



Global Earth Observation
for integrated water resource assessment

Gap analysis of data requirements in support of European policies

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Authors	Markéta Jindrová (GISAT)
Reviewers	Micha Werner (UNESCO-IHE)
Contributors	Frederiek Sperna-Weiland (Deltares) Kymo Slager (Deltares) Maggie Kossida (SEVEN) Anastasia Tekidou (SEVEN) Klio Monokrousou (SEVEN) Clara Linés Díaz (UNESCO-IHE) Pere Quintana Seguí (OdE)
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LIST OF ABBREVIATIONS

AEMET	State Meteorological Agency (Agencia Estatal de Meteorología)
APSF	Areas of Potentially Significant Flood Risk
ASTER	Advanced Spaceborne Thermal Emission and Reflection Radiometer
ATEAM	Advanced Terrestrial Ecosystem Analysis and Modelling
AWACF	Australian Water Accounting Conceptual Framework
AWAS	Australian Water Accounting Standard
CAPRI	Common Agricultural Policy Regional Impact Analysis
CEDEX	Centro de Estudios y Experimentación de Obras Públicas
CEEA	Committee of Experts on Environmental-Economic Accounting
CGIAR	Consultative Group on International Agriculture Research
CHE	Hydrographic Confederation of the Ebro River (Confederación Hidrográfica del Ebro)
CHMI	Czech Hydrometeorological Institute
CIS	Common Implementation Strategy
CLC	Corine Land Cover
CLU	Conserved Land Use
CORINE	Coordination of Information on the Environment
CPWF	Challenge Program on Water and Food
CR	Czech Republic
CWSD	Communication on Water Scarcity and Droughts
CZK	Czech Crowns
DAMPOS	Dam Positioning
Delft FLS	Delft Flooding System
DG ENV	Environment Directorate-General
DIBAVOD	Digital database of hydrological data (Digitální Báze Vodohospodářských Dat)
ECA & D	European Climate Assessment and Data set
ECRINS	European Catchments and Rivers Network System
EDO	European Drought Observatory
EEA	European Environmental Agency
EG WSD	Expert Group on Water Scarcity and Droughts
ELDRED	European Lakes and Reservoirs Database
EO	Earth Observation
E-OBS	Daily gridded observation dataset for precipitation, temperature and sea level pressure in Europe
EPH	Experimental Probabilistic Hypersurface
EPIC	Environmental Policy Integrated Climate
E-PRTR	European Pollutant Release and Transfer Register
ERHIN	Assessment of Water Resources deriving from snowfall (Evaluación de los Recursos Hídricos Procedentes de la Innivación)
ESDB	European Soil Database
ET	Evapotranspiration
ETC	European Topic Centre



EU	European Union
FAO	Food and Agricultural Organisation
FD	Flood Directive
FEC	Functional Elementary Catchment
FHM/FHMs	Flood Hazard Map/s
FRM/FRMs	Flood Risk Map/s
FRMP	Flood Risk Management Plan
GES	Good Ecological Status
GIS	Geographical Information System
GMES	Global Monitoring for Environment and Security
GPWAR	General Purpose Water Accounting Reports
GRDC	Global Runoff Data Center
HWSD	Harmonized World Soil Database
ICOLD	International Commission on Large Dams
ICOLD	International Commission on Large Dams
ICT-Section	Information and Communication Technology Section
IPPC	Integrated Pollution Prevention and Control
IRZ	Integrated Pollution Registry (Integrovaný Registr Znečišťování)
IWMI	International Water Management Institute
IWRM	Integrated Water Resource Management
JQ	Joint Questionnaire
JRC	Joint Research Center
KNMI	Royal Netherlands Meteorological Institute (Koninklijk Netherlands Meteorologisch Instituut)
LUMP	Land Use Modelling Platform
LUSI	Land Use and Spatial Information
MAGRAMA	Ministry of Agriculture, Food and Environment (Ministerio de Agricultura, Alimentación y Medio Ambiente)
MARS	Monitoring Agricultural Resources
MFA	Material Flow Accounts
MLU	Modified Land Use
MoA	Ministry of Agriculture
MODIS	Moderate Resolution Imaging Spectroradiometer
MoE	Ministry of Environment
MS/MSs	Member State/s
MWU	Managed Water Use
NACE	The Statistical Classification of Economic Activities in the European Community
NAM	National Accounting Matrix
NAMEA	National Accounting Matrix including Environmental Accounts
NAMWA	National Accounting Matrix including Water Accounts
NAMWARB	River Basin NAMWA
NDVI	Normalised Difference Vegetation Index
NOAA-AVHRR	National Oceanic and Atmospheric Administration- Advanced Very High Resolution Radiometer



