Working Paper

Water accounting at Statistics Canada:

The inland fresh water assets account

Paper produced for the

London Group of Environmental Accounting

Rome, November 2003

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National Environmental Accounting in Canada: Water Accounts

The development of water accounts, from a national accounting perspective, can be defined as: the process of systematically measuring the renewal, flow and stock of surface and sub-surface water, in physical, quality and monetary terms. The main purpose behind the development of the Canadian Water Accounts (CWA) is to have an accounting framework for water that will provide information on the disposition and flow of water assets in Canada. The focus of this paper is the ongoing water accounting research and development that is taking place at Statistics Canada, with a particular emphasis on asset accounting. The Canadian Water Accounts (CWA) currently consist of physical economic flow accounts and hybrid flow accounts. Research is now underway towards the development of a water assets (stock) account.

Given the importance of water renewal and the magnitude of the movement of water within the hydrological cycle, it is generally considered that flows of water are more significant than the stocks. It follows that physical flows accounts are a useful starting point in building water accounts. This is partly the case at Statistics Canada, where physical flows within the economy have been bench marked for four separate occasions, the last time stamp being 1996. Canada has however yet to produce complete physical accounts for water flows within the environment, a necessary step on the path to creating an adequate asset account.

Building the water assets account is an important step in assessing the sustainability of socio-economic activities. Water assets are part of the stocks of goods and services that provide the many environmental inputs required to support socio-economic activity. The behaviour of water assets over time, both quantitatively and qualitatively, indicate the long-term reliability of water resources. Knowledge of this behaviour is crucial when measuring the decoupling of economic growth from environmental pressures, a fundamental tenet of sustainable development [OECD, 2002]. If the growth of socio-economic activities is to be sustainable, the capacity of the stocks of natural capital to furnish these inputs must be maintained over time. Either that or a substitute, capable of delivering an equivalent input, must be found [SEEA, 2003, 1.51]. Generally speaking, there exists no known substitute to water.

This paper examines the concept of environment accounting, and how it is applied to water accounts in Canada. It then turns to an analysis of the handbook of Integrated Environmental and Economic Accounting 2003, specifically looking at the asset classification and how it applies in building the water assets account. The paper then presents the methodology used to produce an initial estimate of water assets, and offers a discussion on an application of the account.

Environmental Accounts

Environmental accounts, although rooted in resource accounting, go beyond the measure of natural resources in purely physical terms. Environmental accounts aggregate national data by linking the environment with the economy, providing an analytical framework, which allows the analysis of both. Ideally the accounts would be focused on answering important policy questions, not simply driven by a desire to build databases. These accounts will have a long run impact on both economic and environmental policy making [Hecht, 1999]. In the absence of such information, policy decisions are taken without a clear understanding of consequences on all users of environmental goods and services.

This is explained by the fact that the accounting approach has numerous advantages. They include: the reconciliation of data from different sources; the bringing together of spatial-temporal references to make the coding of the data coherent; to combining of stock and flows in a budget structure; and the integration of environmental "elements" and economic "agents" to allow not only a global accounting, but also an analytical one [Babillot and Margat, 1999].

These accounts entail comprehensive coverage rather that providing micro data about individual cases, and contain time series data produced on a regular basis. For these reasons such accounts will always provide national figures, with appropriate levels of spatial disaggregation for meso-level data.

In the case of water, accounts should help to clarify issues such as the impact of water use on water availability and quality, both within and outside the economy. A full set of environmental accounts should provide the same answers for other stocks of natural capital, such as forests and land, and allow the analysis to be conducted in an integrated manner, e.g. the relationship between deforestation, change in land use and water availability.

One advantage of compiling water accounts versus simple water statistics is that indicators are derived from an accounting system in which economic and environmental information are presented side by side, using common classifications and definitions. Thus users can link physical and monetary data in a consistent framework to study the impact on the environment of different sectors of the economy and the resource requirements by the economy as a result of structural changes. The accounts offer an integrated view of water supply and uses by industry and by purpose.

The main thrust for building such accounts is therefore that they will provide governments with the necessary tools for developing sustainable economies. This goal is however not achieved, mainly because accounts include neither meaningful adjusted macroeconomics indicators (such as a "green GDP"), nor the value of the non-marketed environmental good and services [Hecht, 2000]. Nevertheless, environmental accounts do provide indicators of macroeconomic performance that take into account the environment as a producer of welfare. In Canada, these indicators are produced by the Canadian System of Environmental and Resource Accounts.

Canadian System of Environmental and Resource Accounts

Developed to provide an environmental dimension to the Canadian System of National Accounts (SNA), the Canadian System of Environmental and Resource Accounts (CSERA) responds to the need for better monitoring of the relationships between economic activity and the environment [Statistics Canada, 1997] Statistics Canada's principal economic statistical framework, the *Canadian System of National Accounts*, has been extended to include measures of the environment's contribution to economic activity and of the economy's effects on the environment. The CSERA has been developed with the specific objective of organizing physical and monetary statistics related to the environment using classifications, concepts and methods that are compatible with the *Canadian System of National Accounts*. Selected sets of existing Statistics Canada economic data have been disaggregated and reorganized to make more explicit environmental information they represented. Various environmental data sets collected by other federal and provincial government departments have been integrated with Statistics Canada's economic statistics to allow a more complete analysis of the relationship between economic activity and the environment. In short, CSERA has three components:

- Natural Resource Stock Accounts: these accounts hold detailed statistics on the size of Canada's natural resource stocks and their contribution to national wealth, as measured in the SNA.

