Environmental Law Centre
UNIVERSITY OF VICTORIA

Community-Based Water Monitoring and Decision Making

An ELC Clinic report prepared for:
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Executive Summary

Community-based monitoring (CBM) is a type of scientific data collection that is led and driven by citizens or non-governmental organizations and seeks to increase direct community involvement in research and monitoring program design. This report considers three core challenges for CBM: (1) ensuring CBM data are credible, (2) ensuring CBM data effectively inform decision-makers, and (3) ensuring CBM data are accessible and aggregated across watersheds and regions. Given the mutual benefits afforded by CBM to communities and governments, this report is intended to identify successful approaches to address these challenges when incorporating CBM water quality data into Canada's water monitoring framework.

This report presents national, supranational and subnational case studies from the United States of America, Australia, and the European Union to examine: (1) how community-based monitoring groups in these jurisdictions collect water quality data, (2) how governments have variously used CBM data in databases and decision making, and (3) how the availability and accessibility of CBM data affects agencies and organizations. The case studies examined offer unique lessons that can be applied in the Canadian context:

United States of America: the United States Environmental Protection Agency offers a model framework of how national governments can provide guidance and coordination for regional CBM activities. This includes the Agency's Quality Assurance Project Plans that outlines procedures to align data formats so that they are usable by the Agency and other departments. Examples from Oregon show how CBM and government data can be integrated and quality controlled so that they are useful for government reporting. Comprehensive watershed management and conservation plans, such as those carried out by the National Estuary Program, offer useful examples of how CBM data can have an impact on decision making at the national level.

Australia: the National Water Quality Management Strategy adopted in 1992 continues to provide a powerful roadmap for local, state and national governments to coordinate the water quality and quantity monitoring necessary to design and implement comprehensive water and ecosystem management plans. The strategy supports CBM data collection (primarily through Waterwatch programs) and exemplifies how volunteer involvement in monitoring can increase the spatial scale of activities while fostering strong community engagement in watershed management and planning. Australian examples point to approaches that governments can use to either develop their own water quality databases that integrate CBM data and / or how to prioritize technical support and funding for existing CBM groups' databases.

European Union: The European Union's Water Framework Directive is a strong model of how a comprehensive water strategy can draw data from multiple sources across jurisdictions to achieve a common vision for water management while embedding enough flexibility to meet local water needs. Examples of software development for CBM database management in countries within the European Union point to helpful approaches to ensure transparency and sustainability of systems in the long-term.

The case studies presented indicate that collecting, using and sharing CBM water quality data would increase the amount of information available on many of Canada's watersheds, and would support a more comprehensive understanding of watersheds and watershed impacts caused by industrial projects, climate change, and government decisions about land use.

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Abbreviations

Australian Capital Territory	ACT
Ambient Water Quality Monitoring System (Oregon)	AWQMS
Anglers' Riverfly Monitoring Initiative (Scotland)	ARMI
Catchment Management Authority (Victoria)	CMA
Centre for Ecology & Hydrology (Scotland)	CEH
Clean Water Act (US)	*CWA*
Department for Environment and Water (South Australia)	DEW
Department of Environment, Land, Water, and Planning (Victoria)	DELWP
Department of Environmental Conservation (New York)	DEC
Department of Environmental Quality (Oregon)	DEQ
Environmental Protection Agency (US)	EPA
Environmental Values	EVs
European Union	EU
Laboratory Analytical Storage and Retrieval (Oregon)	LASAR
Murray-Darling Basin NRM Board (South Australia)	Murray-Darling Board
National Estuary Program (US)	NEP
National Water Quality Management Strategy (Australia)	NWQMS
Natural Resource Management (South Australia)	NRM
Natural Resources SA Murray-Darling Basin (South Australia)	NR SAMDB
Quality Assurance and Quality Control	QA/QC
Quality Assurance Project Plan (US)	QAPP
River Basin Management Plan (EU)	RBMP
Scottish Environment Protection Agency	SEPA
Strategic Water Information Management System (South Australia)	SWIMS
Total Maximum Daily Load	TMDL
United States	US
Water Framework Directive (EU)	WFD

Introduction

This report presents national, supranational[1] and sub-national cases studies from the United States of America, Australia, and the European Union. It examines how community-based monitoring (CBM) groups in these jurisdictions collect water quality data, how governments have used CBM data in databases and decision making, and how the availability and accessibility of CBM data affect agencies and organizations. This report is intended to identify possible methods of incorporating CBM data into Canada's water monitoring framework. Collecting, using, and sharing CBM water quality data would increase the amount of information available on many of Canada's waterways, and would support a more comprehensive understanding of watersheds and watershed impacts caused by industrial projects, climate change, and government decisions.

Community-based monitoring is a type of scientific data collection that is led and driven by communities or non-governmental organizations and seeks to increase direct community involvement in research and monitoring program design.[2] This type of monitoring is an important piece of any water research framework because communities have greater access to their own watersheds than federal or regional government staff. Local communities can perform more frequent water sampling than a government agency or an academic institution, which can facilitate a better understanding of watershed health and support data-driven decision making.[3] The amount of available scientific information about water and environmental flow currently varies across the country, and our lack of consistent monitoring of crucial data that could guide our understanding of water rights has major repercussions for water law in Canada.[4] The Forum for Leadership on Water recommends the use of watershed management boards to bring local and Indigenous knowledge in to fill the gaps and improve current systems.[5] More frequent sampling can enable faster responses to water quality issues when the health of a waterway starts to deteriorate. However, if CBM data are not used to inform government decision-making, then their potential is wasted. By incorporating CBM into decision-making processes pursuant to laws and regulations, Canadian governments can use CBM data to supplement their own data collection systems and watershed planning, and ensure the widest possible range of data are available for consideration by decision makers.

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[1] *E.g.* the European Union. See Jackson Krase, "The European Union: Supranational or Intergovernmental?" *Medium* (27 July 2017), online: <https://medium.com/@jskrase/the-european-union-supranational-or-intergovernmental-7980f7b5b4a1>.
[2] NWT Water Stewardship, "Community-based monitoring", online: <www.nwtwaterstewardship.ca/communitymonitoring>.
[3] Pooling Water Knowledge working group, "Realizing the Potential of Community Based Monitoring in Assessing the Health of Our Waters" *World Wildlife Foundation* (September 2016), online: <awsassets.wwf.ca/downloads/realizing_the_potential_of_community_based_monitoring_in_assessing_the_health_of_our_.pdf> [Pooling Water Knowledge, "Realizing the Potential"].
[4] For an examination of current shortcomings in the British Columbia context, see Deborah Curran, "Leaks in the system: environmental flows, aboriginal rights, and the modernization imperative for water law in British Columbia" (2017) 50:2 *UBC L Rev* 233.
[5] Peigi Wilson, "The Blue Paper: Water Co-Governance in Canada" (2013) Forum for Leadership on Water, online: <https://docs.wixstatic.com/ugd/c3d5ce_b5d7609f5430425fae71c87dfb6b36c5.pdf>.

Part one of this report examines the United States (US), including case studies from New York and Oregon. Part two considers Australia, with case studies from Victoria and South Australia. Part three examines water quality initiatives in the European Union (EU), with case studies from Scotland and Finland. Each case study discusses how CBM data are collected, how governments use CBM, and how data are made accessible to the public. As a result, this report speaks to three core challenges for CBM:

- ensuring CBM data are credible,
- ensuring CBM data effectively inform decision-makers, and
- ensuring CBM data are accessible and aggregated across watersheds and regions.[6]

[6] Pooling Water Knowledge, "Realizing the Potential", *supra* note 3 at 8.

1. The United States of America

The main US government department that supports and implements CBM is the Environmental Protection Agency (EPA). The EPA has ten regional offices that have supported volunteer monitoring in various ways. EPA offices have provided technical assistance related to data quality control, served as contacts for volunteer programs in their region, managed grants to state agencies that include provision for volunteer water monitoring and public participation, and provided information exchange services for volunteers. Some offices have held regional workshops to bring volunteers together and build partnerships.[7] The EPA has also managed a listserv for volunteer monitoring program coordinators,[8] supported a national newsletter for volunteer monitors, prepared and regularly updated a directory of volunteer monitoring programs,[9] and published manuals on volunteer monitoring methods and on planning and implementing volunteer programs.[10] However, many of the EPA webpages that used to discuss these activities have been archived or removed entirely, and may no longer reflect actual EPA practice under the current administration (2017-2021).[11]

In the EPA's CBM framework, Quality Assurance Project Plans (QAPPs) outline the procedures that those who conduct a monitoring project are expected to follow to ensure that the data they collect and analyze meets project requirements. CBM groups are allowed to generate their own QAPPs for their specific organization, but the data quality and collection standards must be equivalent to the QAPP the EPA recommends they follow. This alternative plan must be approved by the EPA before any funding is made available, and should be approved by any governmental agency using the data. In 1996, the EPA released a Guide to QAPPs to encourage and facilitate the development of volunteer QAPPs. The Guide includes clear explanations and examples, and emphasizes that EPA-funded monitoring programs must have an EPA-approved QAPP before sample collection begins if the data is to be submitted for use by governments or other public bodies.[12]

Much of the EPA's direct contact with CBM groups occurs through the National Water Quality Monitoring Council, which is sponsored by the EPA, the United States Geological Survey, and the Advisory Committee on Water Information.[13] They produce a variety of tools for CBM volunteers,[14] and

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[7] United States Environmental Protection Agency, "EPA's Volunteer Monitoring Program" (4 October 2012), *EPA's Web Archive*, online: <https://archive.epa.gov/water/archive/web/html/epasvmp.html> [EPA, "Volunteer Monitoring"]. This information is archived and may not reflect current EPA practice.

[8] United States Environmental Protection Agency, "The Volmonitor Listserver" (6 March 2012), *EPA's Web Archive*, online: <https://archive.epa.gov/water/archive/web/html/listinstruct.html>.

[9] United States Environmental Protection Agency, "National Directory of Volunteer Monitoring Programs (9 June 2017), online: <https://web.archive.org/web/20170610022314/https://yosemite.epa.gov/water/volmon.nsf/Home?readform>. This page is no longer available on the EPA website or archive.

[10] EPA, "Volunteer Monitoring", *supra* note 7. This information is archived and may not reflect current EPA practice.

[11] United States Environmental Protection Agency, "EPA Web Archive", online: <https://archive.epa.gov/>; Brady Dennis & Juliet Eilperin, "Trump's budget takes a sledgehammer to the EPA" *Washington Post* (16 March 2017), online: <www.washingtonpost.com/national/health-science/budget-reflects-trumps-vow-to-cut-epa-in-almost-every-form/2017/03/15/0611db20-09a5-11e7-a15f-a58d4a988474_story.html?utm_term=.a2c559761460>.

[12] United States Environmental Protection Agency, "The Volunteer Monitor's Guide to Quality Assurance Project Plans" (September 1996), online: <www.epa.gov/sites/production/files/2015-06/documents/vol_qapp.pdf>.

[13] National Water Quality Monitoring Council, online: <https://acwi.gov/monitoring/index.html>.

[14] National Water Quality Monitoring Council, "Volunteer Monitoring Program Directory", online: <https://acwi.gov/monitoring/vm/programs/vm_map.html>.

host National Monitoring Conferences that bring together government agencies, the private sector, Indigenous peoples, and local groups to share knowledge and data. Approximately 700 people attended the last conference in 2016,[15] and the next has been scheduled for spring 2019.[16]

The EPA also oversees the National Estuary Program (NEP), a place-based non-regulatory program intended to protect and restore the water quality and ecological integrity of nationally significant estuaries. Section 320 of the *Clean Water Act* (*CWA*)[17] authorizes the program and allows public and non-profit agencies, institutions, organizations, and individuals to receive NEP grants.[18] Congress has designated 28 estuaries located along the Atlantic, Gulf, and Pacific coasts, and in Puerto Rico as estuaries of national significance.[19] Through local NEPs, CBM groups help to monitor the state of these estuaries and their surrounding watershed, and generate information for Comprehensive Conservation and Management Plans to address long-term water quality and living resource challenges and priorities.[20] Local NEPs conduct sampling and provide data to the EPA, which publishes those data along with a GIS map on their website.[21] As with many other databases, once the CBM data is entered into the government database it is not possible to distinguish it from other data.