NUTS	Nomenclature of Territorial Units for Statistics (Nomenclature des Unités Territoriales Statistiques)
nWEI	Normalised Water Exploitation Index
NWI	National Water Initiative
OECD	Organisation for Economic Co-operation and Development
ONS	Observatorio Nacional de la Sequía
PFRA	Flood Risk Assessment
PoMS	Programmes of Measures
POVIS	Flood Information System (Povodňový Informační Systém)
PTK	Productieteam kaarten
RBD	River Basin District
REQ	Regional Environmental Questionnaire
RIZA	Netherlands Institute for Inland Water Management and Water Treatment (Rijksinstituut voor Integraal Zoetwaterbeheer en Afvalwaterbehandeling)
RWR	Renewable Water Resources
SAIH	Automatic System for Hydrologic Information (Sistema Automático de Información Hidrológica)
SEEAW	System of Environmental-Economic Accounting for Water
SIMPA	Integrated System for Rainfall-Runoff Modelling (Sistema Integrado de Modelización Precipitación-Aportación)
SOBEK	Modelling Suite for Flood Modelling
SoE	State of the Environment
SUGAR	Surface Water/Groundwater contribution index
ULU	Utilized Land Use
UNSD	United Nations Statistics Division
WA	Water Accounting
WA+	Water Accounting Plus
WACF	Water Accounting Conceptual Framework
WEI	Water Exploitation Index
WEI+	Water Exploitation Index Plus
WF	Water Footprinting
WFD	Water Framework Directive
WG WA	Working Group on Water Accounts
WGF	Work Group on Floods
WISE	Water information System for Europe
WMO	World Meteorological Organization



1 EXECUTIVE SUMMARY

This report introduces a gap analysis of data requirements in support of European policies. Following delivery D 2.2: 'Review report on European Policies' which was submitted in September 2014, this report represents a second deliverable (out of three) of Task 2.1: 'Comprehensive datasets and information in decision making and policy at a European level'. Together with deliverable D 2.5 a gap analysis of data requirements is carried out at two different levels: European and river basin level. This report closely follows the first report from September 2014 and develops it further.

This report represents another output of a 4-year international project "EarthH2Observe: Global Earth Observation for Integrated Water Resource Assessment". The main aim of the project is to integrate all available water related data in order to construct a global water resource re-analysis dataset which would help to improve water management at all levels.

Later on this report will be extended by a 'Report on opportunities for complementing data requirements in support of European policies through remotely sensed data products'.

Each chapter is divided into the following subchapters: Brief overview of the policy in a given country & specific requirements; Process of implementation (stages of implementation, who is responsible for implementation, milestones, current state); Data used and needed in order to adhere to the policy requirements; Gaps and possible improvements (data required vs data available, data missing at all, data with insufficient frequency, data in insufficient scale, etc.); Summary on gap analysis.

The directives and policies reviewed in this report are: Floods Directive (2007/60/EC), Communication on Water Scarcity and Droughts (COM(2007) 414 final) and Water Accounting framework as being developed by the European Environment Agency.

2 INTRODUCTION

This report reviews and looks into gap analysis of selected European policies related to water. It represents one of the deliveries of the project 'earthH2Observe'. 'EarthH2Observe: Global Earth Observation for Integrated Water Resource Assessment', which is an international project that aims at integrating all available water related data from different sources (earth observations, in-situ datasets and models) in order to construct a consistent global water resource re-analysis dataset of sufficient length (several decades). Earth Observation (EO) products will be supported by case studies and validated based on end-user needs and metrics, ensuring the value of the project's final datasets for local and regional decision making and water management at local, European and global level.

All together there are many datasets related to water available, but these are mostly inconsistent due to different approaches in each country. There are various methods of data capture, countries use different resolutions and each has different requirements. In order to use the data more efficiently earthH2Observe project will integrate all different types of water related data to support decision making where needed. With the founding of the European Union (EU) and integration in general, many new policies were established and many existing ones were updated. In order to implement these policies, consistent supporting data is needed.

This report represents the second stage of a long-term task 'Comprehensive datasets and information in decision making and policy: EU perspective'. The first report provides a fact sheet summarising basic information about European policies related to water and datasets used and needed to fulfil the requirements of these policies. Both reports are written as a desk review. This delivery provides a gap analysis identifying gaps in existing datasets relevant to selected water related policies at European scale and the potential of augmenting existing datasets with EO data and thus improving their transparency and use.

Several directives were chosen to be subject of the gap analysis. These are the ones where the potential of improvement in data needs by using EO data is significant and expected. First of all the Flood Directive was reviewed independently in two countries; the Netherlands and the Czech Republic. Another major topic is water scarcity and droughts and this issue was studied in the Ebro Basin in Spain. The third topic that is examined is the issue of Water Accounting, which was introduced recently by the European Environment Agency (EEA). This is expected to have a big potential in improving the management of water resources.

This gap analysis was carried out for the following directives and policies:

- Flood Directive (2007/60/EC)
- Communication on Water Scarcity and Droughts (COM(2007) 414 final)
- Water Accounting.

For each of the selected policies this report gives an overview, describes the implementation process, summarises data used and needed, discusses the gaps and possible improvements, and gives a summary of the previous.

In a final stage in June 2017, close to the end of the project, we will report on opportunities for complementing data requirements and on how the gaps can be filled in by using some of the datasets that will be provided from earthH2Observe project.



