat has been mitigated (or compensated for) by the implemented management instrument(s). This gap may arise due to a lack of understanding of the causal relationships of the threat with the outcome of interest or from a lack of monitoring/surveillance data to assess outcomes of interest. For instance, do increases in the population of an indicator species necessarily reflect a reduction in the exposure of an ecosystem to a specific threat?

Note that “science” includes many disciplines—physical, natural, biomedical, and economic and other social sciences—although we focus on the physical and natural sciences within this background document.

This framing of the issue points to three distinct elements of the focus question: (1) threats to fresh water; (2) management instruments to implement public policy; and (3) science and scientific evidence to assess threats and management approaches. Figure 1 provides a schematic of the relationship between these three components, with an emphasis on environmental impact, as well as a fourth component identified as “Other Considerations.” “Other Considerations” includes political will, budget decisions, regional and sectoral impacts of management instruments, jurisdictional staff capacities and other factors that are not discussed further but could be subject of numerous additional workshops.

Figure 1.1. Schematic of the elements of the focus questions



1.2 IISD and Fresh Water

IISD takes an independent, evidence-based approach to the development of policy recommendations and tools to help Canadian and international jurisdictions, industry and other stakeholders meet the many challenges of integrating environmental and social priorities with economic development. As the agency responsible for the Experimental Lakes Area, IISD also conducts world-class freshwater science in collaboration and partnership with scientists and research agencies in Canada and around the world.

IISD has an interest in, and commitment to, freshwater management. IISD is willing to leverage its policy and science expertise, as well as its capacity to convene diverse talents, to initiate, develop, facilitate and/or coordinate efforts to advance a coordinated and cohesive approach to protecting aquatic ecosystems and to sustainable use of water resources.

1.3 Workshop Objectives

Assessing the degree to which the public policy regime addresses threats to Canada's freshwaters is multi-faceted and requires input from a range of experts and stakeholders. Even a first step of developing an inventory of relevant policies across Canadian jurisdictions would take considerable effort. Similarly, assessing whether science research and policy are sufficiently aligned to address known and emerging threats is an energetic undertaking. Before expending substantial effort toward these ends, IISD wishes to "test" elements of a proposed approach at the workshop.

The specific objectives for the workshop are to discuss:

1) A proposed threat classification for Canadian fresh water
2) A proposed methodology to assess public policy gaps with respect to threats
3) A proposed approach to develop a systematic and robust water science research agenda
4) Next steps to build on the discussions.

Depending on the discussion, next steps (4) may include:

- An approach to further vet the threats typology
- A process for development of a database of Canadian public policy on water
- An approach to develop a science research agenda, based on a refined methodology
- Applicability to a pan-Canadian approach for freshwater policy.

1.3.1 Scope of the Preliminary Analyses

The scope of the tools developed and workshop discussion includes surface fresh water and groundwater. For the purposes of the initial analyses, it was assumed that management instruments have been fully implemented and that they address intended threats stated in objectives of the instrument. We expect that this assumption is not valid in all cases, but an assessment of the performance of instruments and verification of environmental outcomes were not the focus of this preliminary step.

A classification system for water management instruments is proposed in Section 2 and a sample of 26 water management instruments is then characterized using this classification scheme. Classification is based on analyses of 80 provisions from these instruments. The proposed typology for threats to fresh water is described in Section 3. Linkages to science are described in Section 4. The proposed methodology to assess gaps in public policy is described in Section 5, and results of a gap analysis are presented to illustrate its potential application. Detailed statistical analyses were not undertaken, since the policy sample is not representative of the full set of Canadian instruments. Results from analysis of the sample are intended to be indicative of the information that might be available through full analyses. Section 5 also discusses potential lines of inquiry for development of a water research agenda to inform policy gaps. Sample scientific questions are presented for illustration purposes.

2. Canadian Freshwater Management

2.1 Canadian Water Policy and Management Approaches

The Canadian Constitution Act of 1867 was written prior to political acknowledgement of environmental form, function and integrity. At that time, "environment" was synonymous with "resources" and the exploitation thereof. Provinces were allocated responsibility for water, but the federal government was deemed responsible for fisheries, navigation and international relations, including agreements pertaining to boundary waters. The arrangement failed to recognize the inherent connection of watersheds with physical geography not political boundaries, the importance of groundwater–surface water interactions or the ultimate fate of all flowing fresh waters to eventually reach a sea. It also created persistent federal–provincial jurisdictional ambiguities that have "led to irregular attention to water issues and [left] some concerns insufficiently addressed by either level of government."[1]

In 1970, the *Canada Water Act* provided the federal government with the authority to act in the interests of water quality for waters that had become impaired to the point of national concern. Later, the 1987 Federal Water Policy recommended "anticipatory and preventive approaches to managing the quality and quantity of Canada's water resources.[2]" The Preamble to the 1999 Canadian Environmental Protection Act (CEPA) recognizes the importance of an ecosystem approach. Provinces also made advances to manage water in a more comprehensive manner; Ontario was well ahead with its Conservation Authorities Act in 1946, which organizes freshwater management on the basis of provincial watershed boundaries.

Despite the advances, Canada lags behind international jurisdictions in managing water resources and ecosystems in a manner that supports a consistent approach to developing watershed and continental basin solutions. Internationally, both the United States and the European Union have aggressively pursued watershed-based improvements in ecosystems and protection of water uses for human and aquatic life. With 46 years of experience in the United States with the Clean Water Act and 16 years of experience in the European Union with the Water Framework Directive, Canada can take lessons learned from international experience to develop a made-in-Canada approach. The challenge of climate change, and its implications for the water cycle, adds further impetus to development of watershed- and ecosystem-based approaches.

[1] Zubrycki, K., Roy, D., Venema, H.D. & Brooks. D. (2011). *Water Security in Canada: Responsibilities of the Federal Government*. Winnipeg: IISD. Retrieved from http://www.iisd.org/pdf/2011/water_security_canada.pdf

[2] Environment Canada. (1987). *Federal Water Policy*. Retrieved from http://publications.gc.ca/collections/collection_2014/ec/En4-247-1987-eng.pdf

2.2 CLASSIFICATION SYSTEM FOR WATER MANAGEMENT INSTRUMENTS

Two attributes of water management instruments are identified in the following subsections (2.2.1 and 2.2.2):
1) Type of instrument; and
2) Objective of the instrument.

2.2.1 Type of Instrument

We have identified five types of water management instrument:

1. **Laws/Statutes (LS)**
   - Requirements stipulated in Canadian law
2. **Regulations And Permits (RP)**
   - Regulations under laws in Canada and permits issued in accordance with regulatory requirements (e.g., provincial discharge permits or water-taking permits).
3. **Policies, Goals And Research (PGR)**
   - Instruments of this type may be enabled by laws (e.g., CEPA's provision for research into hormone-disrupting substances) or they may lay out aspirational goals and priorities with no legislative authority (e.g., Canadian Council of Ministers of the Environment's [CCME's] Strategic Vision for Water; the Federal Sustainable Development Strategy).
4. **Treaties And Agreements (TA)**
   - Agreements may be binding or they may be entered into with cooperation of all parties but unsupported by legislation; they address shared or inter-jurisdictional water issues (e.g., Master Agreement on Apportionment for the waters of Alberta, Saskatchewan and Manitoba or the Boundary Waters Treaty with the United States).
5. **Guidelines And Standards (GS)**
   - Instruments of this type may be non-binding (e.g., CCME's water quality objectives) or they may be enforced through reference in laws, regulations or permits (e.g., Ontario's provincial water quality objectives).