At the state level, CBM has the potential to play a larger role in the governmental data structure. In New York, Friends of The Bay is a community-based group that seeks to protect and restore the Oyster Bay/Cold Spring Harbor estuary and surrounding watershed. In Oregon, CBM plays a larger role in data collection, and Department of Environmental Quality staff support the incorporation of volunteer monitoring data into government databases and reporting.

New York

CBM Initiatives and Government Use of CBM Data

Friends of the Bay is a volunteer group on Long Island that conducts water quality monitoring in Oyster Bay, Cold Spring Harbor, and the surrounding watershed.[22] Friends of the Bay developed their current Water Quality Monitoring Program in cooperation with the EPA, the United States Fish and Wildlife Service, New York State Department of Environmental Conservation (DEC), local governments, and other citizen monitoring groups around Long Island Sound.[23] From April to October, CBM volunteers collect weekly samples at 19 open water body locations in the Oyster Bay watershed, under an EPA-certified

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[15] Advisory Committee on Water Information, "10th National Monitoring Conference" (2016), online: <https://acwi.gov/monitoring/conference/2016/index.html>.
[16] Advisory Committee on Water Information, "Working Together for Clean Water National Monitoring Conference", online: <https://acwi.gov/monitoring/conference/index.html>.
[17] *Clean Water Act*, 33 USC §1251 (1972), online: <www.epa.gov/sites/production/files/2017-08/documents/federal-water-pollution-control-act-508full.pdf> [*CWA*].
[18] *Ibid* at s 320(g)(1); United States Environmental Protection Agency, "Overview of the National Estuary Program (NEP)", online: <www.epa.gov/nep/overview-national-estuary-program> [EPA, "National Estuary Program"].
[19] EPA, "National Estuary Program", *supra* note 18.
[20] *Ibid*.
[21] United States Environmental Protection Agency, "NEPmap", online: <https://gispub2.epa.gov/NEPmap/index.html> [EPA, "NEPmap"].
[22] Friends of the Bay, "Annual Water Quality Reports", online: <friendsofthebay.org/research-monitoring/annual-water-quality-report/>.
[23] *Ibid*.

QAPP that allows their data to be included in government reporting.[24] New York State's DEC appears to use data from Friends of the Bay and other CBM groups when generating water body reports to fulfill federal *CWA* requirements.[25] New York's Oyster Bay/Huntington Bay Watershed Reports mention Friends of the Bay's activities under "Management Action" for Oyster Bay Harbor, Mill Neck Creek, and Cold Spring Harbor.[26]

Public Access to Data

Data collected by Friends of the Bay are publicly available on the group's website in PDF form. Unlike other CBM groups, Friends of the Bay do not use an open access integrated database.[27]

Oregon

CBM Initiatives and Government Use of CBM Data

Oregon uses CBM data and volunteers to support government reporting and decision-making. Oregon's Department of Environmental Quality (DEQ) website states that data gathered by over 50 participating volunteer groups is primarily used by volunteer organizations for local decisions and education programs.[28] However, the DEQ also uses volunteer monitoring data for watershed assessments and reporting, determining if the state's waters meet water quality standards, and Total Maximum Daily Load (TMDL) documentation or development.[29]

The DEQ's 2009 Volunteer Water Quality Monitoring QAPP explains how CBM organizations that use state funding or equipment are to collect and submit the data they generate to the DEQ so those data can be added to the DEQ's database.[30] According to QAPP, before uploading CBM data into the database, DEQ staff review each submitted dataset to ensure data quality. Data are organized into batches based on the sample collectors and analyst, when the samples were collected and analyzed, and what equipment was used. Quality control test results are then compared to control limits defined in the DEQ's Data Quality Matrix and Data Validation quality assurance guidelines, and data are assigned one of four data quality classifications.[31] The DEQ generally only uses "A" level, and sometimes "B" level CBM data for legal or regulatory purposes, but lower-quality CBM data can also help to inform

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[24] *Ibid.*

[25] *CWA, supra* note 17; New York State Department of Environmental Conservation, "The Waterbody and Priority Waterbodies List", online: <www.dec.ny.gov/docs/water_pdf/wipwlintro.pdf>; United States Environmental Protection Agency, "National Directory of Volunteer Environmental Monitoring Programs", 4th ed (January 1994) at 292, online: <https://nepis.epa.gov/Exe/ZyPURL.cgi?Dockey=20004LSO.TXT>.

[26] New York State Department of Environmental Conservation, "Fact Sheets: Oyster Bay/Huntington Bay Watershed" at 10, 15, 24, online: <www.dec.ny.gov/docs/water_pdf/wiatllisobhb.pdf>.

[27] Friends of the Bay, "Friends of the Bay Water Quality Data", online: <friendsofthebay.org/research-monitoring/friends-of-the-bay-water-quality-data/>.

[28] Oregon Department of Environmental Quality, "Volunteer Monitoring", online: <www.oregon.gov/deq/wq/Pages/WQ-Monitoring-Volunteer.aspx>.

[29] *Ibid*; personal communication (phone conversation) with Nick Haxton, Interim Volunteer Monitoring Coordinator, Oregon Department of Environmental Quality (4 April 2018).

[30] Oregon Department of Environmental Quality, "Volunteer Water Quality Monitoring QAPP" (10 November 2009) at 1, 7-25, online: <www.oregon.gov/deq/FilterDocs/volunteerQAplan.pdf> [Oregon DEQ, "QAPP"].

[31] *Ibid* at 7.

restoration activities or identify a need for further study in an area.[32] All data also has to be associated with a physical location defined in terms of longitude and latitude. If data were not collected at an existing monitoring station, a new station can be created by submitting geolocation data to the DEQ.[33] Although the DEQ is in the process of reviewing and updating the 2009 QAPP, it currently reflects the DEQ's past and present methods of processing CBM data.[34]

Prior to 2017, the DEQ added CBM data to their Laboratory Analytical Storage and Retrieval (LASAR) database.[35] In 2017, the DEQ replaced the aging LASAR system with a new Ambient Water Quality Monitoring System (AWQMS).[36] Currently, AWQMS only holds staff-collected data dating back to 2013.[37] All the CBM water quality data from the old LASAR database are stored in an interim internal database, alongside any CBM data that DEQ has received, reviewed, and classified since LASAR was retired.[38] However, the DEQ plans to expand AWQMS to include these (and future) CBM water quality data, as well as pre-2013 DEQ-collected data that was formerly available through LASAR.[39]

Oregon used LASAR to support a variety of services and programs, including the state-wide water quality assessments and reports they are required to provide to the EPA. Every two years, the DEQ prepares an Integrated Report to meet federal *CWA* requirements. *CWA* s 305(b) requires a report on the overall condition of Oregon's waters, while s 303(d) requires identification of waters that do not meet water quality standards and where a TDML pollutant load limit needs to be developed.[40] If CBM groups are producing A- or B-level data, they can directly contribute to Oregon's *CWA* reporting. To prepare their 2018 Integrated Report, the DEQ will be relying on a combination of staff-collected data stored in AWQMS and non-AWQMS volunteer data that meet quality assurance requirements.[41] In addition to data from existing Volunteer Monitoring Program participants that the DEQ receives through established data reporting procedures, DEQ is currently seeking additional data from anyone else who "collect[s] water quality data in Oregon" and is interested in contributing to the Integrated Report.[42]

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[32] *Ibid* at 7, 25; Haxton, *supra* note 29. A-level data are data of known quality that meet the control limits set out in the DEQ's QAPP, and B-level data are data of known but lesser quality due to incomplete or poorly performing quality control results, method limitations or comments.
[33] *Ibid* at 20.
[34] Haxton, *supra* note 29.
[35] Oregon DEQ, "QAPP", *supra* note 30 at 21.
[36] AWQMS is an off-the-shelf application that also powers water quality systems in other states. See Oregon Department of Environmental Quality, "Ambient Water Quality Monitoring Data Portal", online: <https://orwater.deq.state.or.us/DataAnalysisIndex.aspx> [Oregon DEQ, "AWQMS"]; Oregon Department of Environmental Quality, Press Release, "DEQ's water quality monitoring system helps Oregon save, share and use water data" (20 February 2018), online: <www.oregon.gov/newsroom/Pages/NewsDetail.aspx?newsid=2592>; Oregon Department of Environmental Quality, "DEQ Databases", online: <www.oregon.gov/deq/Data-and-Reports/Pages/default.aspx>.
[37] Oregon Department of Environmental Quality, "Water Quality Monitoring Data", online: <www.oregon.gov/deq/wq/Pages/WQdata.aspx>.
[38] Haxton, *supra* note 29.
[39] *Ibid*.
[40] *CWA, supra* note 17; Oregon Department of Environmental Quality, "Water Quality Assessment", online: <www.oregon.gov/deq/wq/Pages/WQ-Assessment.aspx>.
[41] Oregon Department of Environmental Quality, "Oregon's 2018 Integrated Report", online: <www.oregon.gov/deq/wq/Pages/2018-Integrated-Report.aspx/>.
[42] *Ibid*.

Data Management and Public Access to Data

Oregon's DEQ manages CBM data through a multi-step process. The DEQ's 2009 QAPP lays out the stages that data go through in order to be integrated into DEQ's database.[43] Figure 1 sets out instantaneous grab water data collection procedures and indicates who controls and has access to data throughout the process.[44] CBM groups that collect the data are only directly involved at the initial stage: though they are able to retain copies of the data for their own systems or reporting, data submitted to the DEQ comes under the control of DEQ staff. Under the old LASAR database, DEQ staff monitored and maintained the data; members of the public could access the data, but had no power to add their own data.

Input	Action	Responsible Party	Output
Instantaneous Grab Water Quality Data			
Raw Field Data and Quality Control Results	Internal data management at the CBO including review for reasonableness, completeness, data quality and existing DEQ LASAR stations[i], entry into electronic data storage, and formatting of data, including duplicate data, and assigned data quality level into an approved electronic format.	CBO staff or volunteers identified in an SAP	Completed electronic data submittal file for DEQ.
Submitted Raw Field Data (DEQ's "original record")	Review for formatting and completeness; create new LASAR stations for new locations, assign appropriate DEQ parameter codes, sampling organization codes, and analytical organization codes.	ODEQ Volunteer Monitoring Specialist	Completed Request For Analysis (RFA) (LIMS field sheet) Needed codes for electronic upload to LIMS
Submitted Raw Field Data	Quality assurance review and reformatting data. Review and analyze all reported quality control information including splits, accuracy reports, duplicates and other results. Review/assign data quality levels to each reported result. Reformat submitted data to LIMS electronic upload comma separated values format and assign all associated LIMS codes. Email electronic upload file and RFA to ODEQ Sample Coordinator.	ODEQ Volunteer Monitoring Specialist	QA memo LIMS electronic upload comma separated file
LIMS Electronic Upload File and RFA	Create LIMS Sampling event number and upload into LIMS	ODEQ Sample Coordinator	DAR
DAR	Review for successful upload and approve DAR.	ODEQ Volunteer Monitoring Specialist, ODEQ Managers	Approved DAR
Approved DARs	Print and sign Final Report.	ODEQ Sample Coordinator	Official Printed Final Report signed.
Release Data	Transfer electronic data to LASAR	ODEQ Technical Services staff	Data accessible on the DEQ webpage
Data in LASAR	Check on sampling event loading into LASAR, review 10% of sampling events for correct data transfer.	ODEQ Volunteer Monitoring Specialist	Verified LASAR data

Figure 1: Instantaneous Grab Water Data Management Procedures, as set out in the QAPP[45]

[43] Oregon DEQ, "QAPP", *supra* note 30 at 21-22.
[44] *Ibid*.
[45] Image courtesy of the Oregon Department of Environmental Quality. See Oregon DEQ, "QAPP", *supra* note 30 at 21. 'CBO' refers to a Community Based Organization, equivalent to CBM groups. 'SAP' refers to each group's Sampling and Analysis Plan.