3 GAP ANALYSIS: FLOOD DIRECTIVE (2007/60/EC)

The purpose of this Directive is to establish a framework for the assessment and management of flood risks, aiming at the reduction of the adverse consequences for human health, the environment, cultural heritage and economic activity associated with floods in the Community [1].

This directive aims to reduce and manage the risks that floods pose to human health, the environment, cultural heritage and economic activity. All MSs shall assess the risk from flooding of all water courses and coast lines. All Member States (MSs) shall map the flood extent, and assets and humans at risk in these areas and take adequate and coordinated measures to reduce this flood risk. This Directive reinforces the rights of the public to access this information and to have a say in the planning process. The Directive introduced a general three-step implementation process which is common and obligatory for all MSs:

- MSs will by 22 December 2011 undertake a Preliminary Flood Risk Assessment (PFRA) of their river basins and associated coastal zones, to identify areas where potential significant flood risk exists.
- MSs will by 22 December 2013 develop Flood Hazard Maps (FHM) and Flood Risk Maps (FRM) for areas at risk of flood damage.
- MSs will by 22 December 2015 draw up Flood Risk Management Plans (FRMP) for these zones. FRMP shall address all aspects of flood risk management, focusing on prevention, protection, preparedness and including flood forecasts and early warning systems.

These steps need to be reviewed and updated every 6 years in a cycle [1].

In order for the implemented measures to be effective these shall be coordinated at the river basins level rather than at the Community level. Each MS assesses the risk within their river basins and coordinated action between the MSs with international river basins is expected. As a consequence the implementation of the Floods Directive will differ somewhat in the different MSs, though the objectives and outcomes are the same. To illustrate the process, as well as identify gaps we provide examples of Flood Directive (FD) management and implementation in selected MSs in the following sections.

3.1 CZECH REPUBLIC

Floods represent a natural phenomenon and from the point of view of the preservation of the landscape and nature their effects on flora and fauna biotopes are not considered to cause damages. Positive impacts of floods were demonstrated by numerous studies. For this reasons FD is not implemented in areas subject to Preservation of Landscape and Nature.

Considering the geomorphological and hydrological characteristics of the upper reaches of international river basins in Czech Republic (CR) the flood damages relevant to Czech population are mainly an issue of natural fluvial floods occurring as a consequence of the overflow of watercourses. This can be caused by regional precipitation, local torrential rain, snow melt, or a combination of the previous. Accompanying side-effects are dam bursts, barriers created by objects flowing in the river, ice congestions, landslides, etc. which worsen the effects of significant fluvial floods.

A Methodical Instruction Guide on Identification of Critical Points which assesses the risk during torrential floods outside the watercourse was created in case of special floods.

Considering the high number of artificial dams in the CR Special floods can be caused by dam burst or dam failure. For these occasions special plans were created for design floods of $Q_{1,000}$ and $Q_{10,000}$ return periods which is in an agreement with the recommendation of the International Commission on Large Dams (ICOLD) and are available to Flood and Emergency Authorities. The likelihood of a special flood caused by dam failure was calculated to be 0.001. For this reason floods of this type were not considered when determining Areas of Potentially Significant Flood Risk (APSFR). However, special methodical plans do exist which would be followed in case of such a special flood occurring.

The methods chosen for the implementation of the FD in the CR are predominantly taking into consideration the risks of fluvial floods.

Based on the current knowledge and expert estimation, the risk of floods should not increase in the future, not even when considering urban planning and climate change. Preparedness of the Czech population and relevant authorities is improving every year, mainly thanks to experience gained during past significant floods.

3.1.1 Overview

There are two competent authorities responsible for the implementation process and fulfilling the requirements of the Directive: the Ministry of Environment (MoE) of the CR & the Ministry of Agriculture (MoA) of the CR.

The Flood Directive was fully adopted in the CR in February 2011 by:

- Act. No 150/2010 Coll., amendment of the Act No. 254/2001 Coll. On Waters
- Public Notice No 24/2011 on River Basin Management Plans and Flood Risk Management Plans.

There are three basin units of management, which are identical to the ones which were created on the base of the Water Framework Directive: Danube, Elbe and Oder.

A national work group “Povodňová směrnice” (“Flood Directive”) was established and it meets regularly since 2008. Members of this work group consists of representatives from the MoE and MoA, Czech Hydrometeorological Institute (CHMI), T. G. Masaryk

Water Research Institute and river catchments administrators. A wider group for the implementation of the Flood Directive includes representatives from Environment, Risk management of the CR regions and Urban Planning trade unions who were appointed in January 2011.

A flood information system “POVIS” was established in order to keep the public updated about the implementation of the Flood Directive. FHMs and FRMs were published via this system as well as FRMPs and local warning systems.

3.1.2 Implementation process

1st Phase: Undertake a PFRA by 22 December 2011 [2]

Data from the following providers: The Czech Office for Surveying, Mapping and Cadastre, Czech Statistical Office, T. G. Masaryk Water Research Institute, public research institution, which are being captured in CR on a regular basis were used to carry out a PFRA. These include information about/from:

- The previous floods
- Reports from complex projects dealing with evaluation of significant floods
- Hydrological characteristics of designed floods with return periods of 5, 20, 50 and 100 years
- Delineated flood zones (return periods 5, 20 and 100 years)
- Digital database of hydrological data (DIBAVOD)
- Geographical maps and data (scale 1: 10,000)
- Data from Czech Statistical Institute on inhabitants and economic activities
- Database of Cultural Heritage (National Heritage Institute)
- Integrated Pollution Registry (IRZ)
- Spill of past floods in 1997, 2002, 2006
- Priorities of Flood protection of individual regions.