2.2.2 Objective of Instrument

A management instrument may address multiple objectives. The objectives, at times, may overlap (e.g., control of water withdrawals and habitat protection) or be in conflict (e.g., interventions in support of navigability, such as dredging, that may adversely affect habitat). For the purposes of this paper, we identify eight classes of objectives for freshwater management instruments:

(a) Control/management of deleterious substances (DEL) (e.g., management or control of pollution releases, effluent quality, product controls, toxics management).

- **(b) Control/management of water withdrawals, transfers or storage (WTS)** (e.g., management or control of water withdrawals from surface or groundwater, bulk water exports, dams, weirs).
- **(c) Potable/source water protection (PSW)** (e.g., management or control related to human drinking water systems, including control of land-based activities to protect source water).
- **(d) Aquatic habitat protection (AHP)** (e.g., management or control related to maintaining the form, function and processes within aquatic ecosystems).
- **(e) Remediation, rehabilitation, compensation of/for damage to water resources and habitat (RRC)** (e.g., requirement for payment or activities to compensate for lost habitat).
- **(f) Control/management of navigation (NAV).**
- **(g) Mitigation/adaptation of/to climate change effects on water cycle, aquatic habitat (CCE).**
- **(h) Research, monitoring, knowledge-sharing, methods development (RMK).**

Instruments may include specific mandatory controls or reporting requirements (through laws or regulations), market-based instruments (e.g., subsidies, tradable permits, etc.), voluntary instruments (such as industry standards or best practices) or information-based instruments (e.g., product labelling). These instrument types are not coded in the database.

2.3 The Instruments Sample

A sample of water instruments was selected for analysis. At least one instrument of each type and at least one example of each objective were included in the sample. Jurisdictional authorities included federal and provincial jurisdictions; instruments from other authorities were not sampled (e.g., territorial, municipal, aboriginal governments, conservation authorities). Some attention was paid to include provisions from key federal laws and examples from related regulations. Provisions from the CCME's Strategic Vision for Water were included, as they reflect a degree of consensus among federal, provincial and territorial governments regarding freshwater priorities. Provisions from the instruments of four provinces were sampled, with no intended reflection on provinces or territories not sampled.

For each of the 26 instruments, one or more paragraphs or clauses were reviewed, for a total of 80 provisions. Each of the 80 provisions was scored by asking: Assuming the instrument was fully implemented as designed, does it have the potential to mitigate, or compensate for, a particular threat? (Yes: score = 1; No: score = 0.)

Table 2.1 Summary of water management instruments in sample.

Jurisdiction	Instrument	Type	No. of provisions assessed	Objectives addressed by one or more provisions
CCME	Strategic Vision for Water	PGR	5	AHP, WTS, DEL, CCE, RMK
Federal	Sustainable Development Strategy	PGR	3	DEL, AHP
Federal	Canadian Environmental Protection Act (CEPA)	LS	7	AHP, DEL,
Federal	Chemicals Management Plan (2016–2020)	PGR	5	DEL, RMK
Federal	Fisheries Act	LS	3	AHP, DEL, RMK
Federal	CEPA Regulation Pulp and Paper Mill Effluent Chlorinated Dioxins and Furans	RP	1	DEL
Federal	Fisheries Act Regulation Mining and Metals	RP	1	AHP, RMK
Federal	Fisheries Act Regulation Pulp and Paper Mill Effluents	RP	1	AHP, DEL, RMK
Federal	Fisheries Act Regulation Municipal Wastewater Effluents	RP	1	AHP, DEL
Federal	Canada Water Act	LS	3	DEL, RRC, RMK
Federal	Canada Drinking Water Quality Guidelines	GS	1	PSW, DEL
Federal	Great Lakes Water Quality Agreement	TA	14	DEL, AHP, PSW, RRC, RMK, WTS
Federal	2020 Biodiversity Goals and Targets for Canada	PGR	3	AHP, DEL
Federal	Navigation Protection Act	LS	1	NAV
BC	Water Sustainability Act	LS	4	DEL, AHP, RRC, WTS
BC	Water Sustainability Act Groundwater Protection Regulation	RP	1	DEL, WTS
BC	Water Sustainability Act Water Sustainability Regulation	RP	2	RRC, AHP
Alberta	Water for Life Strategy	PGR	3	AHP, DEL, PSW, WTS, RMK
Ontario	Water Resources Act	LS	2	DEL
Ontario	Provincial Water Quality Objectives, 1994	GS	8	DEL, AHP, WTS
Ontario	Environmental Protection Act	LS	2	DEL, RRC, AHP
Ontario	Lake Simcoe Protection Plan Act	LS	1	AHP, DEL, WTS
Ontario	Water Resources Act Water Taking and Transfer Regulation	RP	1	WTS, AHP
Ontario	Clean Water Act	LS	1	PSW
Nova Scotia	Water for Life Strategy	PGR	5	WTS, DEL, RRC, AHP, RMK
Provincial	Prairie Provinces Water Board Master Agreement on Apportionment	TA	1	DEL[3]

[3] While the PPWB has a focus on water quantity, the provision included in the database pertained to DEL objectives.

3. Threats to Fresh Water

Identification and classification of threats is the first step in a potential process to rank or compare threats so that priorities can be established or policy developed to address gaps.

A water threat classification system was developed based on the International Union for Conservation of Nature's (IUCN's) approach to threat classification for species at risk.[4] The Canadian Committee on the Status of Endangered Wildlife in Canada (COSEWIC) has adopted the IUCN threat classification system as an aid to determining species' risk assessments.[5]

Similar to the goals of the IUCN[6] for species at risk of extinction, an agreed set of water threats might be used to develop a system that can be applied consistently by different institutions, to different waterbodies, to assess the condition of water resources or habitat. The IUCN has a "threats calculator" for species at risk that considers other threat dimensions, including impact, scope, severity and timing. To that end, if a threats classification system is pursued, subsequent steps would include development of criteria to assess the condition and priorities of waterbodies /aquifers.

As with the IUCN threat classification system, the proposed freshwater threat classification system is hierarchical. Four broad classes (Level 1) of threats (Section 3.1) have 13 more specific threat categories (Level 2) (Section 3.2), which in turn include more specific threats (Level 3) (Section 3.3). A fourth level could be added to some of the threats. For example, threat 7.1 (Domestic, commercial, institutional surface wastewater effluents) could be further defined in terms of the individual contaminants in the wastewater effluents from various upstream sources.