- Material and Energy Flow Accounts: these accounts hold data pertaining to the extraction and use of natural resources by businesses, households and governments. They also gather statistics on the generation of various wastes by industries, households and governments, and on the management of these wastes.

- Environmental Protection Expenditure Accounts: these accounts hold data on expenditures made by businesses, households and governments for the purpose of environmental protection.

Amongst the three components are distributed data on subsoil, timber and land assets, and energy and water flows. These flows for water are limited to economic or sub-economic transactions involving socio-economic water users, and are compiled in an Economic Water Flow Account. The water assets account is not yet compiled in part because one aspect of the CSERA, the spatial component, needs to be developed further. This component, one that arguably cross-cuts all type of environmental accounts, is explored next.

Spatial Environmental Information System

An important aspect of the CSERA, one that cross-cuts these three CSERA components described in the introduction, is that of geography. Some of the accounts, such as Land Accounts, are geo-referenced, while others, such as Timber Assets or the Sub-soil Assets accounts, do not yet have detailed spatial attributes. Those accounts with the spatial attribute are brought together in the Spatial Environmental Information System (SEIS). Environmental geographic units, such as terrestrial ecozones and drainage basins, as well as statistical, administrative and political boundaries, are maintained in SEIS. SEIS holds data that describe the actual geography of the land, i.e. physical foundation, land cover and land use, but also census, survey and remote sensing information.

The water assets account could not be developed without the framework provided by the SEIS. The SEIS: provides the spatial dimension that is required to model hydrologic attributes that are not measured; allows for interpolation between data points when data is measured; and, it enables us to reconcile partial data sets that are complementary. The SEIS is, in fact, the system that allows spatial accounting. All of these aspects will be presented in the section on the water balance.

The Canadian Digital Drainage Area Framework

The SEIS also supports Statistics Canada's accounting application of the Canadian digital drainage area framework (CDDAF)[1]. This framework consists of several layers of hydrological features, including rivers, lakes and watershed boundaries. The layers are built as a database in a nested hierarchy depicting the drainage system in Canada, from the five ocean drainage basins down to 978 sub-sub-basins. The framework also includes the location of 3,500 hydrometric stations and their respective drainage areas. The framework represents a major improvement, in terms of integration, precision and standardization, over what was available in the past. It allows for detailed analysis of human activity and surface water levels, run-off, flood and drought, hydroelectric potential and water quality. It is also a tool for planning, analyzing and managing environmental monitoring networks, particularly the hydrometric, water quality and climate networks.

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[1] CDDAF was created through a three-year partnership between Statistics Canada's Environment Accounts and Statistics Division and two other federal departments: Natural Resources Canada and Environment Canada. It is available free online on the Natural Resources Canada Geogratis website (http://geogratis.cgdi.gc.ca/). The drainage area layers are to become have become a formal Sa Statistics Canada Standard Geography.

The watershed is widely recognized as a logical unit for integrating, analyzing and presenting hydrological, environmental and socio-economic information. This is especially true in environmental accounting, where the drainage hierarchy can be compared, to some degree, to the Input-Output system of the SNA. This aspect will be further developed in the section titled “Surface Water Balance”.

This paper has tried, so far, to explain the benefits of using an accounting framework to report on water assets and flows. It has also briefly reviewed the application of the national environmental accounting framework in Canada. The remainder of this paper describes the specifics of accounting for water assets, starting with a review of the accounting framework.

The System of integrated Economic and Environmental Accounting

The 2003 System of integrated Economic and Environmental Accounting (SEEA) represents a major development over its predecessor, published as an appendix in the *Handbook of National Accounting* [United Nations, 1993]. SEEA is designed around flow accounts that measure transactions within the economy and stock accounts that identify national assets and liabilities [Harris and Fraser, 2002]. This section analyses how water is classified in SEEA, and reviews challenges that Canada will have to meet in developing the Water Assets table. This section also suggests some modifications to SEEA-defined assets, either in the core or the periphery of the table.

Asset Classification

There were two major changes in the classification of water in SEEA as compared with the 1993 Handbook. First, surface water volume was not recognized as an explicit asset in 1993, but appeared only in association with land areas (Figure 1, EA24). SEEA now recognizes freshwater resources as a distinct natural resource asset – a resource that can be extracted from the environment and brought into the economic system for use in a variety of ways. (Figure 1, EA1).

Second, groundwater resources were considered as a distinct asset in the 1993 handbook, but only as long as scarcity led to the “enforcement of ownership and/or use rights, market valuation and some measure of economic control”. In 2003, all groundwater resources are recognized, with the understanding that while certain resources may not provide benefits today, they provide option and bequest benefits for the future.