Because of the very low likelihood of torrential floods outside watercourses, floods caused by dam failure, dam burst or other water management infrastructure failure are not considered. Only fluvial floods are being considered when determining APSFR.

The following steps were performed in order to determinate APSFR:

- a) Basic parameters to be considered in individual flood risk scenarios were quantified. For all affected urban areas a census was taken and the value of affected assets was calculated (Data of the Czech Statistical Institute on inhabitants and economic activities) for a scenario of designed floods of 5, 20 and 100 years return period.
- b) Affected urban areas were determined on the base of the following criteria: ≥ 25 people affected by flood risk per year or affected assets worth of ≥ 70 million Czech Crowns (CZK) per year.
- c) Significant sources of pollution within flood areas were identified (Integrated Register of Pollution (under IPPC)). Areas with a potential risk of pollution during flooding Q_{100} were added to the list of affected areas from b).

- d) Listed buildings in flood areas Q_{100} were identified and considered (National Culture Heritage Database) when finalising the list of affected areas from c).
- e) Parts of watercourses where there is a potential significant flood risk were delimited by T. G. Masaryk Water Research Institute and individual catchment administrators. 269 parts of watercourses were delineated of the total length of 2966 km in the area of CR which is 26 % of all watercourses in CR. For these 269 areas FHMs and FRMs were drawn up in 2013.
- f) For the areas determined in e) mapping of flood risk for a design flood Q_{500} was performed. These areas were also compared to spillage of floods in 1997, 2002, 2006, 2009 and 2010.
- g) A map layer was created containing the affected parts of watercourses which define areas of potential significant flood risk with all relevant attributes. The resulting layer was made public on the Flood Information System (POVIS) website. In June 2011 this was open for public comments. Questions were answered but no comments were submitted thus the layer was approved in the original form.

Table 1 shows values of basic parameters for PFRA for a scenario of flood with 100 years return period (Q_{100}).

Table 1: Values of basic parameters for PFRA for a scenario of flood with 100 years return period (Q_{100}).

	Population	Communications [km]	Built-up area [ha]	Asset value [millions CZK in 2006]
Total in CR	10,160,406	388,950	185,091	12,416,936
Total in affected urban areas Q_{100}	8,555,378	246,877	137,643	10,140,261
Affected by spillage Q_{100}	396,864	11,074	11,145	746,278
% in affected urban areas	4.46	4.47	8.1	7.36

Extent of the past floods in 1997, 2002, 2006, 2009 were taken into account.

Past floods:

Significant floods are being evaluated within complex projects funded by state budget since 1997. This includes fluvial floods in July 1997, August 2002, March and April 2006, torrential floods in June and July 2009, fluvial floods in May and June 2010 and in August 2010.

For the purpose of PFRA floods since 1968 were assessed (see Table 2). For each type of flood the following conditions have to be fulfilled in order to consider the flood to be significant.

A) Fluvial floods (11 cases considered in PFRA)

- return period $\geq Q_{100}$
- area flooded by Q_{100} intensity $\geq 2000 \text{ km}^2$ and ≥ 3 profiles
- local floods with number of casualties ≥ 3 or damage ≥ 250 million CZK (9.25 million EUR)

B) Pluvial floods



- Damage \geq 250 million CZK (9.25 million EUR)

Floods of this type do not occur in CR. If they do they are a side-effect of a fluvial flood and the damage is contained in the total damage of fluvial flood.

C) Groundwater floods (without any hydrological relation to a fluvial flood)

- Damage \geq 250 million CZK (9.25 million EUR)

Floods of this type do not occur in CR.

D) Floods caused by dam failure (special floods) (without any hydrological relation to a fluvial flood) (1 case considered in PFRA)

- number of casualties \geq 3

Table 2: Overview of significant past floods in the CR.

Flood	Type of flood	Area affected	Maximum return period achieved	Consequences	Documentation
19 August 1974	Special flood (during natural flood)	Mnichovka, burst of Hubacov dam	Natural flood > 100 Special flood 5x Q ₁₀₀	5 casualties, material damage unknown	Article within a Collection
March 1981	Spring flood, snow melt & rain	Upper Elbe catchment, Ohre, Mze, Sazava, Morava catchment	20-50, sporadically 100	Unknown	Hydrological report
July 1981	Summer flood, regional rain	Otava, Berounka, Elbe, lower Vltava catchment	50-100, sporadically > 100	Unknown	Hydrological report
July 1997	Summer flood, 2 waves	Odra, Morava and part of upper Elbe catchment	100-500, sporadically > 500	62.6 billion CZK, 50-60 casualties	Complex project (CHMI), report from the Elbe catchment administrator
July 1998	Torrential flood	Dedina, Bela	> 100	1.8 billion CZK, 6 casualties	Hydrological report, report from the Elbe catchment administrator
March 2000	Spring flood, snow melt & rain	Upper Elbe, Jizera catchment	50-100, sporadically > 100	3.8 billion CZK, 2 casualties	CHMI report, reports from the catchment administrators
August 2002	Summer regional flood, 2 waves	Vltava, Berounka, lower Elbe catchment	200-1000, some places > 1000	73.1 billion CZK, 17-19 casualties	Complex project (T. G. Masaryk Water Research Institute), reports from the catchment administrators
March/April	Spring	Dyje, Morava,	50-100,	6 billion CZK,	Complex project



