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The CHANGING WEALTH *of* NATIONS

TECHNICAL REPORT

Adding Water to the Changing Wealth of Nations

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1 https://seea.un.org/events/water-accounting-sustainable-development-goals-side-event-un-2023-water-conference.
2 https://seea.un.org/events/london-group-environmental-accounting-28th-meeting.

Executive summary

INTRODUCTION

Water consumption is increasing around the world due to the growing population and economy. Compounding the problem of increased water use is that the availability of water is changing due to climate change, historical overuse of groundwater, and declining water quality. Understanding the uses and values of water and how these are changing should lead to more effective water policy and management. Estimating the value of water and adding it to The Changing Wealth of Nations (CWON) would help to make clear the importance of water to the economy and embed water into macroeconomic thinking.

CWON aims to account for the wealth of nations by providing comparable monetary measures of natural capital and other asset classes, grounded in the balance sheet approach of the System of National Accounts (SNA) and its extension, the System of Environmental-Economic Accounting (SEEA). The World Bank has a long-standing interest in the valuation of natural capital and in using national wealth as a measure of progress. Water is a vital part of natural capital but has yet to be included as one of the assets recorded in CWON. Despite some physical water stocks being depleted (for example, groundwater) or degraded (for example, by pollution), the cost of this is not yet recognized in the estimates of national wealth in any country.

The objective of this report is to assess the feasibility of valuing water as a natural capital asset in at least 150 countries for possible inclusion in CWON. Water represents a portfolio of assets, including surface water, groundwater, and soil water ("green" water). Recycled water ("gray" water) is not considered a water asset as it is derived from water extracted from the environment and circulates within the economy. Ocean water is not considered an asset needing valuation as it is essentially limitless and industrial processes are needed to make it suitable for most uses (for example, desalination for drinking water and pumping for cooling).

The report identified three approaches for estimating values consistent with the value of the other natural capital assets in CWON: (1) asset-by-asset, (2) use-by-use, and (3) service-by-service.

The service-by-service approach, based on the supply of water-related ecosystem services, is the most feasible at the scale required. This approach relies on incomplete environmental and economic data, a meta-analysis of valuation studies, and global models using many assumptions—all of which will probably result in low-quality estimates. New data sources and models are in development and expected to be available in the near future, which should lead to higher-quality estimates. The use-by-use approach is possible but problematic. Data is only available for a small number of countries and uses (agriculture, hydroelectricity, households) at this stage. This approach should become more feasible in future as more countries adopt natural capital accounting. The asset-by-asset approach, which uses the value of tradable water rights and separates the water value from land value (for example, hedonic pricing), is currently not possible due to a lack of information.

THREE APPROACHES TO WATER VALUATON

The three water valuation approaches identified are consistent with the SNA and SEEA. These approaches are:

1. **Asset-by-asset.** This approach is a bottom-up country-by-country assessment based on the trade of assets related to water. These assets are water rights, which in the SNA are taken to represent the value of water and land value, which embodies at least part of the value of water, which is also recognized in the SNA. Neither is possible at present as the trade of water rights is limited to a few countries and the data needed to separate the value of water from the land on which it occurs is not possible with current data sources.

2. **Use-by-use.** This approach is another bottom-up approach based on country-level data. It assesses the use of water by different industries—agriculture, mining, manufacturing, energy, water supply, education, health, and so on—with water as one input to production. In this approach, the value of the water used is taken to be embedded in the value added of each industry, rather than just the price paid per unit volume of water used, which may be subsidized or zero in the case of the use of "green" water in rain-fed agriculture. The use-by-use approach requires information about the amount and sources of water used by each industry, for each country. SEEA water supply and use tables would provide this information, but these are only available for a small number of countries at the level of detail needed. Many countries have information on the value of agricultural production and agricultural water use. Agriculture would likely account for a large proportion of water value, so a partial estimate using this approach could be made. While the existing SEEA accounts could be used to make assumptions for the countries that do not have water accounts to generate an estimate of value, the estimate would be of low quality. Because of this, the use-by-use approach is not presently feasible.

3. **Service-by-service.** This top-down approach would be based on global models and data sources that estimate the use of water-related ecosystem services of water supply and water filtration. There are several other water-related ecosystem services but the two identified are the most relevant and tractable to measure. This approach is like the ecosystem service approach currently used to value forests in CWON. The approach would use global hydrological data sources and methods to estimate the physical quantities of services used, with prices derived from a meta-analysis of the values of these services in the literature. While this is possible and the most suitable method at present, there are data constraints, with relatively few studies separately estimating the value of water-related ecosystem services, and the geographic distribution of studies is uneven.

The key advantage of the service-by-service top-down approach is that it can be done relatively easily, while its weakness is that the place-to-place variations in value are hidden and that any resulting estimates would be accompanied by many caveats. The advantage of the bottom-up approaches is that the estimates are likely to be a more accurate reflection of the uses and values of water within countries and that the development of water accounts, particularly at subnational levels, is likely to be of use for individual countries. The difficulty with the use-by-use approach is that few countries have existing national water accounts at the level of detail required.

BACKGROUND

Several natural capital assets are already included in CWON—minerals, fossil fuels, forests, mangroves, and marine fisheries. CWON's wealth accounts are designed to provide comparable monetary measures of natural capital and other asset classes, grounded in the balance sheet approach of the System of National Accounts (SNA) and its extension, the System of Environmental-Economic Accounting (SEEA). The SNA and SEEA are international statistical standards that provide a framework for integrating environmental (such as hydrological and water quality data) and economic information (such as the costs and income associated with the supply and use of water).

A variety of concepts and methods are used to value natural capital assets. The SNA and SEEA both use the concept of exchange values, with the net present value (NPV) of the future expected income based on current uses; a common method used to value natural resources. In the case of water, a range of market factors, including that water is often provided at cost or is subsidized, means that the NPV approach will significantly undervalue water assets. The SNA and SEEA provide for other valuation methods, including hedonic pricing, replacement cost, and the value of property rights (for example, tradable water rights). These methods are increasingly being used in ecosystem accounting, and the literature on the valuation of ecosystem services is rapidly growing.

NEXT STEPS

To move forward with water valuation, a combination of the use-by-use bottom-up and service-by-service top-down options could be used to generate estimates for discussion. This would stimulate interest in the broader natural capital, water, and accounting communities by providing experimental estimates of water value as well as case studies to help understand the regional variation in water value. This would aid the:

- **Discovery of additional data sources and methods for water valuation** to assist with estimates based on the three approaches identified in this report. International agencies, countries, and research organizations hold a wealth of data and methods and not all of these have been identified.
- **Identification of other possible approaches to water valuation** not considered in this report.
- **Development of partnerships** to leverage the use of existing knowledge, identify data gaps and deficiencies, and seek additional resources for improving data sources for estimating the value of water in a systematic and comprehensive manner.
- **Promotion of the collection of data and methodological innovation** to enable reliable estimates of water value to be regularly produced.

For the estimates, a top-down approach could be done for 150 countries, while a bottom-up approach could be tried for a selection of countries. This would also provide more information for comparing the merits of the use-by-use and service-by-service approaches. The results of the use-by-use bottom-up approach could also be used to calibrate the service-by-service top-down approach, while the bottom-up estimates for individual countries could replace those made from the top-down. Reasons for discrepancies can be investigated and resolved.

An issue identified as part of the report is the extent to which the value of water is already counted in the other natural capital assets already valued in CWON. At present, the value of water is embedded in the value of agricultural and forested land, and the contribution of water to these assets is likely to be very large. Water value would also be included in the value of renewable energy (hydropower), which is being added to CWON. If a separate water value is produced for CWON, then care would need to be taken to ensure that the value of water assets is appropriately attributed and not double counted within the other CWON assets.

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ACRONYMS AND ABBREVIATIONS

ABS	Australian Bureau of Statistics
ADB	Asian Development Bank
ANCA	Advancing Natural Capital Accounting
AQUASTAT	FAO's Global Information System on Water and Agriculture
ARIES	Artificial Intelligence for Environment and Sustainability
BC3	Basque Centre for Climate Change
BOD5	five-day biochemical oxygen demand
CGIAR	Consultative Group for International Agricultural Research
CWON	Changing Wealth of Nations
EC	European Commission
EDG	electronic discussion group
EEA	European Economic Area
EnhaNCA	Enhance Natural Capital Accounting Policy Uptake and Relevance
EPA	Environmental Protection Agency
FAO	Food and Agriculture Organization
GPS	Global Program on Sustainability
IBNET	International Benchmarking Network for Water and Sanitation Utilities
IHE Delft	IHE Delft Institute for Water Education
IMF	International Monetary Fund
ISIC	International Standard Industrial Classification
IUCN	International Union for Conservation of Nature
IWMI	International Water Management Institute
MAIA	Mapping and Assessment for Integrated Ecosystem Accounting
MLMWSS	Ministry of Land Management, Water and Sanitation Services
NCAVES	Natural Capital Accounting and Valuation of Ecosystem Services
NPV	net present value
OECD	Organisation for Economic Co-operation and Development
SDG	Sustainable Development Goal
SEEA	System of Environmental-Economic Accounting
SNA	System of National Accounts
SRU	Standard river unit
UN	United Nations
UNESCO	United Nations Educational, Scientific and Cultural Organization
UNSD	United Nations Statistics Division
USGS	United States Geological Survey
WA+	Water Accounting Plus
WHO	World Health Organization
WMO	World Meteorological Organization
WRI	World Resources Institute
WWAP	World Water Assessment Programme
WWF	World Wildlife Fund

1 Introduction

"What is water worth? There is no easy answer to this deceptively simple question. On the one hand, water is infinitely valuable—without it, life would not exist. On the other, water is taken for granted—it is wasted every single day."

Audrey Azoulay, Director-General of UNESCO

This quote from the foreword to *World Water Development: Valuing Water* (UN 2021) captures both the challenge of and a key motivation for water valuation. The underlying logic is that if we understand how water is used, then we can better value water so that it may be used more carefully and not wasted.

A better understanding of the uses and values of water is needed. This is particularly the case in the parts of the world affected by water scarcity and the resulting competition for water between sectors and the environment (Falkenmark 1986; d'Odorico et al. 2020). With the availability of water changing (for example, Konapala et al. 2020), groundwater being depleted (for example, Thomas and Famiglietti 2019; Jasechko et al. 2017), water quality declining (for example, Delpa et al. 2009), climate change making floods and droughts more common and less predictable (for example, Kreibich et al. 2022), and the global undertaking to meet Sustainable Development Goal 6 on water supply and sanitation (SDG 6), the management of water and investment in water supply and sanitation are pressing issues (UN 2021). In the context of changing water demand and supply, it is recognized that both supply- and demand-side approaches are needed, and that appropriate water pricing is one way to manage demand (Grafton et al. 2020).

The World Bank has a long-standing and ongoing interest in the valuation of water for decision-making (for example, Young 1996; Briscoe et al. 1998; Komives 2005; Ying et al. 2010; Damania et al. 2017; Andrés et al. 2019; Kind et al. 2020; Andrés et al. 2021; World Bank 2022; Siikamäki et al. 2023). The World Bank also collects data on water supply, sanitation, and irrigation infrastructure as well as water resources,[3] including information on water prices (World Bank 2014, 2022).

The challenges to monetary water valuation are both theoretical and practical and require a multidisciplinary approach to understand and address them. In general, science is needed to provide information on water volume and quality, while economics is needed to provide information on water price. The need for both can be seen when water value is expressed as a function of price and quantity, or $mv = p * q$, where mv is equal to monetary value, p is price, and q is the quantity of water used.

The purpose of this report is to explore the feasibility of including water in the World Bank's The Changing Wealth of Nations (CWON) database. CWON aims to account for the wealth of nations from different types of natural capital, using the System of National Accounts (SNA)[4] and its extension, the System of Environmental-Economic Accounting (SEEA),[5] and

3 World Bank Water Data: https://wbwaterdata.org/; and IBNET: https://wbwaterdata.org/ibnet.
4 https://unstats.un.org/unsd/nationalaccount/sna2008.asp.
5 https://seea.un.org/.

the balance sheet approach. It does this by examining the challenges of water valuation in the context of CWON, providing background information on the science, economics, and accounting related to water as well as the SNA, the SEEA, and CWON itself. This background is needed because while readers may be familiar with CWON and one or more aspects of water valuation, they may not be familiar with all aspects of water valuation. This is particularly the case for water accounting linked to the SNA and SEEA, which integrates the science and economics of water in a way that is unfamiliar to many.

One source of confusion is that the terminology and concepts used in the discussion of water valuation are highly technical and vary between different disciplines, and sometimes within disciplines (Box 1.1). A range of glossaries related to water are available[6] and the terminology related to the valuation of natural resources is varied. For example, the terms natural resource, natural capital, and environmental and ecosystem assets are used synonymously and interchangeably to mean stocks. A stock is a physical volume of a substance measured at a point in time (for example, the volume of water in a dam on January 1 of a particular year). As such, a large portion of this report is devoted to the explanation and definition of key terms so that a common understanding may be reached. The terminology used in this report will follow that used in the SEEA-Water Glossary, which is presented in Appendix 1 of this report.

This report provides short introductions to water valuation literature (section 1.1), CWON (section 1.2), and the SNA (section 1.3). The SNA is included as the concepts and methods used to value assets in the SNA underpin those used in CWON. The report then examines water and ecosystem accounting, and in particular the SEEA, as a potential solution to some of the challenges to water valuation (section 2) and assesses valuation options consistent with the SEEA and SNA (section 3). Section 4 examines the data sources and methods available for generating value estimates. Section 5 proposes a way forward.

6 See, for example, the International Glossary of Hydrology (WMO 2012), the FAO's Global Information System on Water and Agriculture of AQUASTAT (https://www.fao.org/aquastat/en/), the UN Glossary of Environmental Statistics (https://unstats.un.org/unsd/publication/SeriesF/SeriesF_67E.pdf), and Water Accounting Plus (https://wateraccounting.un-ihe.org/wa-definitions-glossary).

Box 1.1: Terminology

The terminology used in the different disciplines involved in understanding water use and water valuation varies. As part of the development of SEEA-Water, an electronic discussion group (EDG) compiled a glossary of terms to aid communication and reach a common understanding (SEEA-Water, paragraph 1.67). This glossary is presented in Appendix 1 and includes terms spanning the fields of hydrology, economics, and accounting. At the time it was considered the best alignment of the terminology of each field. The EDG considered many information sources, including the International Glossary of Hydrology[7] (WMO 2012), the FAO's Global Information System on Water and Agriculture of AQUASTAT,[8] the United Nations (UN) Glossary of Environmental Statistics,[9] and the SNA (EC et al. 2009) and SEEA (UN et al. 2003) glossaries. It should be noted that some of the glossaries have been updated since the adoption of SEEA-Water.

