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Issue #16: The treatment of water in artificial reservoirs[1]

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[1] This outcome paper has been prepared by the SEEA Editor. It is based on papers presented to the London Group of Experts on Environmental Accounting and discussions among those experts. Investigation and research for this outcome paper was led by Alessandra Alfieri of the UN Statistical Division, Michael Vardon of the Australian Bureau of Statistics and Michael Nagy of the Austrian Statistics Office.

A. Introduction

1. The amount of water evaporated from surface water bodies can represent a large proportion of the available water. In particular, the World Commission on Dams (WCD) estimated that evaporation from reservoirs is in the order of 188km^3 per year, which equates to more than 8% of the totals human consumption of freshwater (WCD 2000). Other studies also show that the increased surface area of reservoirs often leads to high volumes lost by evaporation.

2. At present evaporation from artificial reservoirs is recorded in the System of Environmental and Economic Accounts 2003 (SEEA-2003) and the SEEA-Water asset account as part of accounting for the change in the stock of water between beginning and end of period. However, evaporation from artificial reservoirs and is not shown in the physical or monetary supply and use tables as it is considered a flow within the environment.

3. Modification of these accounts or changes to the relevant accounting treatment to better represent evaporation may lead to significant improvement in the representation of evaporation in the SEEA water accounts reflecting that the construction of dams can lead to a substantial increase in evaporation. In turn this could lead to better decisions on the building of reservoirs, the allocation of water, and the calculation of water consumption and productivity for the units operating artificial reservoirs.

4. An additional consideration that emerges through the paper is whether the accounting treatments applied in the case of water should be aligned with the accounting treatments for other natural resources, such as timber, where there can be a reasonable degree of economic management and intervention.

5. The treatment of water in artificial reservoirs was discussed by the Expert Group Meeting (EGM) on the International Recommendations on Water Statistics (IRWS) held in New York, USA, 5-7 November 2008. The EGM identified the issue is being one that needed clarification in the SEEA revision process. It has subsequently been considered by the London Group at a number of its meetings.

6. This paper considers the relevant issues concerning the treatment of artificial reservoirs focusing on the boundary drawn for the SEEA supply and use tables. In this discussion the treatment of water resources more generally in the 2008 System of National Accounts (SNA) is of relevance. This discussion takes place in section B. In section C artificial reservoirs are defined more precisely and in section D two other issues concerning terminology in water accounts are considered. Recommendations for the revised SEEA are included at relevant points in the paper. An annex provides detail on two examples used in the paper to explain the proposed accounting treatment.

7. One issue noted by the London Group concerns valuation. At this stage the valuation of water remains a complex measurement issue. It is discussed at reasonable length in SEEA-Water but given the difficulties posed, it is recommended that the issue not be dealt with in SEEA Volume 1 but rather picked up in the context of SEEA Volume 2. Consequently this outcome paper, which is focused on the recommendations for SEEA Volume 1 does not cover the issue of the valuation of water.

B. The treatment of water resources and artificial reservoirs

Description of an alternative treatment

8. Broadly speaking, three categories of water resource can be described. First, there are water resources that are not used for economic purposes because they are not accessible or close to human habitation. These water resources may still play an important role in various ecosystems and hence are considered to be within the SEEA asset boundary.

9. Second, there are water resources that are largely unmanaged in economic terms but from which water is abstracted on a regular basis for a variety of economic purposes, examples include water abstracted from aquifers and rivers.

10. Third, there are water resources that exist due to active human intervention and management, usually involving the construction of dams and associated barriers. This water is stored and abstracted for a variety of economic purposes including the supply of water for use in the economy, the generation of hydro-electric power, flood protection and aquaculture. Water stored in artificial reservoirs are a significant component within this category.

11. In practice there will be water resources that do not fit neatly into any of the three categories but this typology is useful in explaining the possible accounting treatments.

12. In the context of the SNA the boundary of water resources is drawn around those water resources which have economic value and for which economic ownership can be determined. Thus most water resources in the scope of the second and third categories defined above will be within scope of the SNA asset boundary.

13. For all SNA water resources, whether largely unmanaged or relatively highly managed, the water is considered to enter the supply of an economy at the time it is abstracted from the water resource. Thus variations in the stock of water resources before any abstraction takes place, for example due to drought or heavy rain, do not affect the estimate of water supplied to the economy. Rather, these changes in the stock of water resources are recorded as other changes in the volume of assets. The SEEA-2003 and the SEEA-Water adopt the same treatment of water resources as the SNA. One consequence of this treatment is that, while the effect of evaporation is accounted for in the system as a whole, there is no direct accounting connection between the extent of evaporation and the production process of water supply.