This chart largely reflects how the DEQ processes CBM data in the post-LASAR era, even though those data are not currently made available to the public at the end of the process. Once the DEQ integrates CBM data into AWQMS, a new submission process for new CBM data will improve processing times and create a larger role for volunteers. DEQ staff members will continue to review all CBM data for quality classification purposes, but trained volunteer monitors will be able to upload their own data directly into AWQMS. The DEQ is developing templates, training, and how-to guides to support this initiative.[46]

Although AWQMS does not yet include CBM data, it provides public read-only access to state-collected water quality monitoring data from across Oregon (see Figure 2). Members of the public can use AWQMS to generate maps, reports, graphs, and intensive datasets. The Map Filtered Locations interface allows the public to click on a point on a map to gain access to raw data to use as needed (see Figure 3). This broad range of tools will also apply to CBM data once they have been integrated into AWQMS.[47]

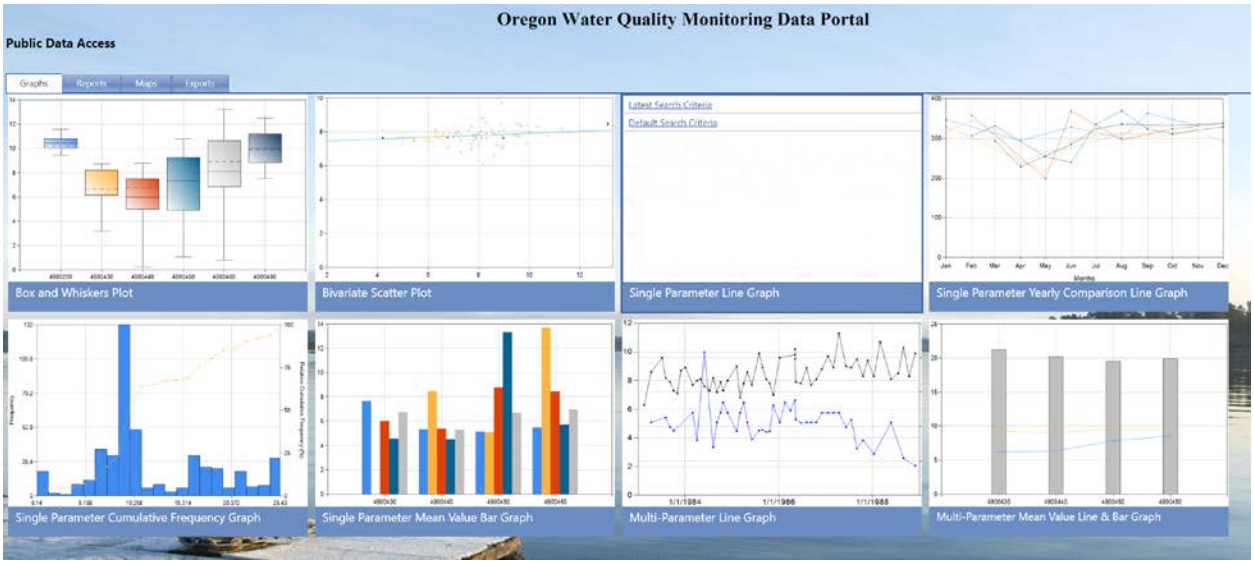

Figure 2: AWQMS Graphs Homepage[48]

[46] Haxton, *supra* note 29.
[47] *Ibid*.
[48] Oregon DEQ, "AWQMS", *supra* note 36, image courtesy of the Oregon Department of Environmental Quality.

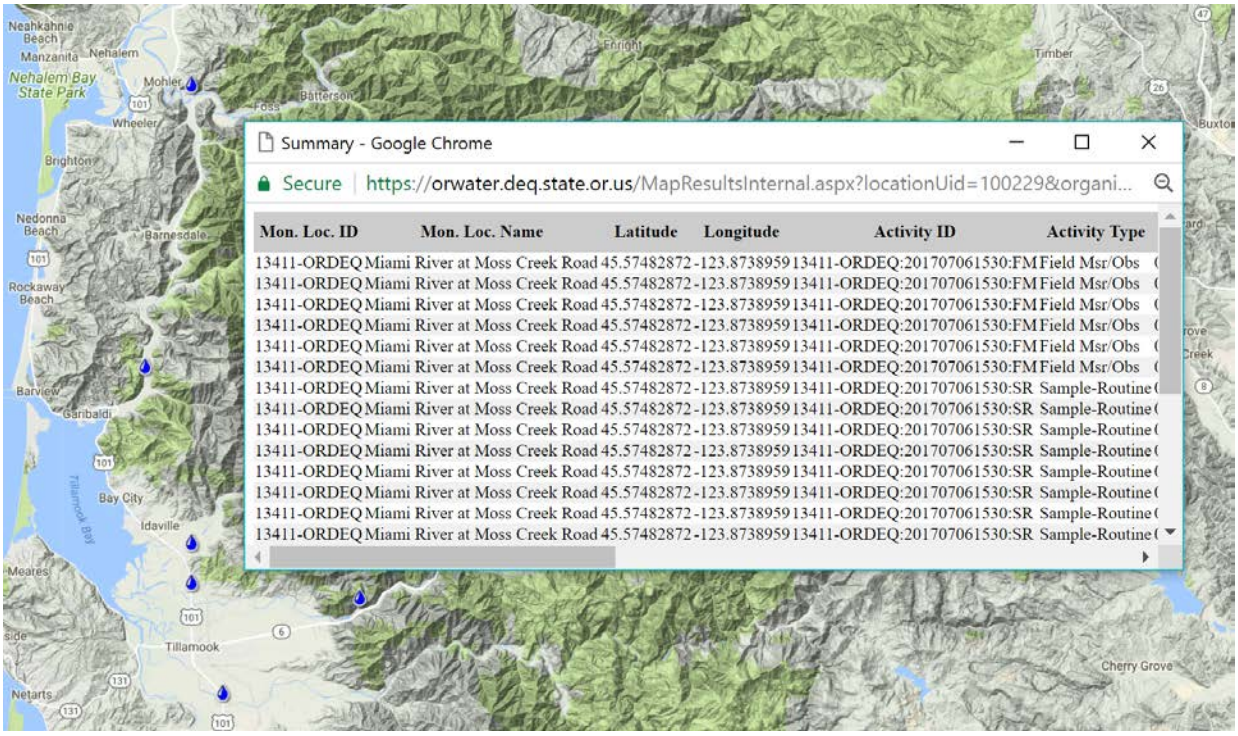

Figure 3: Sample search using the AWQMS Map Filtered Locations interface[49]

In summary, Oregon's DEQ has made high-quality CBM data accessible to the public in the past and intends to do so again in the near future, using a streamlined process that should help to reduce the upload and access delays that existed under LASAR.[50]

Summary and Application in Canada

Many aspects of Oregon's system can be seen as best practices for CBM and government data interaction. The DEQ's data ranking role ensures that CBM data are used within the scope of their potential, and guards against questionable or unreliable results. The public will soon have access to these CBM data again via a reliable government-run website with broad functionality. Canadian provinces could implement a similar system by creating or assigning a branch within each existing provincial ministry to oversee the creation and implementation of an inter-Ministry data agglomeration and review system, including a CBM quality assurance role for one or more civil servants in each ministry.

The federally run NEPmap database[51] is another attractive aspect of the US system because the estuary data it contains are specific to critical habitats that often face human interference and pollution. This approach may be harder to implement in Canada due to the delicate balance of jurisdiction over

[49] *Ibid*, image courtesy of the Oregon Department of Environmental Quality. The dataset is too large to be clearly represented in Figure 3 – to view the full dataset, see Oregon Department of Environmental Quality, "AWQMS – Miami River at Moss Creek Road", online: <https://orwater.deq.state.or.us/MapResultsInternal.aspx?locationUid=100229&organizationUid=100000&mode=DataAnalysisFiltered>.

[50] Haxton, *supra* note 29.

[51] EPA, "NEPmap", *supra* note 21.

intertidal zones and estuaries along the longest coastline in the world.[52] Despite this, the creation of a federal database on the status of these priority ecosystems also is important.

Friends of the Bay's weekly water sampling during the warmer months can also be seen as a best practice. Canadian CBM groups could aim to achieve similar sampling frequency for specific water bodies, such as where water quality results fluctuate significantly or ecosystem impacts are of particular concern.

[52] Oliver Smith, "Britain has more coastline than Brazil – but which country has the most seaside?" *The Telegraph* (22 August 2017), online: <www.telegraph.co.uk/travel/maps-and-graphics/countries-with-longest-coastlines/>.

2. Australia

In Australia, water quality monitoring is considered necessary to reinforce environment protection policies and programs, help control pollution, underpin environmental reporting, develop water quality standards, and create guidelines against which to assess monitoring data.[53] Monitoring programs are run by state and local government bodies, industrial groups, independent consultants, community programs, and research or management groups from universities and Commonwealth agencies. [54] The federal government has developer a national framework for monitoring and reporting on water quality to improve the quality and consistency of water monitoring across Australia.[55]

Since 1992, the Australian and New Zealand governments have taken a joint approach to improving water quality in their waterways.[56] They have developed the National Water Quality Management Strategy (NWQMS) in cooperation with state and territorial governments.[57] The NWQMS process involves community and government partners developing and implementing management plans for each catchment, aquifer, estuary, coastal water, or other water body. Local government, community organisations, and other agencies are able to implement these plans using the NWQMS to protect agreed-upon environmental values (EVs).[58] The government's water quality management process uses the concept of EVs to set local water quality targets, either directly or in partnership with communities.[59] The Council of Australian Governments has supported NWQMS development by adopting a package of market-based and regulatory measures – including appropriate water quality monitoring and catchment management policies and community consultation and awareness – to ensure access to sustainable water resources that meet each community's needs.[60]

The NWQMS Implementation Guidelines express support and encouragement for the involvement of CBM groups:

> *Community/landholder involvement in catchment monitoring can offer great benefits, yielding information of both scientific and practical relevance, helping to develop shared ownership of catchment knowledge and commitment to action, and modifying previous approaches to land and water management... monitoring could*

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[53] Australian and New Zealand Environment and Conservation Council, "National Water Quality Management Strategy Guidelines No 7a – Australian Guidelines for Water Quality Monitoring and Reporting – Summary" (October 2000) at 1, online: <www.agriculture.gov.au/SiteCollectionDocuments/water/nwqms-monitoring-reporting-summary.pdf> [ANZECC, "Guidelines Summary"].
[54] *Ibid* at 3.
[55] *Ibid* at 3; Australia, Department of Agriculture and Water Resources, "Australian guidelines for water quality monitoring and reporting" (7 March 2018), online: <agriculture.gov.au/water/quality/nwqms/nwqms-australian-guidelines-water-quality-monitoring-reporting>.
[56] Australia, Department of Agriculture and Water Resources, "National Water Quality Management Strategy" (22 August 2016), online: <agriculture.gov.au/water/quality/nwqms>.
[57] *Ibid*.
[58] *Ibid*.
[59] Australia, Department of Agriculture and Water Resources, "National Water Quality Management Strategy: Implementation guidelines" (7 March 2018), online: <agriculture.gov.au/water/quality/nwqms/nwqms-implementation-guidelines>.
[60] *Ibid*; ANZECC, "Guidelines Summary", *supra* note 53 at 1.