The glossary is important because some terms mean different things in different contexts. For example, water use and water consumption. In the SNA water consumption is split into two components: the use of water by industries (termed intermediate consumption) and the use of water by households (termed final consumption). In a hydrological context what the SNA is calling water consumption would be termed water use or water withdrawal, and hydrological consumption would be all the water withdrawals less that amount returned to the surface water, groundwater, or soil water. The glossary enables different communities, countries, and organizations to understand how their definitions relate to those in SEEA-Water. Over time understanding should increase and the terminologies and related definitions become better aligned.

7 https://library.wmo.int/index.php?lvl=notice_display&id=7394#.Y3Fwe3ZxWUk.
8 https://www.fao.org/aquastat/en/databases/glossary/.
9 https://unstats.un.org/unsd/environmentgl/#:~:text=The%20UNSD%20Glossary%20of%20Environment,development%20indicators%2C%20and%20environmental%20accounting.

1.1 WATER VALUATION

Water valuation is contentious (for example, Schmidt 2019; d'Odorico et al. 2020) and arises because of the characteristics of water and its use in the economy (UN 2012a; Easter et al. 1997; Young 1996; Fenichel et al. 2016; Grafton et al. 2020; Wheeler et al. 2023). Key characteristics include the following:

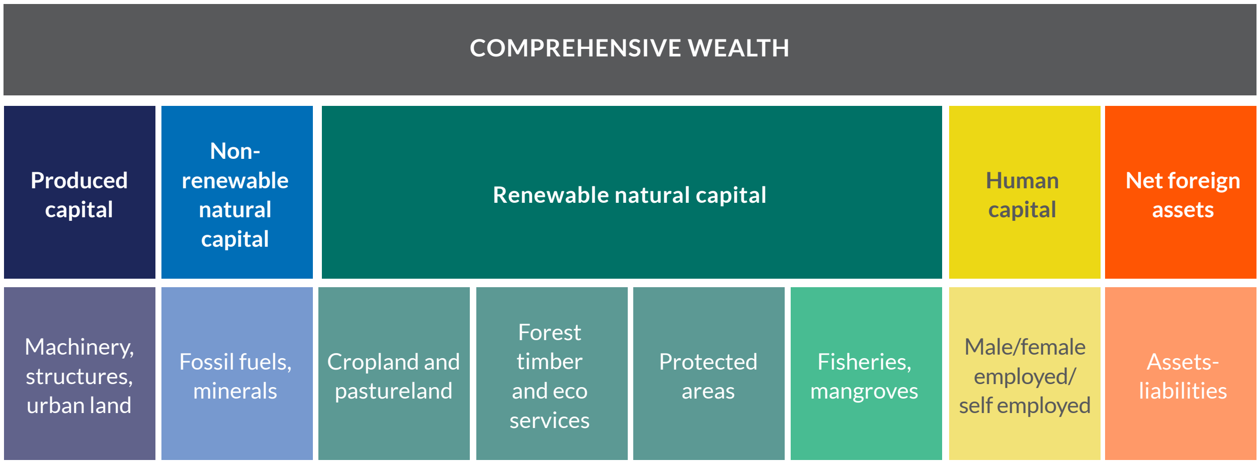
- **Water is a heavily regulated product** for which the price charged (if any) often bears little relation to its economic value or even the cost of supply. This situation is more common in water-scarce low-income countries where water may be supplied to some users at no charge. Such practices occur in part because the natural characteristics of water inhibit the emergence of competitive markets that establish economic value.
- **Water supply often has the characteristics of a natural monopoly** because water storage and distribution have economies of scale.
- **Where and when water is scarce, the water may be rationed** or there are restrictions on particular types of uses (for example, parks and gardens are not permitted to use water).
- **Property rights,** essential for competitive markets, are often absent and not always easy to define when the uses of water exhibit characteristics of a public good (such as flood mitigation) or a collective good (such as a sink for wastes), or when water is subject to multiple and/or sequential uses (for example, first hydropower and then irrigation).
- **Water is a "bulky" commodity** with a very low weight-to-value ratio, inhibiting the development of markets beyond local areas.
- **Large amounts of water are abstracted for own use by sectors other than those under ISIC Division 36** (water collection, treatment, and supply), such as agriculture, mining, and energy (see section 1.3 for definitions of industries and sectors). Water abstraction for own use, while theoretically in the scope of the SNA, in practice is not. As such, own use of water is not necessarily recorded as an input to production, so the use of water by an industry and the value of water to an industry may be underestimated. For example, the value of water's contribution to agricultural production and agricultural land is not explicit but is embedded in the operating surplus of the agricultural industry and the value of land.

Because of these factors, the observed values of water, and in particular the water supplied by the water supply industry (which is usually done "at cost"), is not a true representation of exchange values and the net present approach commonly used for natural resources in the SNA is not possible. As such, alternative valuation methods are needed.

1.2 NATURAL CAPITAL ASSETS AND CWON

CWON is published every two to three years by the World Bank. It was last published in 2021 and provided estimates of wealth from 1995 to 2018 for 146 countries (World Bank 2021). CWON contains a portfolio of assets, including human capital (broken down by gender) and natural capital (both renewable and non-renewable), in addition to the traditional measures of wealth (Figure 1.1). The number of natural capital assets included in CWON has grown over time (compare World Bank 2018 and World Bank 2021).

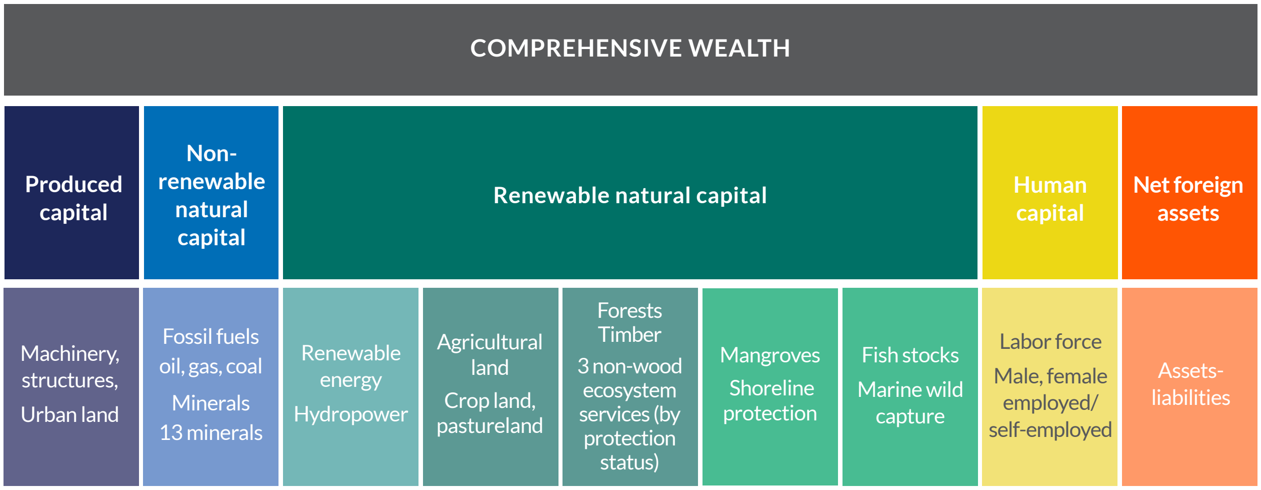
FIGURE 1.1: THE SCOPE OF THE CHANGING WEALTH OF NATIONS, 2021



Comprehensive data on natural capital is lacking in most countries, and where information exists, the values reported vary in terms of their scope (for example, which types of natural capital are measured), methods used, and quality (Brandon et al. 2021). While there are limits to the estimates, natural capital typically declines as a share of a nation's total wealth as it builds other forms of capital (CWON 2021).

Five renewable natural capital assets are currently included in CWON: agricultural land (cropland and pasture), forests (timber and non-wood ecosystem services), protected areas, mangroves, and marine fisheries. A range of additional assets and extensions to the valuations of existing assets are being investigated for possible inclusion in the next CWON, including renewable energy and carbon retention services (Figure 1.2). Within this framework water can be a renewable or non-renewable asset. Non-renewable water is sometimes known as fossil water, which is defined by Foster and Loucks (2006) as "water that infiltrated usually millennia ago and often under climatic conditions different from the present, and that has been stored underground since that time." Once this type of groundwater has been accessed via a well, it is vulnerable to contamination (Jasechko et al. 2017). Renewable water is surface water and soil water ("green" water) as well as the water found in aquifers that are recharged by surface water. Recycled water ("gray" water) is not considered a water asset as it is derived from water extracted from the environment and circulates within the economy. Ocean water is not considered an asset needing valuation as it is essentially limitless and industrial processes (such as desalination and pumping; Zhou and Richard 2005) are needed to make it suitable for most uses.

FIGURE 1.2: THE SCOPE OF THE CHANGING WEALTH OF NATIONS, 2024



The natural capital assets used in CWON are equivalent to the environmental assets defined in the SEEA Central Framework (see section 2). In the SEEA Central Framework environmental assets are defined as *"the naturally occurring living and non-living components of the Earth, together constituting the biophysical environment, which may provide benefits to humanity"* (SEEA Central Framework, paragraph 2.17).

1.3 THE SYSTEM OF NATIONAL ACCOUNTS AND ITS RELATIONSHIP TO CWON

The valuation in CWON is grounded in the balance sheet approach of the SNA (CWON 2021). The SNA balance sheet includes stocks of manufactured (produced) assets and non-produced assets. Non-produced assets are environmental assets, and include mineral and energy resources, land, timber, and fish (Obst and Vardon 2014). Water is one environmental asset, but no country records a value for water in their balance sheet. The value of land, which is included in the balance sheet of some countries, may embody the value of water (and is discussed later in this section). The SNA balance sheets also include the value of contracts, leases, licenses, and similar intangibles, and the net positions on financial assets and liabilities. For water, this would include the value of water licenses and tradable water rights.

The CWON approach to the valuation of natural capital is consistent with the SNA and the methods it uses. For inclusion on the SNA balance sheet, an asset must provide a stream of income to the direct owner of the asset or from the potential sale of the asset. The SNA asset values use the concept of exchange value; that is, the value at which an asset or good, or service would be transacted if it were exchanged between a willing buyer and a willing seller. The net present value (NPV) method is often used to value non-renewable (such as minerals and fossil fuels) and renewable (such as forested land) forms of natural capital. Most entries in the national accounts use observed transactions at market prices.

Market transactions are defined as the *"amounts of money that willing buyers pay to acquire something from willing sellers"* (2008 SNA, paragraph 3.119).

The SNA notes that a market price depends on the context in which the transaction occurs, including in monopolistic or monopsonistic (single buyer from multiple sellers) situations (see SNA, paragraph 3.119). As such, the market prices used in the SNA reflect market imperfections from the perspective of economic theory (Barton et al. 2019).

The SNA also records non-observed transactions for which market prices need to be estimated (for example, for public education). The SNA uses two general approaches for this: (1) market prices of similar items (adjusted for quality and other differences as required) (2008 SNA, paragraph 3.123), and (2) where no appropriate market exists, prices may be derived by the amount that it would cost to produce them (2008 SNA, paragraph 3.135). Most services provided by the government to the public are valued at cost (for example, education, health, and defense).

Some environmental assets are directly traded in markets, for example, mineral deposits and land. In these cases, the SNA values them based on the observed market transaction. In some cases, assets are not exchanged for cash (money). This includes forest resources, where these assets are valued using resource rent and NPV (EC et al. 2009). Resource rent and NPV are well-established techniques in economics and accounting. It is also the case that some types of assets can be valued in more than one way, for example, the sale of mineral deposits, the rights to mineral deposits, or the NPV of the sale of minerals from the deposits.

The SEEA, which is discussed in more detail in section 2, extends the physical scope of assets and transactions beyond the SNA to include natural resources and ecosystem services (Eigenraam and Obst 2018). In the SEEA, the assets do not need to be owned or provide a stream of income; they just have to exist. This expanded scope enables all water resources to be included in the accounts regardless of their ownership or use and expands the range of valuation methods that can be used. The SEEA provides methods for the valuation of natural resources and ecosystem services that are consistent with the concept of exchange value and go beyond the methods used in the SNA (UN 2012a; UN et al. 2014; UN et al. 2021).

CWON's use of exchange value means that the benefits of aligning with SNA-compatible balance sheets go hand in hand with the limitations of this approach (World Bank 2021). In practice, natural capital is usually more difficult to value in market terms as, for example, these assets often do not have defined owners, or readily observable market prices, and governance can distort prices. These assets are nonetheless essential to human well-being and enhance the value of more traditional assets as well as having intrinsic value beyond monetary considerations. As such, neither the SNA balance sheet nor the current CWON wealth accounts provide a full picture of natural capital and its depletion or degradation. Failing to inform the owners, managers, and users of the true value of natural capital often results in overuse or degrading asset values (Pearce and Atkinson 1993). Many negative impacts on natural capital are gradual and visible to markets long after the critical ecosystems degrade, making them subject to the "tragedy of the horizon" (Carney 2015).

While the SNA has its limitations, it can address some of the challenges with water valuation. On the practical side, the SNA is a source of information in its own right, providing information on the production and consumption of goods and services; the value added of industries,[10] including the water supply, sanitation, and agricultural industries; and water-related assets (for example, the value of water supply and sanitation infrastructure). The SNA is also supported by a large information system that has more detailed information than that included in the accounts. For example, the value of inputs used in water-related industries, including the running costs of the water supply industry (for example, the value of labor and energy) and the location of their operations, and the market value of water used by agriculture.

The SNA defines the economy and identifies and classifies its different parts. It defines the economy as *"the entire set of resident institutional units."* Resident refers to the economic territory (country) in which the institutional unit operates (SNA, paragraph 4.10), while an institutional unit is defined as *"an economic entity that is capable, in its own right, of owning assets, incurring liabilities and engaging in economic activities and in transactions with other entities"* (SNA, paragraph 4.2). An institutional unit may be a single establishment, or a group of establishments known as an enterprise (see SNA chapter 5).