14. The focus of discussion for this issue concerns whether the SNA and SEEA-2003 treatment should be applied to all water resources or whether, in the case of relatively highly managed water resources used primarily as part of the production process of water supply, such as artificial reservoirs, an alternative treatment should be considered. No alternative treatment is proposed for the category of largely unmanaged water resources.

15. In broad terms the alternative is that for certain relatively highly managed water resources (generically referred to in the following as artificial reservoirs) the water should be considered to enter the supply of an economy at the time that it enters the artificial reservoirs rather than at the time it is abstracted from them. Consequently changes in the stock of water in artificial reservoirs, including changes due to evaporation, would be regarded within the scope of the supply and use tables and accounting for evaporation would be within the same context as other flows in the abstraction and distribution of water through the economy.

16. The application of this alternative treatment only to artificial reservoirs is considered consistent with the degree of general management surrounding artificial reservoirs. Put differently, there is a production process that is being undertaken in the construction of walls and dams and the ongoing management of water levels that makes artificial reservoirs a distinctly different type of water resource comparer to aquifers for example. Thus the degree of management and human intervention in the creation of the water resources is an important factor to consider in determining an appropriate accounting treatment.

17. The alternative treatment is akin to the distinction currently made in the SNA between cultivated and non-cultivated forests. Those forests that are actively managed, for example plantation forests, are considered cultivated and the growth of the trees is considered as output of a production process recorded on an ongoing basis as the growth occurs. On the other hand, for those forests that are not actively managed the supply to the economy is only deemed to occur at the time of logging.

Accounting implications

18. In accounting terms the alternative treatment expands the production boundary relative to the SNA. Rather than recognizing the initial supply to the economy at the point of abstraction, the initial supply to be recorded is equal to the inflow to the artificial reservoir. This is likely to come from two sources associated rivers and catchments and direct precipitation. All outflows from the artificial reservoirs also need to be estimated including abstraction and evaporation.

19. If the artificial reservoir itself is regarded as being owned and managed by a distinct economic unit then the output of this unit would be calculated as output (i.e. water abstracted and delivered to other economic units) plus the change in inventories. The change in inventories is the net inflows and outflows – or net recharge – for the artificial reservoir. All else being equal higher rates of evaporation will lead to negative changes in inventories which will in turn be reflected in higher levels of use of water.

20. In this sense the evaporation from artificial reservoirs is being considered a cost within the production process and thus the alternative treatment serves to raise awareness of the cost of evaporation.

21. Following SNA principles, water is considered a product at the time it enters the supply of an economy. Under the 2008 SNA and SEEA-2003, water is considered to become a product at the time it is abstracted. Under the proposed treatment, water from artificial reservoirs would be considered a product when it enters the reservoir rather than when it is abstracted. This change implies that, in national accounting terms, water within artificial reservoirs is produced. In effect, the water in the artificial reservoir is recognized as inventory ready for future sale in the same way as coal extracted from the ground before further processing is an inventory. Importantly, its quantity can be determined at specific points in time, most notably at the beginning and end of each accounting period such that changes in inventory can be recorded.

22. Since inventories are a store of product that can be moved between accounting periods it is important that they are reflected on the statement of assets and liabilities (balance sheets) of the owning units. Following national accounts principles inventories are by definition store of products and are hence considered to be part of the category “produced assets”. Thus following national accounts principles water in artificial reservoirs would be considered within a broader asset classification as part of produced assets. Thus outcome is consistent with the treatment of a range of natural resources considered to be relatively highly managed including plantation forests and livestock.

23. The classification of assets for the revised SEEA is being considered under SEEA revision issue #10: Classification of assets and the final structure of the classification will need to consider the outcomes for this issue.

Discussion

25. There are a number of analytical implications that emerge from the proposed approach. They relate to implications that flow from considering the water in artificial reservoirs as being a product in the economy.

26. First, emissions to water that flow into artificial reservoirs would not be recorded as flows to the environment but rather would be considered as emission flows within the economy.