2006	flood, snow melt & rain	Sazava, Luznice, etc. catchment	sporadically > 100	9 casualties	(T. G. Masaryk Water Research Institute), reports from the catchment administrators
June 2006	Summer flood	Dyje catchment	100-200, sporadically 1000	Unknown	Hydrological report
June/July 2009	Torrential flood	Area of Novojicinsko, Jesenicko, Decinsko	100, > 100, some places >> 100	8.5 billion CZK, 15 casualties	Complex project (CHMI)
May/June 2010	Summer flood, 2 waves	Odra, Morava catchment	20-50, sporadically > 100	5.1 billion CZK, 3 casualties	Complex project (T. G. Masaryk Water Research Institute), reports from the catchment administrators
August 2010	Summer flood with features of torrential flood	Smeda, Luzicka Nisa, Ploucnic, Kamenice catchment	50-100, > 100, sporadically > 1000	10.1 billion CZK, 5 casualties	Complex project (CHMI), reports from the catchment administrators

If the significant past floods would occur again in the future the consequences in many areas would not be as bad thanks to the measures introduced (flood barriers, etc.), reduction of vulnerable activities in flood zones and development of the early warning system.

Flood risk is expressed by the characteristics of designed floods with return period 5, 20 and 100 years which is processed by CHMI. For these theoretical floods the boundaries of flood zones are delineated by catchment administrators by using hydraulic models, topography, location of watercourses and their geomorphological characteristics, location of urban areas and anti-flood measures.

2nd Phase: Develop FHM and FRM by 22 December 2013

FHMs show the flood extent (flooding/inundation), water depth or water level and flow velocity where appropriate. These maps were developed for scenarios of floods with a return period of 5, 20, 100 and 500 years (Q5, Q20, Q100 and Q500). All together 12 maps were created.

FHM divides flood areas into four categories according to the degree of danger: High, Medium, Low and Residual. This map is then considered in urban planning and when building flood control structures. The recommendations for each category of risk are the following:

High risk

- No new building development or extension of existing building development is allowed
- Flood control structures which can mitigate the flood risk should be considered for existing building development, alternatively prepare a plan of displacement

Medium risk



- Urban development restricted
- Construction of sensitive buildings (e.g. medical buildings) unsuitable
- Extension of building sites should be avoided

Low risk

- New construction possible, owners shall be alerted to the risk
- Special measures shall be adapted for sensitive buildings

Residual risk

- Flood control structures shall be considered in long-term urban planning
- Special measures shall be adapted for sensitive buildings
- Construction of buildings with high risk of potential damages shall be avoided

FRM combines hazard data for each area with vulnerability and susceptibility of buildings and structures to the damages. There are three categories of vulnerability according to the functional use. A value of maximum acceptable risk is assigned to each category.

Low risk

- Housing, technical and transportation infrastructure, production areas and storehouses

Medium risk

- Sport, recreation

High risk

- Forests, agricultural land, urban green areas

FRM highlights areas where maximum acceptable risk is exceeded.

3rd Phase: Draw up FRMP by 22 December 2015

This documentation includes issues, such as costs and benefits analysis, flood extent and development, retention potential of floodplains and flooded areas, goals of water protection, land and water management, urban planning, land use, nature preservation, shipping transportation and port infrastructure.

FRMP cover all aspects of Flood Risk Management and focus mainly on prevention, protection, preparedness, including flood forecasting and early warning systems. They take into account the characteristics of the particular river basin or sub-basin.

FRMP consist of the following parts:

- Related PFRA
- FHM and FRM for areas with significant risk
- Description of relevant goals of flood risk management
- List of measures ordered by priority which are being introduced in order to reach the goals of flood risk management
- In case of international river basin the methodology of cost and benefits analyses performed by individual countries in order to assess the measures with international consequences

A first draft of the FRMP was made available on the 22nd of December 2014 and the final FRMP will be published by the 22nd of December 2015.

Coordination and information exchange in international catchment areas

Responsibilities related to the international catchments are fulfilled by Expert flood groups of International Commission for the Protection of the Danube, Elbe and Odra River, by work groups of Transboundary Water Commission with Germany, Austria, Poland and Slovakia, and by European Work Group on Floods (WG F). There were numerous meetings, workshops and conferences where international APSFR were presented and discussed. The management of all the international catchments within CR was approved by the relevant international partners.