An industry consists of a group of establishments engaged in the same, or similar, kinds of activity at a particular location (SNA, paragraphs 5.2, 5.46, 5.2) and is classified using the International Standard Industrial Classification (ISIC).[11] The ISIC is a hierarchical structure with 21 sections followed by divisions, groups, and classes. For example, agriculture (section A, division 1), mining (section B), manufacturing (section C), electricity (section D, division 35), water supply (section E, division 36), sewerage (section E, division 37), public administration and defense (section O), education (section P), and human health (section Q). Table 1.1 defines the industries of most relevance to water valuation, while a more complete list and discussion of industries are found in SEEA-Water (pp. 27–32). The five sectors in the SNA are non-financial corporations, financial corporations, government, non-profit institutions serving households, and households (SNA, paragraph 4.24). Establishments are classified as both an industry and a sector. For example, a commercial farm producing rice would be classified as an agricultural industry and as a non-financial corporation.

10 Value added is the contribution of each industry (as defined in the SNA) to gross domestic product.
11 https://unstats.un.org/unsd/publication/seriesm/seriesm_4rev4e.pdf

TABLE 1.1: DEFINITIONS OF INDUSTRIES AND SECTORS OF MOST RELEVANCE TO WATER VALUATION

INDUSTRY OR SECTOR NAME	ISIC CLASSIFICATION	ISIC DEFINITION	RELATIONSHIP TO WATER VALUATION
Agricultural industry	Section A, division 1	This refers to the exploitation of vegetal and animal natural resources, comprising the activities of growing crops, raising and breeding animals, and harvesting timber and other plants, animals, or animal products from a farm or their natural habitats.	Agriculture is generally the largest user of water via rain-fed agriculture, livestock, and irrigation. The water may be directly abstracted from water resources or be obtained from the water supply industry.
Mining industry	Section B	The extraction of minerals occurring naturally as solids (coal and ores), liquids (petroleum), or gases (natural gas). Extraction can be achieved by different methods such as underground or surface mining, well operation, and seabed mining.	Mine de-watering—pumping groundwater out of mines to allow the extraction of minerals and fossil fuel—can be a large user of water. The pumping of water is a use but not necessarily a consumption of water* as some water is returned to the environment (with the groundwater usually returned to surface water).
Manufacturing industry	Section C, class 1104	This section includes class 1104, which is the manufacture of soft drinks; production of mineral waters and other bottled waters.	Bottled water is often a high-value but low-volume source of water for households. Other manufacturing processes use water to a greater or lesser extent during production.
Electricity industry	Section D, class 3510	This class includes the generation of bulk electric power, transmission from generating facilities to distribution centers, and distribution to end users. It includes the operation of generation facilities that produce electric energy, including thermal, nuclear, hydroelectric, gas turbine, diesel, and renewable (emphasis added).	Water is used for cooling in thermal electrical production and for hydroelectric power. Hydroelectric power generation is a very large user of water but not a consumer of it.* This is because the water used for hydroelectricity is used "in-stream" and is almost immediately returned to the hydrological system after use.
Water supply industry	Section E, class 3600	This class includes water collection, treatment, and distribution activities for domestic and industrial needs. Collection of water from various sources, as well as distribution by various means, is included. The operation of irrigation canals is also included.	The water supply industry is a large user (but not consumer*) of water and often the main supplier of water to other industries, including agriculture, and households.
Sewerage industry	Section E, class 3700	This includes the operation of sewer systems or sewage treatment facilities that collect, treat, and dispose of sewage.	The sewerage industry receives water from other industries via sewer systems or other means (for example, collection from septic tanks and cesspools), treats wastewater, and releases water, treated or untreated, into the environment and can also supply wastewater to other industries.
Household sector	From SNA	This a group of people who share the same living accommodation, who pool some, or all, of their income and wealth, and who consume certain types of goods and services collectively, mainly housing and food.	Households are generally large users of water from the water supply industry. Households may also directly abstract water from the environment (for example, from wells or rivers).

**The difference between water use and water consumption is discussed in section 2.1 of this report.*

The SNA concept of own-account production is relevant to understanding water use and water valuation. Own-account production is defined as the *"production of all goods that are retained by their producers for their own final consumption or gross capital formation"* (SNA, paragraph 6.27). For water, this means that water abstracted by the agricultural industry for use in its operations, for example, irrigating crops, would be counted as water production even though there was no transaction between economic units. Similarly, the abstraction of water by households from wells would also be treated as production. The implication of this is that the water produced in this way is valued and recorded, at least in theory, in the SNA as if there were a transaction between different economic units.

2 Water Value in the Context of CWON

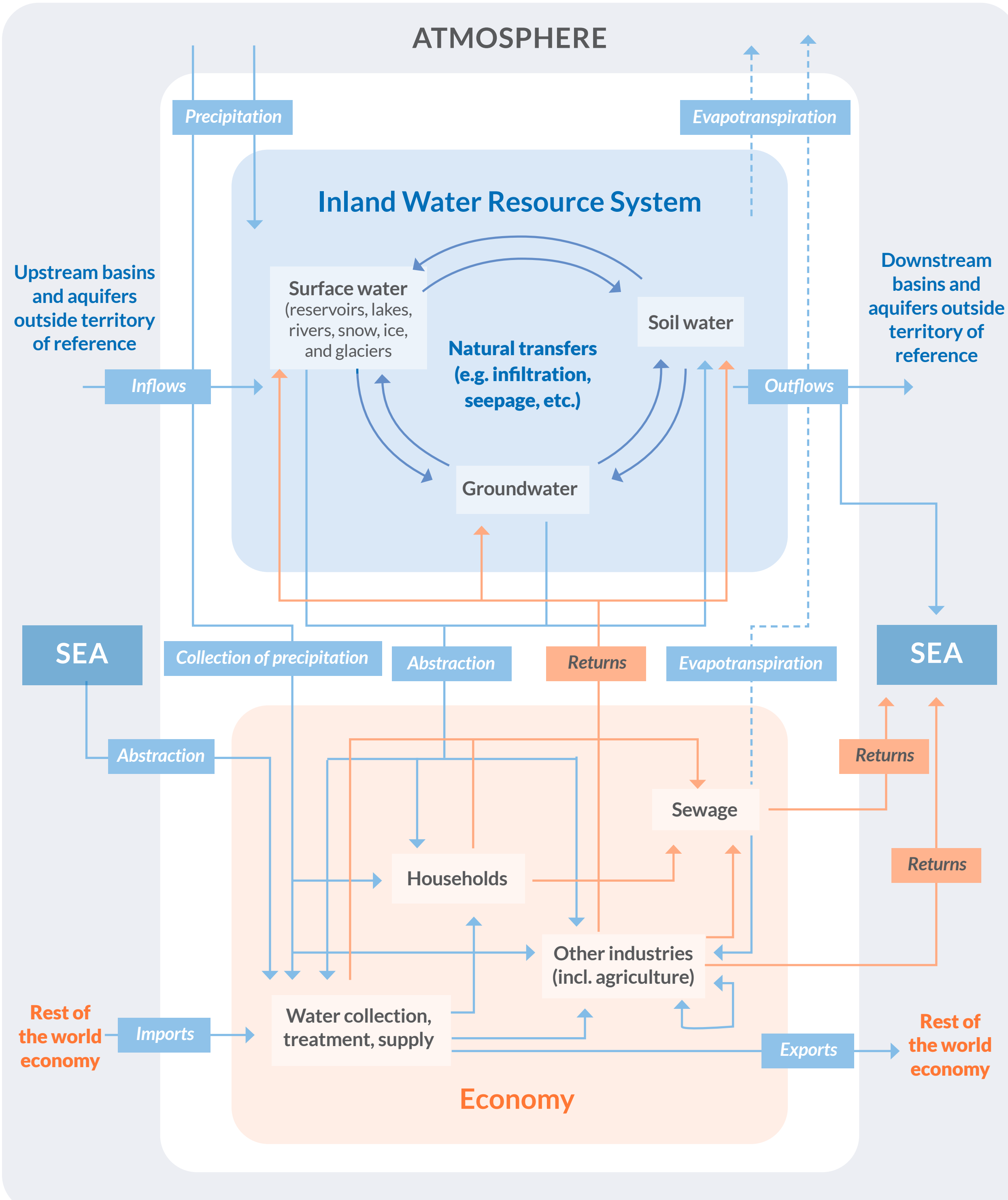
To generate a value for water, information is needed on the physical volumes of water in the environment and the water used by people and the economy. A water price may be directly observed, such as when a household purchases water directly from a water utility or a farmer from an irrigation water supplier. This is the price that would be recorded in the SNA (section 1.3), but because of the characteristics of water and water markets, this price is not an accurate reflection of value (section 1.1). The use of "green" water in rain-fed agriculture is not recorded in the SNA, although the value of agricultural production and agricultural land is.

To estimate water value, the exchanges of water between the environment and economy, and within the economy need to be estimated. A stylized representation of these exchanges is shown in Figure 2.1. There are flows of water: between types of water resources (for example, between surface water and groundwater), from the different water resources into the economy (for example, from surface water to the water supply industry), between different industries and sectors of the economy[12] (for example, from the water supply industry to households and from households to the sewerage industry), and from the economy to water resources.

Water accounting provides a framework for recording these physical water flows and the value of exchanges. There are several types of water accounting frameworks in use. The SEEA is the focus of this report because of its comprehensive coverage of physical water resources and the uses of water in the economy and society. It also directly aligns with the valuation concepts and methods currently used in CWON, is the most commonly used water accounting system in the world (Vardon et al. 2023), and is an international statistical standard by the United Nations (UN 2012a; UN et al. 2014; UN et al. 2021).

12 The difference between an industry and sector is explained in section 1.3.

FIGURE 2.1: OVERVIEW OF THE HYDROLOGICAL SYSTEM AND ITS INTERACTIONS WITH THE ECONOMY



Source: After SEEA-Water (UN 2012a).

After the SEEA, the most commonly used system is Water Accounting Plus[13] (WA+; Box 2.1) (Vardon et al. 2023), with additional frameworks used within countries (for example, Godfrey and Chalmers 2012) and in corporate accounting (for example, Burritt and Christ 2017). These other frameworks are less suitable for global water valuation as they are not based on common standards, their scope and coverage are limited, and the degree of integration of physical and monetary data is more limited. In addition, these systems were not intended to derive detailed national estimates of all water uses for all water users, nor to estimate the value of natural capital, in this case water assets.

These other systems tend to focus on either the economic or hydrological aspects of water and range in scale from individual water utilities to the basin or country level. For example, WA+ is primarily a hydrological system, accounting for the physical flows of water at the river-basin scale. Although WA+ includes agricultural water use, a detailed breakdown of water uses in other parts of the economy, or society more generally, is not included. The production value resulting from all water uses is also not part of WA+. As WA+ does not use the international classifications of industry,[14] sector,[15] or product,[16] the hydrological data from WA+ cannot be easily linked to the economic information in the SNA or the information systems that underpin the SNA. In addition, WA+ does not include the value of water supply and sanitation infrastructure or the running costs for providing these services. While business-level water accounting does account for these economic aspects and the concept of exchange value is consistent with the SNA, the spatial coverage is limited to water utilities with water accounts, which is seldom, if ever, national (Vardon et al. 2023).

13 https://wateraccounting.un-ihe.org/welcome-water-accounting-plus-0.
14 The SNA and SEEA use the International Standard Industry Classification (ISIC), https://unstats.un.org/unsd/publication/seriesm/seriesm_4rev4e.pdf.
15 The sectors in the SNA and SEEA are financial corporations, non-financial corporations, government, households, and non-profit institutions supporting households.
16 The SNA and SEEA use the Central Product Classification (CPC), which lists all the goods and services produced and consumed in the economy, https://unstats.un.org/unsd/classifications/unsdclassifications/cpcv21.pdf. The CPC does not classify ecosystem services.

Box 2.1: Water Accounting Plus

Water Accounting Plus (WA+) is an open-access platform developed for basin-level water accounting (Karimi et al. 2013). The framework was developed by the IHE Delft Institute for Water Education, the International Water Management Institute, and the UN Food and Agriculture Organization. WA+ combines remotely sensed data with global data sets and ground measurements to produce standardized tables, graphs, indicators, and maps.

The WA+ framework is primarily depletion water accounting that tracks water consumption. However, it has much in common with the SEEA and is focused on basin-level hydrological processes. The abstraction (withdrawal) of water for use in the economy is recorded, with the amount of water used recorded by land use category and measured by tracking evaporation in space and time. Water is shown as abstracted and consumed by agriculture, industry, and domestic users. Industry may be equated with all industries other than agriculture used in the SEEA and domestic is equivalent to the household sector. The framework does not directly link to related economic data, but the data sources and methods can, and are, used to construct SEEA-based accounts—and in particular the asset account—and to estimate the use of soil water by agriculture.

A key feature of WA+ is that it is an integrated modeling system, providing a framework along with data and methods that enable the framework to be populated. The framework comes with a glossary,[17] supported by a range of online material and references,[18] and an open-access online course.[19]

2.1 SEEA-WATER

The SEEA is an extension of the SNA (see section 1.3) and SEEA-Water (UN 2012a) is a module under the umbrella of the SEEA Central Framework (UN et al. 2014). SEEA-Water is one of several thematic publications under the SEEA umbrella (for example, SEEA Applications and Extensions, SEEA-Energy, SEEA Agriculture, Forestry and Fisheries, and SEEA Ecosystem Accounting). The International Recommendations for Water Statistics guides SEEA-Water on the data sources and methods needed to populate water accounts (UN 2012b).

The physical scope of SEEA-Water is shown in Figure 2.1. The water resources and related flows shown in Figure 2.1 are all defined and classified in SEEA-Water. There are 22 standard water accounts in SEEA-Water, covering water stocks and flows in physical and monetary terms, as well as accounts for water quality and water emissions (for example, nitrogen, potassium, and phosphorous dissolved in water), and economic accounts for expenditure on protecting and treating water. These are in addition to the value of the water supply and sanitation infrastructure and the input costs (for example, labor and energy) that are included in the SNA (see section 1.3).

17 https://wateraccounting.un-ihe.org/wa-definitions-glossary.
18 https://wateraccounting.un-ihe.org/publications-0.
19 https://wateraccounting.un-ihe.org/capacity-building.

The main accounts of relevance to water valuation are for water assets and water supply and use. Before describing these, it is necessary to define some terms used in accounting.