27. Second, when a new artificial reservoir is created, the initial filling of the reservoir would be considered an increase in inventories and an increase in production. This initial increase in production may not sit easily with the concepts of change in inventories and output as generally understood – especially in the case of a very large new reservoir.

28. Third, defining the boundaries around the management of artificial reservoirs might not be straightforward. The issue here is whether the management and production process surrounding artificial reservoirs can be constrained to the artificial reservoirs only or whether the management generally extends to consider the water basin more generally. Thus the boundary between what is produced and what is not produced may not be neat. More generally, distinguishing between artificial reservoirs and other managed water bodies might be difficult in some cases.

29. Finally, it is the case that the new treatment will require a change in the structure of the traditional supply and use tables for water to incorporate a change in inventories column (this is presented in the next sub-section).

30. One suggestion to avoid these accounting and analytical implications is to retain the current treatment whereby water is considered to become a product when abstracted from reservoirs but to also explicitly record memorandum items estimating the amount of evaporation as part of the supply and use table structure. This may provide the information required to better consider evaporation although it is recognized that it falls well short of embedding the accounting for evaporation in the key aggregates.

Recommendation 16.1: That in the revised SEEA, the production boundary of the SNA should be extended such that water in artificial reservoirs should be treated as entering the supply of the economy at the time it enters the artificial reservoir and the net recharge of water to artificial reservoirs should be recorded as a change in inventories.

Examples

31. Based on examples described schematically in Annex 1, the following two tables show the relevant accounting entries for the current SEEA-2003 treatment (Table 1) and the proposed treatment (Table 2). The key differences to note are

- The changed amounts of abstraction from the environment by the water supply industry (ISIC 36) - 100 units under the SEEA-2003 treatment and 160 units under the proposed treatment. This reflects the change in the point at which the water is considered to enter the supply of the economy.
- The changed total supply of water by the water supply industry – 100 units in the SEEA-2003 treatment and 140 units under the proposed treatment. This reflects the fact that some of the increased abstraction has been stored (positive change in inventories of 30 units) and there is also a need to account for returns of water to the environment of 10 units.
- The estimation of water consumption by the water supply industry. Under the SEEA-2003 treatment all water abstracted is distributed and hence water consumption is zero. Under the proposed treatment evaporation needs to be accounted for and this is reflected in the estimate of water consumption of 20 units.

Table 1: Physical supply and use tables for water: SEEA-2003/2008 SNA treatment

Use table

Physical units

		Industries (by ISIC Rev.4 categories)				Households	Total
		01-03	10-33	36	Total		
From the environment	**1 - Total abstraction** (=1.a+1.b = 1.i+1.ii)	**40**	**5**	**100**	**145**	**5**	**150**
	1.a Abstraction for own use	40	5		45	5	50
	1.b Abstraction for distribution			100	100		100
	From water resources:						
	1.i Artificial reservoirs			100	100		100
	1.ii Other inland water resources	40	5		45		45
Within the economy	**2. Use of water received from other economic units**	**60**	**15**		**75**	**25**	**100**
3. Total use of water (=1+2)		**100**	**20**	**100**	**220**	**30**	**250**

Supply table

Physical units

		Industries (by ISIC Rev.4 categories)				Households	Total
		01-03	10-33	36	Total		
Within the economy	**4. Supply**			**100**	**100**		**100**
	of which:						
	Water for delivery			100	100		100
To the environment	**5. Total returns (= 5.a+5.b)**	**58**	**2**		**60**	**10**	**70**
	5a. To artificial reservoirs						
	5b. To other sources	58	2		60	10	70
6. Total supply of water (= 4+5)		**58**	**2**	**100**	**160**	**10**	**170**
7. Consumption (=3-6)		**42**	**18**	**0**	**60**	**20**	**80**

Note: grey cells indicate zero entries by definition.