There are several international projects dealing with Implementation of the FD which support the cooperation amongst international partners. These are listed in Table 3 below.

Table 3: International projects dealing with Implementation of the Flood Directive.

Project Name	Participating countries	Websites	Description	Realisation
LABEL	Germany, CR, Austria, Hungary	http://www.label-eu.eu	Adaptation to flood risk in the Elbe catchment and part of Danube and Tisa catchment	2009-2012
Danube FLOODRISK	Countries of the Danube catchment (CR is an observer)	http://group.danube-floodrisk.eu	Support to implementation of the FD in the main watercourses of Danube catchment	2009-2012
CEframe	Austria, Slovakia, Hungary, CR	http://www.ceframe.eu	Harmonisation of the flood protection in transboundary catchments of Morava, Dyje, Danube, Lajta	2010-2013
REX Integrated Prevention	Germany, CR, Poland, France	NA	Exchange of experience in integrated prevention for natural disasters	2011

Public involvement in FD implementation

Public involvement is stated in the Directive and public has a right to comment on the implementation in several stages.

There are several levels of involvement in the implementation.

a) Fundamental work group Flood Directive "Povodnova smernice"

It has 12 members who are representatives of relevant ministries, CHMI, T. G. Masaryk Water Research Institute and River catchments administrators. They support decision making of relevant ministries. The group meets once a month since 2008, they discuss implementation approach and communicate with all other groups.

b) Wider work group Flood Directive "Povodnova smernice"

Discussing regional issues and commenting on implementation process. It consists of 41 members- representatives from Environment, Risk management

of CR regions and Urban Planning trade unions. The group meets with the Fundamental work group at least once a year.

- c) International cooperation
- d) Public involvement

Public can submit comments on the implementation of the Flood Directive. All information is available to the public through POVIS websites and through thematic seminars. Communication is realised via the members of the Work group "Povodňová směrnice". POVIS contains information on contacts, flood log, flood zones, possible funding, Flood Directive implementation, seminars and trainings, FHM, FRM, FRMP and local warning systems.

3.1.3 Data used & needed

In order to carry out a PFRA, delimit APSFR and keep the dataset updated the following data was used:

- Information on previous floods
- Reports from complex projects dealing with evaluation of significant floods
- Hydrological characteristics of designed floods with return periods of 5, 20, 50 and 100 years
- Delineated flood zones (return periods 5, 20 and 100 years)
- Digital database of hydrological data (DIBAVOD)
- Geographical maps and data (scale 1: 10,000)
- Data from Czech Statistical Institute on inhabitants and economic activities
- Database of Cultural Heritage (National Heritage Institute)
- Integrated Pollution Registry (IRZ)
- Spill of past floods in 1997, 2002, 2006
- Priorities of Flood protection of individual regions.

The main datasets that need to be kept updated are information on population and asset value.

Important step in future flood prediction is to log and map any flood which occurs. The following data should be recorded:

- Flood extent
- Water level
- Water depth
- Flow velocity
- Water flow

In the process of future flood prediction it is important to consider the following phenomena:

- Climate change (temperature, precipitation)
- Changes in Land use
- Changes in natural flood plains

- Anti-flood measures introduced

3.1.4 Gaps & possible improvements

The more precise data measurement during floods would make the prediction of future floods more accurate. This includes precise and consistent measurement of flood extent, water level, water depth, flow velocity and water flow.

Together with constant recording and update on population (number of inhabitants) and asset value flood risk in the future can be assessed more precisely.

Important data in flood modelling under different climate scenarios include mainly temperature and precipitation together with snow depth and snow cover extent which can help to assess the potential flood risk in the future.

3.1.5 Summary

Future floods

To assess the negative effects of future floods hydrological characteristics of designed floods with selected return period were used. Statistical analysis used for this calculation is based on the assumption of homogeneity of the input data and constancy of the hydrological regime. It assumes that the likelihood of floods in future will be the same as it was in the past. A long enough time line of observation is necessary. The prediction and calculation of future floods is connected with uncertainty and the lower the likelihood of certain characteristics the higher the uncertainty. For example the error related to calculation of flood with a return period of Q_{100} is between 15 % and 60 %. When talking about future floods it is necessary to consider the following which might change their size and occurrence:

- Climate change
- Changes in land use
- Changes in natural floodplains
- Anti-flood measures introduced

For future floods prediction it is necessary to better understand the process of climate change and quantify it. There are climate models predicting changes in temperature but not so many prediction in changes of precipitation. Precipitation is expected to increase in northern Europe and decrease in southern Europe. CR lies in the middle so no significant trend is expected. However, a slight increase in precipitation is expected during winter and a slight decrease in summer. Possible changes in flood regime are, however, related to the changes in extreme precipitation regime- both long regional and short local.

There are two points of view as to floods caused by snow melt. One is increase in precipitation in winter; the other is increase in temperature. The likelihood of these floods is, however, expected to be smaller because the current trend is at least one thaw period during winter which reduces snow accumulation.

There are projects looking into the changes in floods based on climate change but they did not come to any unambiguous conclusion. More investigation into climate change is needed.