> *range from an expensive formal scientific program to a less expensive community-based monitoring system… [or] a combination of the two.*[61]

The federal government created the Australian Guidelines for Water Quality Monitoring and Reporting in 2000 as part of a broader set of NWQMS guidelines. They outline recommended best practices for setting up a water monitoring program.[62] Although these Monitoring Guidelines are now 18 years old, they continue to be a crucial NWQMS document.[63] They lead the reader through all aspects of a monitoring program: setting objectives, designing studies and an effective sampling program, conducting laboratory analyses, choosing suitable data analyses in conjunction with monitoring and sampling program design, and reporting results and conclusions.[64] The target audience for the Monitoring Guidelines was individuals with at least basic technical training, and some of the scientific language they contain may not be accessible to members of the public who lack a background in water management.[65]

Much of Australia's water-focused CBM data collection takes place through Waterwatch programs, which promote water quality monitoring as a tool to involve communities in local water management.[66] Waterwatch Australia was founded in 1993 as a national network of citizen scientists – individuals, community groups, and school groups – who regularly check their local waterways, take action to help maintain water quality, and help raise community awareness about water.[67] As of 2000, Waterwatch Australia was collating community-collected data using a Waterwatch Australia Data Management System, which the Australian government may have been using to support its environmental reporting.[68] However, Waterwatch activity now primarily takes place at the state or territorial level.[69] In the Australian Capital Territory (ACT), for example, Upper Murrumbidgee Waterwatch monitors over 320 sites in partnership with the territorial government, and stores its data in an Atlas of Living Australia database.[70] The ACT's 2014 Water Strategy seeks to better integrate Waterwatch activities into a

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[61] Australian and New Zealand Environment and Conservation Council, "NWQMS Implementation Guidelines" (1998) at 22, online: <agriculture.gov.au/SiteCollectionDocuments/water/nwqms-implementation-guidelines.pdf>.
[62] ANZECC, "Guidelines Summary", *supra* note 53 at 4. For the full Guidelines document, see Australian and New Zealand Environment and Conservation Council, "National Water Quality Management Strategy Guidelines No 7 – Australian Guidelines for Water Quality Monitoring and Reporting" (October 2000), online: <agriculture.gov.au/SiteCollectionDocuments/water/nwqms-monitoring-reporting.pdf>.
[63] Australia, Department of Agriculture and Water Resources, "Australian and New Zealand Guidelines for Fresh and Marine Water Quality" (1 August 2016), online: <www.agriculture.gov.au/water/quality/guidelines>.
[64] ANZECC, "Guidelines Summary", *supra* note 53 at 4.
[65] *Ibid*.
[66] ANZECC, "Guidelines Summary", *supra* note 53 at 3.
[67] Waterwatch Australia, "What is Waterwatch?", online: <www.waterwatch.org.au/>.
[68] ANZECC, "Guidelines Summary", *supra* note 53 at 3.
[69] Waterwatch Australia was essentially disbanded in 2011, and its current online presence consists of a single webpage that links to active programs in Victoria, New South Wales, and the Australian Capital Territory - see Waterwatch Australia, *supra* note 66. However, state and territorial chapters have been networking, and hope to build coordinated momentum through a federally-funded nationwide water bug monitoring event in October 2018. Personal communication (phone call) with Deirdre Murphy, Waterwatch Victoria Program State Coordinator (9 April 2018).
[70] "Upper Murrumbidgee Waterwatch" (17 July 2017), online: <www.act.waterwatch.org.au/>; Upper Murrumbidgee Waterwatch, "Upper Murrumbidgee Waterwatch monitoring site", online: Atlas of Living Australia, <root.ala.org.au/bdrs-core/umww/home.htm>.

broader monitoring program, and also aims to increase the scope of Waterwatch monitoring and the use of Waterwatch data in government reporting by 2044.[71]

CBM programs in several Australian states also collect and make water quality data available to government and/or the public. The state of Victoria has an active Waterwatch chapter that collects data and provides them to regional Waterwatch coordinators. Waterwatch Victoria also operates a water monitoring database under a Creative Commons licence. South Australia has multiple CBM organizations whose data are used by government in different ways. The South Australian government appears to do a better job of integrating CBM data into its own database than the Victorian government. However, the regional CBM database for South Australia's Murray-Darling Basin does not have quite as many features as most of the GIS-based databases discussed in this report.

Victoria

CBM Initiatives and Government Use of CBM Data

Waterwatch Victoria has been connecting local communities with waterway health and sustainable water management issues since 1993.[72] Citizen scientists monitor water quality across the state, and their data are made available online through Waterwatch Victoria's Waterwatch Data Portal.[73] In 2016/2017, 1,598 Waterwatch volunteers collected data at 780 sites across Victoria.[74] The spatial coverage provided by these CBM data "value-adds to [government] monitoring programs such as the Water Measurement Information System, and fills local monitoring gaps".[75] For example, Waterwatch volunteers contributed to the state government's 2010 Index of Stream Condition "by collecting monthly water quality data at 264 sites."[76] More recently, Waterwatch-collected water quality data was included in the State government's 2016-2017 Report Card on water quality in Port Phillip Bay, and the Waterwatch Victoria Program State Coordinator continues to seek new opportunities for CBM data to be used by government.[77]

The state government supports Waterwatch Victoria by buying equipment, hosting capacity-building events, and employing the Waterwatch Victoria Program State Coordinator and regional Waterwatch coordinators across the state. These regional coordinators link Waterwatch volunteers to regional Catchment Management Authorities (CMAs), and "facilitate partnership opportunities" on watershed

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[71] ACT Government, "ACT Water Strategy 2014-44: Striking the Balance" (August 2014), online: <www.environment.act.gov.au/__data/assets/pdf_file/0019/621424/ACT-Water-Strategy-ACCESS.pdf>.
[72] Waterwatch Victoria, "Welcome to Waterwatch Victoria", online: <www.vic.waterwatch.org.au/cb_pages/welcome_to_waterwatch_victoria.php>.
[73] Waterwatch Victoria, "Waterwatch Data Portal", online: <www.vic.waterwatch.org.au/water_data_portal.php> [WV, "Waterwatch Data Portal"]. Data appear to be added to the portal regularly, and some sites include results from as recently as 19 March 2018 – see, *e.g.*, Seven Creeks 2053 Euroa-Mansfield Rd (GB_SEV016).
[74] Victoria, Department of Environment, Land, Water & Planning, "EstuaryWatch & Waterwatch Annual Achievements Report 2016-17" (2017), online: <issuu.com/gsdm/docs/12821_annual_achieve_report_2017?e=1695326/48821593> [DELWP, "Annual Achievements"].
[75] *Ibid*.
[76] Victoria, *Victorian Waterway Management Strategy* (East Melbourne: Department of Environment and Primary Industries, 2013) at 64, online: <https://www.water.vic.gov.au/__data/assets/pdf_file/0023/52547/VWMS_Part2.pdf> [Victoria, *VWM Strategy*].
[77] Victoria, Yarra & Bay, "Report Card 2016-2017" (12 January 2018), online: <yarraandbay.vic.gov.au/report-card/report-card-2017>; Murphy, *supra* note 69.

health between all levels of government, the private sector, and the community.[78] Each CMA works on different types of projects with Waterwatch volunteers, and uses the resulting CBM data in different ways.[79] The state government's *Victorian Waterway Management Strategy* for 2013-2021 acknowledges the "decades of benefits" provided by Waterwatch, and commits to aligning community monitoring with government waterway management programs "so that the data collected can increasingly be used to inform the management of waterways and will be publicly available."[80] However, Victoria's Department of Environment, Land, Water and Planning (DELWP) does not integrate Waterwatch data into its own public-facing databases. DELWP's website directs users seeking "data and information on community water monitoring" to the Waterwatch Victoria site rather than the department's own online tools.[81]

Public Access to Data

The Waterwatch Data Portal[82] allows members of the public to view, analyze, and download CBM data collected by Waterwatch volunteers across the state.[83] Trained, registered Waterwatch volunteers can upload their data to the Data Portal themselves, but these data only become publicly accessible once a regional coordinator has vetted and approved them.[84]

Waterwatch Victoria uses a four-level Data Confidence Framework to classify CBM water quality data. Data that meet the two most rigorous standards can be put to a broader range of uses than data that meet the other two standards, which are primarily used for education and awareness-raising.[85]Unlike other programs that primarily use QA/QC models to rank data, Waterwatch Victoria also uses monitoring frequency as a metric, with infrequent sampling contributing to lower quality rankings.[86] In 2016-17, 90 percent of the water quality data collected and uploaded to the Data Portal met the two most rigorous standards.[87]

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[78] Victoria, *VWM Strategy, supra* note 76 at 64; Victoria, Department of Environment, Land, Water and Planning, "Water education", online: <https://www.water.vic.gov.au/liveable-cities-and-towns/water-education>; Murphy, *supra* note 69.
[79] See DELWP, "Annual Achievements", *supra* note 74 at 16-35.
[80] Victoria, *VWM Strategy*, *supra* note 76 at 59 & 64.
[81] Government of Victoria, Department of Environment, Land, Water & Planning, "Water Measurement Information System" (15 August 2016), online: <data.water.vic.gov.au/monitoring.htm> [DELWP, "WMIS"]; Murphy, *supra* note 69.
[82] WV, "Waterwatch Data Portal", *supra* note 73.
[83] Waterwatch Victoria, "View data", online: <www.vic.waterwatch.org.au/cb_pages/view_waterwatch_data.php>.
[84] Murphy, *supra* note 69.
[85] Waterwatch Victoria, "Data confidence and interpretation", online: <www.vic.waterwatch.org.au/cb_pages/data_confidence.php>. The chart on this page remains largely accurate in 2018, with the exception of the references to now-defunct databases in the bottom row – Murphy, *supra* note 69.
[86] *Ibid*.
[87] DELWP, "Annual Achievements", *supra* note 74 at 17.

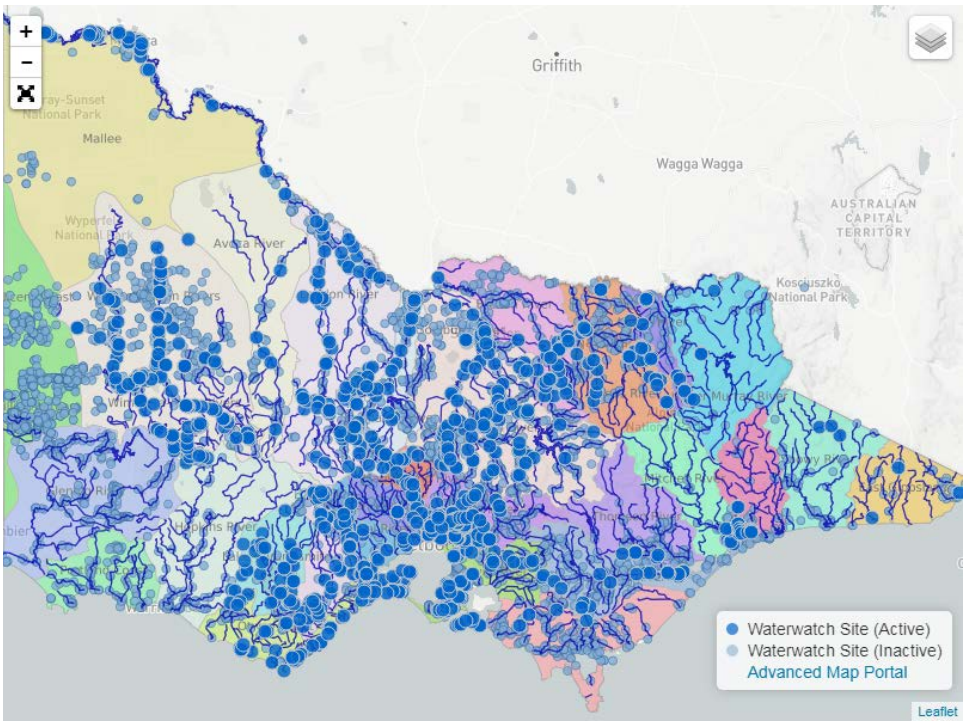


Figure 4: Waterwatch Victoria GIS Data Portal Map[88]

Waterwatch Victoria's Data Portal operates under a Creative Commons Attribution License, which allows other users to reuse, remix, and share the CBM data legally, but preserves Waterwatch Victoria's copyright. Under this license, Data Portal content is available to be used in any way, but users must always credit Waterwatch Victoria and link to their website.[89]

In addition to the Waterwatch Data Portal, Waterwatch Victoria's website also hosts a Waterwatch Map Portal, which allows users to select various other data layers to overlay Waterwatch's core CBM data. One of these layers consists of data pulled from DELWP's main water monitoring database, the Water Measurement Information System.[90] This level of transparent data integration arguably makes Waterwatch Victoria's database more robust than the state government's.[91]

South Australia

CBM Initiatives and Government Use of CBM Data

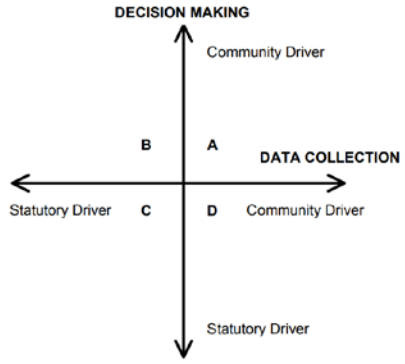
In South Australia, the Department for Environment and Water collaborates with the state's eight regional Natural Resource Management (NRM) Boards, community groups, and other agencies to

[88] Image from WV, "Waterwatch Data Portal", *supra* note 73, reproduced under a Creative Commons Attribution (CC BY) licence.
[89] Creative Commons Australia, "About the Licences", online: <creativecommons.org.au/learn/licences/>.
[90] Waterwatch Victoria, "Waterwatch map portal", online: <www.vic.waterwatch.org.au/water_watch_map>; DELWP, "WMIS", *supra* note 81; Murphy, *supra* note 69.
[91] Murphy, *supra* note 69.

monitor and collect water data that facilitate informed decision-making around water resources.[92] Data collected through the government's State Water Monitoring Network is integrated with data collected by community organizations and regional NRM Boards.[93] These data support regular status reporting and governmental and non-governmental decision-making.[94]

A 2005 report on CBM in the Murray-Darling Basin NRM region reveals substantial CBM efforts, including "monitoring of wetlands, surface water quality, groundwater, aquatic and terrestrial biodiversity, and land condition".[95] The report describes the spectrum of community involvement in monitoring through a quadrant plot:

Spectrum of Community Involvement in Natural Resource Monitoring



Community involvement in natural resource monitoring can cover a broad spectrum of types of monitoring and levels of involvement. The diagram above and the table below illustrate this spectrum.