Table 2: Physical supply and use tables for water: Proposed treatment

Use table

Physical units

		Industries (by ISIC categories)				Households	Changes in inventories (ISIC 36)	Total
		01-03	10-33	36	Total			
From the environment	**1 - Total abstraction** (=1.a+1.b = 1.i+1.ii)	**40**	**5**	**160**	**205**	**5**		**210**
	1.a Abstraction for own use	40	5		45	5		50
	1.b Abstraction for distribution and storage			160	160			160
	1.i From water resources:							
	Other inland water resources	40	5	150	195	5		200
	1.ii From other sources							
	Collection of precipitation			10	10			10
Within the economy	**2. Use of water received from other economic units**	**60**	**15**		**75**	**25**	**30**	**130**
3. Total use of water (=1+2)		**100**	**20**	**160**	**280**	**30**	**30**	**340**

Supply table

Physical units

		Industries (by ISIC categories)				Households	Changes in inventories (ISIC 36)	Total
		01-03	10-33	36	Total			
	4. Supply			**130**	**130**			**130**
	of which:							
Within the economy	Water for delivery			100	100			100
	Water for storage			30	30			30
To the environment	**5. Total returns to other sources**	**58**	**2**	**10**	**70**	**10**		**80**
6. Total supply of water (= 4+5)		**58**	**2**	**140**	**200**	**10**		**210**
7. Consumption (=3-6)		**42**	**18**	**20**	**80**	**20**	**30**	**130**
Of which: Changes in inventories							30	30

C. Defining artificial reservoirs

32. As noted in the previous section artificial reservoirs are one of a number of types of water resource that might be considered to be relatively highly managed. This section proposes a definition of artificial reservoirs and proposes a range of inclusion and exclusions. Fundamental to the considerations in this section are the degree to which there has been investment in constructing the water resource, the degree to which there is regular management of water levels and the extent to which the water itself is used in subsequent production processes.

33. Based on consideration of a variety of definitions of artificial reservoirs (see Annex 2) the following is proposed as the definition for use in the revised SEEA.

> *Artificial reservoirs are man-made reservoirs used for storage, regulation and control of water resources.*

34. This definition includes any kind of water bodies which have been created in a location where no water body existed before as well as bodies of water which, as a result of physical

alterations by human activity, are substantially changed in character. In this context physical alterations mean changes to e.g. the size, slope, discharge, form and shape of river bed of a water body. Also included are cascading systems of dams in rivers even where the character may remain more river-like and large water storage tanks.

35. Clearly excluded are all kinds of natural water bodies (e.g. natural lakes or free flowing river stretches) even if the water is being used by the economy for abstraction or various in-situ uses (navigation, fishery, abstraction, power production without damming etc.).

36. However, it is recognised that even within this definition there are a large number of water bodies which may not be considered to be the type of water bodies to which the proposed change in treatment should be applied. For example, fish ponds would fall within the definition of artificial reservoirs but do not seem to fall within the intended scope of the proposed treatment.

37. In order to determine the treatment of borderline cases, it is proposed that any reservoir where a regular human intervention is needed to maintain a certain water level, water volume, storage capacity or water quality is considered an artificial reservoir for the purposes of the proposed treatment. A clear indication is if the regular interventions are binding from a legal or technical perspective (e.g. there is a legislation or a maintenance plan enforcing certain measures). This excludes interventions which are only necessary in extreme situations such as floods and droughts. It excludes also pure monitoring activities (e.g. measuring of water level or water quality), ad-hoc measures (such as repair and renewal of installations) and interventions which have to be done in longer intervals (such as once per month or per year).

38. From a practical perspective there are certain challenges in classifying individual reservoirs and gathering data. As a starting point the target artificial reservoirs might be defined using the definition of "large dams" as defined by the World Commission on Dams as they are also considered as those artificial reservoirs having the biggest impact on the total water balance of reservoirs.

39. The WCD definition for a large dam is :

> *"A dam with a height of 15m or more from the foundation. If dams are between 5-15m high and have a reservoir volume of more than 3 million m3, they are also classified as large by the International Commission on Large Dams."* (Glossary of WCD-Report 2000. http://www.unep.org/dams/WCD/report/WCD_DAMS%20report%20annexes.pdf)

40. As a second step estimates of non-covered artificial reservoirs should be included for high-evaporation countries.

Recommendation 16.2: That for the purposes of applying the treatment outlined in recommendation 16.1 the scope of artificial reservoirs should be man-made reservoirs used for storage, regulation and control of water resources where a regular human intervention is needed to maintain a certain water level, water volume, storage capacity or water quality.