3.1 A Canadian Freshwater Threat Classification

A possible system for classifying threats to freshwater resources considers anthropogenic activities or conditions that pose potential risks to freshwaters and the nature of impacts to freshwater attributes that become (or may become) altered in response to threat exposure.[7] For the purposes of this discussion, we consider four broad classes of attributes: potential impacts on freshwater resource *quantity*, *quality* and *habitat* as well as *pervasive* or *cross-cutting* conditions that may affect freshwater resource quantity, quality and habitat. In the proposed

[4] IUCN. (n.d.). *Threats Classification Scheme (Version 3.2)*. Retrieved from http://www.iucnredlist.org/technical-documents/classification-schemes/threats-classification-scheme
[5] See COSEWIC (2015). *Instructions for the Preparation of COSEWIC Status Reports*. Retrieved from http://www.cosewic.gc.ca/default.asp?lang=En&n=09142408-1
[6] See IUCN. (2001). *2001 Categories and Criteria*. Retrieved from http://www.iucnredlist.org/static/categories_criteria_3_1
[7] In environmental impact assessment terminology, such attributes are referred to as *valued ecosystem components* (VECs) and in risk assessment, they are called *assessment endpoints*.

system, threats are associated with a particular attribute (i.e., quantity, quality or habitat) based on the human activity or other condition expected to create the principle direct effect. Note that a particular threat may also affect other water attributes. For example, water withdrawals for irrigation from streams directly affects water quantity, but may also indirectly affect water quality (e.g., increased contaminant concentrations due to reduced volumes) as well as habitat quality.

The classes of threats to fresh water are:

A. **Quantity—Threats 1 to 6:** These threats include changes to hydrology, geomorphology, groundwater recharge and altered water distribution or storage patterns. Specific threats include: land uses that alter precipitation runoff volumes; water withdrawals (including use with return flows and consumptive use); constructed water reservoirs and dams; transfer of water from ground to surface (e.g., potable systems with groundwater sources that discharge wastewater effluents to surface waters; French drains; some agricultural drains).

B. **Quality—Threats 7 and 8:** These threats include contaminant releases from identifiable sources (e.g., industrial effluents) and from diffuse, non-point sources (such as contaminants in road runoff). Note that the threats do not necessarily identify the true source of contaminants; for example, consumer product residues are a source of pollution found in domestic wastewater effluents whereas wastewater treatment plants are not the true source.

C. **Habitat—Threats 9 to 11:** These threats include habitat loss (e.g., wetland loss), thermal regime changes and aquatic community changes. The aquatic community changes are intended to be those which, in turn, affect water quality or quantity. For example, the invasive zebra mussel alters water column light penetration, with consequences for water quality and eutrophication.

D. **Pervasive/Cross-cutting—Threats 12 and 13**: These threats include climate change, which poses a wide ranging of threats and alterations to the water cycle. Threats in the Natural Conditions group pertain to conditions that are not directly attributable to anthropogenic activities but that may pose threats to human use of aquatic resources or use by other species.

3.2 Threats to Freshwater Resources and Aquatic Habitat: Summary level

The 13 threats to fresh water, within the four classes, are:

A. Quantity
1. Residential and commercial land use/development
2. Agricultural land use/development
3. Transportation and service corridors
4. Natural resource extraction
5. Water resource withdrawals

6. Other altered water distribution, flow or storage

B. Quality

7. Contaminants, source-specific releases
8. Contaminants, diffuse releases

C. Habitat

9. Aquatic habitat alteration
10. Thermal pollution
11. Alteration of biotic communities

D. Pervasive/Cross-cutting

12. Climate change and altered water cycle
13. Natural conditions

3.3 Threats to Fresh Water: List

The following list provides a third level of specificity to the proposed classification.

A. Quantity

1. Residential and commercial land use/development—*hydrology/geomorphology/groundwater recharge*
    - 1.1. Urban areas
    - 1.2. Commercial and industrial areas
    - 1.3. Tourism and recreation areas
2. Agricultural land use/development—*hydrology/geomorphology/groundwater recharge*
    - 2.1. Annual and perennial non-timber crops
    - 2.2. Livestock farming and ranching
    - 2.3. Wood and pulp plantations
3. Transportation and service corridors—*hydrology/geomorphology/groundwater recharge*
    - 3.1. Roads, paved
    - 3.2. Roads, unpaved including forestry and other resource extraction access
    - 3.3. Utility and service lines
    - 3.4. Shipping lane construction and maintenance (e.g., dredging, hardened corridors, locks)
    - 3.5. Airports and railroads
4. Natural resource extraction—*hydrology/geomorphology/groundwater recharge*
    - 4.1. Oil, gas, oil sands, including tailings water storage
    - 4.2. Natural gas fracking
    - 4.3. Minerals and metals mining and quarrying, including tailings water storage
    - 4.4. Forestry
5. Water resource withdrawals—*quantity*
    - 5.1. Surface water extraction with return flow
    - 5.1. Surface water extraction for consumptive use (i.e., not returned to source waterbody)
    - 5.3. Groundwater extraction with return flow
    - 5.4. Groundwater extraction for consumptive use (i.e., not returned to source aquifer)

6. Other altered water distribution, flow or storage
    - 6.1. Hydroelectric storage and generation
    - 6.2. Other anthropogenic storage, dams
    - 6.3. Urban stormwater facilities
    - 6.4. Anthropogenic transfer of groundwater to surface
    - 6.5. Anthropogenic interconnection of watersheds not naturally connected
    - 6.6. Alternative energy generation (e.g., wave action, wind turbines in water)
    - 6.7. Anthropogenic watercourse alteration (e.g., channelization)
    - 6.8. Loss of floodplain connectivity to watercourse

B. Quality

7. Contaminants, source-specific releases
    - 7.1. Domestic, commercial, institutional surface wastewater effluents
    - 7.2. Domestic, commercial, institutional septic systems
    - 7.3. Industrial effluents
    - 7.4. Agricultural effluents (e.g., animal wastes, milkhouse wash water)
    - 7.5. Underground storage facilities (e.g., fuel tanks)
    - 7.6. Surface storage facilities (e.g., road salt storage, scrap metal yards)
    - 7.7. Garbage and solid waste landfills
    - 7.8. Resource extraction surface water pollution (e.g., oil, gas, mining, quarries)
    - 7.9. Resource extraction groundwater pollution (e.g., fracking, underground mining)
    - 7.10. Transportation spills—motor vehicles and rail
    - 7.11. Transportation spills—pipelines
    - 7.12. Other pollution releases due to accidents (e.g., industrial accidents)
    - 7.13. Freshwater aquaculture
8. Contaminants, diffuse releases
    - 8.1. Road use and maintenance—paved (e.g., salts, car deposits)
    - 8.2. Road use and maintenance—unpaved
    - 8.3. Urban land uses and operations (e.g., cosmetic pesticides, fire-fighting foams)
    - 8.4. Agricultural land uses and operations (e.g., fertilizers, pesticides)
    - 8.5. Other diffuse sources (e.g., land-applied municipal biosolids, buried infrastructure)
    - 8.6. Airborne pollutants
    - 8.7. Historic deposits of pollutants to surface water bodies
    - 8.8. Historic deposits of pollutants to groundwater
    - 8.9. Erosion from anthropogenic activities (e.g., boating, beach area weeding)
    - 8.10. Commercial activities (e.g., pollution from shipping, fishing)
    - 8.11. Recreational activities (e.g., pollution from boating, swimming)