Quadrant	Monitoring type	Example from SAMDB
A	Community participants collect data for information and influence at the local scale	Regional Waterwatch Program
B	Statutory or professional bodies collect data to inform and influence community based management.	Floating-flag Test Well Program
C	Monitoring by statutory authorities and professional bodies to fulfil statutory requirements.	*This type of monitoring is not considered 'community-based'*
D	Community participants collect data to meet a statutory responsibility	Angus-Bremer Water Management Committee

Figure 5: Spectrum of Community Involvement in Natural Resource Monitoring in South Australia[96]

Quadrant D of Figure 5 reveals the Angas-Bremer Water Management Committee's role in collecting data to help the state government fulfill statutory responsibilities. This elected committee has

[92] South Australia, Department for Environment and Water, "Water monitoring policy, guidelines and procedures" (2017), online: <https://www.environment.sa.gov.au/topics/water/monitoring/policies-and-guidelines>. [DEW, "Water monitoring policy"].
[93] South Australia, Department for Environment and Water, "State Water Monitoring Network" (2017), online: <https://www.environment.sa.gov.au/managing-natural-resources/water-resources/monitoring/about/state-water-monitoring-network> [DEW, "SWM Network"].
[94] *Ibid*.
[95] SA Murray-Darling Basin Integrated Natural Resources Management Group Inc., "A Review of Community Based Monitoring in the South Australian Murray-Darling Basin" by Patrick O'Connor, Paul Dalby & Annie Bond (2005) at 9, online: <https://data.environment.sa.gov.au/Content/Publications/SAMDB_community_monitoring_review_2005.pdf>.
[96] *Ibid* at 14, image courtesy of the SA Murray-Darling Basin Natural Resources Management Board. Note: Angas-Bremer is misspelled in the chart.

represented 160 irrigators on the Angas Bremer floodplain for nearly 40 years, and has worked closely with irrigators and government specialists to develop and implement innovative water management policies.[97] As the Murray-Darling Basin NRM Board (the Murray-Darling Board) recently noted, "[t]he Committee has the broad support of its community and takes an interest in ensuring water resources are used sustainably."[98] Each irrigator owns and monitors a 6 metre monitoring well on their property, records the height and salinity of the water table four times a year, and reports their data to the Committee each year.[99] The Committee has historically used these data to prepare annual reports to the Department on behalf of these irrigators.[100] These collective annual reports may take the place of individual irrigation reports required under the 2013 *Water Allocation Plan for the Eastern Mount Lofty Ranges*[101] and the 2017 *Water Allocation Plan for the River Murray Prescribed Watercourse*.[102]

Natural Resources SA Murray-Darling Basin (NR SAMDB) also supports a Waterwatch program. Waterwatch-collected data helps NR SAMDB monitor long-term trends and waterway conditions, the effects of local land management activities, and the performance of WAPs, and can also support community education and information sharing.[103] Trained volunteers use loaned equipment to measure various indicators of waterway health, including flow rates, turbidity, salinity, pH, and macroinvertebrates (water bugs).[104] Relatively simple monitoring protocols give an indication of differences between and within catchments, and changes over time. If a site's health seems to be deteriorating and various parameters reach specified trigger levels,, further investigation by a government agency may be warranted. Trained volunteers enter their data into the Murray-Darling Board's Community Monitoring Online Database, and these data are then analyzed and relayed back to the community through catchment-specific reports.[105] The data are also sent to the Bureau of Meteorology in accordance with DEW's obligations under the *Commonwealth Water Act 2007*, and are incorporated into a national water resource database.[106]

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[97] Angas Bremer Water Management Committee Inc., "Angas Bremer Region Water Management", online: <www.angasbremerwater.org.au/>.
[98] SA Murray-Darling Basin Natural Resources Management Board, *Water Allocation Plan for the River Murray Prescribed Watercourse* (2017), online: <www.naturalresources.sa.gov.au/files/sharedassets/sa_murray-darling_basin/water/allocation_plans/river_murray_2017/river-murray-wap-final-gen.pdf> [Murray-Darling Board, *WAP for the Murray*].
[99] *Ibid*; Angas Bremer Water Management Committee Inc., "History of the Angas Bremer Experience", online: <www.angasbremerwater.org.au/history.php>.
[100] Murray-Darling Board, *WAP for the Murray, supra* note 99 at 129.
[101] SA Murray-Darling Basin Natural Resources Management Board, *Water Allocation Plan for the Eastern Mount Lofty Ranges* (2013), online: <www.naturalresources.sa.gov.au/files/sharedassets/sa_murray-darling_basin/water/allocation_plans/emlr/emlr-wap-plan.pdf>.
[102] Murray-Darling Board, *WAP for the Murray, supra* note 99.
[103] Natural Resources SA Murray-Darling Basin, "Waterwatch" (16 March 2018), online: <www.naturalresources.sa.gov.au/samurraydarlingbasin/get-involved/citizen-science/water-monitoring> [NR SAMDB, "Waterwatch"].
[104] *Ibid*.
[105] *Ibid*; SA Murray-Darling Basin Natural Resources Management Board, "Community Monitoring Online Database", online: <www.samdbnrm.sa.gov.au/portals/9/CDMT/index.asp> [Murray-Darling Board, "CMO Database"]; see also SA Murray-Darling Basin Natural Resources Management Board, *Community Monitoring Toolkit* (2013), online: <www.naturalresources.sa.gov.au/files/sharedassets/sa_murray-darling_basin/volunteers/community-monitoring-toolkit-full-gen.pdf>.
[106] NR SAMDB, "Waterwatch", *supra* note 104; DEW, "Water monitoring policy", *supra* note 93; *Water Act 2007* (Cth).

Public Access to Data

South Australia currently makes its water resource data – including integrated CBM data – available to the public through its WaterConnect portal, which includes a number of interactive map databases.[107] However, DEW is in the process of replacing this system with a single Strategic Water Information Management System (SWIMS), which will give the public access to DEW's entire water dataset in a single database, and allow faster access to real-time data. SWIMS is scheduled to be released in 2018.[108]

At the regional level, the Murray-Darling Board's Community Monitoring Online Database allows CBM participants to share their local knowledge and publicly showcase their contribution to water management.[109] This online database uses Google Maps and pin markers rather than GIS layered maps (see Figure 6). CBM data from all marked points on the map are made accessible to all members of the public, but only trained volunteers can enter data into the system.

Images	Site	Date	Zone	Flow	Depth	Salt	Calib	Model	Nit	Phos	pH
	ANG-400	21/03/2017	Unspecified			3460			0.1	1	7
	CUR-010	27/02/2017	Unspecified			4370					7.9
	CUR-020	27/02/2017	Unspecified			3450					7.9
	CUR-030	27/02/2017	Unspecified			2060					7.7
	CUR-040	27/02/2017	Unspecified			2800					7.8
	CUR-050	27/02/2017	Unspecified			770					7.1
	TOO-010	27/02/2017	Unspecified			690					6.5

Figure 6: Community Monitoring Online Database, South Australian Murray-Darling Basin NRM Board[110]

[107] South Australia, "WaterConnect" (23 January 2017), online: <https://www.waterconnect.sa.gov.au/Pages/Home.aspx>; DEW, "SWM Network", *supra* note 94; South Australia, Department for Environment and Water, "Strategic Water Information Management System project", online: <https://www.environment.sa.gov.au/managing-natural-resources/water/monitoring/projects-and-activities/strategic-water-information-management-system> [DEW, "SWIMS"].
[108] DEW, "SWIMS", *supra* note 109.
[109] Murray-Darling Board, "CMO Database", *supra* note 106; Natural Resources SA Murray-Darling Basin, "Citizen science" (16 March 2018), online: <www.naturalresources.sa.gov.au/samurraydarlingbasin/get-involved/citizen-science>.
[110] Murray-Darling Board, "CMO Database", *supra* note 106, image courtesy of the South Australian Department for Environment and Water. The dataset is too large to be clearly represented in Figure 6.

Summary and Application in Canada

In terms of best practices, the Waterwatch Victoria database is very user-friendly and logical in terms of copyright. Using a Creative Commons licence means that as long as the CBM group is credited properly when data are reused, an individual reproducing data from the database does not have to worry about who specifically gathered the data. If Canadian governments are not willing to create publicly accessible government databases that integrate CBM data, as Oregon plans to do with AWQMS, then a high-quality CBM database hosted by a CBM group with government funding and staff support is a reasonable second option.

However, one major consideration with this type of database is the need to ensure data quality is identified correctly. Without a trained civil servant, professional staff of a independent organization or academic professional assuring users that the data are of a certain quality, there could be concerns about whether a QA/QC plan is being followed or whether it is adequate. If the database is monitored by someone who does not know or understand all aspects of the QA/QC plan, the quality of the data could be brought into question, limiting their usefulness. Additionally, if CBM data are stored in a database that is not hosted or managed by government, then government may be less likely to use these data for decision-making or for any meaningful reporting. Care should be taken to avoid or mitigate these problems if Canada adopts aspects of the Victorian model.

Although the South Australian water regime operates somewhat differently from Canada's, South Australia's practice of requiring water users to monitor water quality monthly and report their results to government may be worth exploring in the Canadian context, particularly if government efforts to encourage voluntary CBM activity fall short in particular regions or jurisdictions. Additionally, the South Australian government's SWIMS database may be a useful model for Canada to consider when choosing a database to present government-collected and CBM water quality data.

Canada could also draw on aspects of the NWQMS model by including community stakeholders in national-level water management planning, and creating national guidelines on how to establish and operate a CBM program.

3. The European Union

Enacted in 2000, the Water Framework Directive (WFD) establishes a framework to protect inland surface waters, transitional waters, coastal waters, and groundwater in all EU Member States.[111] The WFD is intended to reduce and prevent water pollution, enhance and protect water and aquatic environments, and promote long-term sustainable water use.[112] Key components include water management based on river basins, a "combined approach" to pollution control that uses both emission limit values and quality standards, and increased citizen involvement.[113]

The WFD made EU Member States responsible for assigning individual river basins within their territory to river basin districts, and making appropriate administrative arrangements for WFD implementation in each district.[114] This included ensuring a river basin management plan (RBMP) for every district was produced by 2011 and reviewed and updated by 2015. Where river basins transcended borders, these basins were assigned to international river basin districts, and RBMPs were coordinated between the relevant Member States.[115] All Member States continue to be responsible for ensuring that their current RBMPs are reviewed and updated every six years.[116] As of 2016, most Member States had updated all their RBMPs for the second WFD cycle (2015-2021), but Ireland, Greece, and Spain had fallen behind.[117]

Under the WFD, all Member States must protect, enhance, and restore all bodies of surface water to achieve 'good' surface water status.[118] In order to provide a "coherent and comprehensive overview" of surface water status in each district, Member States were required to establish water monitoring programmes by 2006 that would measure the volume and level or flow rate of surface waters, as well as their ecological status, chemical status, and ecological potential.[119] Annex V of the WFD sets out detailed criteria for measuring surface water status.[120] Elements to be considered for rivers include the composition and abundance of aquatic flora and fauna; the quantity and dynamics of water flow; connection to groundwater bodies; river continuity and depth and width variation; the structure of the river bed and riparian zone; thermal, nutrient, and oxygenation conditions; and salinity and acidification