The SEEA defines water assets as consisting *"of fresh and brackish water in inland water bodies, including groundwater and soil water"* (SEEA Central Framework, paragraph 5.474). This excludes water in oceans, seas, and the atmosphere, although these assets are part of the overall accounting system. Within this overarching definition, three classes of water assets are described in SEEA-Water (UN et al. 2012a), with one asset, surface water, having subclasses:

- **Surface water** is water that flows over or is stored on the ground surface regardless of its salinity level or other dimensions of water quality. Surface water includes water in *artificial reservoirs*, which are purpose-built for water storage, regulation, and control; lakes, which are large bodies of standing water occupying a depression in the earth's surface; *rivers and streams*, which is the water flowing continuously or periodically in channels; snow and ice, which include permanent and seasonal layers of snow and ice on the ground surface; and *glacier*s, which are accumulations of snow of atmospheric origin.
- **Groundwater** is water found in aquifers. An aquifer may be unconfined, by having a water table and an unsaturated zone, or confined when it is between two layers of impervious or almost impervious formations. Aquifers can discharge into rivers, lakes, and wetlands and can manifest as base flow, be the sole source of river flow during dry periods, or be recharged by lakes or rivers during wet periods.
- **Soil water** is suspended in the uppermost belt of soil and can be discharged into the atmosphere by evapotranspiration, absorbed by plants, flow to groundwater, or flow to rivers (runoff). Part of the transpiration and absorption of water by plants is used in economic production (such as the growing of crops, and trees for timber), as is the evaporation of water from land used for economic production. Transpiration also results in biomass production that is not directly used in the economy.

The water flows recorded in the SEEA asset account (Table 2.1) are defined as follows:

- **Precipitation** is the volume of atmospheric wet precipitation (such as rain, snow, and hail) before evapotranspiration takes place.
- **Evapotranspiration** is the quantity of water transferred from the soil to the atmosphere by evaporation and plant transpiration.
- **Inflows** are the water that flows into a stream, lake, reservoir, container, basin, aquifer system, and so on. It includes inflows from other territories/countries.
- **Outflows** are the flows of water out of a stream, lake, reservoir, container, basin, aquifer system, and so on. It includes outflows to other territories/countries and the sea.
- **Abstractions** are the amounts of water removed from any source, either permanently or temporarily, in a given period of time by economic units for final consumption and production activities. Water used for hydroelectric power generation and desalination[20] is also considered to

20 Desalination is recorded as the abstraction of saltwater.

be an abstraction. Total water abstraction can be broken down according to the type of source, such as water resources and other sources, and the type of use (for example, by industries).

- **Returns** represent the total volume of water returned from the economy into surface water and groundwater during the accounting period. Returns can be disaggregated by the type of water returned (for example, irrigation water and treated and untreated wastewater) and by the industry that returned the water.

- **Wastewater** is water that is of no further immediate value to the purpose for which it was used or in the pursuit of which it was produced because of its quality, quantity, or time of occurrence. However, wastewater from one user can be a potential supply of water to a user elsewhere (see reused water). It includes discharges of cooling water.

- **Reused water** is wastewater delivered to a user for further use with or without prior treatment. Recycling within industrial sites is excluded.

The volume of water resources and changes in the volume of water resources are recorded in the physical asset account (Table 2.1). A water asset account is similar to a water balance (Vardon et al. 2012). The asset account records the opening and closing stocks of each water resource within a country or region and the sources of increase and decrease in stocks. These increases can be to natural inflows (such as precipitation) or human activity (such as the return of wastewater). Similarly, a decrease can be due to natural outflows (such as evaporation) or human activity (for example, the abstraction of water for agricultural production).

TABLE 2.1: PHYSICAL WATER ASSET ACCOUNT

Units (for example, million m3, megaliters, acre-feet)	EA.131 Surface water				Ground-water	Soil water	Total
	Reser-voirs	Lakes	Rivers and streams	Snow, ice, and glaciers			
Opening stocks							
Increases in stocks Returns from the economy Precipitation Inflows from upstream territories from other resources in the territory							
Decreases in stocks Abstraction Evaporation/actual evapotranspiration Outflows to downstream territories to the sea to other resources in the territory							
Other changes in volume*							
Closing stocks							

*These are due to, for example, the discoveries of water, or the use of different estimation techniques leading to increases or decreases in the volume of the opening or closing stock. As a last resort, it can also be used for the attribution of changes that cannot be attributed to other causes (that is, used as a balancing item).

TABLE 2.2: SIMPLIFIED WATER SUPPLY AND USE TABLE

Physical or monetary units of measurement	Economy										
	Agriculture	Mining	Manufacturing	Water supply	Sewerage	Energy	All other industries	Households	Rest of the world (imports and exports)	Environment	**Total**
SUPPLY											
Natural resources											
Surface water											
Groundwater											
Soil water											
Products											
Potable water											
Non-potable											
Water											
Reused water											
Wastewater											
Return flows											
Surface water											
Groundwater											
Soil water											
USE											
Natural resources											
Surface water											
Groundwater											
Soil water											
Products											
Potable water											
Non-potable											
water											
Reused water											
Wastewater											
Return flows											
Surface water											
Groundwater											
Soil water											

Gray is nil by definition.

The abstraction of water from the environment and its use within the economy and return to the environment are shown in supply and use tables. The full supply and use tables show many industries and types of flows. These large and complex tables are presented in Appendix 2, and a simplified supply and use table is shown in Table 2.2. This table can be used for physical and monetary units of measurement. An example of a simplified supply and use table from Botswana is shown in Appendix 3.

As water use is shown by the industries and sectors used in the SNA (see section 1.3), this information is directly linked to the SNA, enabling many indicators to be produced. For example, the value added[21] per cubic meter of water used for each industry. The amount of wastewater generated and, if there are linked emission accounts, the pollution load of the wastewater can also be shown by each industry.

The physical flow accounts have matching accounts in monetary terms. That is, instead of the flows of water being shown in physical units (for example, cubic meters, megaliters, or acre-feet), they are shown in values (for example, $, €, or ¥). In practice, the monetary table is seldom compiled (section 2.4), and when it is, the table is often limited to the fees and charges paid to the water supply and sewerage industries. In this case, the total value of fees and charges is usually known but can only be attributed to a few industries or sectors (for example, agriculture, other industries, and households).

Transboundary flows are shown for both the hydrological and economic systems. The upstream and downstream flows are when water from one country goes to another and are recorded in the water asset account (Table 2.1). For the economic system, water may be imported from or exported to countries. This is shown in the supply and use tables and allocated to the "rest of the world," with imports reflected in the supply side of the table and exports in the use. The imports and exports can be via water piped across borders. These exports are not exports of "virtual water"—the amount of water consumed that is embodied in, for instance, exported agricultural commodities (d'Odorico et al. 2019), although accounts from the SNA and SEEA-Water are used to calculate "water footprints," a type of "virtual water" (Hoekstra and Mekonnen 2012).

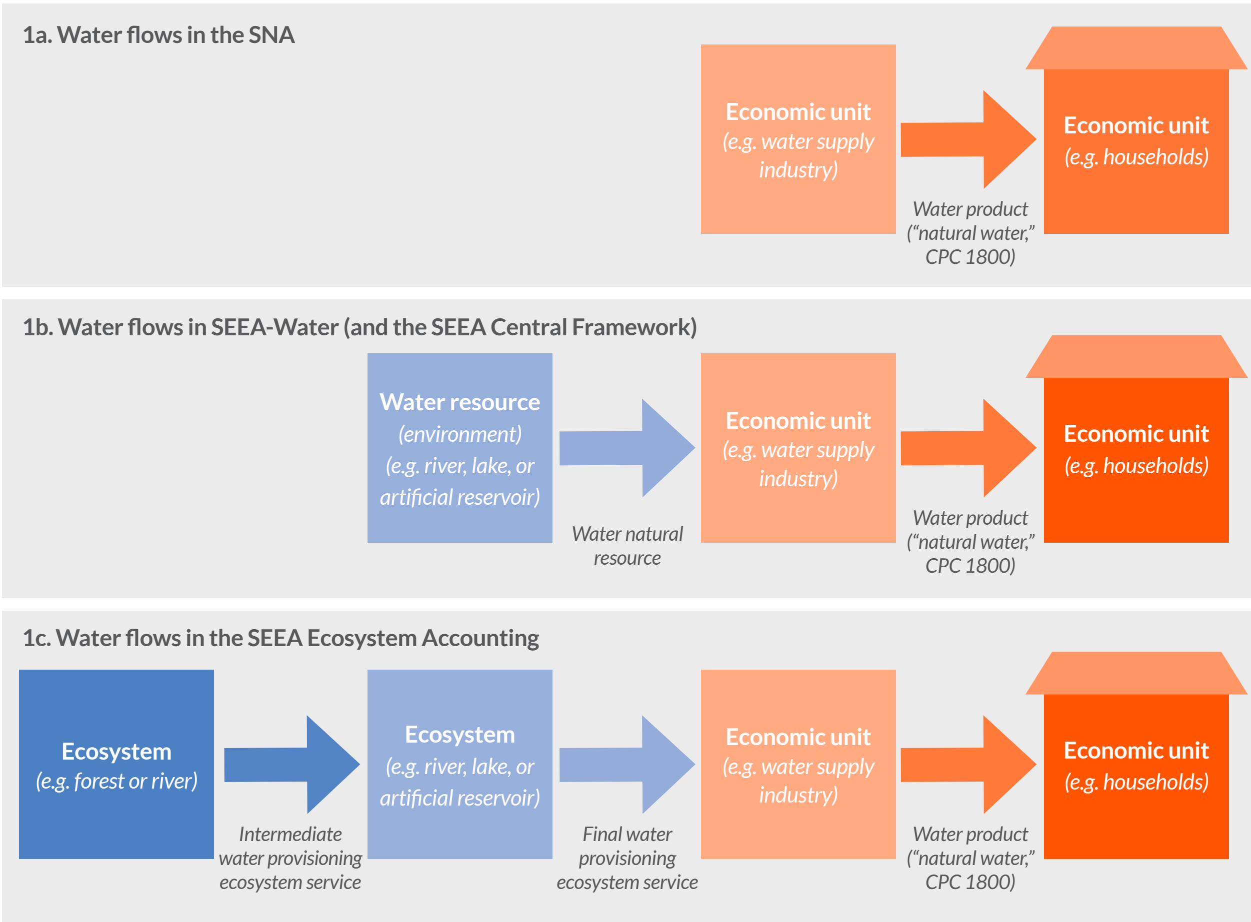
Transborder water is identified in SEEA-Water. Water is divided by national borders. For surface water this is relatively straightforward. However, the delineation of groundwater is more difficult as water from a common groundwater source can be accessed from either side of the national border. Since at least 145 countries share an aquifer with a neighboring country,[22] allocating the stock of water to a particular country is important for valuation.

2.2 SEEA ECOSYSTEM ACCOUNTING

Ecosystem services are the benefits that nature provides to people (for example, Daily and Matson 2008). Ecosystem accounting has been widely adopted and gained increasing traction (Hein et al. 2020). It has also been embraced by influential reports (for example, Dasgupta 2021; World Bank 2021). Ecosystem services are defined as *"the contributions of ecosystems to the benefits that are used in economic and other human activity"* in the SEEA Ecosystem Accounting (paragraph 2.14). Ecosystem services are usually outside the scope of the SNA (Eigenraam and Obst 2018). The expanded coverage of water flows in the SEEA Ecosystem Accounting compared to the SNA is shown in Figure 2.2.

21 Industry value added is the contribution of each industry to gross domestic product..
22 https://www.un-igrac.org/news/water-crossing-borders-64-worlds-countries-share-transboundary-aquifers-their-neighbours.

FIGURE 2.2: EXPANDING COVERAGE OF THE SNA, SEEA-WATER, AND THE SEEA ECOSYSTEM ACCOUNTING



Source: Vardon (2022).

The SEEA Ecosystem Accounting is a spatially based, integrated information framework for organizing biophysical and monetary information about ecosystems (UN et al. 2021). The framework aims to make visible the contributions of the environment to the economy and people, and record the impacts of economic and other human activity on the environment. The SEEA Ecosystem Accounting was developed through a multidisciplinary process and was adopted as an international statistical standard by the UN in 2021.

The SEEA Ecosystem Accounting represents the biophysical environment in terms of spatially distinct areas of different ecosystem types (for example, forests, grasslands, wetlands, cultivated areas, urban areas, rivers, coastal areas, and coral reefs). Ecosystem types are classified using the Global Ecosystem Typology (Keith et al. 2020). Each spatial area is accounted for in a manner that is broadly analogous to the treatment of produced assets and the associated flow of services recorded in the SNA.

Ecosystem services come from ecosystem assets. The water-related ecosystem assets provide several water-related ecosystem services and are listed in the SEEA Ecosystem Accounting as follows:

- **Water supply services** reflect the combined ecosystem contributions of water flow regulation, water purification, and other ecosystem services to the supply of water of appropriate quality to users for various uses including household consumption.
- **Water purification (water quality regulation) services** are the ecosystem contributions to restoring and maintaining the chemical condition of surface water and groundwater bodies through the breakdown or removal of nutrients and other pollutants by ecosystem components that mitigate the harmful effects of the pollutants on human use or health.
- **Water regulation (baseline flow maintenance) services** are the ecosystem contributions to regulating river flows, groundwater, and lake water tables. They are derived from the ability of ecosystems to absorb and store water, and gradually release water during dry seasons or periods through evapotranspiration and hence secure a regular flow of water.
- **Water flow regulation (peak flow mitigation) services** are the ecosystem contributions to regulating river flows, groundwater, and lake water tables. They are derived from the ability of ecosystems to absorb and store water, and hence mitigate the effects of floods and other extreme water-related events. Peak flow mitigation services are supplied together with river flood mitigation services in providing flood protection. This is a final ecosystem service.
- **Flood control (river flood mitigation) services** are the ecosystem contributions to regulating river flows, groundwater, and lake water tables. They are derived from the ability of ecosystems to absorb and store water, and hence mitigate the effects of floods and other extreme water-related events. Peak flow mitigation services are supplied together with river flood mitigation services in providing flood protection.
- **Nursery population and habitat maintenance services** are the ecosystem contributions necessary for sustaining populations of species that economic units ultimately use or enjoy either through the maintenance of habitats (for example, for nurseries or migration) or the protection of natural gene pools. This service may be an input to several different ecosystem services, including biomass provision and recreation-related services (for example, for fish harvested from rivers or lakes).
- **Recreation-related services a**re the ecosystem contributions, through the biophysical characteristics and qualities of ecosystems, that enable people to use and enjoy the environment through direct, in-situ, physical, and experiential interactions with the environment. This includes services to both locals and non-locals, that is, tourists (for example, canoeing on a river).
- **Visual amenity services** are the ecosystem contributions to local living conditions, through the biophysical characteristics and qualities of ecosystems that provide sensory benefits, especially visual (such as views of a river or snow, ice, and glaciers). This service combines with other ecosystem services, including recreation-related services and noise attenuation services, to underpin amenity values.