Changes in land use can cause changes in future floods. This is because of possible changes in infiltration rate and runoff rate and size. In CR the changes in land use are minimal and conducted based on regional and urban planning which considers flood risk. Thus changes in land use are not considered to have any major effect on future



floods. The issue might arise with increase of impervious surface. Local increase in construction of urban areas might cause significant increase in local flood runoff in small urban catchments.

Natural flood plains have a major significance in floods because they have the ability to accumulate flood water and decrease the flow rate. Decrease in number of natural flood plains is recorded from the past years which are caused mainly by urban construction. However, the recent strategy prefers the retaining of natural flood plains and the construction of artificial flood plains outside urban areas.

3.2 THE NETHERLANDS

3.2.1 Overview

The flood directive aims to establish a framework for the assessment and management of flood risks, aiming at the reduction of the adverse consequences for human health, the environment, cultural heritage and economic activity associated with floods in the European community [1]. The flood directive forces Member States (MSs) to assemble information, establish (inter)national communication and make national and cross-border flood risk management plans.

In the Netherlands, a multitude of competent authorities responsible for flood risk management, divided in flood protection, spatial planning and crisis management, work together on the national implementation of the Floods Directive. These are; national government representatives, regional water authorities, provinces, emergency and public health services, and municipalities (see Table 4 for a more detailed overview).

Table 4: Authorities involved in national implementation of the Flood Directive.

Scale	Party	Role
International Level	European Commission	Manages the Directive and is responsible for implementation and reviewing of the Directive by MSs
	Germany, Belgium and France-as partners of the Netherlands in the International River Commissions	Responsible for mandatory international coordination of water safety
National Level	Ministry of Infrastructure and the Environment	Ultimately responsible for implementation and reporting to Brussels
	Department of Waterways and Public Works (Rijkswaterstaat)	Responsible for implementation and reporting to Brussels
	Ministry of Security and Justice	Liaison on behalf of the safety regions
	Inspectorate for Transport, Public Works and Water Management	Responsible for review of policies and regulations
	Delta Commissioner	Involved with climate change
Local Level	Water Boards (UvW) and Rijkswaterstaat	Responsible for providing information about primary and secondary barriers and regional flood simulation and the like
	Provinces (IPO)	1. Coordination at regional level 2. Management of FRMs 3. Responsible for providing information about primary and secondary barriers and regional flood simulation and the like



	like
Association of Dutch River Municipalities	Provide information about secondary barriers, emergency management plans at safety region level
Safety regions	Provide information primarily about emergency management plans

The Netherlands includes four units of management, describing portions of larger international river basins lying within their territory; i.e. Scheldt basin, Meuse basin, Rhine basin and the Ems basin. For each of these river basins, the following information is requested by the Directive and reported to the Commission:

- (1) PFRA,
- (2) FHMs & FRMs,
- (3) FRMPs.

3.2.2 Implementation process

In Table 4 the general roles of different parties involved in the implementation are described. Below, it is described which organisations played which specific role in the process of implementation-stages.

1. PFRA

The aim of the PFRA is to identify areas in which potential significant flood risks exists or can be expected to arise in the future, based on available or readily derivable information. The Netherlands has not conducted the PFRA, thereby relying on the discretionary provision of Article 13 (1b) of the FD, which provides that MSs may decide not to undertake the PFRA for those areas where they have decided before 22 December 2010 to prepare FHMs and FRMs.

2. FHMs and FRMs

FHMs and FRMs are designed to raise awareness among the public and the (local) authorities of the nature and extent of flood risks and provide information for determining an approach to managing the risks. The FD sets out the requirements in terms of the types and contents of the maps.

National Dutch FHMs and FRMs are produced by a production team, called 'Productieteam kaarten' (PTK), chaired by the Director of the operational ICT-section of the provinces and including representatives of the provinces, waterboards, Rijkswaterstaat and Deltares. The main objective of the PTK was to manage the production of the FHMs and FRMs, in conformation with the FD requirements and additional requirements laid down in the national implementation plan and formally set out in a legal document called 'provinciale regeling'.

The additional requirements laid down in the national implementation plan are centred on the production of functional national FHMs and FRMs, in addition to the list required by the FD (see

Table 5 for the complete list of produced maps).



Table 5: Obligatory and optional national Flood Hazard and Flood Risk Maps.

Flood Hazard Maps	Flood Risk Maps
<i>Flood extent</i>	<i>Indicative number of affected inhabitants</i>
<i>Maximum water depths</i>	<i>Type of economic activity of the affected area</i>
<i>Maximum flow velocity</i>	<i>Affected IEC-installations</i>
First time of arrival	<i>Affected protected areas (Directive 2000/60/EC)</i>
Flood duration	Maximum damage potential
Maximum rise rate	Vulnerable objects (e.g. schools, hospitals etc.)
Simultaneously threatened areas	Vulnerable cultural objects (e.g. national monuments)
Sources of flooding	

Non-italic = optional additional maps

The Directive requires maps to be made for three *scenarios*: with a low, middle and high probability. In the Netherlands this is translated to modelled water levels (based on [3]) that exceed probability of 1/10 per year (high), 1/100 – 1/500 per year (middle) and 1/1000 per year and less (low).