D. Terminology

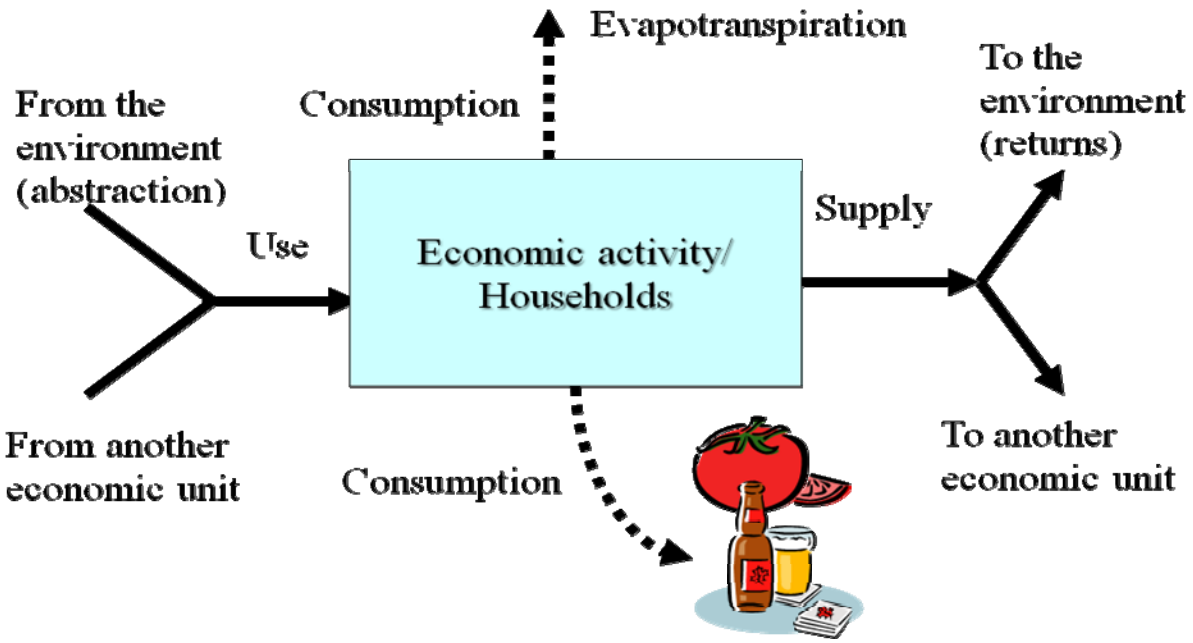
41. There are two terms commonly used in the discussion of water accounts that have caused some confusion as they do not relate directly to the use of similar terms in standard national accounts. This section describes the two terms and makes two recommendations.

Water consumption

42. The London Group questioned the use of the term "water consumption" as the concept being measured appeared inconsistent with the concept of consumption in the national

accounts. In water statistics 'water consumption' is understood as the difference between water use and water supply or the water intake and the water discharge of an economic unit. This is depicted in Figure 1.

Figure 1: Water flows



43. SEEA-Water defines water consumption as

> "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, consumed by households or livestock. It is calculated as a 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 and malfunctioning metering."

44. Water consumption consists of two main components:

i. Water incorporated into a product (e.g. in form of soft drinks, agricultural products or chemical products)
ii. Water evaporated (e.g. during a cooling process or increased open water surface) or transpired by plants and animals. The technical term for consumption processes including evaporation and transpiration is evapo-transpiration. Evapo-transpirated water is one of several forms of water loss (others are e.g. leakages).

45. In effect the concept underlying the term water consumption in water accounts and statistics is the amount of water no longer available for supply to another economic unit or returned to the environment. This is related but different from the concept of consumption in the national accounts which focuses on the value and volume of goods and services consumed to meet individual and collective human needs or wants (2008 SNA 9.39).

46. The difference concerns (i) the treatment of evaporation which is included in the concept of water consumption but does not represent a good or service consumed to meet individual or collective needs; and (ii) that the other component of water consumption relates to the

incorporation of water into other products as opposed to the use of water itself – for example for washing, drinking and irrigation.

47. From a national accounts perspective the term water consumption would most likely be interpreted as being the amount of water consumed as water by businesses (as intermediate consumption and which would include the amount of water incorporated into products at some stage in the production cycle) and by households (as final consumption). Thus there is relatively little consistency between the use of the term water consumption between national accountants and water statisticians.

48. In the context of alignment with other areas of physical flow accounting, i.e. energy accounts and material flow accounts, both of these area have concepts closely aligned with the water accounts concept of water consumption, although different terms are applied in these different accounts (for example the related concept is net energy use in energy accounting). Therefore, while there may be a difference between this general concept and the concept of consumption in the national accounts, there seems no doubt that in a physical flow accounting context the concept defined by water consumption needs to be recognized.