- **Spiritual, artistic, and symbolic services** are the ecosystem contributions, through the biophysical characteristics and qualities of ecosystems, that are recognized by people for their cultural, historical, aesthetic, sacred, or religious significance. These services may underpin people's cultural identity and may inspire people to express themselves through various artistic media.

Other types of ecosystem assets may also supply some of these services, for example, forests provide a water purification service and riparian vegetation provides water flow regulation services. This raises the issue of potentially double counting the value of ecosystem services, which is addressed in sections 2.2 and 3.4

The long list of water-related ecosystem services illustrates the challenge of water valuation. For CWON, it is difficult to estimate the value of all these ecosystem services. The two most important services for valuation are water supply and water purification. Water purification is important as the quality of water is a key determinant of its possible uses (for example, for drinking water) and hence its value.

The SEEA Ecosystem Accounting makes a distinction between the final and intermediate use of ecosystem services. Water supply is the most important final ecosystem service, and it embodies many of the services described above. Final ecosystem services *"are those ecosystem services in which the user of the service is an economic unit – i.e., business, government or household"* (paragraph 6.24), while intermediate services *"are those ecosystem services in which the user of the ecosystem services is an ecosystem asset and where there is a connection to the supply of final ecosystem services"* (paragraph 6.26). This distinction is necessary to avoid double counting (see section 4.4) and it is common for the value of an intermediate service to be embedded in a final service. For example, the value of the water purification service can be embedded in the water supply service (Vardon et al. 2019).

A basic ecosystem service account, adapted for water-related ecosystem services and ecosystem assets, is shown in Table 2.3. The rows represent the services and the columns represent the supply by the water-related ecosystem assets and the use by different parts of the economy.

TABLE 2.3: A SIMPLIFIED SUPPLY AND USE ACCOUNT FOR WATER-RELATED ECOSYSTEM SERVICES AND ASSETS

	Economy							Environment							
Physical or monetary units of measurement. The units of physical measure will vary by service	Agriculture	Mining	Manufacturing	Water supply	Energy	All other industries	Households	Reservoirs	Lakes	Rivers and streams	Snow, ice, and glaciers	Groundwater	Soil water	Other ecosystems types	**Total**
SUPPLY															
Water supply services															
Water purification services															
Water regulationr															
Recreation-related services															
USE															
Water supply services															
Water purification services															
Water regulationr															
Recreation-related services															

Gray is nil by definition.

2.3 DIFFERENCES BETWEEN SEEA-WATER AND THE SEEA ECOSYSTEM ACCOUNTING

There are differences in classifications and terminology and overlaps in the coverage of SEEA-Water and the SEEA Ecosystem Accounting (Vardon 2022). An implication of this is that care must be taken to avoid double counting the value of water assets if the information on water value is taken from the different types of SEEA-based accounts by countries.

The asset classifications in SEEA-Water and the SEEA Ecosystem Accounting are similar but have some minor differences (Table 2.4). Their classifications of surface water assets are the same, while the classification of groundwater assets and oceans and seas is more detailed in the SEEA Ecosystem Accounting. A key difference between the two systems is that SEEA-Water includes soil water ("green water"), whereas this is not explicitly included in the assets in the SEEA Ecosystem Accounting.

TABLE 2.4: COMPARISON OF THE ASSET CLASSIFICATIONS IN THE SEEA CENTRAL FRAMEWORK, SEEA-WATER, AND THE SEEA ECOSYSTEM ACCOUNTING

SEEA CENTRAL FRAMEWORK AND SEEA-WATER	SEEA ECOSYSTEM ACCOUNTING	NOTES FOR DETERMINING THE SCOPE AND DEFINITIONS OF WATER ASSETS FOR VALUATION
Surface water • Rivers and streams • Lakes • Artificial reservoirs • Snow, ice, and glaciers	Freshwater • F1 Rivers and streams • F2 Lakes • F3 Artificial reservoirs[23] • T6 Polar-alpine (cryogenic)	Direct correspondence between SEEA-Water, the SEEA Central Framework, and the SEEA Ecosystem Accounting.
Groundwater	• SF1 Subterranean freshwater • SF1 Anthropocentric subterranean freshwater • FM1 Semi-confined transitional waters	The SEEA Ecosystem Accounting subdivides groundwater into three classes. In SEEA-Water and the SEEA Central Framework groundwater includes all of these sources and could be similarly divided.
Soil water	• Water use in rain-fed agricultural and cultivated forest ecosystems	SEEA-Water and the Central Framework only identify soil water, which is found in all ecosystem types with soil. However, in practice the use of soil water is only estimated for rain-fed agricultural ecosystems. The use of soil water can be shown by the ecosystem types used in the SEEA Ecosystem Accounting.
	Traditional • TF1 Palustrine wetlands • MFT1 Brackish tidal systems	SEEA-Water and the Central Framework do not explicitly recognize these assets although water assets consist *"of fresh and brackish water in inland water bodies, including groundwater and soil water"* (SEEA Central Framework, paragraph 5.474). These would likely be recorded as abstractions from surface water (that is, lakes).
Seas and oceans	Marine • M1 Marine shelf • M2 Pelagic ocean waters • M3 Deep sea floors	SEEA-Water included seas and oceans as a source of water for desalination and cooling water as well as receiving return flows from the economy and river outflows. The ocean accounts described in the SEEA Ecosystem Accounting do not consider marine ecosystems as a possible source of water.

23 Artificial reservoirs include all human-built water storages, from rainwater collection and small farm dams to large artificial reservoirs (for example, Hoover Dam, Kariba Dam, and Bhakra Nangal Dam).

2.4 UPTAKE OF WATER AND ECOSYSTEM ACCOUNTING

According to the United Nations, in 2021, 89 countries were producing or developing SEEA-based accounts, up from 54 countries in 2014.[24] The degree of uptake varies by region. Of the countries reporting SEEA-based accounts, Europe and North America combined had the highest percentage of countries at an advanced stage of implementation (95 percent) and Africa the lowest (24 percent), although in the 1990s many water accounts were produced in southern Africa (for example, Lange 1998; Lange et al. 2007). National-level ecosystem accounting is still emerging (Bordt and Saner 2018), with about 20 countries developing ecosystem accounts (Hein et al. 2020). There are numerous local or regional examples of ecosystem accounting, including water-related ecosystem services (for example, Keith et al. 2017; Capriolo et al. 2020; Taye et al. 2021; Deeksha and Shukla 2022), with a few at the national level (Bordt and Saner 2019).

A review of water accounting identified just over 200 water accounts (Appendix 4). The number of countries undertaking water accounting is estimated to be 67, with 49 of these countries having produced accounts only once. The SEEA was the most popular system in use (49 percent), followed by Water Accounting Plus[25] (28 percent). Accounts were produced by a range of organizations and published as "official" accounts (for example, MLMWSS 2018) or in the academic literature (for example, Bagstad et al. 2020). The most common type of accounts produced was the physical supply and use tables (n=70) and physical asset accounts (n=69). Few countries (n=13) produced monetary supply[26] and use tables and only two countries—Namibia and the Philippines—have produced a monetary asset account, but this was a long time ago. The use of soil water is seldom recorded (for example, ABS 2013). Weckström et al. (2020) noted that most countries had highly aggregated industries and sectors shown in the water supply tables, and only three countries—Australia, Denmark, and the Netherlands—included more than 30 industries and sectors. A small number of industries limits the usefulness of water accounting for computable general equilibrium modeling and input-output analysis.

For CWON, if more countries had water accounts or accounted for water-related ecosystem services, then there would be a ready source of information on water value at a country level. However, no country has monetary accounts for water assets, and at present, few countries have accounts of sufficient detail that would enable estimations of water value to be directly derived from country-level information. Because of this, other options for water valuation are needed, for estimates of water value to be made for 150 or more countries.

24 United Nations. 2021 Global Assessment of Environmental-Economic Accounts. https://seea.un.org/sites/seea.un.org/files/global_assessment_2021_background_doc_update.pdf

25 https://wateraccounting.un-ihe.org/welcome-water-accounting-plus-0.

26 Australia, Botswana, Denmark, Israel, Jordan, Namibia, the Netherlands, Palau, the Philippines, Samoa, South Africa, Spain, and Zambia.

3 Water Valuation Options for CWON

Valuing water assets for CWON can be approached from at least three perspectives: asset-by-asset, use-by-use, and service-by-service (ecosystem services).

The first approach is the direct valuation of water assets from observed market transactions within countries. The other two approaches use valuations based on the water used by industries, sectors, and households to derive a value for water assets using resource rent and net present value. The use-by-use approach would use country-level data, while the service-by-service approach would use global data sources and models. The value of water assets derived using the service-by-service approach would likely be larger than that of the use-by-use approach as there are many ecosystem services derived from water assets, whereas the use-by-use approach effectively only values the water supply ecosystem service. Section 4 provides information on the data sources and methods available to support each option, with a focus on their suitability for CWON.

3.1 ASSET-BY-ASSET

The direct value of water assets is not usually observed in markets. However, while the water assets themselves are not traded, their value can be determined through the value of water rights, which are a *"permit to use a natural resource"* within the SNA (paragraph 17.324) and are distinct from the value of land (Comisari and Vardon 2013). A *"permit to use a natural resource"* is a type of financial asset in the SNA (paragraph 3.36).

Although water rights are a financial asset, in the SNA the value of the water rights traded can be taken to represent the value of the water asset that underpins the financial asset. While some countries and regions have tradable water rights—for example, Australia, Chile, Iran, South Africa, and parts of the United States (UN 2021)—using these to value water is unfeasible for countries without water rights, which is most countries. There is also concern about the functioning of some markets for water rights (Garrick et al 2020). As such, using water rights to value water assets for inclusion in CWON is not feasible in the short term, except for the few countries with water rights.

Land is traded in most, if not all, countries. As part of the asset "land," the SNA includes *"water associated with land,"* which relates to *"any inland waters (reservoirs, lakes, rivers, etc.) over which ownership rights can be exercised and that can, therefore, be the subject of transactions between institutional units"* (2008 SNA, paragraph 10.175). While not specifically mentioned, soil water is also part of land in the context of the SNA, and soil water can only be accessed via land, for example, by growing rain-fed crops (Comisari and Vardon 2012). Hedonic pricing could be used to decompose the value of land into the value of water and land. This has been done at local levels (for example, Moore et al. 2020). However, a large amount of data is needed for hedonic pricing. The information needed includes the price of land traded, the total area of land able to be traded,[27] the physical characteristics of the land

27 Note that all land can be traded. For example, the area of land in national parks.

including the level of rainfall, the value of economic production on the land, and other economic factors such as proximity to transport infrastructure.

This data would need to be obtained for each country and would have to be built "bottom-up." The data requirements represent a significant barrier to estimating the value of water assets using hedonic pricing, hence this approach to valuing water assets is unsuitable for CWON at this time.

3.2 USE-BY-USE

The use-by-use approach is another bottom-up approach. It would be done country by country using assessments of water use by different industries—agriculture, mining, manufacturing, energy, water supply, education, health, and so on—with water as one input to production. In this approach, the value of the water used is embedded in the value added by each industry, rather than just the price paid per unit volume used (which may be zero in the case of using "green" water in rain-fed agriculture). The use-by-use approach requires information from the SNA on industry value added and the amount of water used by each industry and the household sector, and the sources of water used by each industry and households. The SEEA's water supply and use tables provide this information, but these are only available for a handful of countries at the level of detail needed for this approach. For this reason, a use-by-use approach based on the SEEA's supply and use tables is not feasible for 150 countries at this time.

A partial estimate based on water use in agriculture would be possible, with the use of global hydrological models, information on the value of agricultural commodities produced, and the costs associated with this production. This approach is similar to that already used in CWON to value agricultural land. If a partial estimate of the value of agricultural water use was made, then this value would probably need to be deducted from the value of agricultural land that is already included in CWON.

3.3 SERVICE-BY-SERVICE

An ecosystem service-by-service approach is already part of CWON. Siikamäki et al. (2023) produced an estimate for the value of forests using ecosystem services, with prices derived from a meta-analysis. The report estimated the value of four water-related ecosystem services: erosion control, flood protection, hydropower, and water services emanating from forests. These services were aligned with the reference list of services in the SEEA Ecosystem Accounting (see section 2.2) and related methods (see section 4). Final and intermediate ecosystem services (see section 2.2) were not distinguished by Siikamäki et al. (2023), hence double counting of value may occur (see section 3.4).

The assessment of forest value by Siikamäki et al. (2023) identified 47 papers including four water-related ecosystem services, with 27 papers on water services, which include water supply and water purification (filtration). Some of the studies used contingent valuation that is not consistent with the concept of exchange value, but the estimates from contingent valuation may be used as input to the simulated exchange method that does generate exchange values (NCAVES and MAIA 2022). Siikamäki et al. (2023) reviewed the studies that used contingent valuation to ensure that the studies were consistent with exchange value. Some popular models, like InVEST, used to estimate the water supply ecosystem service are not fully aligned with the SEEA ecosystem services definition as these estimate the potential supply of water (essentially runoff) and not the use of water by industries and sectors. An examination of the 27 papers is needed to establish if the estimated volume of water supplied or purified aligns with the SEEA definition of ecosystem services, and if there is any possible double counting of water-related service flows (see Figure 2.2).

The ecosystem service-by-service approach can be, and in the case of forests has been, used to generate values for natural capital assets. This approach could be extended to all other ecosystem assets beyond forests, including water-related ecosystem assets like surface water and groundwater.

If an ecosystem service approach is used to value water assets, then the number and type of ecosystem services that contribute to value need to be determined. If the valuation is based on the single ecosystem service of water supply, then it would in theory be equal to the value calculated by the use-by-use approach, since the water supply ecosystem service is equivalent to the amount of water abstracted for use (see section 2.2). It is important to note that the use of "green" water in agriculture is already included in the value of agricultural land, so is a source of double counting (see section 3.4). If the valuation of ecosystem services extends to other ecosystem services (for example, recreation-related services), then the value of the water assets will be greater than the value calculated using the use-by-use approach as more factors are contributing to water value.

3.4 DOUBLE COUNTING

Whatever approach is taken to value water assets, there is likely to be double counting of value within the natural capital assets already included in CWON or planned to be included in CWON.

Double counting of the value of water assets would occur in the valuation of forests, agricultural land, and renewable energy. The forest valuation explicitly includes the value of water-related ecosystem services (Siikamäki et al. 2023), while the value of water is embedded in the value of agricultural products used to value agricultural land (Gerber et al. 2020). The value of soil water used for agricultural production is also included in the value of land in the balance sheet of the SNA. The valuation of renewable energy, which is planned to be included in the next CWON, will also include the value of water in the generation of hydroelectricity.