C. Habitat

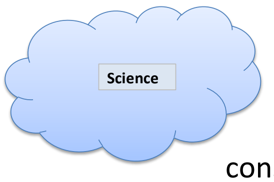
9. Aquatic habitat alteration
    - 9.1. Wetland loss
    - 9.2. Riparian area loss
    - 9.3. Barriers to migration or movement (e.g., perched culverts, weirs, dikes)
    - 9.4. Alteration of nutrient or energy flows
    - 9.5. Sediment regime change, including stream bank stability
    - 9.5. Other habitat alteration or loss (e.g., concrete lining)

10. Thermal pollution
    10.1. Urban heat island and other urban heat sources
    10.2. Industrial and energy generation cooling system discharge
11. Alteration of biotic communities
    11.1. Invasive and non-native species (plants, animals)
    11.2. Freshwater aquaculture
    11.3. Fisheries resource extraction (fishing, molluscs, other)

D. Pervasive/Cross-cutting

12. Climate change and altered water cycle
    12.1. Drought
    12.2. Precipitation pattern change (intensity, duration, frequency)
    12.3. Evapotranspiration change
    12.4. Soil moisture change
    12.5. Temperature extremes (air, water)
    12.6. Habitat and biotic community shifting and alteration
    12.7. Loss of hydrologic stationarity (i.e., ability to forecast water conditions)
    12.8. Shifting seasonal water phase change (e.g., spring freshet, winter freeze, lake ice extent and phenology)
    12.9. Other climate impacts
13. Natural conditions
    13.1. Environmental stochasticity
    13.2. Slope failures, avalanches or landslides
    13.3. Natural background contaminants (e.g., arsenic, uranium)

4. Linkages to Science



Management instruments to mitigate or compensate for threats to water resources are typically undertaken in a cycle that reflects available information. Management instruments that have been deployed must be assessed with respect to meeting their objectives and other considerations (enforceability, cost, etc.). Adjustments are made and the cycle begins again. A management instrument's objectives, clauses or policy statements may identify, either explicitly or implicitly, scientific knowledge and gaps.

There are three points at which scientific inquiry enters the freshwater management model (Figure 1):

(1) What are the threats to surface and groundwater? To what extent are these threats understood and to what extent can they be characterized (e.g., in terms of magnitude, scope, severity and cumulative effects)? Scientific information is needed about the potential effects of the threat(s) across spatial and temporal scales of interest (i.e., local to continental basin and immediate/acute to long-term/chronic).
(2) For the management outcomes of interest (e.g., water quality, water quantity, habitat), what options exist to mitigate threats, what is the predicted effect of different threat mitigation options and how can outcomes be estimated? What mechanisms, including compensation, are potentially effective for mitigating impacts? An understanding of pathways, fate, effects and other aspects of the threat for the desired outcomes are typically needed to assess management options. (Note that identifying the management outcomes of interest may be informed by science but these are normative decisions.)
(3) To what extent have deployed management instruments been effective in mitigating or compensating for threats? Given the management instruments deployed, are the effects of implementation discernable? Why or why not?

Scientific gaps take many forms within each of these entry points, including:

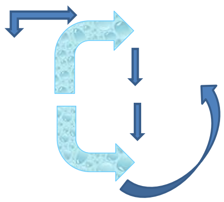
- *Unidentified and poorly characterized threats at one or more spatial/temporal scales.* Science must be continuously applied with the expectation that there will be newly identified threats, such as threats that develop from interactions in the environment. For example, acid rain was an unanticipated consequence of air pollution, bioaccumulation in fish tissue an unanticipated consequence of mercury pollution and malnutrition in fish a consequence of micro-plastic beads in consumer products. Also, threats may be understood at a specific scale but gaps exist at other scales. For example, nanosilver may have been studied at a laboratory scale for short time periods but not in the field at larger watershed/aquifer or basin scales or over time periods of years or decades. Inadequate threat characterization is a scientific gap that impedes comprehensive assessment of threat priorities.

- *Selection of sources, pathways and effects to be mitigated/compensated*. The sources and pathways of threats may not be fully characterized. For example, if prevention of eutrophication of a lake system is a management objective, how much phosphorus can be added annually, and what is the acceptable loading from various sources, taking into consideration re-suspension/re-dissolution of phosphorus from sediments as concentrations decrease in the water column? The causal relationships between a threat and achievement of a desired management outcome also may not be fully understood. For example, aquatic biodiversity decline in urbanizing watersheds has been associated with changes in flow, temperature, contaminants, sediment regime change, food sources and other factors. If protection of aquatic biodiversity in urbanizing watersheds is an objective, selecting the appropriate mitigation measure(s) then depends on the extent to which the observed changes in aquatic biodiversity are causally attributable to each of these factors. Gaps in the scientific evidence for sources, pathways and causal linkages between threats and desired outcomes preclude development of appropriate mitigation instruments.

- *Effects of threat mitigation/compensation*. Evaluating the success of mitigation or compensation may be hampered by scale-related scientific gaps (e.g., results over the long term and/or larger spatial areas). For example, as plastic microbeads are eliminated from consumer products, when will the benefits be detectable considering historic deposition? Are further measures needed to mitigate the effects of legacy contamination or other sources? In the case of compensation, scientific assessment may be hampered by the deployment of compensation activities in a different location than the target effect. Also, positive or negative outcomes may be achieved which were not originally intended, confounding assessments of the effectiveness of management instruments. Gaps in the science needed to assess the effects of management instruments to achieve desired outcomes preclude informed feedback to the management cycle.

In addition to scientific gaps, the issue of scientific uncertainty contributes to scientific research needs. Scientific uncertainty with respect to water issues can be expected to become increasingly important as climate change continues to manifest through the water cycle and aquatic ecosystems. Also, issues of sufficient data at appropriate scales to assess trends in threats contribute to scientific unknowns and uncertainties.

5. Proposed Methodology



This section outlines the proposed methodology and the results of an initial analysis on a sample of water instruments.

5.1 Management Instrument Gaps

The proposed methodology is intended to assess the extent to which existing and potential future threats to Canada's fresh waters are addressed by the existing suite of management instruments. The method involves four steps:

(1) Develop an inventory of relevant existing management instruments.
(2) For each instrument (i.e., laws, regulations, policy statements, trade agreements and guidelines), examination of specific provisions identifies the set of objectives to which the provision applies, or could potentially apply.
(3) For each instrument, assuming it is (or will be) fully implemented, determine the extent to which the instrument could mitigate or compensate for specific threats based on the set of associated objectives. The result is a matrix of instrument provisions (rows) and threats (columns); a value of "1" indicates that the instrument has at least some potential to address the threat in question, whereas as "0" indicates that it does not.
(4) Identify gaps and trends in threats addressed by management instruments. For instance, the matrix may identify threats for which there are few existing management instruments with the potential to address them. In a similar fashion, one can identify potentially well-addressed threats, i.e., threats that are, at least notionally, addressed by a comparatively large set of instruments.