In SEEA, the classification system of environmental resources distinguishes between the stocks of natural resources, and system assets such as terrestrial and aquatic ecosystems. Stocks of natural resources can be divided between renewable and non-renewable resources, between economic assets covered by the SNA and those outside the SNA "boundary"[2], and between assets which may be consumed by the economy and those which may be used indirectly by the economy. In the case of physical accounts, a distinction is made between changes in quantity and changes in quality and/or the classification of the resource [SEEA, 2003]. What is particular about water is that water is found in each and every one of these categories; however, we cannot say that we currently have appropriate data for any one of those categories. In the next section, five examples of data-related issues, and three concept-related matters, are provided. These examples further demonstrate the need for water accounting research and development in Canada.

Figure 1

SEEA ASSET CLASSIFICATION

Asset Category
EA.1 Natural Resources
EA.13 Water resources (cubic metres)
EA.131 Surface water
EA.1311 In artificial reservoirs
EA.13111 For human use
EA.13112 For agricultural use
EA.13113 For electric power generation
EA.13114 For mixed use
EA.1312 In natural waterbodies
EA.13121 Lakes
EA. 13122 Rivers and streams
EA.132 Groundwater
EA.1141 Aquifers
EA.1142 Other groundwater
EA.2 Land and surface water (hectares)
Of which, recreational land
EA.24 Major waterbodies
EA.241 Lakes
EA.242 Rivers
EA.243 Wetlands
EA.244 Artificial reservoirs
EA.2441 For drinking water
EA.2442 For irrigation
EA.2443 For electric power generation
EA.2444 For multiple purposes
EA.25 Other land
EA.254 Permanent snow and ice

Source:
United Nations et. al. Integrated Environmental and Economic Accounting 2003 , Final draft circulated for information prior for official editing.

Data limitations

The measurement of the asset "Surface Water" (EA.131) in Canada is limited. It is widely quoted that Canada possesses 9% of the planets accessible freshwater stocks, and 20% of renewable water flows, but actual national estimates of run-off are dated (~1960) and coarse (1:7 million). Total stream flow statistics are occasionally produced, but only account for the largest rivers with no compilation of detailed statistics.

Water held in Artificial Reservoirs (EA. 1311) is not generally measured in Canada, even if a reservoir in Canada has been recognized as a significant component of the nation's hydrologic cycle. These reservoirs have the capacity to store

[2] The boundary divides those assets over which ownership rights have been established and are forced and that provide an economic benefit to the owner, from those that are not. (Vaze, 1997)

significant amounts of water. The occasional inventory of large dams in Canada [Canadian Dam Association, 2003] does not provide the amount of water contained by those dams, and neither does it give the amount that should be contained, i.e. the operational capacity of the reservoirs. But it does provide the *gross capacity,* i.e., the maximum amount of water that could be retained. Gross storage capacity in large dams is 880 km^3 of water, which represents 27% of total annual stream flow in Canada[3].

Lake volume (EA.1312) data in Canada is not generally available. The estimated two million lakes in Canada hold unknown volumes of water. Estimates of average volume exist for 80 of the largest lakes [Environment Canada, 1975; World Lakes Database, 2001]. Appropriate volume data would have to be estimated using detailed terrain elevation modelling, regression analysis, and other analytical methods.

Water held in Rivers (EA1313) is defined in SEEA as the average volume held in the riverbed. The attainment of this objective is unlikely in Canada, given the geographical scope of the country and the complexity of its hydrological network - there are more than 8500 named rivers in Canada, and countless other un-named rivers and streams. Instead, Canada will rely on the alternative that is proposed in SEEA, i.e. that of the mean annual run-off [SEEA, 2003, 8.112], equivalent to the "accumulated flow" concept proposed by Margat [1986; 1996].

Ground water (EA.132) is essential for many Canadians. In 1996 close to 9 million Canadians relied on ground water resources for their drinking water. Despite this reliance, Canada does not have a comprehensive national-scale inventory of its ground water resources (Geological Survey of Canada, 2003).

It is obvious that there are very real data challenges to developing a water assets account for Canada. But there are also some conceptual issues that seem to point to the need to adapt SEEA to Canada's needs. For example, some of the vital water resources in Canada, and some of the negative urban externalities are not included in the suggested SEEA asset classification.

First, in SEEA, glaciers are excluded from the water resources category. The reason given for this omission is that glacial ice is not abstracted, and that water abstraction does not affect the stock of glaciers, since it only occurs downstream. Although this reasoning may apply from the SNA asset boundary perspective, it does not take into consideration the natural capital perspective. Glaciers are an important component of the water supply

[3] This tells little about actual level of water resources actually stored; currently, reservoirs in northern Quebec are close to the minimum operational level

in Western Canada, where they represent the primary source for base flow[4]. The flow might not impact the stock, but the stock greatly impacts the flows. In other words, glaciers provide direct use benefits as well as option benefits. Glaciers definitely warrant a "special column" in the asset account. In comparison, the surface (area) measures for water included in the asset classification (EA24) hold little explanatory power[5], and the definition[6] could be improved upon. Also, precipitation that falls on glaciers and that does not sublimate eventually becomes streamflow; therefore one could argue that glaciers only retain precipitation for a time span determined by the characteristics of the glaciers, and the location of the precipitation.