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[111] EC, *Parliament & Council Directive 2000/60/EC of 23 October 2000 establishing a framework for Community action in the field of water policy*, [2000] OJ, L 327/1, Article 1, online: <eur-lex.europa.eu/resource.html?uri=cellar:5c835afb-2ec6-4577-bdf8-756d3d694eeb.0004.02/DOC_1&format=PDF> [EC, *WFD*].
[112] *Ibid*.
[113] EC, Environment, "Introduction to the new EU Water Framework Directive" (8 June 2016), online: <ec.europa.eu/environment/water/water-framework/info/intro_en.htm>.
[114] EC, *WFD*, *supra* note 112, Article 3.
[115] *Ibid*, Articles 3 & 13.
[116] *Ibid*, Article 13.
[117] EC, Environment, "Status of implementation of the WFD in the Member States" (28 October 2016), online: <ec.europa.eu/environment/water/participation/map_mc/map.htm>. For example, Ireland published its draft RBMP for the second cycle in February 2017, and does not yet appear to have published a finalized second cycle RBMP. See Ireland, Department of Housing, Planning and Local Government, "Public Consultation on the draft River Basin Management Plans for Ireland 2018-2021" (28 February 2017), online: <www.housing.gov.ie/water/water-quality/river-basin-management-plans/public-consultation-draft-river-basin-management>.
[118] EC, *WFD*, *supra* note 112, Article 4.
[119] *Ibid*, Article 8.
[120] *Ibid*, Annex V.

status.[121] Although Member States were to aim to achieve 'good' surface water status for all water bodies by 2015, efforts continue, and a final deadline has been set for 2027.[122]

The WFD requires all Member States to "encourage the active involvement of all interested parties" in WFD implementation, but primarily contemplates public involvement in RBMP planning and revision processes rather than via CBM.[123] Nevertheless, some Member States collect water-related CBM data, and may be using these data to help them fulfill the WFD's surface water monitoring requirements. In Scotland and Finland, government departments provide support for CBM activities and maintain WFD-related water databases that may incorporate some CBM data

Scotland

WFD Implementation, CBM Initiatives, and Government Use of CBM Data

The Scottish Environment Protection Agency (SEPA) is responsible for Scotland's river basin management planning, and develops RBMPs on behalf of the Scottish Government. These RBMPs cover actions for all responsible authorities in Scotland, and summarize the state of the water environment, pressures that create water quality issues, actions to protect and improve the water environment, and implementation outcomes.[124] Scotland's most recent RBMPs set ambitious surface water targets and appear to exceed Directive requirements by planning for a 12-year period, 2015-2027.[125] SEPA makes WFD-related information available through two water quality databases, the Water Environment Hub[126] and the Water Classification Hub.[127]

Scotland's Environment Web, a government-run gateway to environmental information, invites citizens to submit data on local environmental observations through various programs.[128] Their Citizen Science Portal lists a handful of water-related citizen science initiatives,[129] and they also provide a list of mobile apps that facilitate citizen science reporting.[130] The Riverfly Partnership's Anglers' Riverfly Monitoring

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[121] *Ibid*.
[122] *Ibid,* Article 4; EC, Environment, "WFD: Timetable for implementation" (8 June 2016), online: <ec.europa.eu/environment/water/water-framework/info/timetable_en.htm>. For a discussion of implementation challenges, see Nikolaos Voulvoulis, Karl Dominic Arpon & Theodoros Giakoumis, "The EU Water Framework Directive: From great expectations to problems with implementation" (2017) 575 Science of the Total Environment 358.
[123] EC, *WFD*, *supra* note 112, Article 14.
[124] Scottish Environment Protection Agency, "River Basin Management Planning", online: <https://www.sepa.org.uk/environment/water/river-basin-management-planning/>.
[125] Natural Scotland, "The river basin management plan for the Scotland river basin district: 2015-2027" (21 December 2015), online: <https://www.sepa.org.uk/media/163445/the-river-basin-management-plan-for-the-scotland-river-basin-district-2015-2027.pdf> [NS, "Scotland RBMP"]; Natural Scotland, "The river basin management plan for the Solway Tweed river basin district: 2015 update" (21 December 2015), online: <https://www.sepa.org.uk/media/218890/rbmp_solway_tweed_2015.pdf> [NS, "Solway Tweed RBMP"].
[126] Scottish Environment Protection Agency, "Water Environment Hub", online: <https://www.sepa.org.uk/data-visualisation/water-environment-hub/> [SEPA, "Water Environment Hub"].
[127] Scottish Environment Protection Agency, "Water Classification Hub", online: <https://www.sepa.org.uk/data-visualisation/water-classification-hub> [SEPA, "Water Classification Hub"].
[128] Scotland's Environment, "Submit your data", online: <https://www.environment.gov.scot/get-involved/submit-your-data/>.
[129] Scotland's Environment, "Citizen science portal", online: <https://www.environment.gov.scot/get-involved/submit-your-data/citizen-science-portal/> [SE, "Portal"].
[130] Scotland's Environment, "Mobile apps", online: < https://www.environment.gov.scot/get-involved/submit-your-data/mobile-apps/>.

Initiative (ARMI) is one of the relevant citizen science projects highlighted by the Portal.[131] Riverfly species are powerful biological indicators of freshwater health, and their abundance can be used to measure water quality.[132] Across the UK, Riverfly Partnership tutors provide one-day workshops for fishing clubs and other organisations that are committed to establishing groups to monitor local water quality by tracking riverfly populations.[133] ARMI groups are trained to use a simple monitoring technique for riverflies that can be used to detect severe disturbances in river water quality. When used alongside routine government monitoring, ARMI monitoring ensures water quality is checked more widely, and can deter incidental pollution and support more rapid responses to severe water quality disturbances.[134] Although ARMI data have supported successful environmental prosecutions in Wales, it is unclear if the Scottish government has put ARMI data to similar or other uses.[135] However, ARMI does receive strategic support from SEPA, and puts Scottish volunteer groups in direct communication with a local SEPA Ecological Contact.[136]

Scotland's two 2015-2027 RBMPs recognize the need to supplement Scotland's "state of the art environmental monitoring" with "information from businesses, voluntary organisations and individuals" in order to identify emerging risks promptly.[137] This recognition is followed by a commitment to "continue to promote and facilitate this important public role in helping protect the quality of the water environment."[138] Both RBMPs also commit Scotland's public bodies to working in partnership with businesses, land managers and voluntary groups and organisations.[139] However, the list of partnerships that supplements this commitment in the Scotland river basin district RBMP suggests a strong focus on NGO involvement in planning, and reveals no specific CBM activities.[140] The only specific commitment in that RBMP that may entail CBM is the promise to work with "voluntary organisations and other institutions… to carry out and coordinate the monitoring needed to give us early warning of… new invasive species, including encouraging help from businesses and the public."[141]

Although the Scottish government may not be using CBM data very extensively in the water context, SEPA has commissioned the creation of citizen science-related resources that may be able to support future water-related CBM in Scotland and/or other jurisdictions. For example, a SEPA-funded 2014 Centre for Ecology & Hydrology (CEH) report provides a strategic framework for deciding whether and

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[131] SE, "Portal", *supra* note 130.
[132] The Riverfly Partnership, "Riverflies", online: <www.riverflies.org/riverflies-1>.
[133] The Riverfly Partnership, "Anglers' Riverfly Monitoring Initiative", online: www.riverflies.org/rp-riverfly-monitoring-initiative [Riverfly, "ARMI"].
[134] *Ibid*.
[135] See The Riverfly Partnership, "Press releases", online: <www.riverflies.org/press-releases>.
[136] Riverfly, "ARMI"; The Riverfly Partnership, "Newsletter" (2017) 4:2 at 1, online: <www.riverflies.org/sites/172.16.0.99.riverflies.local/files/RP%20Newsletter%20vol%204%20issue%202%202017.pdf>.
[137] NS, "Scotland RBMP", *supra* note 126 at 10; NS, "Solway Tweed RBMP", *supra* note 126 at 16.
[138] *Ibid*; *ibid*.
[139] NS, "Scotland RBMP", *supra* note 126 at 4; NS, "Solway Tweed RBMP", *supra* note 126 at 4.
[140] Natural Scotland, "Appendices to the river basin management plan for the Scotland river basin district: 2015-2027" (21 December 2015), Appendix 8, online: <https://www.sepa.org.uk/media/163444/appendices-to-the-river-basin-management-plan-for-the-scotland-river-bsin-district-2015-2027.pdf>.
[141] NS, "Scotland RBMP", *supra* note 126 at 39.

when to use a citizen science approach for environmental monitoring.[142] CEH also released a simplified guide to the framework with SEPA support.[143]

Public Access to Data

Scottish CBM water data is available through the Riverfly Partnership's online data repository for ARMI. Launched in 2014, this online tool maps all the ARMI sites across the UK, and provides public access to site-specific ARMI data.[144] Graphs depict changing riverfly taxon abundance over time, often in relation to the minimum abundance threshold or 'trigger level' for a given monitoring site (see Figure 7).[145] Interested users can also search for data by catchment, river, site, or ARMI group.[146] The UK-wide map of ARMI sites indicates that Scottish monitoring is taking place primarily in southern Scotland, although monitoring has also occurred at a handful of sites in the Highlands.[147]

Date	Score	Site Threshold	Site name	River name
Apr 13, 2009	13		Site 4 - River Avon @ Lovell's Glen	Avon, Scotland
May 17, 2009	13		Site 4 - River Avon @ Lovell's Glen	Avon, Scotland
Jun 29, 2009	18		Site 4 - River Avon @ Lovell's Glen	Avon, Scotland
Jul 27, 2009	16		Site 4 - River Avon @ Lovell's Glen	Avon, Scotland
Sep 20, 2009	13		Site 4 - River Avon @ Lovell's Glen	Avon, Scotland
Nov 8, 2009	13	8	Site 4 - River Avon @ Lovell's Glen	Avon, Scotland
Mar 21, 2010	10	8	Site 4 - River Avon @ Lovell's Glen	Avon, Scotland
Apr 27, 2010	12	8	Site 4 - River Avon @ Lovell's Glen	Avon, Scotland
May 31, 2010	13		Site 4 - River Avon @ Lovell's Glen	Avon, Scotland
Jun 28, 2010	16		Site 4 - River Avon @ Lovell's Glen	Avon, Scotland

Figure 7: Target Group Abundance over time, River Avon @ Lovell's Glen [148]

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[142] Michael Pocock et al, *A Strategic Framework to Supplement the Implementation of Citizen Science for Environmental Monitoring: Final Report to SEPA* (Wallingford, UK: Centre for Ecology & Hydrology, May 2014), online: <https://www.ceh.ac.uk/sites/default/files/hp1114final_5_complete.pdf>.

[143] Michael Pocock et al, "Choosing and Using Citizen Science: a guide to when and how to use citizen science to monitor biodiversity and the environment" Centre for Ecology & Hydrology (2014), online: <https://www.ceh.ac.uk/sites/default/files/sepa_choosingandusingcitizenscience_interactive_4web_final_amended-blue1.pdf>.

[144] Ben Fitch, "Riverfly Partnership launches online database for ARMI" The Riverfly Partnership (23 July 2014), online: <www.riverflies.org/riverfly-partnership-launches-online-database-armi>.

[145] The Riverfly Partnership, "Graphs – Target Group Abundance", online: <www.riverflies.org/graphs-target-group-abundance> [Riverfly, "Graphs"].

[146] The Riverfly Partnership, "Open Data", online: <www.riverflies.org/open-data>.

[147] The Riverfly Partnership, "Maps – Target Group Abundance", online: <www.riverflies.org/maps-target-group-abundance> [Riverfly, "Maps"].

[148] The Riverfly Partnership, "Graphs – Target Group Abundance", online: <www.riverflies.org/graphs-target-group-abundance>, image courtesy of the Riverfly Partnership. The dataset is too large to be clearly represented in Figure 7 – to view the full dataset, select "Avon, Scotland".

The Riverfly Partnership ensures ARMI data integrity by requiring volunteers who wish to upload data to register and indicate whether their local Ecology Contact has approved their monitoring site and set a trigger level.[149] If monitoring data uploaded by a registered volunteer suggest that taxon abundance for a site has fallen below the applicable trigger level, the local ARMI group coordinator will verify those results and alert the local Ecology Contact.[150] Volunteers can use the system track what actions are taken in response to their results.[151]

SEPA's Water Environment Hub and Water Classification Hub databases are far more comprehensive than the ARMI data repository. Both Water Hubs use Spotfire, a visual data analysis tool, to overlay multiple sets of environmental data and allow users to filter them in various ways.[152] The Water Environment Hub[153] presents "the story of Scotland's water environment" by comparing actual water conditions in 2014 with projected conditions in 2021, 2027, and the longer term, and indicating planned restoration actions and restoration timelines in response to localized water quality pressures. Users can generate nation-wide GIS maps (see Figure 8), charts, and data using multiple variables, including condition metric (*e.g.* water quality or fish migration access), water type, and year. Users can also choose to filter which water bodies are shown by location, condition, category, and/or designation.