Expanding on this methodology, future analyses could further include other attributes and data that may be important in evaluating the adequacy of the existing policy regime. For example:

- Additional variables regarding the water instruments, such as the age of the instrument. These data would allow assessment of older versus newer approaches, or the extent to which the current suite of instruments lag behind scientific information on emerging threats.
- Assessment of specific threats at a finer level of detail (see Section 3.3).
- Comparison of the scope and coverage of management instruments that do not have force of law (e.g., aspirational policy statements and strategies) with those instruments that have statutory jurisdictional authority/responsibility with enforceable consequences.
- Comparison of the scope and coverage of management instruments by jurisdiction or watershed/aquifer.

This methodology to identify management instrument gaps does not directly address the question of scientific gaps or research needs.

5.2 Scientific Research Needs

The question of whether there are clear approaches to align water science and water policy is broad but can be conceptualized in terms of the three entry points for science (Figure 1), as described in Section 4. With respect to identification of relevant scientific gaps and development of priorities for research needs, three general lines of inquiry can be pursued: 1) examining the science of the threats; 2) examining the scientific basis for management instruments implemented or planned; 3) examining the outcomes expected or achieved by management instruments intended to address a threat.

Examining the science of the threats

- Where a gap has been identified (i.e., a threat is not addressed by a management instrument), assess the degree to which the gap is attributable to a lack of substantive scientific evidence. It is possible the threat has not been addressed due to priorities, costs or other factors other than a lack of compelling scientific evidence.
- Are there trends in threats (e.g., magnitude, scope, severity, pervasiveness) that indicate a need for further study (e.g., worsening effects, unintended consequences, changing baseline conditions)?
- In some cases, scientific gaps are identified within a management instrument itself, recognizing that better understanding of the threat is needed (i.e., those provisions with research, monitoring, knowledge-sharing or methods development [RMK] objectives).

Examining the scientific basis for management instruments

- Whether is it a new instrument, or a review of an existing instrument, the scientific basis for potential instrument(s) to mitigate the threat needs to be clear. Clarity is necessary to assess the success of the instrument to mitigate the threat, to make adjustments as needed to the approach if results are not achieved or if other threats are exacerbated.

Examining the outcomes

- Where a management instrument has been implemented, assess the degree to which desired outcomes have been achieved. If they have not been achieved, assess the degree to which the result is attributable to scientific needs (versus implementation effort or other factors). In cases where scientific gaps contributed to a failure to achieve desired outcomes, there may be a need for better understanding of the causal mechanisms to achieve desired outcomes. There may also be a need for information to design the instrument (assumed pathways, assumed scale of effect of the instrument, etc.), or better understanding of the threat itself or conditions that have changed since the instrument was deployed (such as changes in climate, biodiversity shifts, recent sources of pollution or stress etc.).

Prioritization of the scientific needs resulting from this exercise is not addressed by this proposed approach. Prioritization considerations include institutional capacity to undertake science and the mandate and interests of institutions with capacity to undertake scientific studies.

It is beyond the scope of our current purposes for the workshop to consider: desired environmental outcomes; the effectiveness of specific instruments; or, the implementation and enforcement efforts supporting various instruments. However, this discussion provides a framework for consideration of science research needs and seeds discussion of criteria to prioritize scientific research to inform management of threats to fresh waters.

5.3 Results of Sample Analyses

Here we demonstrate a potential approach to assessing the adequacy of Canadian management instruments to protect freshwater resources and habitat. In this analysis, threats were assessed primarily by Class (A, B, C, D), although one analysis considers the 13 threat categories.

An overview of the types of management instruments in the sample indicates threats in all classes were addressed to some extent (Table 5.1).

Table 5.1 Types of Management Instruments and Frequency of Threats Addressed

Instrument Type	Instrument provisions in the database (Number)	Frequency of threats addressed by threat class				Total frequency of threats addressed by type
		A Quantity	B Quality	C Habitat	D Pervasive	
1. Laws/Statutes (LS)	24	9[8]	33	23	2	**67**
2. Regulations and permits (RP)	7	1	5	9	0	**15**
3. Policy, goals, research (PGR)	31	36	44	34	1	**115**
4. Treaties and agreements (TA)	16	42	27	20	4	**93**
5. Guidelines and standards (GS)	2	0	3	1	0	**4**
Totals	**80**	**88**	**112**	**87**	**7**	**294**
Normalized for comparison[9]		**14.7**	**56.0**	**29.0**	**3.5**	

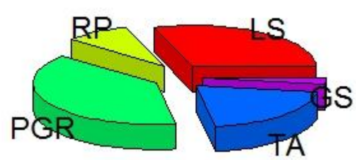


***Figure 5.1 At a glance*: Instrument types in the database—there were a total of 80 management instruments in the sample database**

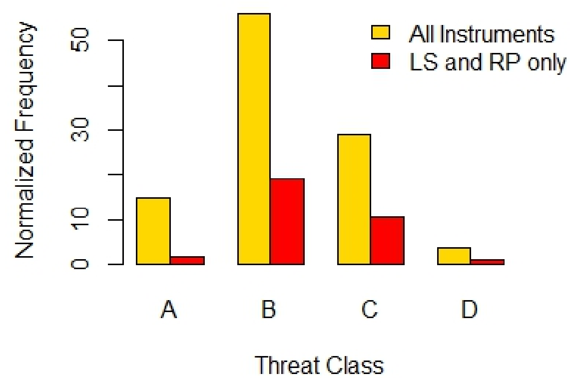


***Figure 5.2. At a glance*: Normalized number of threats (by Threat Class) addressed by all instrument types (yellow) and by only types LS and RP (red)**

[8] Within the 24 laws/statutes, Quantity threats were addressed nine times. There are six groups of threats for Quantity, so across the 24 provisions, the total potential frequency to address Quantity was 144 times (i.e., 6 x 24). The last row (Normalized for Comparison) makes adjustment for the differing numbers of threat categories in the four Classes.

[9] There are six groups of threats for Quantity; 2 for Quality; 3 for Habitat; and, 2 for Pervasive. The normalized figures are calculated by dividing the total number of threats for each Class by the number of threats in that class.