Second, it can be argued that storm water be considered in SEEA's physical flow account. Although storm water could not necessarily be considered an asset or an emission, it represents a negative impact of urbanization that should be documented. In cities, snow accumulation needs to be removed, and rain precipitation is either channelled directly to a surface water body, or towards the municipal wastewater treatment plants, where it combines to the wastewater and, under normal circumstances, is treated. Detailing these water movements could benefit the SEEA framework as it would provide additional information regarding the cost/benefit of water related infrastructure and water treatment.

A third element which is not explicitly developed in the SEEA handbook is the necessity to have appropriate support from a geographical information system (GIS) and specialists, along with an adequate digital hydrological framework. For example, three dimensional interpolation methods that have been developed by the oil and gas industry to estimate reserves, can be applied to estimate groundwater. These techniques rely on the use of GIS. For surface water, a detailed digital hydrologic network needs to be coupled with climatic data, again using GIS. These techniques are explored in the remainder of this paper, in the context of estimating surface water areas and volumes for the Water Assets account.

Water assets account

The water assets account states the opening stock of water, describes the flows that account for variations of this initial stock, and state the stock at the end of the period. The flows represent transactions of water between the environment and the economy, and also movements of water within the hydrological cycle, as long as they account for the differences between the opening and closing stocks (SEEA, 2003, 8.74).

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[5] An estimated 12% of Canada, or 1.2 million km^2, is covered by lakes and rivers. While many provinces have a substantial amount of water in comparison to their population, only 3% of the area covered by water in Canada is located in inhabited regions.

[6] "bodies of water large enough to be separately identified from the surrounding land" [SEEA 2003, 7.70].

Figure 2 is the water assets account table for surface water and groundwater resources, as it is suggested in the SEEA manual. The classification of water resources does not include water in soil and vegetation, snow and ice, although it was earlier argued that Canadian tables should include glacial ice, in a separate column. The alternative could be to account for "solid water" in Glacier, Permafrost and Permanent Snow Accounts.

Figure 2

Table 8.7 An asset account for inland water

Million cubic metres

		EA.131 Surface water			EA.132 Ground-water	Total
		EA.1311 Reservoirs	EA.1312 Lakes	EA.1313 Rivers		
Opening Stocks		1 500	2 700	300	150 000	154 500
Abstraction (-)		1 580		972	765	3 316
Residuals (+)	Returns from irrigation			47	50	97
	Wastewater			441	268	709
	Lost water in transport			141	300	441
	Others			1 457		1 457
Net precipitation (+)			100	2 175		2 275
Inflows (+)				9 000	1 100	10 100
Net natural transfers (+/-)		1 650	110	-1 715	- 45	0
Evaporation from water bodies (-)		170	216	133		519
Outflows (-)	To other country			2 300	380	2 680
	To the sea			8 000	1 000	9 000
Other Volume changes	Due to natural disaster					
	Discovery (+)					
	Others					
Closing Stocks		1 400	2 694	300	149 229	153 623

Source: Constructed water example.

Figure 3 represents the first attempt at populating a water asset table. It includes some suggested modifications to the structure of the table that is presented in the SEEA manual (figure 2). It should be noted that only fresh inland water is considered.

Opening Stocks

Row 1: The measure of the opening stock is a calculation that has previously never been attempted in Canada. It was mentioned earlier that data on water quantity in reservoirs is incomplete in the sense that only data for large dams are compiled, and that the variable collected is inappropriate for our purpose. Nevertheless, the maximum amount of water contained by large dams in Canada is entered in the asset table. Coefficients could be used to adjust this value.

While water held in lakes is measured for a few of the larger lakes (80, to be exact), volume for the remaining two million smaller lakes remains unknown. These lakes are, however, relatively shallow, and most likely do not contribute much when compared, for example, to Lake Superior, or the 645 other lakes that are larger than 100km^2. Based on the relationship between the area and the volume of the lakes for which volumes are known quantities, these 645 lakes would hold 17398 km^3 of water. This value contains some uncalculated overlap with reservoirs data; this issue will be solved in due time.

The adaptation of the SEEA's assets table to Canada's need could include a value for wetlands, although it could be argued that wetlands are more important from the perspective of the area, not volume. This appears to be so for SEEA, because wetlands appear in the land and water area (EA.243). Nevertheless, wetlands could still be added to the matrix of transfers between surface water bodies (Table 8.8 in SEEA 2003) because water logged land are an important factor in the distribution of flow, especially in flat terrain.

As mentioned previously, Canada has collected little information on its groundwater stocks and flows. Conceptually, we suggest that groundwater be broken down further since there are specific issues with water renewal and water quality that are related to the type of aquifer.. Groundwater assets could alternatively be measured as the sustainable yield rather than as the volume in storage [Australian Bureau of Statistics, 2000]. This approach is similar to the "accumulated flow" concept used to measure water held in rivers.