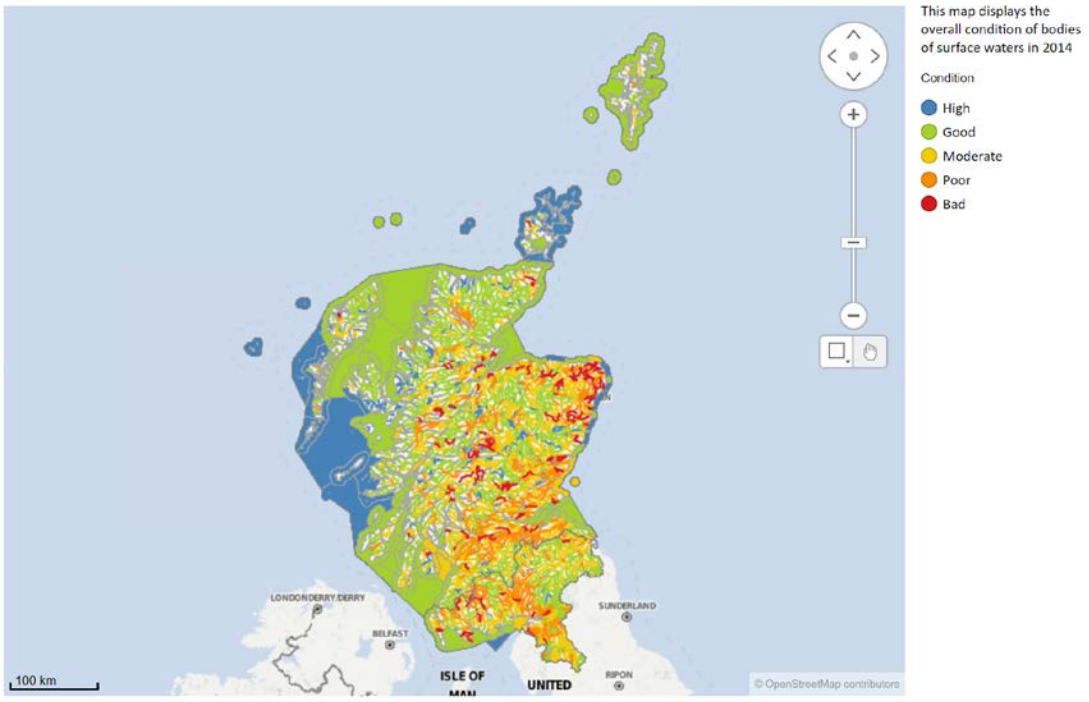

Figure 8: Water Environment Hub: Overall Condition of Bodies of Surface Waters in 2014[154]

[149] The Riverfly Partnership, "Register", online: <www.riverflies.org/register>.
[150] Fitch, *supra* note 145.
[151] The Riverfly Partnership, "ARMI Data", online: <www.riverflies.org/riverflies-gis-home>.
[152] SEPAView, "Spotfire – a new, innovative way to display water quality information" (20 June 2013), online: <https://www.sepaview.com/2013/06/spotfire-a-new-innovative-way-to-display-water-quality-information/>.
[153] SEPA, "Water Environment Hub", *supra* note 127.
[154] *Ibid*, "Overall condition of bodies of surface waters in 2014". This map contains SEPA data © Scottish Environment Protection Agency and database right 2015. All rights reserved. It is reproduced from Ordnance Survey material with the permission of Ordnance Survey on behalf of the Controller of Her Majesty's Stationery Office © Crown Copyright. Any

Water Environment Hub users can also search for detailed information on a single water body (see Figure 9) to view a breakdown of its current and projected condition, as well as when and how impacted aspects of its current condition will be addressed to bring it in line with the "Good" standard required by the WFD.

River Garry from Garry Intake to Errochty Water confluence is a river (ID: 6911), in the River Tay catchment of the Scotland river basin district. The main stem is approximately 13.2 kilometres in length. The water body has been designated as a heavily modified water body on account of physical alterations that cannot be addressed without a significant impact on water storage for hydroelectricity generation.

Condition in 2014 and future objectives

	2014	2021	2027	Long Term
Overall	Bad	Good	Good	Good
Access for fish migration	Poor	Good	Good	Good
Water flows and levels	Bad	Good	Good	Good
Physical condition	Good	Good	Good	Good
Freedom from invasive species	High	High	High	High
Water quality	Good	Good	Good	Good

Hover over the 'When will it be addressed?' column to view further explanations, if present. Note: if no pressures are shown below there are no pressures present for this water body or protected area.

Impacted Condition	What pressures are responsible?	What activity is responsible?	How will the pressure be addressed?	Who is responsible?	When will it be addressed?
Access for fish migration	Barrier to fish migration	Hydroelectricity generation	Regulation	SEPA and the business responsible (SEPA and the business responsible)	2015-2021
Water flows and levels	Water abstraction	Hydroelectricity generation	Regulation	SEPA and the business responsible	2009-2015
	Water storage	Hydroelectricity generation	Regulation	SEPA and the business responsible	2009-2015

Further explanation/comments on pressures (if available)

284: Fish Barrier ID. Barrier is on this wb.

Article 4 explanation links

Theme	Were cycle one objecti...	2021 - Reason for not meeting good...	2027 - Reason for not meeting ...	Link to informa...
Access for fish ...	No			BARRC1

Figure 9: Water Environment Hub: Detailed Information on a Single Water Body[155]

The Water Classification Hub[156] functions similarly to the Water Environment Hub, but serves a different purpose. Rather than predicting future water quality, it shows the annual classification status of surface waters, ground waters, and protected areas in Scotland from 2007-2016. Like the Water Environment Hub, the Water Classification Hub allows users to generate nation-wide maps, charts, and data. However, data are available for 10 years, and the range of available condition variables is also significantly broader – for example, users can choose to view surface water status based on the presence of alien species, dissolved oxygen levels, mercury levels, or pH levels. Location, condition, category, and designation filters are also available. Searching for detailed information on a single water

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[155] *Ibid*, 6911: River Garry from Garry Intake to Errochty Water confluence. This image contains SEPA data © Scottish Environment Protection Agency and database right 2015. All rights reserved. The following terms and conditions govern any further use of these data: Scottish Environment Protection Agency, "Terms and Conditions of Use of Data" (February 2016), online: <https://www.sepa.org.uk/media/219134/sepa-general-data-reuse-statement-v31.pdf>.

[156] SEPA, Water Classification Hub, *supra* note 128.

body in the Water Classification Hub will generate a breakdown of actual water quality from 2008-2016 based on nearly thirty measurement parameters (see Figure 10).

River Garry from Garry Intake to Errochty Water confluence is a river (ID: 6911), in the River Tay catchment of the Scotland river basin district. The main stem is approximately 13.2 kilometres in length. The water body has been designated as a heavily modified water body on account of physical alterations that cannot be addressed without a significant impact on water storage for hydroelectricity generation.

Water classification data for selected water body

ID	Name	Parameter	2008	2009	2010	2011	2012	2013	2014	2015
6911	River Garry from Garry Intake to Errochty Water confluence	1: Overall status	Bad ecological...	Bad ecological...	Bad ecological...	Bad ecological...	Bad ecological...	Bad ecological...	Bad ecological...	Bad ecological...
		1-1: Pre-HMWB status	Bad	Bad	Bad	Bad	Bad	Bad	Bad	Bad
		1-3: Overall ecology	Bad	Bad	Bad	Bad	Bad	Bad	Bad	Bad
		1-3-1: Physico-Chem	High	High	High	High	High	High	High	Good
		1-3-1-1: Temperature	High	High	High	High	High	High	High	High
		1-3-1-2: Soluble reactive phosphorus	High	High	High	High	High	High	High	High
		1-3-1-4: Dissolved Oxygen	High	High	High	High	High	High	High	High
		1-3-1-9: Acidity	-	-	-	-	-	High	High	Good
		1-3-1-9-2: pH	High	High	High	High	High	High	High	Good
		1-3-2: Biological elements	Poor	Poor	Poor	Poor	Poor	Poor	Poor	Poor

Figure 10: Water Classification Hub: Detailed Information on a Single Water Body[157]

It is unclear whether SEPA's Water Hubs currently contain any CBM data, although the Water Environment Hub's terms and conditions do refer to the possibility of incorporating information from non-government sources. Apparently, "some organizations have asked for the opportunity to share their environmental data to help improve river basin management and catchment planning" by providing "data and information to improve local evidence on the cause of a problem… or a new response to a problem".[158] Interested parties are invited to contact their local SEPA RBMP Co-ordinator to learn more.[159] This suggests SEPA may choose to incorporate CBM data into the Water Environment Hub in future, even if it has not yet done so. Although the Water Classification Hub's terms and conditions do not currently highlight this possibility, that Hub's role as a source of detailed annual classification data may make it an even better candidate for CBM data integration if these data are used to facilitate the classification of certain surface waters in future years.

Finland

WFD Implementation, CBM Initiatives, and Government Use of CBM Data

Finland has a long history of water-focused CBM. Not only have Finnish volunteer monitors been measuring water levels and other hydrological indicators since the early 20th century, they also collected and analyzed water quality samples at 200 stations between 1913 and 1931, until the Great Depression

[157] *Ibid*, 6911: River Garry from Garry Intake to Errochty Water confluence". This image contains SEPA data © Scottish Environment Protection Agency and database right 2016. All rights reserved. The map is covered by copyright © OpenStreetMap contributors, <www.openstreetmap.org/copyright>. Some features of this map are based on digital spatial data licenced from the Centre for Ecology and Hydrology, © NERC. The following terms and conditions govern any further use of these data: Scottish Environment Protection Agency, "Terms and Conditions of Use of Data" (February 2016), online: <https://www.sepa.org.uk/media/219134/sepa-general-data-reuse-statement-v31.pdf>. The dataset is too large to be clearly represented in Figure 11.

[158] SEPA, "Water Environment Hub", *supra* note 127, Terms and Conditions.

[159] *Ibid*.

ended that monitoring program.[160] In the 21st century, Finland has redesigned its environmental monitoring to be compatible with EU rules, and has tried to reduce monitoring costs since the 2008 recession – in part through "increased use of applications of citizen science and increased co-operation between the public, private and voluntary sectors".[161] In terms of WFD implementation, Finland adopted second-cycle RBMPs for its eight river basin districts in December 2015.[162] As of 2015, 85 percent of the surface area of Finnish lakes and 65 percent of the surface area of Finnish rivers was in good or excellent condition in 2015, but up to 75 percent of the surface area of Finnish coastal waters was in poorer condition.[163] The Finnish government has recently invested in technical infrastructure for collecting, managing, sharing, and using environmental data through the Envibase project, a collaboration between the Finnish Environment Institute (SYKE) and two other government institutions.[164] Launched in 2015, Envibase is intended to build capacity for environmental observation, "produce concrete tools… to support environmental monitoring and research" and "promote the… harmonisation and open use of information on the environment".[165] Redesigning how citizen observations are used in environmental monitoring is one of Envibase's key objectives.[166] The Envibase webpage on citizen observation services discusses mobile communications technology's ability to facilitate faster, more flexible CBM data collection, and the necessity of managing and sharing CBM data in a centralized way to maximize its usefulness.[167]

SYKE supports freshwater CBM through Järviwiki, a multi-lingual web service that crowd-sources observations and photos on Finnish lakes.[168] SYKE has also partnered with schools in Western Finland to teach students about observing waterway conditions, how to use SYKE's open data monitoring systems, and how to construct simple digital monitoring devices.[169]

Public Access to Data

SYKE launched Järviwiki in 2011 to promote citizen engagement with local water protection and monitoring, and continues to support its operation through open-source software upgrades, limited