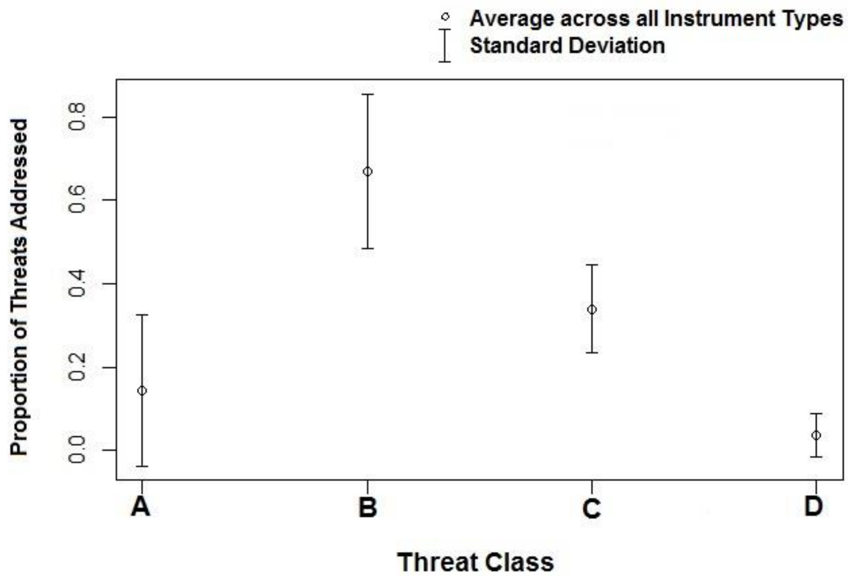


***Figure 5.3. Proportion of Threats Addressed by Threat Class*: The average proportion of threat categories addressed across all instrument types by Threat Class. (If all threat categories were addressed by all provisions, the proportion would be 1.)**

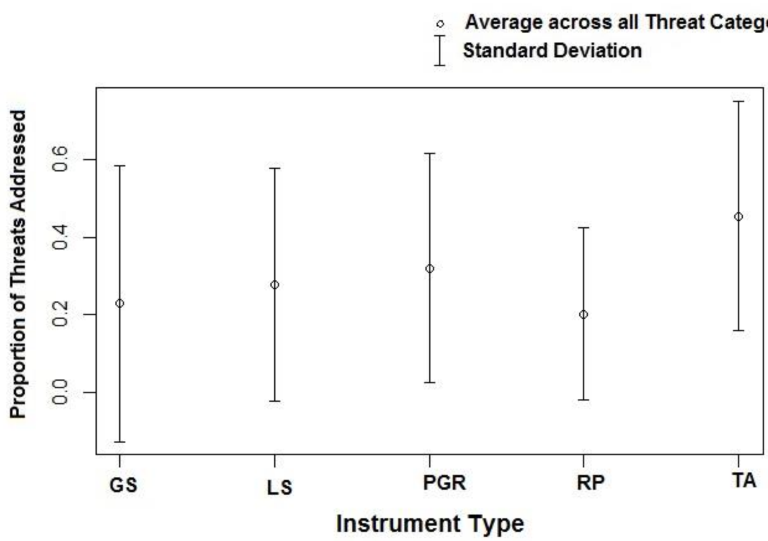


***Figure 5.4. Proportion of Threats Addressed by Instrument Type*: The average proportion of threat categories addressed by Instrument Type.**

***Observations on the sample database*:**

- Relative to other threats, those for water quality were addressed, in some manner, more frequently by the sample instruments than other threat classes; habitat threats were addressed more frequently than quantity (see the plot *Proportion of Threats Addressed by Threat Class)*. However, it might be predicted that the early focus on water quality by Canada would be reflected in the current mix of threats managed through instruments. Since the database has more federal instruments than provincial ones, and quantity may be considered a provincial responsibility, no definitive conclusions can be drawn from this sample.
- Regulations tended to be very focused instruments (i.e., 15 threats addressed by seven instruments) whereas agreements tended to range most broadly (i.e., 93 threats addressed by 16 instruments). Policies, goals and research instruments tended to address

more threats than laws/statutes. (See the plot *Proportion of Threats Addressed by Instrument Type).*

- These high-level numbers indicate a *potential* issue with the assumption that instruments are fully implemented as intended. Preambles in laws, policy statements and negotiated trade agreements may state intentions to address threats, but the degree to which the threat is actually addressed through enforceable measures may be very different.

An overview of the objectives within the sample database (Table 5.2) indicates that at least some instruments have more than one objective (80 provisions had a total of 135 objectives). The table presents three numbers that capture the same information different ways: (1) number of threats addressed (2) normalized number of threats;[10] (3) proportion (as percent) of threats in the class addressed by the provisions.[11]

Table 5.2 Objectives of management instruments and threats addressed

		Number (Normalized) [Percent] threats addressed, by objective, for Class:			
Objective	**Number of provisions with this objective**	**A Quantity**	**B Quality**	**C Habitat**	**D Pervasive**
Deleterious Substances (DEL)	**51**	46 (7.7) [15][12]	93 (46.5) [91]	45 (15.0) [29]	1 (0.5) [1]
Aquatic Habitat Protection (AHP)	**36**	58 (9.7) [27]	50 (25.0) [69]	61 (20.3) [56]	2 (1.0) [3]
Withdrawals or transfers (WTS)	**13**	42 (7.0) [54]	15 (7.5) [58]	19 (6.3) [49]	1 (0.5) [4]
Remediation, rehabilitation, compensation (RRC)	**9**	8 (1.3) [15]	9 (4.5) [50]	20 (6.7) 74]	1(0.5) [6]
Research, monitoring, knowledge-sharing (RMK)	**20**	12 (2.0) [10]	25 (12.5) [63]	18 (6.0) [30]	4 (2.0) [10]
Potable Source Water Protection (PSW)	**4**	6 (1.0) [25]	5 (2.5) [100]	3 (1.0) [25]	0 (0) [0]
Navigation (NAV)	**1**	0 (0) [0]	0 (0) [0]	0 (0) [0]	0 (0) [0]
Climate change effects mitigation/ adaptation (CCE)	**1**	0 (0) [0]	0 (0) [0]	0 (0) [0]	1 (0.5) [50]
Total	**135**				

[10] There are six groups of threats for Quantity; two for Quality; three for Habitat; and two for Pervasive. The normalized figures are calculated by dividing the total number of threats for each Class by the number of threats in that class.

[11] Calculated as the number of threats addressed divided by the number of potential threats, (which was the product of the threats in the Class and the number of instruments with the objective) times 100.

[12]For example, of the 51 provisions with an objective to address deleterious substances (DEL), water quantity threats were addressed 46 times, which is equivalent to 7.7 times when normalized for six Quantity threat categories and accounts for 15 per cent of the total potential number of times Quantity could have been addressed by the 51 provisions.