As recommended, the Water assets account in Canada should include glaciers. Glaciers are an important fresh water resource in Canada. While the volume of water in the Great Lakes is estimated to be 23 000 km^3, the volume of water contained in terrestrial glaciers is estimated to be approximately 35 000 km^3.

Figure 1

An asset account fo inland fresh water (km^3)

Row number			EA.131 Surface Water			EA.132 Groundwater		Total	EA.nc	Total
			EA.1311 Reservoirs	EA.1312 Lakes	EA.1313 Rivers	EA.nc Shallow aquifers	EA.nc Deep aquifers		Glaciers	
1	Opening Stock		880	17398	3315	.	.	21593	35000	56593
2	Abstraction			41		1		42	.	.
3	Residuals	Return from irrigation	.	.	.	.	.	.	.	.
		Wastewater		31		1702		1733		
		Lost in transport	…	…	…	2	…	2	.	.
		Others	.	.	.	.	.	.	.	.
4	net precipitation (1)			3200		.	.	3200	.	.
5	Inflows			52				52	.	.
6	Net natural transfers		.	.	.	.	.	.	.	.
7	Evaporation from water bodies			403		…	…	403		
8	Outflows	To other countries		192		.	.	192	.	
		To the sea		3123		.	.	3123	.	
9	Other Volume Changes	Due to natural disaster	.	.	.	.	.	.	.	.
		Discovery	.	.	.	.	.	.	.	.
		Others	.	.	.	.	.	.	.	.
10	Closing Stock		.	.	.	.	.	.		

Notes:

The stock in reservoirs refers to operational capacity of large dams; data excludes dams smaller then 15 meters in height.

The stock of lakes refers to Great Lakes, Canadian portion only.

Stock in rivers refers to annual accumulated flows, based on the long term average.

(1) This row should be replaced by four rows: precipitation, evapotranspiration, evaporation, and their balance, net precipitation

. Not available

… Not applicable

Flows

Water is often described as a renewable resource. This is only partly true. For example, although the Great Lakes (including the United States' portion) contain 23 000 km^3 of water, 98% of this amount is "fossil" water, leftover from the last ice age. Therefore, only the flow portion of the asset table describes the renewable portion of water.

Row 2: The abstraction row data is from the physical flow accounts that were constructed by Statistics Canada for four time periods, the latest being 1996. These accounts do not allow the differentiation between those abstractions from lakes, rivers or reservoirs, only that of surface and groundwater. In completing this table, Canada could add an "other" column, since part of the abstractions is not classified[7], or this small amount could be proportionally distributed amongst the three surface water body types.

Row 3: The residual row will include wastewater discharges and losses in transport. Returns from irrigation are not measured, and would represent a challenge that cannot be currently met. Losses in transport require appropriate analysis, but a value of 35% of water treated is cited as a common estimator of transport losses for large urban areas.

Row 4: The next row represents a significant challenge. The SEEA manual suggests that "net" precipitation be recorded in the table. Net, or efficient, precipitation is rain, snow, dew and hail that reaches lakes (directly), rivers and reservoirs (directly and via run-off), and groundwater (by infiltration). Simply defined – net precipitation is the remaining part of precipitation after the evapotranspiration process has occurred. The SEEA argument is that evapotranspiration accounts for movement of biological water - water that is outside the production boundary, i.e. outside the measurement of opening and closing stocks of an asset account. However, evapotranspiration, or the lack thereof, will affect, for example, the maturation of crops and thereby explain, in areas of "wet" agriculture, increased irrigation. Evapotranspiration therefore does influence the movement of water within the boundary of production.

Also, *real* evapotranspiration (as opposed to *potential*), however difficult to measure, holds the key to the appraisal of "efficient" precipitation. In the absence of a measurement of real evapotranspiration, one cannot tell of the relationship between stream flow and base flow, i.e. the part of the river that flows out of aquifers. In other words, groundwater discharge (and recharge) cannot be estimated without a measure of net precipitation based on the balance between precipitation and evapotranspiration. In summary, we suggest adding two rows to account for gross precipitation and evapotranspiration.

Row 5: The next row, "inflows", is relatively straightforward to estimate, at least as a total. The breakdown by class of surface water body will be calculated using CDDAF, which is currently being incorporated into SEIS. Inflows from groundwater will eventually be modelled, but currently have not been appropriately quantified.

Row 6: Net natural transfers are defined by SEEA as the difference between inflows to one type of water resource from all the others and the outflows from the same water resource to all the others. For example, the so-called coal bed natural gas mining brings to the surface large quantities of (polluted) groundwater; inversely, one process for

[7] One of the surveys upon which the physical flow account is based, indicates to respondents with small intakes of water, that they are free to skip any detail regarding water abstraction, and only fill in total water intakes, re-circulated, and discharged.

extracting oil uses consists of injecting water (as vapour) underground. The calculation of net natural transfers is the culmination of the "Surface Water Balance", which is discussed later.