Another source of double counting would arise if an ecosystem service approach is adopted and the final and intermediate ecosystem services are not distinguished. It is usual for the final ecosystem service of water supply to use the intermediate service of water purification, which could result in double counting (see Figure 2.2).

4 Data Sources and Methods

If the value of water is to be included in CWON, then it should be consistent with the valuation of other natural assets in CWON, which is based on the SNA and exchange values (see section 1.3). At a country level, ready-made estimates of water value from SNA balance sheets or water accounts are not available. In the absence of such estimates, a range of data sources, models, and valuation methods consistent with exchange values are needed.

4.1 VALUATION METHODS

The SEEA Ecosystem Accounting provides a list of five methods to calculate the value of natural resources and ecosystem services that are consistent with exchange values (UN et al. 2021). In the order of preference, these methods are ones where the price is:

- Directly observable
- Obtained from markets for similar goods and services
- Embodied in a market transaction
- Based on revealed expenditures (costs) for related goods and services
- Based on expected expenditures or markets.

The first valuation method is problematic for several reasons (UN 2012a; see also section 1.1). First, water is an essential good, so while water is transacted in markets, the price of distributed water for drinking ("potable water" or "tap water") or industry use (for example, irrigated agriculture) is almost always subsidized. Second, water supply authorities are mostly state-owned enterprises, which do not seek to maximize profit but to provide an essential service. It is usual for the water to be provided "at cost"—that is, the payments made reflect only the capital and running costs, and no payment is made for the water (for example, Wheeler et al. 2023). In many cases, water is provided for use at less than cost. This results in zero or negative resource rents, implying no value (for example, Obst et al. 2016). While the methods based on observable prices are problematic, the observed values can at least be recorded, and this has been done by several countries and presented in SEEA-Water monetary supply use tables (for example, for Australia, the Netherlands, and Zambia).

For many countries, and in particular, low- and middle-income countries, water is "self-supplied." That is, rather than water being supplied to people and industries (including agriculture) via a water distribution network, people and industries extract water from wells, rivers, and lakes or collect rainwater in tanks and dams. This own-account production—while theoretically in the scope of the SNA (section 1.3)—is not usually recorded in the SNA in practice.

Because the observed prices are distorted and own-account production may be missing, alternative methods for water valuation are required. The need for such methods is recognized in the SEEA Ecosystem Accounting and methods for water-related ecosystem services are outlined by NCAVES and MAIA (2022). For water provisioning and water purification services, at least four methods are possible:

- **Productivity change.** For water provisioning, this is done using partial and general equilibrium models and looking at the impacts of a reduction in water supply on the output in different sectors of the economy (for example, Calzadilla et al. 2013; Roson and Damania 2016; Mul et al. 2020).

- **Replacement cost methods.** For water provisioning, this is where a source of water is valued based on the cost of obtaining the water from the lowest cost source (adjusted for water quality) (for example, Edens and Graveland 2013; Keith et al. 2017). An example would be using the cost of providing water through desalination. For water purification, this would be the capital (that is, infrastructure) and running costs of purifying water to the same level of water quality (for example, La Notte et al. 2012; Schenau et al. 2022)
- **Value of water rights.** For water provisioning, this is where they are separately identified (from land values), and trading in water rights takes place such that a market is established. These rights are financial assets and may be connected to a permanent right to abstract water or an annual allocation of water (Comisari and Vardon 2013).
- **Avoided damage costs.** For water purification, this is the reduction in water purification and treatment costs that arises from having the ecosystem service.

The damage to human health from water pollution (hence, lack of water purification service) is another potential approach that has been used in accounting (for example, Angeles and Peskin 1998) and in accordance with the notion of exchange values (that is, it is a type of avoided loss).

There are a range of sources and online databases for the valuation of ecosystem services and water, for example, a review of water valuation literature (EPA 2017), the Valuing Water Database,[28] the TEEB Valuation Database,[29] and the Ecosystem Services Valuation Database.[30] These sources can be investigated and any studies on water valuation could be used in a meta-analysis building on the work of Siikamäki et al. (2023).

4.2 GLOBAL DATA SOURCES AND METHODS

As ready-made country-level information on water assets, water use, and water-related ecosystem services is unavailable for most countries, global data and methods need to be investigated. These data sources and methods could be applied to the use-by-use or service-by-service approaches.

Kind et al. (2020) examined the feasibility of valuing water using the currently available global water databases and hydrological models. A list of global water databases and hydrological models is found in Appendix 5. Since the review by Kind et al. (2020), additional data sources and methods have become available, including an upgrade of the WA+ platform (Box 2.1), the development of ARIES for SEEA[31] (Box 4.1), and updates to IBNET (World Bank 2022). Further investigation is needed to determine the suitability of these data sources and models for the use-by-use or service-by-service approaches.

28 https://ceowatermandate.org/resources/valuing-water-database-2019/
29 https://teebweb.org/publications/other/teeb-valuation-database/
30 https://www.esvd.net/
31 https://seea.un.org/content/aries-for-seea

Box 4.1: ARIES for SEEA

Artificial Intelligence for Environment and Sustainability (ARIES) was developed by the Basque Centre for Climate Change (BC3). It is an application using a suite of models for estimating ecosystem services based on available data and open-source software (k.LAB[32]). ARIES for SEEA was developed in a partnership between the UN and BC3 and provides a user interface to compile SEEA-based ecosystem accounts. The ARIES application specifically considers the users (or beneficiaries) of ecosystem services, which sets it apart from other ecosystem service models like InVEST,[33] which do not use a definition of ecosystem services compatible with the SEEA. The ARIES for SEEA application can produce accounts and related maps for ecosystem extent, ecosystem condition, and selected ecosystem services. The ecosystem services currently available in ARIES for SEEA are crop provisioning, climate regulation, and soil erosion control. Crop provisioning and climate regulation are both available in physical and monetary terms, while only a physical estimate of erosion control is available. Nature-based tourism is planned to be added soon. The addition of the water supply ecosystem service in physical terms is being investigated based on the approach of Fasel et al. (2016) (Ken Bagstad, pers.com). ARIES for SEEA uses the global ecosystem[34] and land cover classifications recommended in the SEEA Ecosystem Accounting.

32 https://integratedmodelling.org/hub/#/register

33 Integrated Valuation of Ecosystem Services and Trade-offs. https://naturalcapitalproject.stanford.edu/software/invest

34 IUCN Global Ecosystem Typology. https://portals.iucn.org/library/node/49250

5 Way Forward

This report confirms the findings of past research—there are theoretical and practical challenges to estimating water value (Table 5.1). We know that water is valuable, but it is difficult to put a monetary value to water assets. The prices paid for water are distorted, the methods for water valuation are many and reflect different concepts of value, and data deficiencies and model assumptions mean that estimates of value will be uncertain.

TABLE 5.1: SUMMARY OF THE THEORETICAL AND PRACTICAL CHALLENGES WITH WATER VALUATION

ASPECTS OF WATER VALUE	THEORETICAL CHALLENGES	PRACTICAL CHALLENGES
Price	Defining the economy and the environment Determining the concept of value to measure: exchange or welfare values	Establishing a price when: • No market transaction occurs • Transactions occur but are subsidized • The value of water is embedded within other assets • The value of water is embedded in the value added of users Economic data gaps and deficiencies, for example: • Access to existing financial information of water suppliers and users • Lack of financial information on water suppliers and users • Spatially explicit or local-level data Multiple methods to estimate water prices Lack of integration with environmental data
Quantity used	Determining when water is physically exchanged between the environment and economy Determining when water is of benefit to people but not physically exchanged	Environmental data gaps and deficiencies for measuring exchanges of water, for example: • Between the environment and the economy • Within the economy • Spatially explicit or local-level data Multiple methods and models to estimate water volume Lack of integration with environmental data

The SEEA provides a clear theoretical framework for water valuation that has been agreed on through international processes. It clearly defines the economy and environment, and the transactions recorded within and between the different parts of the economy and environment are standardized. The use of the SEEA also ensures conceptual harmony with the other assets already included or planned to be included in CWON. Practically, the SEEA provides a platform for reconciling different data sources. However, producing estimates for 150 or more countries would be difficult with the available data sources and methods, and any estimates generated would be uncertain and have many caveats.

5.1 OPTIONS FOR VALUATION

For an asset to be included in CWON, comparable estimates of value need to be made for 150 or more countries, drawing on publicly accessible data and accepted valuation methods. Three valuation options are identified: asset-by-asset, use-by-use, and service-by-service.

The direct valuation of water assets, the asset-by-asset approach, is not possible as there are few markets for water rights and tradable permits, nor is there data that would enable the value of water to be separated from the value of land.

Two options remain for water valuation at the scale required for inclusion in CWON, a use-by-use bottom-up approach or a service-by-service top-down approach:

- The bottom-up approach would estimate the total use of surface and soil water (and possibly some groundwater) at the country level by examining the supply and use of water in the economy and the value added by each industry using water. This approach builds on the work of Kind et al. (2020) and can leverage some country valuations (for example, Edens and Graveland 2014; Fenichel et al. 2016) and the countries with existing SEEA-based supply and use tables (such as Australia; ABS 2022).

- Top-down approaches would estimate the volumes of ecosystem services at a global level using global data and hydrological models to estimate the volume of water and apply prices from a meta-analysis of valuation studies to all countries. This could be done for one or more water-related ecosystem services and would extend the approach of Siikamäki et al. (2023).

Each option has its advantages and weaknesses. Each would draw on the best available hydrological and economic information. Global data sources and methods can provide much of the hydrological information on the total amount of water abstracted from the environment (section 4.2), as well as its use by some industries, notably agriculture—the largest user of water.

The price per unit volume (for example, million cubic meters) of water is a challenge for both use-by-use and service-by-service. For the service-by-service top-down approach, it is logical to start by using the prices from the meta-analysis of Siikamäki et al. (2023) that are already used to estimate the water-related ecosystem services from forests. Any extension of this analysis (section 4.1) could be integrated into CWON to obtain a value for water assets. For the use-by-use bottom-up approach, there is some country-level data on water prices and the volume of water use, but it is scattered, and significant effort would be needed to consolidate this information.

The advantage of the top-down approach is that it can be done relatively easily, while its weaknesses are that the place-to-place variations in value due to relative water scarcity are not apparent and many caveats would be attached to any estimate. For this option, the degree of consistency with the SEEA of each of the studies used for valuation services, beyond those already assessed by Siikamäki et al. (2023), would need to be assessed. This includes how the ecosystem services are defined, the methods used to estimate service flows, and the use of exchange values. If ARIES for SEEA delivers a module for estimating the physical water supply ecosystem service in the near future, as planned, then there is a ready source of SEEA-aligned information for extending the coverage of these ecosystem services beyond forests. The use of other models and platforms is also possible.

The advantage of the use-by-use bottom-up approach is that the estimates are likely to more accurately reflect the uses and values of water within countries and that the development of water accounts, particularly at subnational levels, is likely to be of use for individual countries. The weakness is that few countries have existing water accounts (Vardon et al. 2023) that can be used for this, and large resources would be needed to develop accounts for 150 or more countries. A case study approach could be used, drawing on the existing water accounts of countries. These countries should represent different income levels and water availability as well as geographical balance. This work would build on previous country work in hydrology, water quality, water valuation, and water accounting.

Both the bottom-up and top-down options could be used. That is, a global-level service-by-service estimate could be prepared along with a selection of country-level use-by-use estimates. This would provide experimental estimates of water value for CWON as well as case studies to help understand the regional variation in water value and how the top-down and bottom-up approaches compare.

Simultaneously undertaking a service-by-service top-down and use-by-use bottom-up approach would improve understanding of the valuation issues and how water valuation could be used in countries. The results of the bottom-up approach can be used to calibrate the top-down approach and the bottom-up estimates for individual countries could replace those made from the top down. Reasons for discrepancies can be investigated and resolved.

5.2 CONCLUSION AND NEXT STEPS

Three approaches for estimating water value consistent with the value of the other natural capital assets in CWON were identified: asset-by-asset, use-by-use, and service-by-service. The service-by-service approach is based on the supply of water-related ecosystem services and is the most feasible at the scale required. However, it relies on incomplete environmental and economic data and many assumptions in models, which will probably result in a low-quality estimate. New data sources and models are in development and are expected to be available in the near future, which should lead to higher-quality estimates in the service-by-service approach. The use-by-use approach is possible but practically difficult. Data is only available for a small number of countries at this stage. In the future, the increasing adoption of natural capital accounting by countries should make this approach easier. The asset-by-asset approach is currently not possible due to a lack of information.

To move forward with water valuation, a combination of use-by-use bottom-up and service-by-service top-down options could be used to generate estimates for discussion. This would stimulate interest in the broader natural capital, water, and accounting communities by providing experimental estimates of water value as well as case studies to help understand the regional variation in water value. This would aid the:

- **Discovery of additional data sources and methods for water valuation** to assist with estimates based on the three approaches identified in this report. International agencies, countries, and research organizations hold a wealth of data and methods and not all of these have been identified.
- **Identification of other possible approaches to water valuation** not considered in this report.
- **Development of partnerships** to leverage the use of existing knowledge, identify data gaps and deficiencies, and seek additional resources for improving data sources for estimating the value of water in a systematic and comprehensive manner.
- **Promotion of the collection of data and methodological innovation** to enable reliable estimates of water value to be regularly produced.

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Appendix 1

Glossary of SEEA-Water

The terminology used in SEEA-Water was developed and agreed by an electronic discussion group (EDG) (SEEA-Water, paragraph 1.67). At the time, it was considered the best alignment of the terminology of each field. The EDG considered many sources' definitions, including the International Glossary of Hydrology[35] (WMO 2012), the FAO's Global Information System on Water and Agriculture of AQUASTAT,[36] the UN Glossary of Environmental Statistics,[37] and the SNA and SEEA (UN et al. 2003) glossaries. It should be noted that some of the glossaries have been updated since the adoption of SEEA-Water in 2007.