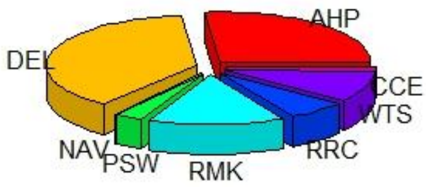


Figure 5.5. At a glance: **Objectives in the database— most instruments had more than one objective (see Table 2.1)**

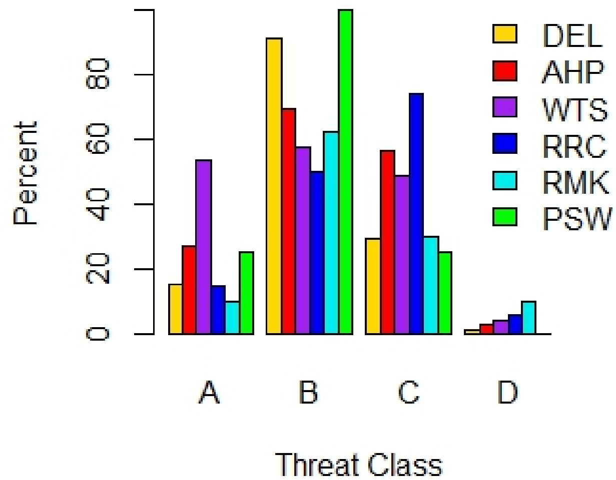


Figure 5.6. At a glance: **Percent of threats (by Threat Class) addressed by instruments with objectives (excluding NAV and CCE)**

***Observations on the sample database*:**

Instruments with an objective for:

- Potable source water protection (PSW) addressed 100 per cent of the potential threats to water quality, meaning each of the four provisions in the database addressed both point and non-point sources of pollution.
- Managing deleterious substances (DEL) addressed 91 per cent of the potential threats to water quality, meaning some instruments must not have addressed both point and non-point source pollutants (which would be appropriate in some cases, such as effluent control regulations designed to manage a specific point source).
- Withdrawals or transfers (WTS) collectively addressed around 50 per cent of the threats to quantity, quality and habitat, indicating that instruments with this objective may address quantity as part of a suite of threats. However, no definitive trends can be inferred regarding from this summary statistic (that is, some instruments may address multiple threat classes and others only water quantity).
- Aquatic habitat protection (AHP) addressed a higher percentage of threats to water quality (69 per cent) than threats to habitat (56 per cent), with less coverage for water quantity threats (27 per cent). This result may indicate that instruments with an objective for water quality tended to also have an objective for habitat protection but that some aspects of threats to aquatic habitat were not included. For instance, controls on deleterious substances (quality) intended to protect habitat may not make mention of possible changes to aquatic communities or thermal regimes.
- Remediation, rehabilitation, compensation (RRC) addressed 74 per cent of threats to habitat, as well as 50 per cent of the threats to water quality; water quantity threats were

generally not addressed by instruments in the sample with RRC objectives (15 per cent of threats).

- Research, monitoring, knowledge-sharing (RMK) addressed 63 per cent of threats to water quality but 10 per cent of threats to water quantity and 30 per cent of threats to habitat. This result is discussed in Section 5.4, Scientific Research Agenda.
- Navigation (NAV) addressed none of the threats. The single navigation instrument in the database was the federal Navigation Protection Act, which identifies navigable waters. The use of watercourses for navigation is a potential source of threats. For instance, Threat 3.4 (quantity changes from shipping lane construction and maintenance) and Threat 8.10. (quality changes from contaminant releases from commercial activities) arise from shipping activities. The provision to identify navigable waters does not mitigate any of the threats.
- Climate change effects of mitigation/adaptation (CCE) were not well represented in the sample database. The 50 per cent coverage of threats in Class D highlights a limitation of summary statistics and possibly the class: the instrument with a CCE objective addressed Threat 12 (Climate change and altered water cycle) but did not, and would not necessarily be expected to, address Threat 13 (Natural Conditions). Thus the coverage of these threats is low in the sample database.

If this sample were representative of Canadian management instruments, this overview would indicate the potential for gaps in coverage of certain threats. For instance, the highest percentage of threats (54 per cent) to water quantity are addressed by instrument with the objective WTS (water transfer and storage). Unsurprisingly, this coverage occurs for instruments with an objective to manage water quantity; however, the result also indicates instruments with a specific objective to address threats to quantity do not address all threats in that class. Note that remaining Class A threats may be addressed by other instruments; conclusions on gaps cannot be drawn from this high-level look.

A more in-depth summary of the types of management instruments indicates that not all listed threats were addressed by each instrument type in the sample database (Table 5.3).

Table 5.3 Number of management instruments addressing threats by type

Type of Management Instrument	Threat (Number of times addressed in the database)												
	Class A Quantity						Class B Quality		Class C Habitat			Class D Pervasive	
	1	2	3	4	5	6	7	8	9	10	11	12	13
1. Laws/Statutes (LS)	1	1	1	1	4	1	18	15	8	7	8	2	0
2. Regulations and permits (RP)	0	0	0	0	1	0	4	1	2	2	5	0	0
3. Policy, goals, research (PGR)	6	6	6	6	5	8	22	22	18	7	9	1	0
4. Treaties and agreements (TA)	7	7	7	7	7	7	13	14	7	6	7	2	2
5. Guidelines and standards (GS)	0	0	0	0	0	0	2	1	1	0	0	0	0
Number of instruments addressing the threat (80 Instruments)	14	14	14	13	20	13	59	53	36	22	29	5	2
Total by Class	88						112		87			7	

***Observations on the sample database*:**

- Of the six threats to water quantity, Threat 5 (Water resource withdrawals) was most frequently addressed (20 times versus about 14 for others in Class A) and the only threat in Class A to be identified in a regulation within the sample database.
- Of the two threats to water quality, point sources (Threat 7) and non-point sources (Threat 8) were both addressed at about the same frequency although point sources were addressed more frequently by regulations.
- Of the three threats in Class C, aquatic habitat alteration (Threat 9) was addressed more frequently than thermal pollution (Threat 10) or aquatic community alteration (Threat 11), although Threat 11 was identified more often in regulations within the sample database.
- Given the methodology, the effectiveness and degree of implementation of the provisions were not assessed.

5.4 Water Research Agenda

Figure 1 and Section 4 identified three broad application points for science in the management of threats to fresh waters (threats, instrument design and instrument evaluation). Section 5.2 identified three corresponding aspects of inquiry to identify science research needs: (1) examining the science of the threats; (2) examining the scientific basis for management instruments implemented or planned; (3) examining the outcomes expected or achieved by management instruments intended to address a threat. In the interests of prompting discussion to develop a water research agenda, these three aspects are discussed further, although not in the order presented.

The proposed methodology is not applicable to (3) (examining the outcomes) since the management instrument database pertains specifically to management instruments as designed or intended, not to actual outcomes achieved. (Objectives codified in the database indicate stated, not actual, outcomes of interest). However, the database could serve as an inventory of instruments and associated water management objectives. Understanding the outcomes or results of the interventions would need additional research efforts not informed by the proposed methodology. In some cases, a suite of instruments would need to be assessed since provisions in one instrument may reinforce or counteract provisions in another (e.g., a policy to encourage vegetation riparian buffers may not achieve stated objectives in regions providing financial incentives to farmers to maximize the area of land under cultivation).

- ➢ A water research agenda could be built around determining the quality of scientific information available to assess outcomes identified in management instruments and follow-up assessments of the actual outcomes achieved relative to the stated objectives.

The proposed methodology could be applied to (2) (examining the management instruments) with additional effort toward database development to expand information on the management instruments. Analysts would need to identify the causal relationship(s) between the management instrument and the outcome of interest (e.g., threat mitigated), then assess whether the instrument has the potential to achieve the outcomes, by answering the questions: (a) Is the assumed causal relationship documented (i.e., is it “scientifically valid per current understanding”?); and, (b) does the instrument mitigate or compensate for the causal factor(s) of the threat? Based on the small sample of instruments reviewed for the database, the assumed causal relationships would often need to be inferred because the sample instruments rarely explicitly stated the underlying causal relationship(s) targeted by each instrument.