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[160] J Kettunen et al, "Changing role of citizens in national environmental monitoring" in C Capineri et al (eds), *European Handbook of Crowdsourced Geographic Information* (London: Ubiquity Press, 2016) 257 at 259 [Kettunen et al]
[161] *Ibid* at 265.
[162] Environment.fi, "River basin districts" (11 November 2013), online: <www.ymparisto.fi/en-US/Waters/Protection_of_waters/Planning_and_cooperation_in_river_basin_districts/River_basin_districts>; EC, Environment, "Finland" (8 June 2016), online: <ec.europa.eu/environment/water/participation/map_mc/countries/finland_en.htm>.
[163] Environment.fi, "State of the surface waters" (12 September 2017), online: <www.ymparisto.fi/en-US/Waters/State_of_the_surface_waters>.
[164] SYKE Finnish Environmental Institute, "ENVIBASE: Boosting the infrastructure of environmental data in Finland" (2015), online: <www.ymparisto.fi/download/noname/%7B2517DCE3-FA9D-49F0-95B6-7EFBF1480CFA%7D/113809> [SYKE, "ENVIBASE"].
[165] SYKE Finnish Environmental Institute, "Environmental information for common use" *Envelope: Newsletter of the Finnish Environment Institute SYKE* (December 2014), online: <mmm.multiedition.fi/syke/envelope/Envelope_2014_2/sivu_5.php>; Environment.fi, "Envibase: Capacity building for environmental observations in Finland" (20 December 2017), online: <http://www.ymparisto.fi/en-US/Envibase>. The Environment.fi site is jointly produced and run by the Ministry of the Environment, SYKE, the Centres for Economic Development, Transport and the Environment, and Regional State Administrative Agencies.
[166] SYKE, "ENVIBASE", *supra* note 165.
[167] Environment.fi, "Envibase: Citizen observation services" (21 September 2016), online: <www.ymparisto.fi/en-US/Envibase/Subprojects/Citizen_observation_services>.
[168] SYKE Finnish Environment Institute, "Järviwiki is about Finnish lakes and sea areas" (20 April 2017), online: <www.jarviwiki.fi/wiki/Main_page> [SYKE, "Järviwiki"].
[169] SYKE Finnish Environment Institute, "Citizens and NGO's – examples of collaboration" (28 February 2018), online: <www.syke.fi/en-US/Services/Citizens_and_NGOs__examples_of_collabora(43453)>.

moderation, and a summer helpline.[170] Anyone can access this freely editable, community based wiki service, but users who want to contribute images and/or observations on water temperature, ice thickness, algal blooms, or other Finnish lake conditions must register first.[171] Users can also take part in discussions on the site. As of 2014, users were uploading over 9,000 observations annually, and site visits were increasing by 25 percent annually.[172] Two hundred users contributed data to Järviwiki in the summer of 2014, 30 contributed data in the winter, and almost 280,000 users visited the site that year.[173]

Unlike many of the other databases discussed in this report, CBM data are not pre-moderated. However, data are colour-coded based on the uploader's level of experience to help users gauge the likelihood of accuracy. Data added by users who have contributed at least 100 edits over 6 or more months of membership appear with an 'Experienced User' tag, while data added by water experts or other individuals with observation training receive an 'Expert' tag. Official information uploaded by SYKE personnel receives an 'Authority' tag.[174] Järviwiki's textual and numerical content is licenced under Creative Commons Attribution licence.[175]

In addition to supporting Järviwiki, SYKE produces its own open data on water resources, surface and ground waters, and other aspects of the environment.[176] SYKE also runs a Metadata Portal[177] that pulls together multiple datasets from different sources, including its River Basin Management dataset (see Figure 11).[178] However, the Metadata Portal is not as user friendly as other databases discussed in this report, and many of the datasets it integrates are only available in Finnish.[179] Additionally, the Metadata Portal does not appear to integrate data from Jarviwiki, and it is unclear whether it integrates CBM data from other sources.

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[170] Kettunen et al, *supra* note 161 at 262.
[171] *Ibid*; SYKE Finnish Environment Institute, "Järviwiki: Terms of use" (1 February 2012), online: <www.jarviwiki.fi/wiki/J%C3%A4rviwiki:Terms_of_use> [SYKE, "Järviwiki: Terms"].
[172] Kettunen et al, *supra* note 161 at 262.
[173] *Ibid*.
[174] *Ibid* at 265.
[175] SYKE, "Järviwiki: Terms", *supra* note 172.
[176] SYKE Finnish Environment Institute, "Open information", (12 March 2018), online: <www.syke.fi/openinformation> [SYKE, "Open information"].
[177] SYKE Finnish Environment Institute, "Metatieto Metadata Portal", online: <metatieto.ymparisto.fi:8080/geoportal/catalog/search/search.page> [SYKE, "Metadata Portal"].
[178] SYKE, "Open information", *supra* note 177.
[179] *Ibid*.

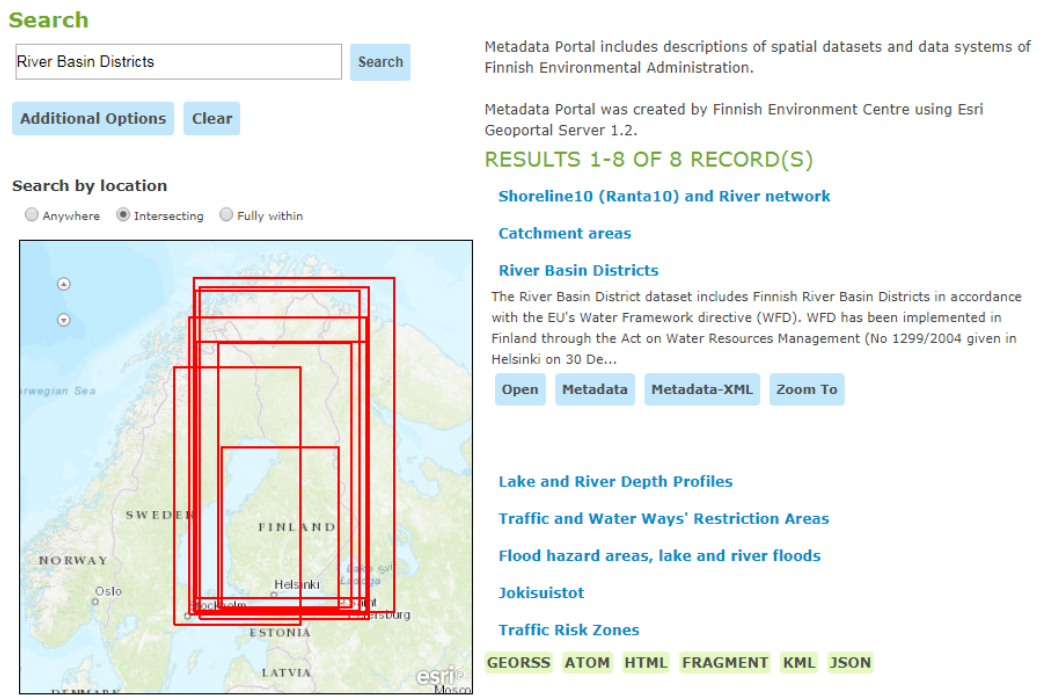

Figure 11: River Basin Districts Highlighted in Finland's SYKE Meta-Database[180]

Summary and Application in Canada

The WFD pairs broad, centralized water protection requirements, ambitious timelines, and transparent planning with flexible local implementation, and may be a useful model for Canada, where jurisdiction over water is shared between different levels of government in complex ways.[181] Implementing a national agreement along with lines of the WFD at the provincial level could be an effective way for a multi-jurisdictional country like Canada to ensure all regions are consistent in their data collection and aim for a uniform standard of water quality. Additionally, requiring both forward- and backward-looking planning and reporting would increase transparency, and improve Canada's chances of achieving baseline water health in every river basin. However, implementing something like the WFD in Canada would likely require more explicit inclusion of CBM to conduct the massive amount of monitoring that would be needed to track water quality in every river basin in Canada.

Scotland's Water Hubs provide an excellent model for communicating water quality data to the public and could serve as a strong model for a future Canadian water database that incorporates both government and CBM data. In the Canadian context, their multi-layer functionality could be used to clearly present government and quality-tested CBM data alongside each other, allowing users to distinguish data sources if desired. The backward- and forward-looking nature of SEPA's two Water Hubs could also be a useful feature for provinces to adopt, particularly if Canada also establishes national water quality goals with a set timeline.

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[180] SYKE, "Metadata Portal", *supra* note 178, image courtesy of the SYKE Finnish Environment Institute.
[181] See, *e.g.*, Deborah Curran, "Water law as a Watershed Endeavour: Federal Inactivity as an Opportunity for Local Initiative" (2015) 28 J Envtl L & Prac 53.

Finland's Järviwiki also provides a possible model for Canadian jurisdictions. Provinces that are willing to provide some CBM support, but unwilling to devote the amount of civil servant time required to check data quality and upload it in a timely manner, could create a similar wiki-style platform to collect and share CBM water observations without pre-moderation.

4. Methodology

The case studies presented in this report were generally identified through national or supranational-level environmental department webpages, although Oregon was specifically recommended by various individuals involved in the project. CBM initiatives in each jurisdiction were primarily identified through references to water-related volunteering and citizen science on government websites and/or in government reports. EU case studies selections were based in part on the availability of English-language information about water-related CBM initiatives in those jurisdictions. Government interactions with CBM groups and/or CBM data were identified through reciprocal references on CBM and government webpages. Where possible, older information was verified and updated through telephone conversations with civil servants involved in implementing the CBM programs in question.

5. Application in Canada

Governments in the United States, Australia, and the European Union are taking advantage of CBM data to supplement government water quality monitoring. Each jurisdiction discussed in this report offers unique lessons that can be applied in the Canadian context.

Drawing on the American examples, Environment and Climate Change Canada could build on the EPA's past practices and provide coordination and cohesive CBM guidance across provincial and territorial jurisdictions, through QAPPs or something similar. Canada could seek to emulate the NEP's use of integrated CBM and government data to create comprehensive conservation and management plans for estuaries and other Canadian waterways. Provincial and territorial governments could encourage CBM groups to sample waters of particular concern as frequently as Friends of the Bay does. Provincial and territorial environment ministries could also model their own CBM-related activities on many of Oregon's current and imminent practices, including integrating CBM water quality data with government data (current), allowing CBM volunteers to upload their own data to a government database (imminent), having civil servants perform quality control checks (current), using high-quality CBM data in government reports (current), and making CBM data available to the public alongside government data in a timely way (imminent).

Drawing on the Australian examples, Environment and Climate Change Canada could use the NWQMS Monitoring Guidelines as a starting point for creating Canadian guidelines on establishing and monitoring a modern CBM program, which could help to standardize CBM activities across the country. The Australian practice of including community stakeholders in water management planning is also a positive one that Canada could seek to emulate. Waterwatch Victoria's extensive network of CBM volunteers may provide a useful precedent for Canadian jurisdictions seeking to engage CBM volunteers on a similar scale, and their use of Creative Commons licencing is also something Canadian governments should consider. If particular provincial or territorial governments are not prepared to create and operate a publicly accessible water quality database that integrates CBM data, then they should seriously consider emulating the Waterwatch Victoria model by providing database funding and quality control support to particularly active CBM groups. Provincial and territorial governments who *are* prepared to create and operate their own database may wish to consider South Australia's forthcoming SWIMS database as a possible model. If voluntary CBM activity ultimately falls short of government expectations in some regions, provincial and territorial governments may be able to supplement these data by requiring water users to provide regular water quality reports or pulling data from existing water user reports.

Drawing on the European examples, the WFD could be a useful model for a national Canadian water strategy with uniform quality requirements, clear planning requirements and timelines, and a significant degree of implementation flexibility at the provincial and territorial level. An explicit commitment to supplement government monitoring with CBM data would likely be necessary to make the WFD model work in Canada. Canadian provinces and territories should seriously consider modeling their own water quality databases on Scotland's Water Hubs, and could use the same software to transparently present past and current government- and CBM-collected water quality data alongside future projections. Finally, if particular provincial or territorial governments are not prepared to run their own database or

provide the amount of civil servant support Waterwatch Victoria receives, then the moderation-free Finnish wiki model may be a feasible alternative.

Implementing any or all of these internationally tested models and methods would significantly increase the amount of water quality data that is available to Canadian decision-makers.. It could provide a clearer understanding of the impacts of industry on local watersheds, point to major shifts in ecosystems as climate change continues, and support data-driven decision-making. By actively promoting the collection of CBM data, its integration into government decision-making, and its communication to the public, we can transform the way we understand water law and become more proactive and less reactionary to water needs.

Future Research

Future research could evaluate Canada's constitution framework and provincial ministerial mandates to see how a national water quality framework could fit into Canada's legal structure. Future research could also involve contacting CBM groups whose water data are being used by governments to gain additional insight into how CBM data collection, integration, and communication currently works on the ground. Best practices for QA/QC methods and for choosing what types of data to collect will also need to be confirmed. Varying government needs and CBM group abilities will need to be considered. The Scottish CBM decision framework and accompanying guide to choosing when and how to use CBM may provide useful starting points for this work.[182]

[182] Pocock et al, *supra* notes 143 & 144.