49. For the overall SEEA then it is recommended that alignment be sought between the concepts of consumption and use within water, energy and material flow accounting. This alignment will permit a better understanding of the different types of physical accounting and also aid in the definition and measurement of measures such as resource productivity.

Recommendation 16.3: That in the revised SEEA the various concepts around consumption and use within water, energy and material flow accounting should be aligned.

Net recharge

50. The term “net recharge” of water in artificial reservoirs is defined as inflows from natural water resources and direct precipitation minus outflows and water exiting through evaporation. The London Group expressed some concerns over the use of this term both with regard to the applicability of the term “net” which has a number of specific meanings in the SNA.

51. As for water consumption, net recharge of water is a well founded concept in water statistics and can be derived with the accounting framework proposed in a manner completely consistent with the SNA calculation of change in inventories.

Recommendation 16.4: That in the revised SEEA the term net recharge be used to reflect the net inflows and outflows from artificial reservoirs and other water bodies including the loss of water through evaporation.

References

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ANNEX 1: Presentations of flows of water under different treatment options.

Figure A1.1: Current treatment: Water in artificial reservoirs entering supply at the time of abstraction

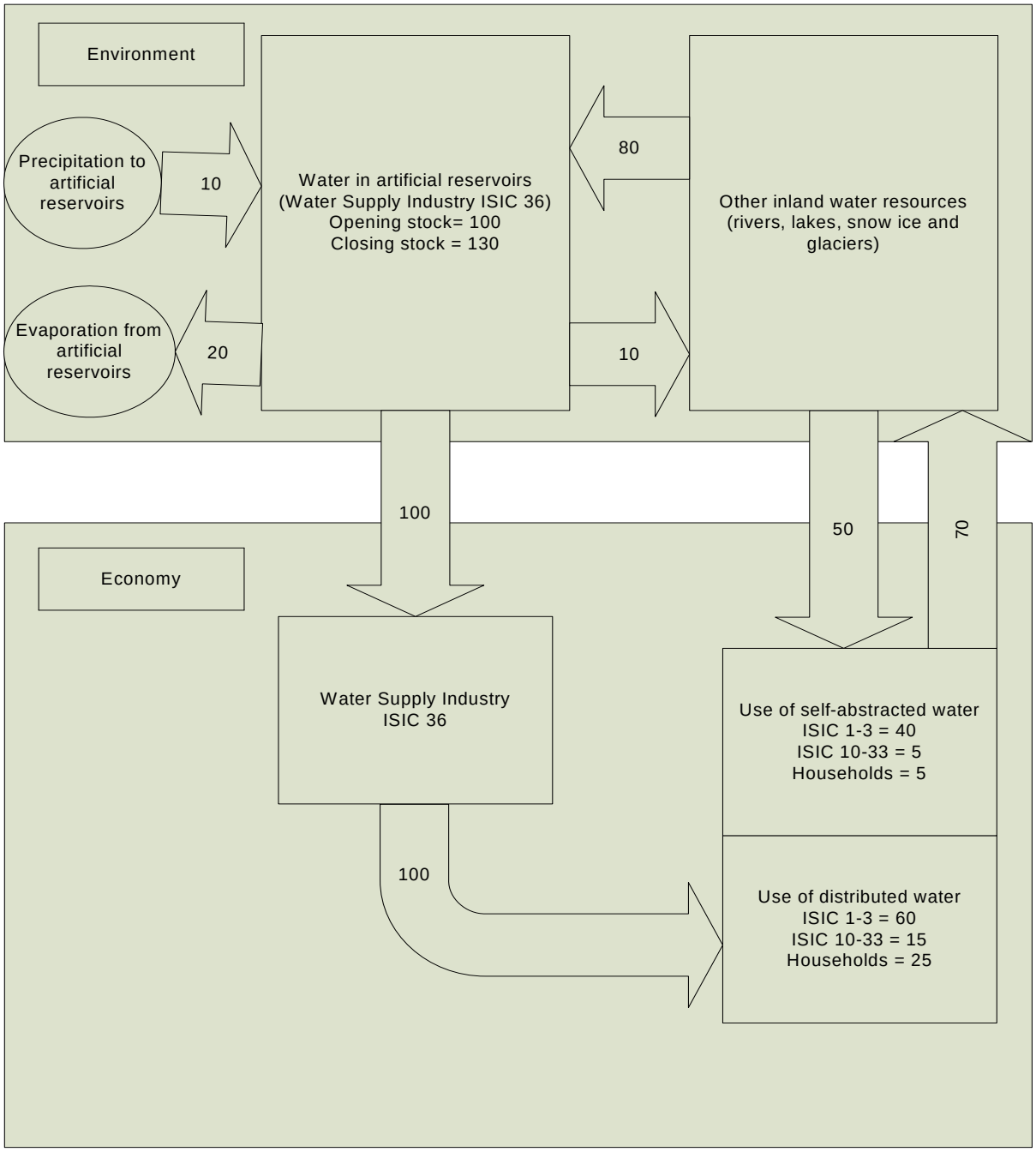
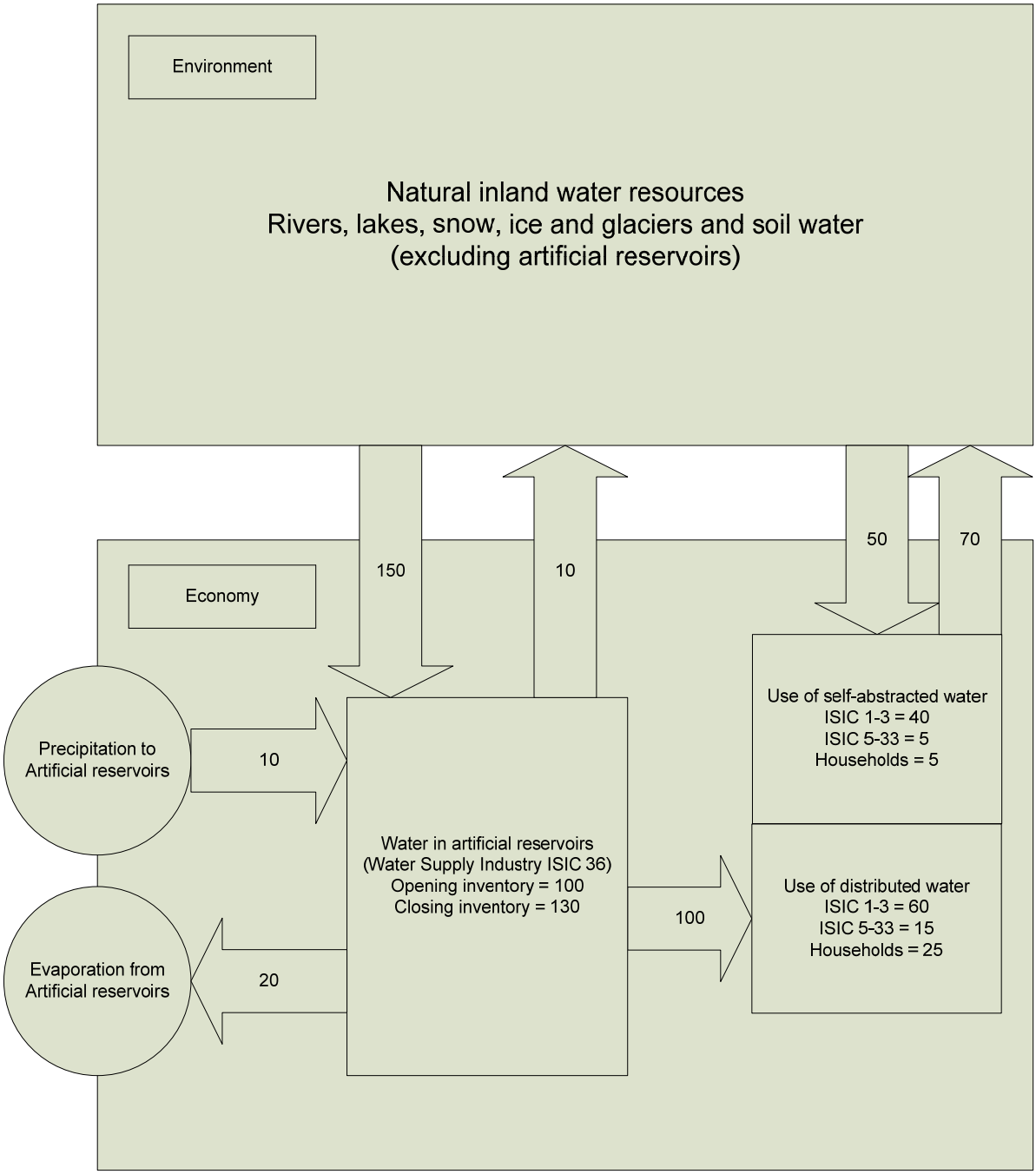


Figure A1.2: Proposed treatment: Water in artificial reservoirs recorded as entering supply of the economy at the time of entering the reservoir



Annex 2: Definitions relating to artificial reservoirs

Different experts and professions have a different understanding of the terms "artificial" and "reservoir" which has led already to confusion and extensive discussions.