Row 7: Inland water covers a significant area of the country (12% of Canada, or 1.2 million km2). Evaporation volume from lakes and rivers is therefore an important phase of the water cycle. Initial estimates indicate that the long-term annual average evaporation over Canada equals 403 km^3. This, and other estimates in this table, will have to be refined to represent annual values, if flows are to be useful to calculate closing stocks. Also, this row should include estimation for the process of sublimation for glaciers.

Row 8: This is the same as in *row 5*, with the difference that a value for glaciers would allow to track the evolution of its stocks: Outflows from glaciers could represent the contribution of glaciers to base flow.

Row 9: Ice jam melts and accidental reservoir releases are two examples of data entries that could be included in this row.

Closing Stocks

Row 10: The results that are captured in the table (figure 3) represent a first attempt at compiling values for national water assets and flows. They are not the outcome of the accounting process suggested in the first portion of this article: They have not been subjected to processes for source data reconciliation, for estimating missing data, for correcting the incompatibility of data vintage, etc. These gaps and limitations explain the absence of closing stocks. Accounting for these assets is a commitment of many years, and the commitment is in its early phases in Canada.

What follows is a description of the methodological framework proposed to build an adequate Inland Fresh Water assets account. The next section briefly explains the approach to accounting initiatives that should allow the completion of the table cells for fresh water.

The Water balance

The foundation of the water accounts is the development of a national geo-referenced water balance. The balance is calculated by accounting for the inflow, outflow, and storage in a hydrologic unit, the drainage basin. In a water balance, precipitation must be in balance with the sum of evapotranspiration from land areas, evaporation from water bodies, stream flow and a residual that is equivalent to water storage, i.e. soil moisture and groundwater.

The use of the water balance approach is common in environmental analysis. There are numerous manuals on its methods and applications. The water balance approach has also been put to use in the legally binding context of regional management of resources to account for the availability and consumption of water (United Stated Department of the Interior, 2000). Completing these balances would allow us to complete most of the water accounts data.

Two aspects of the water balance are central in completing the water assets table: The Climatic Water Balance and the Surface Water Balance.

The Climatic Water Balance

The Climatic Water Balance (CWB) refers to the exchanges of water (in gaseous, liquid and solid states) between the atmosphere and the Earth. It can be simplified to the expression

$$CWB = P - ET - E - R - S$$

where the CWB is the result of precipitation (P) less evapotranspiration (ET), evaporation (E), run-off (R) and storage (S). All four elements of the balance and their interactions can be investigated in detail. This paper will only quickly describe the methodology that has been applied to calculate these variables

Precipitation

Precipitation data is a point measure usually expressed in a linear unit (e.g. mm). The raw data is, by definition, not adjusted for shortcomings that stem from the location of the measurement, the type of instrument, and other error-inducing variables. The quality of the information will therefore increase if the data is appropriately adjusted. Data issues that should be considered consist of change of site location and observing procedure over time; instrument deficiencies leading to measurement errors; disregard for the measurement of trace elements (such as dew), and under-catch caused by the wind; the effect of viscosity when emptying the rain gauge, and snow density. For example, in Canada, the corrected time series results in an increase in precipitation of 1.7% of mean precipitation per decade over 1948-1995.

Given that climatic variables are measured at weather stations, and that the accounting framework points to the need for volumetric information, point values need to be converted to surfaces. The development of different methods to interpolate climatic data from sparse networks of stations has been a focus of research in geography for much of this century (Price *et al.*, 1999). There is no one method accepted for Canada since each method has its own limitations.

Evapotranspiration

Until recently, the last attempt to map nation-wide evapotranspiration (ET) in Canada was found in the Canadian Hydrological Atlas (Fisheries and Environment Canada, 1978). The ET values were calculated for 10 000 km^2 raster cells based on evaporation measurements taken with Class "A" pan data at selected weather stations. The fact that this ET map dates back over a quarter century stems partly from the fact that calculating ET requires more complex modelling than mapping precipitation, since it is not as easy to observe. There exists several methods for estimating ET and examples of their application are relatively common. Most recent work on ET estimates uses remote sensing data along with climatic data (for example, Liu, 2003)

Evaporation

Inland water covers a significant area of Canada (12%). Therefore, evaporation represents a considerable outflow. In Canada evaporation is gauged at 247 weather stations using an instrument known as a Class "A" pan. The value it gives is roughly equivalent to evaporation from a small lake area. This data needs to be interpolated to obtain a volumetric measure.

Initial estimates of the climatic wate balance in Canada are as follows:

$$CWB = P - ET - E$$

$$CWB = 6{,}341 - 2{,}676 - 403 - R - S$$

As mentioned, S (storage) is held constant. R (run off) is discussed next.

The Surface water balance

The Surface Water Balance (SWB) refers to the exchanges of water (in liquid form) between different areas on and below the surface of the Earth. It therefore refers to run-off from one area to another. It can be simplified to the expression

$$SWB = i\,(s+g) - o\,(s+g)$$

where the SWB is the result of water inflow (i), both on the surface (s) and in the ground (g), less water outflow (o), again on the surface and below ground. Biological water (water held in plant and animal life) and soil moisture are kept constant.