Abstraction: The amount of water that is removed from any source, either permanently or temporarily, in a given period of time for final consumption and production activities. Water used for hydroelectric power generation is also considered to be abstraction. Total water abstraction can be broken down according to the type of source, such as water resources and other sources, and the type of use. (EDG)

Abstraction for distribution: Water abstracted for the purpose of its distribution. (EDG)

Abstraction for own use: Water abstracted for own use. However, once water is used, it can be delivered to another user for reuse or for treatment. (EDG)

Actual evapotranspiration: The amount of water that evaporates from the land surface and is transpired by the existing vegetation/plants when the ground is at its natural level of moisture content, which is determined by precipitation. (EDG)

Actual final consumption of general government: The value of the government's total final consumption expenditure less its expenditure on individual goods or services provided as social transfers in kind to households. It is thus the value of the expenditures that the government incurs on collective services. (Based on 2008 SNA, paragraph 9.103)

Actual final consumption of households: The value of the consumption of goods and services acquired by individual households, including expenditures on non-market goods or services sold at prices that are not economically significant and the value of expenditures provided by government and non-profit institutions serving households. (2008 SNA, paragraph 9.81)

Aquifer: A geologic formation, group of formations, or part of a formation that contains sufficient saturated permeable material to yield significant quantities of water to wells and springs. (USGS)

Artificial reservoirs: Manmade reservoirs used for storage, regulation, and control of water resources. (EDG)

Brackish water: Water with a salinity content between that of freshwater and marine water. (EDG)

Catchment (synonym: river basin): An area having a common outlet for its surface runoff. (UNESCO/WMO International Glossary of Hydrology, 2nd ed., 1992)

Cooling water: Water which is used to absorb and remove heat.

35 https://library.wmo.int/index.php?lvl=notice_display&id=7394#.Y3Fwe3ZxWUk
36 https://www.fao.org/aquastat/en/databases/glossary/
37 https://unstats.un.org/unsd/environmentgl/#:~:text=The%20UNSD%20Glossary%20of%20Environment,development%20indicators%2C%20and%20environmental%20accounting.

Determinand: Parameter, water quality variable, or characteristic of water quality.

Direct use benefits: Benefits derived from the use of environmental assets as sources of materials, energy, or space for input into human activities. (SEEA-2003, paragraph 7.36)

Economic unit: A unit that engages in production and/or consumption activities.

Emission to water: The direct release of a pollutant into water, as well as its indirect release by transfer to an off-site wastewater treatment plant. (Based on the European Commission, 2000, Guidance document for EPER implementation: According to Article 3 of the Commission Decision of 17 July 2000 (2000/479/EC) on the implementation of a European Pollutant Emission Register (EPER), https://wedocs.unep.org/handle/20.500.11822/1004?show=full)

Evapotranspiration: The quantity of water transferred from the soil to the atmosphere by evaporation and plant transpiration. (EDG)

Exports: Water that exits the territory of reference through mains or other forms of infrastructure. (EDG)

Final consumption expenditure of households: The expenditure, including imputed expenditure, incurred by resident households on individual consumption goods and services, including those sold at prices that are not economically significant. (2008 SNA, paragraph 9.94)

Freshwater resources: Naturally occurring water having a low concentration of salt. (EDG)

Glaciers: An accumulation of ice of atmospheric origin generally moving slowly on land over a long period. (UNESCO/WMO International Glossary of Hydrology, 2nd ed., 1992)

Gross capital formation: The total value of the gross fixed capital formation, changes in inventories and acquisitions less disposal of valuables for a unit or sector. (2008 SNA, paragraph 10.31)

Groundwater: Water which collects in porous layers of underground formations known as aquifers. (SEEA-2003)

Groundwater recharge: The amount of water added from outside to the zone of saturation of an aquifer during a given period of time. Recharge of an aquifer is the sum of natural and artificial recharge. (EDG)

Hydroelectric power generation, water use for: Water used in generating electricity at plants where the turbine generators are driven by falling water. (USGS, https://pubs.usgs.gov/chapter11/)

Hydrological cycle (synonym: water cycle): The succession of stages through which water passes from the atmosphere to the Earth and returns to the atmosphere: evaporation from the land, sea, or inland water, condensation to form clouds, precipitation, accumulation in the soil or in bodies of water, and re-evaporation. (UNESCO/WMO International Glossary of Hydrology, 2nd ed., 1992)

Imports: Water that enters the territory of reference through mains or other forms of infrastructure. (EDG)

Inflow: Water that flows into a stream, lake, reservoir, container, basin, aquifer system, etc. It includes inflows from other territories/countries and inflows from other resources within the territory. (EDG)

Intermediate consumption: The value of the goods and services consumed as inputs by a process of production, excluding fixed assets, the consumption of which is recorded as consumption of fixed capital; the goods or services may be either transformed or used up by the production process. (Based on 2008 SNA, paragraph 6.213)

Irrigation water: Water artificially applied to land for agricultural purposes. (UNESCO/WMO International Glossary of Hydrology, 2nd ed., 1992)

Lake: A generally large body of standing water occupying a depression in the Earth's surface. (EDG)

Mine water (synonym: mining water use): Water used for the extraction of naturally occurring minerals including coal, ores, petroleum, and natural gas. It includes water associated with quarrying, dewatering, milling, and other on-site activities carried out as part of mining. Excludes water used for processing, such as smelting and refining, or slurry pipeline (industrial water use). (USGS, http://pubs.usgs.gov/chapter11/chapter11M.html)

Non-point source of pollution: Pollution sources that are diffused and without a single point of origin or not introduced into a receiving stream from a specific outlet. The pollutants are generally carried off the land by stormwater runoff. The commonly used categories for nonpoint sources are agriculture, forestry, urban areas, mining, construction, dams and channels, land disposal, and saltwater intrusion. (UNSD, online glossary of environment statistics)

Option benefits: Benefits derived from the continued existence of elements of the environment that may one day provide benefits for those currently living. (SEEA-2003, paragraph 7.37)

Outflow: Flow of water out of a stream, lake, reservoir, container, basin, aquifer system, etc. It includes outflows to other territories/countries, to the sea, and to other resources within the territory. (EDG)

Perennial river: A river which flows continuously throughout the year. (Based on UNESCO/WMO International Glossary of Hydrology, 2nd ed., 1992)

Point source of pollution: Emissions for which the geographical location of the discharge of the wastewater is clearly identified, for example, emissions from wastewater treatment plants, power plants, and other industrial establishments.

Population equivalents: One population equivalent (p.e.) means the organic biodegradable load having a five-day biochemical oxygen demand (BOD5) of 60 g of oxygen per day. (OECD/Eurostat joint questionnaire on inland water)

Potential evapotranspiration: The maximum quantity of water capable of being evaporated in a given climate from a continuous stretch of vegetation covering the whole ground well supplied with water. It thus includes evaporation from the soil and transpiration from the vegetation of a specified region in a given time interval, expressed as depth. (EDG)

Precipitation: The total volume of atmospheric wet precipitation, such as rain, snow, and hail, on a territory in a given period of time. (EDG)

Recycled water: The reuse of water within the same industry or establishment (on site). (EDG)

Reused water: Wastewater delivered to a user for further use with or without prior treatment. Recycling within industrial sites is excluded. (EDG)

River basin (see also catchment): An area having a common outlet for its surface runoff. (EDG)

Rivers and streams: Bodies of water flowing continuously or periodically in a channel. (EDG)

Runoff: The part of precipitation in a given country/territory and period of time that appears as stream flow. (EDG)

Sewage sludge: The accumulated settled solids separated from various types of water, either moist or mixed with a liquid component, as a result of natural or artificial processes. (OECD/Eurostat joint questionnaire on inland water)

Social transfers in kind: Individual goods and services provided as transfers in kind to individual households by government units (including social security funds) and non-profit institutions serving households, whether purchased on the market or produced as non-market output by government units or non-profit institutions serving households. The items included are (a) social security benefits and reimbursements; (b) other social security benefits in kind; (c) social assistance benefits in kind; and (d) transfers of individual non-market goods or services. (Based on 2008 SNA, paragraph 8.141)

Soil water: Water suspended in the uppermost belt of soil or in the zone of aeration near the ground surface that can be discharged into the atmosphere by evapotranspiration. (EDG)

Standard river unit (SRU): A river stretch of one kilometer with a water flow of one cubic meter per second. (SEEA-2003, paragraph 8.128)

Supply of water to other economic units: The amount of water that is supplied by one economic unit to another and recorded net of losses in distribution. (EDG)

Surface water: Water which flows over, or is stored on, the ground surface. It includes artificial reservoirs, lakes, rivers and streams, glaciers, snow, and ice. (EDG)

Trade margin: The difference between the actual or imputed price realized on a good purchased for resale (either wholesale or retail) and the price that would have to be paid by the distributor to replace the good at the time it is sold or otherwise disposed of. (2008 SNA, paragraph 6.146)

Transboundary waters: Surface or ground waters which mark, cross, or are located on boundaries between two or more states; wherever transboundary waters flow directly into the sea, these transboundary waters end at a straight line across their respective mouths between points on the low-water line of the banks. (UNECE, 1992, https://unece.org/fileadmin/DAM/env/water/publications/brochure/Water_Convention_e.pdf)

Transport margin: Transport charges payable separately by the purchaser in taking delivery of goods at the required time and place. (2008 SNA, paragraph 6.141)

Urban runoff: That portion of precipitation on urban areas that does not naturally percolate into the ground or evaporate, but flows via overland flow, underflow, or channels, or is piped into a defined surface water channel or a constructed infiltration facility.

Use of water received from other economic units: The amount of water that is delivered to an economic unit from another economic unit. (EDG)

Wastewater: Water which is of no further immediate value to the purpose for which it was used or in the pursuit of which it was produced because of its quality, quantity, or time of occurrence. However, wastewater from one user can be a potential supply of water to a user elsewhere. It includes discharges of cooling water. (EDG)

Water body: A mass of water distinct from other masses of water. (UNESCO/WMO International Glossary of Hydrology, 2nd ed., 1992)

Water consumption: That part of water use which is not distributed to other economic units and does not return to the environment (to water resources, sea, and ocean) because during use it has been incorporated into products or consumed by households or livestock. It is calculated as the difference between total use and total supply; thus, it may include losses due to evaporation occurring in distribution and apparent losses due to illegal tapping as well as malfunctioning metering. (EDG)

Watercourse: A natural or manmade channel through or along which water may flow. (UNESCO/WMO International Glossary of Hydrology, 2nd ed., 1992)

Water losses in distribution: The volume of water lost during transport through leakages and evaporation between a point of abstraction and a point of use, and between points of use and reuse. Water lost due to leakages is recorded as a return flow as it percolates to an aquifer and is available for further abstraction; water lost due to evaporation is recorded as water consumption. When computed as the difference between the supply and use of an economic unit, it may also include illegal tapping. (EDG)

Water returns: Water that is returned to the environment by an economic unit during a given period of time after use. Returns can be classified according to the receiving media (water resources and sea water) and to the type of water (such as treated water and cooling water). (EDG)

Water supply: Water leaving/flowing out from an economic unit. Water supply is the sum of water supply to other economic units and water supply to the environment. (EDG)

Water supply to the environment: See water returns.

Water supply within the economy: Water which is supplied by one economic unit to another. Water supply within the economy is net of losses in distribution. (EDG)

Water use: Water intake of an economic unit. Water use is the sum of water use within the economy and water use from the environment. (EDG)

Water use from the environment: Water abstracted from water resources, seas, and oceans, and precipitation collected by an economic unit, including rain-fed agriculture. (EDG)

Water use within the economy: Water intake of one economic unit, which is distributed by another economic unit. (EDG)

Appendix 2

Physical water supply and use accounts—Example from the SEEA Central Framework

Physical supply table for water

	Abstraction of water; production of water; generation of return flows							Flows from the rest of the world	Flows from the environment	Total supply
	Agriculture, forestry, and fishing	Mining and quarrying, manufacturing and construction	Electricity, gas, steam, and air conditioning supply	Water collection, treatment, and supply: Total (excluding household activity)	Water collection, treatment, and supply: Household activity	Sewerage	Other industries	Imports		
Sources of abstracted water										
Inland water resources										
Surface water									440.6	440.6
Groundwater									476.3	476.3
Soil water									50	50
Total									966.9	966.9
Other water sources										
Precipitation									101	101
Sea water									101.1	101.1
Total									202.1	202.1
Total supply abstracted water									1,169	1,169
Abstracted water										
For distribution				405.6						405.6
For own-use	108.4	114.6	404.2	23	10,8	100.1	2.3			763.4
Wastewater and reused water										
Wastewater										
Wastewater to treatment	17.9	117.6	5.6	1.4	235.5	0	49.1			427.1
Own treatment										0
Reused water produced										
For distribution						42.7				42.7
For own use		10								10
Return flows of water										
To inland water resources										
Surface water			300		0.5	52.5	0.2			352.7
Ground water	65	23.5		47.3	4.1	175	0.5			311.3
Soil water										0
Total	65	23.5	300	47.3	4.6	227.5	0.7			664
To other sources		5.9	100		0.2	256.3				362.2
Total return flows	65	29.4	400	47.3	4.8	483.8	0.7			1,026.2
Evaporation of abstracted water, transpiration, and water incorporated into products										
Evaporation of abstracted water	76.2	43.2	2.5	1.8	10	0.7	3.6			138
Transpiration										
Water incorporated into products										
Total supply	**267.5**	**314.8**	**812.3**	**479.1**	**261.1**	**627.3**	**55.7**	**0**	**1,169**	**3,986.8**

Physical use table for water

	Abstraction of water; intermediate consumption; return flows							Final consumption	Flows from the environment	Flows from the rest of the world	Flows to the environment	Total use
	Agriculture, forestry, and fishing	Mining and quarrying, manufacturing and construction	Electricity, gas, steam, and air conditioning supply	Water collection, treatment, and supply		Sewerage	Other industries	Households		Exports		
				Total (excluding household activity)	Household activity							
Sources of abstracted water												
Inland water resources												
Surface water	55.3	79.7	301	4.5	0	0.1						440.6
Groundwater	3.1	34.8	3.2	423.1	9.8	100.1	2.3					466.5
Soil water	50											50
Total	108.4	114.5	304.2	427.6	9.8	0.1	2.3					957.1
Other water sources												
Precipitation				0	1	100						100
Sea water			100	1.1								101.1
Total	0	0	100	1.1	1	100	0					201.1
Total use abstracted water	108.4	114.5	404.2	428.7	10.8	100.1	2.3					1,158.2
Abstracted water												
Distributed water	38.7	45	3.9	27.4	0	0	51.1	239.5		0		405.6
Own use	108.4	114.6	404.2	23	0	100.1	2.3	10.8				763.4
Wastewater and reused water												
Wastewater												
Wastewater received from other units				0		427.1				0		427.1
Own treatment	12	40.7										0
Reused water												
Distributed reuse												
Own use												
Total	12	40.7	0	0	0	427.1	0	0		0		479.8
Return flows of water												
Returns of water to the environment												
To inland water resources											668.6	668.6
To other sources											362.4	362.4
Total return flows											1,031	1,031
Evaporation of abstracted water, transpiration, and water incorporated into products												
Evaporation of abstracted water											138	138
Transpiration												
Water incorporated into products												
Total use	**267.5**	**314.8**	**812.3**	**479.1**	**10.8**	**627.3**	**55.7**	**250.3**	**0**	**0**	**1,169**	**3,986.8**