The United Nations Environment Programme (UNEP), the European Environment Agency (EEA) and the World Commission on Dams use different definitions for the terms "reservoir" and "artificial reservoir". These definitions are:

UNEP: *"Reservoirs are artificial lakes, produced by constructing physical barriers across flowing rivers, which allow the water to pool and be used for various purposes. The volume of water stored in reservoirs worldwide is estimated at 4 286 km3"* (Groombridge and Jenkins, 1998[2]). This definition refers to dams only, but excludes for example flooded gravel pits, fish ponds or any kind of natural surface water or groundwater.

EEA: There are 2 definitions available of which definition a) refers to artificial reservoirs made by damming (similar to UNEP definition) whereas definition b) refers to all kind of reservoirs which are used for economic purposes. Definition b) excludes natural surface waters or groundwater which is actually not used by the economy:

"Reservoirs are human-made lakes created by the damming of rivers to serve one or more purposes, such as hydropower production, water supply for drinking, irrigation and flood protection." [3]

"Water reservoir: Artificial or natural area of water, used for storing water for domestic or industrial use." [4]

World Commission on Dams: *"Any natural or artificial holding area used to store, regulate or control water."* (Glossary of WCD-Report 2000[5]). This definition goes beyond the UNEP and EEA definitions (it includes artificial reservoirs, ponds and natural systems) but excludes natural systems which are not used by the economy (e.g. glaciers, lakes in remote areas, etc.).

Considering the above definitions, a reservoir can be defined as: any natural or artificial holding capable of storing, regulating or controlling water. Consequently this includes all natural lakes, groundwater bodies, rivers, glaciers and any kind of artificial water holdings (ponds, dams, storage tanks, canals). Thus from a technical point of view a water reservoir is any kind of artificial or natural water container, but also water stored in frozen form.

Since the term "reservoir" refers to both natural and artificial water holdings it is important to introduce the term "artificial reservoir" (as a sub-category of "reservoirs"). From an environmental perspective it is not simple in all cases to distinguish "altered" or "artificial" water bodies from "natural" water bodies.

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[2] http://www.unep.org/dewa/assessments/ecosystems/water/vitalwater/02.htm

[3] http://www.eea.europa.eu/themes/water/european-waters/reservoirs-and-dams

[4] http://glossary.eea.europa.eu/terminology/concept_html?term=water%20reservoir

[5] http://www.unep.org/dams/WCD/report/WCD_DAMS%20report%20annexes.pdf

The following presents existing definitions related to natural and artificial:

EEA:

"**Natural area**" (also used in the EEA definition of the term "reservoir", see above): "*An area in which natural processes predominate, fluctuations in numbers of organisms are allowed free play and human intervention is minimal.*" (EEA Glossary[6])

"**Artificial lake**": "*Lakes created behind manmade barriers.*" (EEA Glossary[7]); However, the EEA considers also water areas which have been created by other human activities such as peat and sand quarrying or fish ponds as "artificial lakes"[8]

European Water Framework Directive[9]**:**

Heavily modified water bodies: "*are bodies of water which as a result of physical alterations by human activity are substantially changed in character and cannot, therefore, meet "good ecological status". In this context physical alterations mean changes to e.g. the size, slope, discharge, form and shape of river bed of a water body.*"

Artificial water bodies: "*are surface water bodies which have been created in a location where no water body existed before and which have not been created by the direct physical alteration, movement or realignment of an existing water body.*"

[6] http://glossary.eea.europa.eu/terminology/concept_html?term=natural%20area

[7] http://glossary.eea.europa.eu/terminology/concept_html?term=artificial%20lake

[8] http://www.eea.europa.eu/themes/water/european-waters/lakes

[9] http://www.eea.europa.eu/themes/water/european-waters/heavily-modified-and-artificial-water-bodies