The main issue in measuring the SWB stems from the limited stream flow data. The monitoring network is comprised of only 1641 gauging stations reporting water levels and stream flow (as of 1999 – the network is reduced every year). If the stations were spatially distributed evenly, each station would represent 6000 km2 of territory. They are not distributed evenly however, nor is the breadth of historical coverage.

The stations are nevertheless precisely located on the network, which allows computation of the specific drainage areas for each station, and the contributing drainage basins located upstream. The logical downstream network also allows us to identify where measured data actually flows. Based on these data points, it is possible to estimate, using on stochastic and deterministic models, the contribution of drainage areas for which stream flow is not measured.

Estimated and measured flow will be compared in drainage areas where streamflow is measured, and the resulting variance will be interpolated across all stations to provide a GIS of expected coverage. This, in addition to the equivalent exercise of the CWB, will determine with precision the error estimate. These coefficients need to be tallied and included in the water asset tables. This is necessary for an adequate interpretation of the accounting data and process.

Run-off, as it appears in the Water Assets table, is estimated at 3315 km^3.

Comparing the Climatic Water Balance and the Surface Water Balances

The water balance equation simplifies a very complex hydrological cycle to a short expression where run-off (R) plus or minus storage (S) is equal to precipitation (P) less evapotranspiration (E) from land and evaporation (E) from water surfaces. Following preliminary estimations for Canada, the equation is as follows:

$$R + S = P - (ET + E)$$

$$3{,}315 +/- S = 6{,}341 - (2{,}676 + 403)$$

According to the estimates provided above, storage = 53km^3. The calculations leading to this figure need to be refined before any statistical credibility be given to the value; however, the small size of the residual (storage = 1.6% of runoff) is interpreted as validating the estimation approach to the CWB.

Water indicators

National environmental accounting proposes a coherent presentation of physical data on the environment and the related socio-economic operations. National scale tabulations, as presented in Figure 3, offer a summary picture of a complex systems comprised of various data sets, themselves issued from measurement, modelling and estimation techniques, and integrated to the largest desirable extent. Data integration remains, arguably, the fundamental task of national environmental accountants.

However, the efforts poured in data integration should not be consumed uniquely in the drafting of potentially meaningless tables. Figure 3 offers no comfort to those worried about water resources in Canada, not does it worry policy makers that do not consider water issues in their economic equations. This indicates the need for synthetic indicators, which could support arguments, on common grounds, from both socio-economic and environmental interests towards measuring the sustainability of development. Two examples follow.

Water and Population

The first indicator concerns the relationship between the location of water resources and demand. It is commonly said that Canada is a water-rich nation. In fact, Canada has the highest amount of efficient precipitation per capita of any large country[8], estimated at 100,000 m^3 per capita in 2001. However, most of the stream flow in Canada occurs in sparsely inhabited places, while only 3% of the area covered by water in Canada is located in the populated ecumene.

The Lake Ontario sub-basin only generated 1,767 m^3 of efficient precipitation per capita in 1996. This means that if Canada's largest city, Toronto, needed to rely solely on water renewed over its hydrologic territory, it could only count on that much for household, commercial, industrial, agricultural and power generation purposes. Home consumption alone averaged 125 m^3 annually in 1998 [Environment Canada]. The general perception of national abundance of the resource has to be balanced by an account of the actual spatial distribution of water in Canada.

To generalise this picture, the spatial distribution of efficient precipitation is summarised for Canada as a whole. This is done by averaging efficient precipitation per capita per sub-basin, then weighting this average by the share of its population, as it appears in the following equation:

$$\frac{\sum_{\text{Sub-Basin}}\left(CWB * \left[\dfrac{\text{Population}}{\text{Total Population}} \right] \right)}{\text{Total Population}}$$

The result of this formula indicates that Canada does not have over 100,000 m^3 of efficient precipitation per capita, but rather 450 m^3. Instead of ranking amongst the leaders in terms of water renewal per capital, Canada ranks 165th amongst nations, between Djibouti and Oman[9].

Water and Industry

The second indicator clarifies to some degree the relationship between industrial water intake and efficient precipitation. A tabulation of industrial water intake demonstrates that, in the *Mixedwood Plains Ecozone* (the area commonly referred to as the Quebec – Windsor corridor), manufacturing establishments and the mining and power generation industries intake at least the equivalent of 59% of the efficient precipitation of the ecozone. For means of comparison, only one OECD country, Hungary, has a higher intensity use of internal water resources[10]. The OECD water stress indicator fixes the threshold for high stress at 40% (OECD, 2001).

This result points again to the fact that the analysis of water use by national economies would gain in credibility, and accuracy, if spatially-detailed expanded national accounts were calculated. National level data is important, particularly for policy purposes (for example, total emissions); but geographic data is more appropriate for environmental analysis (for example, concentrations).