- ➢ A water research agenda could be built around assessing the strength of the implicit or explicit relationships embedded within management interventions to address stated threats. Where threats are not sufficiently addressed, the information would feed into the research agenda for (1) examining the threats. Where causal relationships are not valid, or are not identified, research could be undertaken to inform revisions to instrument design to modify assumed pathways, effects, sources etc.

The proposed methodology applies most directly to (1) (examining the threats). It is principally designed to identify gaps in threats addressed by management interventions, although the tool does have some limitations that are worth considering before undertaking full development:

- The depth of inventory desired in the database would need to be assessed against the level of effort to build the database. The necessary effort increases considerably if coding is done to the level of list, versus threat category or threat class.
- If threats are coded to the level of the list (See Section 3.3), more specificity could be developed to identify gaps in addressing individual threats, but some ambiguity would also be introduced where instruments are not elaborated to a sufficient level. For instance, broad policy statements, such as those found in the Great Lakes Water Quality Agreement, cannot be coded reliably to a level other than class. In the sample database, it was assumed that all threats to quantity (six threats), quality (two threats) and habitat

(three threats) were addressed where information was only available to the level of class. This assumption presents the potential to underestimate gaps in threats addressed.

- Similarly, if a database is developed with the assumption that instruments are fully implemented (i.e., the assessment in (2) above is not undertaken), there is the potential that gaps in threats will be missed because the stated objectives are assumed to address the threat.
- If additional threats are identified, the analyses would need adjustment, especially if the analysis is carried out at the list level of detail.

Despite these limitations, there are opportunities to develop a water research agenda based on an analysis of gaps in threat categories. (If analyses were undertaken at this level, instruments with only the class level of detail could either be excluded from the database or the assumption made that all threats are addressed.)

- ➢ A science research agenda could be built around investigation of threats that have not been addressed, or that are not addressed by a comprehensive suite of instruments.
- ➢ A water research agenda could be built around stated science needs within instruments. Examining instruments with an RMK objective, it is clear that many scientific research needs were identified at the time of instrument design.

5.4.1 Sample Scientific Questions

1. With respect to stated science needs within the instruments with RMK objectives in the sample database, several themes emerged:

a. There is a need for examination of multiple simultaneous pollutants, for example:

- What are the causal factors underlying lingering effects of pulp and paper effluents on aquatic biota?
- What are the cumulative and long-term effects of multiple pollutants (e.g., CEPA toxics, endocrine disruptors, watersheds with industry and municipal wastewater effluents) on habitat?
- What is the appropriate spatial scale to assess effects on habitat of multiple pollutants (watercourse/aquifer, watershed, basin)? Linkages with estuaries and ocean health could also be made, although these were outside the scope of our purposes for the workshop.

b. For substances being considered for listing as CEPA toxics, there are questions of pathway, effect, etc., for example:

- What are the appropriate scales to assess effects (temporal and spatial)?
- How reliable have extrapolations from laboratory studies to landscape-scale releases been for substances assessed in the past?

c. Instruments with RMK objectives in the sample had less focus on quantity and habitat, but scientific questions were still discernable:

- What flow is required to maintain aquatic habitat health and how much water can be extracted from surface and aquifer sources before a threshold is reached? This question becomes complicated considering flow and thermal effects of climate change on habitat.

- When withdrawals affect stakeholder(s), what are the conditions under which compensation in a different watercourse/aquifer is acceptable to protect aquatic outcomes of interest?
- Under what conditions is compensation for lost habitat in another location acceptable?

2. With respect to potential gaps in threats addressed, if the sample database is indicative of trends in a representative sample, potential questions include:

   a. Are landscape-scale threats to water quantity sufficiently addressed? If not, what are some specific gaps?

   b. Are climate mitigation/adaptation threats sufficiently addressed? If not, what are some specific gaps?

5.4.2 Prioritization of Research

Two lines of inquiry could be used to prioritize research. First, a system similar to the one used by the IUCN and COSEWIC to identify the status of species at risk could be developed to assess the condition of waterbodies/aquifers. Building on the IUCN concept for a “threats calculator,” other threat dimensions (e.g., impact, scope, severity and timing) could be identified and a systematic approach to assessing risks associated with threats developed. One option would be to undertake an assessment spatially (e.g., by continental water basin or on a finer-scale watershed basis) to identify the most significant threats (per current science) by basin/watershed; trends in pan-Canadian issues could then be assessed. It would be important to consider both potential acute and chronic impacts on resources/habitat as well as anticipated climate change-induced trends. The European Union’s approach to identifying ecological status may also be informative in terms of scale(s) of waterbody and variables included. Inevitably, threats and/or waterbodies for which there is little or insufficient information on which to make an assessment would be identified. These data gaps could feed into a water research agenda. Management instrument gaps in addressing priority threats could be assessed for/by relevant jurisdictions with responsibilities for the basin/watershed.

A second line of inquiry pertains to taking the stated water management priorities by jurisdictions at face value and examining gaps in management instrument design and implementation to address those priorities. Scientific research needs already identified within existing management instruments would also be included in an inventory of potential research priorities. Identified gaps may reveal any or all of the scientific research needs discussed above (i.e., through examining the threats; examining the existing management instruments; examining the outcomes).

Looking at the results of the two lines of inquiry, research priorities could readily be defined where the threats assessment and stated priorities align and there are management instrument gaps or recognized scientific needs. For example, if climate-induced drought (Threat 12.1) is a stated jurisdictional priority and is a prevailing threat in a given basin/watershed, but there are no management instruments to maintain water quantities to protect aquatic biodiversity, scientific research into minimum water flows to maintain viable aquatic life may become a priority for the jurisdiction. For individual jurisdictions with water management responsibilities, the prioritization may tilt toward resolving gaps in stated priorities. For other researchers, the prioritization may be influenced by high priority threats to watersheds/aquifers within their region.

Where the lines of inquiry do not align, outstanding threats that are not addressed by management instruments and that are not stated jurisdictional priorities may need a process (and advocacy) to raise the issue and inspire required policy development and scientific research.

6. Key Questions for Discussion

1. Threats to water: Review of the proposed typology

i. Are the proposed threat classification and threat categories useful; are there key elements missing?

ii. Would higher-resolution characterization of threats (e.g., in a manner similar to the IUCN threats calculator) be useful? If so, what other threat attributes (e.g., geographical scope, magnitude, etc.) would be most useful?

2. Management Instruments: Review of proposed methodology

i. Is this methodology useful? If not, why? If so, how might it be improved?

ii. Does Canada need a systematic mapping of instruments/policies to identify gaps and trends? If so, at what geographical scale(s)?

3. Science: Toward a systematic and robust research agenda

i. Is the proposed characterization of science gaps and science-policy misalignment useful? How might it be improved?

ii. What other criteria might be used to prioritize scientific research to inform the design, implementation or evaluation of threat management or mitigation measures?

4. Next Steps

i. Suggestions for a larger IISD forum in 2017?