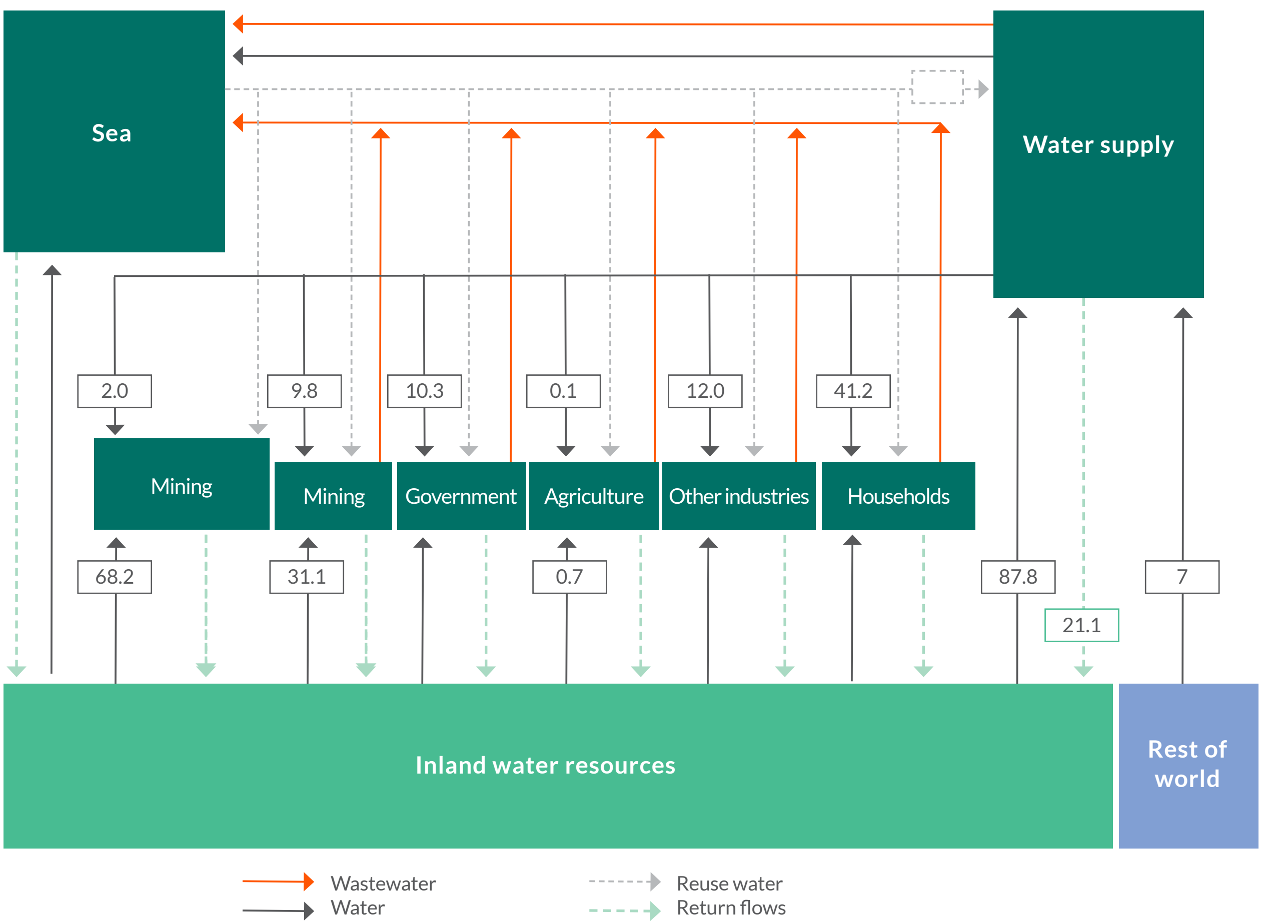
Source: SEEA Central Framework.

Appendix 3

Botswana as an example of water accounting supply and use tables

Figure A3.1 shows the physical supply and use of water in Botswana for 2014–15. The water accounts for Botswana are simplified supply and use tables. Many of the flows recorded and shown in Figure A3.1 were estimated, for example, the direct abstraction of water by households used coefficients of water use, while the flows returning from the economy to the environment use hydrological modeling. The scope of the accounts was also limited to surface water and groundwater; the use of soil water by rain-fed agriculture was not estimated.[38] An interesting feature of Botswana's account is that it shows the imports of water, which are supplied by the water supply industry in South Africa. These imports are not all of the water flows that enter from upstream countries.

FIGURE A3.1: BOTSWANA—PHYSICAL WATER SUPPLY AND USE, 2014–15 (MILLION M³)



Source: Botswana Water Accounting Report (MLMWSS 2018).

38 The use of soil water by rain-fed agriculture was considered out of scope but could be estimated using tools such as WA+ and CropWat. https://www.fao.org/land-water/databases-and-software/cropwat/en/

Appendix 4

Review of water accounting

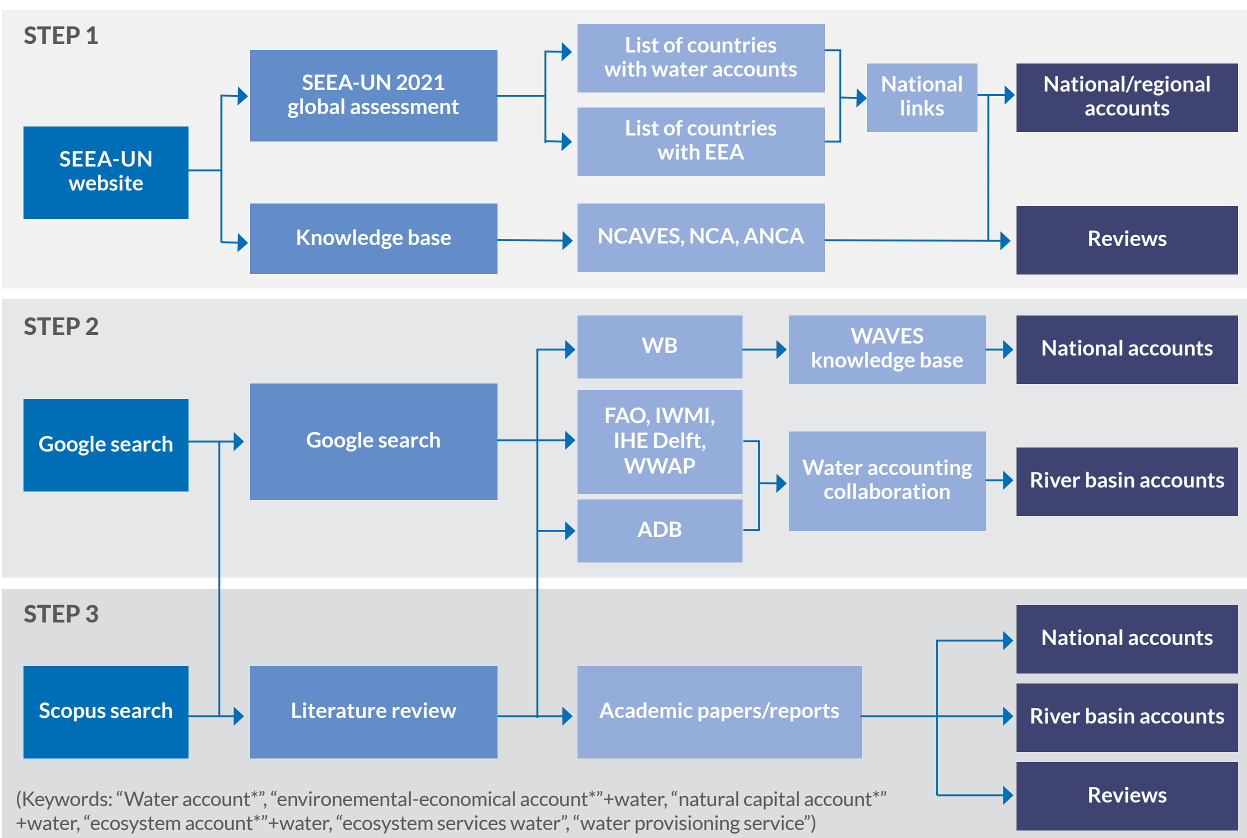
A4.1 INTRODUCTION

A global review was undertaken to assess the uptake of water accounting. The review is based on a database of water accounts compiled by the Australian National University as part of ongoing research into SEEA-based accounting. The summary results of the review are presented in section 2.4 of the main report, with more presented in Vardon et al. (2023). This appendix provides the data sources and methods for the review.

A4.2 DATA SOURCES AND METHODS

A three-step process was employed to identify water accounts (Figure A4.1). The first step was a search of known lists or sources of water accounts on the UN SEEA website.[39] The second step was a Google search and the third step was a search of the academic literature via Scopus and Google Scholar. The second and third steps ensured a broader coverage of water accounting as the UN and World Bank sources were primarily of accounts produced by governments or international agencies supporting governments using a SEEA-based accounting approach.

FIGURE A4.1: SEARCH PATHWAYS



Source: Vardon et al. (2023).

39 https://seea.un.org/

The first step was a thorough search of the UN SEEA website. From the results of the 2021 Global Assessment (which collected a wealth of information on the status and progress of implementation of the SEEA in countries), a list of countries with water accounts was made. Following the links provided on the SEEA website or by searching the official website of responding institutions provided in the list, national water accounts were accessed and downloaded. A similar search was expanded to other countries on the list that reported having other environmental accounts or ecosystem accounts. In addition, the knowledge base of the SEEA-UN website was searched for related literature and project documents supported by the UN, including the "Natural Capital Accounting and Valuation of Ecosystem Services" (NCAVES), the "Enhance Natural Capital Accounting Policy Uptake and Relevance" (EnhaNCA), and "Advancing Natural Capital Accounting" (ANCA).

The second step was a Google search for initiatives of other international organizations. This led to the knowledge base of WAVES and various water accounting initiatives led by the Asian Development Bank (ADB), the Food and Agriculture Organization (FAO) in cooperation with the World Water Assessment Programme (WWAP), the International Water Management Institute (IWMI), and the IHE Delft Institute for Water Education (IHE Delft). While the WAVES knowledge base provides access to mostly national-level water accounts, the other sources focused more on water accounts for river basins. The Google search also helped find water accounts of some countries or regions, especially those with highly visible webpages for water accounts, such as Australia and Europe.

The third step involved carrying out a systematic search in the Scopus database and Google Scholar to find water accounts and reviewing documents from academic and other sources. The following keywords were used: "water account*"; "environmental account*" +water; "environmental and economic account*" +water; "economic-environmental account*" +water; "natural capital account*" +water; "ecosystem account*" +water; "ecosystem services water"; and "water provisioning service." No other restrictions were set. As a result, more than 2,000 journals and documents of all types were found, of which about 500 had the keyword "water account*" in the title. These were scanned to find water accounts and most of the accounts found were for river basins.

The water accounts found were entered into a Microsoft Access database that was developed specifically to store and classify the accounts. The database was structured into six tables connected to each other by a unique letter account. The six tables were:

- **General information:** Publishing agency, institutionalized status, search strategy, sources of water account, and reviewed documents with links.
- **Boundaries and methodology:** Type of water accounts, adopted framework and methodology, and spatial boundaries.
- **Sector and industry coverage:** Industries covered by ISIC classification; typical sector split shown in agriculture, energy, and mining industry; and agricultural commodities covered.
- **Timeframe:** Publishing year, reference year, length of the time series, and gaps.
- **Physical scope:** Key physical indicators including import and export of water, water sources, losses, evaporation, return of water and wastewater, types of produced water assets, and split shown for treated and untreated water for water treatment plants, wastewater treatment plants, and desalination plants.
- **Economic scope:** Key economic indicators including the running cost of water treatment, wastewater treatment, and desalination; the value of produced water assets; and other economic information such as the value of irrigated agriculture, rain-fed agriculture, and hydroelectricity.

Appendix 5

Global water databases and hydrological models

	AQUASTAT	EUROSTAT	OECD. STAT	WISE	WRR	UNSD	WATER RISK FILTER	WASH
Publisher	FAO	European Commission	OECD	EEA	WRI	UN	WWF	UNICEF/WHO
Geographic coverage	Global	Europe	Global	Europe	Global	Global	Global	Global
Spatial resolution	National/ regional	National/state/ RBD	National	National, RBD, sub-unit	Regional, national	National	Sub-basins	National
Time coverage	1958–2017	1970–2016	1970–2016	2002–2012	1959–2011 + future projections	1990–2016	2000 – present + future projections	1950–2019
Relevant variables	• Sectoral surface water abstracted • Groundwater abstracted • Freshwater abstracted as the proportion of renewable water • Renewable freshwater resources	• Sectoral surface water abstractions • Fresh groundwater abstracted • Renewable freshwater resources	• Renewable freshwater resources • Total water abstractions • Return flow • Water use	• Sectoral water abstractions • Water use per supply category and economic sector	• Renewable freshwater resources • Annual water withdrawals • Water stress index • Modeled water availability and use for current and future climate conditions	• Sectoral water abstracted • Net freshwater supplied • Renewable freshwater resources	• Renewable freshwater resources • Water scarcity • Aridity • Water depletion • Baseline water stress • Access to safe drinking water • Future water discharge and water stress	Proportion of population using: • Drinking water services • Sanitation services • Piped drinking water sources • Sanitation facilities connected to sewer networks
Main data sources	• National statistical institutes • Modeled values • Eurostat/ UNSD/OECD	• OECD/ Eurostat joint questionnaire • National statistical institutes • Agricultural institutes • Universities	• OECD / Eurostat joint questionnaire • National statistical institutes • AQUASTAT	• Obligated national WFD reports of EEA member countries and cooperating countries	• AQUASTAT/ PCR-GLOBWB and other sources	• National statistical institutes • UNSD/UNEP questionnaire • AQUASTAT	• OECD • CGIAR • WRI • WaterGAP • UN IGRAC • UNICEF/ WHO • Various scientific publications	• National statistical institutes

Source: Kind et al. 2021.

WORLD BANK GROUP