Conclusion

Water accounts are not merely esoteric statistical datasets. They are built, analyzed and disseminated in order to measure the sustainability, or lack thereof, of water resources. This article has explained the structure of the Canadian System of Environmental and Resource Accounts, emphasizing the need to further expand both the scope of the National Accounts, to include natural capital, and the spatial component, the Spatial Environmental Information System. This component is essential to create appropriate Water Accounts. These accounts need to be compiled by different geographic boundaries (administrative, ecological or hydrological) if they are to allow the appropriate political, *ecosystemic* and hydrologic analysis regarding the sustainability of water use.

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[8] For our purposes, a large country is defined as a country with a population of over 5 million or a country with an area larger than 500 000km^2. Overall, Canada occupies the 10th rank. [UNESCO, 2003].

[9] Efficient precipitation per capita for Djibouti and Oman is, of course, not calculated with the population-weighted formula; it follows that the comparison is for an illustrative purpose only.

[10] Industrial water use represents the average value for Hungary, not for an Hungarian ecozone. It follows that the comparison serves an illustrative purpose only.

It has been explained that Statistics Canada has built an economic water flow account, but that the environmental assets and flows components need to be develop, to provide the necessary context to evaluate the sustainability of socio-economic activities. Some issues regarding the asset classification, as proposed by SEEA, were detailed, leading to modifications to the Water Assets table to suit the needs of Canada. Appropriate estimation of opening stocks will require a lot of geographical analysis, which cannot be resolved in the immediate future. Appropriate estimation of flows, which are the focus of current efforts, will be based in a dual–entry accounting method based on the calculation of the climatic water balance and surface water balance. These in term allow for water indicators that better depict water issues in Canada. This implies that, if such indicators are to be of any use internationally, the methodology employed to develop them will have to be adopted by the international community.

References

Australian Bureau of Statistics, 2000, Concepts, sources and methods for Australia's water account, Sub-regional Training Workshop on Environmental Statistics, Bangkok.

Babillot, P., et J. Margat, 1999, « La comptabilité nationale de l'eau en France : instrument d'analyse et de gestion patrimoniale » in *La Houille Blanche* No. 3-4.

Environnement Canada, 1975, Canadian Survey of the Water Balance of Lakes, The Secreteriat, Canadian National Committee, International Hydrological Decade.

Fisheries and Environment Canada, 1978, Hydrological Atlas of Canada, Ministry of Supply and Services Canada, Ottawa.

Geological Survey of Canada, *Canadian Framework for Collaboration on* , www.cgq-qgc.ca/cqsi/template/doc/STRATEGY-DRAFT17.pdf (accessed August 14, 2003).

Harris M. and I. Fraser, 2002, "Natural resource accounting in theory and practice: A critical assessment" in *The Australian Journal of Agricultural and Resource Economics,* 46:2, pp.139-192.

Hecht, J.E., 1999, "Environmental Accounting, Where We Are Now, Where We Are Heading" in *Resources for the Future*, 135, pp.14-17.

Hecht, J.E., 2000, *Lessons Learned From Environmental Accounting: Findings From Nine Case Studies*, Washington, D.C.: IUCN – The World Conservation Union, 42p.

International Commission on Large Dams, 2003, *Dams in Canada*, Montréal: Canadian Dam Association.

Liu J. , J.M. Chen, J. Cihlar , 2003, "Mapping evapotranspiration based on remote sensing: An application to Canada's landmass", in *WATER RESOURCES RESEARCH*, 39;7, 1189.

Margat, J., 1996, *Les ressources en eau; Conception, evaluation, cartographie, comptabilité, Manuels et méthodes #28, Organisation des Nations-Unies pour l'alimentation et l'agriculture.*

Margat J., 1986, "Le compte des eaux continentales", in *Les comptes du patrimoine naturel*, Les Collections de l'INSÉÉ, Compte et Planification, Institut National de la Statistiques et des Études Économiques, No. 137-138, pp. 285-428.

Organisation for Economic Co-operation and Development, 2001, *OECD Environmental Indicators, Towards Sustainable Development*, Paris: OECD.

Organisation for Economic Co-operation and Development, 2002, *Indicators to measure decoupling of environmental pressure from economic growth*, Paris: OCDE.

Price, D.T., D.W. McKenney, I.A. Nalder, M.F. Hutchison, J.L. Kesteven, 1999, "A comparison of two statistical methods for spatial interpolation of Canadian monthly mean climate data" in *Agricultural and Forest Meteorology*, 101, pp. 81-94.

Statistics Canada, 1997, *Linking the Environment and the Economy, Concepts, Sources and Methods, of the Canadian System of Environment and Resource Accounts*, Catalogue Number 16-505-GPE, Ottawa.

UNESCO, 2003, Water for People, Water for Life, the United Nations World Water Development Report, UNESCO.

United Nations, 1993, "Integrated Environmental and National Accounting" in *Handbook of National Accounting*, United Nations Statistical Division: New York.

United Nations, 2003, *Integrated Environmental and Economic Accounting 2003, Final draft circulated for information prior to official editing*, United Nations Statistical Division: New York.

United Stated Department of the Interior, 2000, *Lower Colorado River Accounting System, Demonstration of technology*, Bureau of Reclamation, Lower Colorado Regional Office.