The Directive is primarily based on natural runoff situations; which is only partly applicable to the Dutch situation with its complex of primary and regional embankments and active water management. In order to know, which specific floods and waterways to include in the maps, a so-called ‘toepassingsbereik’ – application scope - was negotiated between the national and regional authorities (see Figure 1). For each waterbody in the Netherlands an assessment is made whether it should be included in the maps or not, based on three main decision criteria:

1. Potential significant risk; e.g. floods due to breach in primary or regional embankments and floods in main unprotected areas along Rhine and Meuse;
2. International cooperation; e.g. floods in regional unprotected areas along smaller rivers and brooks; and
3. Coherent mapping; e.g. floods in unprotected areas along regional embankments and floods due to breaches in local embankments.

Regional water authorities are left free to include more waterbodies in their flood risk assessments.



Figure 1: Toepassingsbereik the Netherlands; scope of application.

The PTK decided not to make *one* set of national FHM and FRMs, but to build a series of centralized information systems in order to produce up-to-date standard national FHM and FRMs, whenever required or needed in the Netherlands (see Figure 2 for a schematic overview).

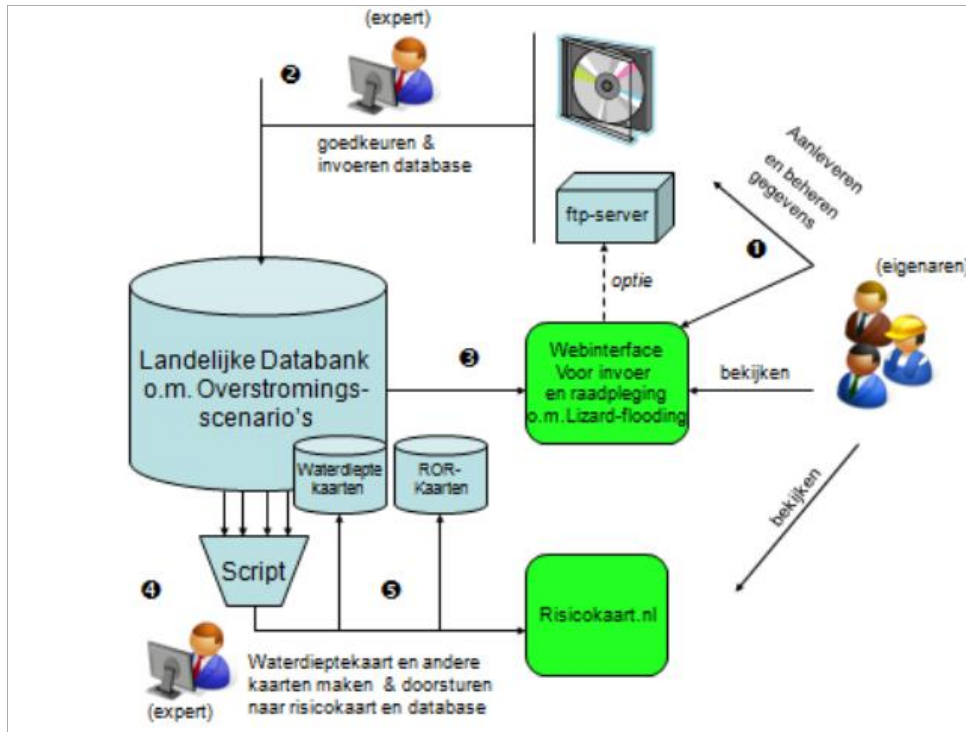


Figure 2: Information systems to produce damage- and risk maps 'on the fly'.

As all data required is scattered through the Dutch national and regional water authorities, a system is designed where each data-owner (province, water boards etc.) is able to provide its data, such as flood simulations (e.g. water depths, velocity from hydraulic models such as SOBEK and Delft FLS in either propriety or standard GIS formats) and metadata. The metadata for each simulation is fundamental in order to make it sustainable for future use. Each simulation that is provided to the central database is quality checked by Deltares according to a specific quality protocol in order to ensure minimal consistent data quality. Up to now, more than 3000 local simulations, produced mainly in earlier projects and assembled in this central national database make up the basis for the national FHMs and FRMs. Basically, for each relevant probability simulations are provided. Floods due to breaches in embankments are simulated and used only for design conditions. The system is designed to provide new simulations or change existing one in a sustainable way. From the central database, scripts are developed, servers installed and other national datasets used (e.g. topography, statistical information, cultural heritage information etc.) to produce and maintain the national FHMs and FRMs, and provide these through multiple data viewers, including the official national portal for natural risk information: www.risicokaart.nl. The operational ICT-section of the Provinces is responsible for the development, maintenance and operation of the national FHMs and FRMs. The data-owners are responsible for the maintenance and quality of the source data. The maps were finalized and frozen in December 2013 and published on risicokaart.nl before the deadline of the 22nd of December 2013 (see Figure 3). Reporting sheets on the maps are delivered to the Commission before the 22nd of March 2014. The national site has been updated with new information in February 2015. The reported information is available as backup.

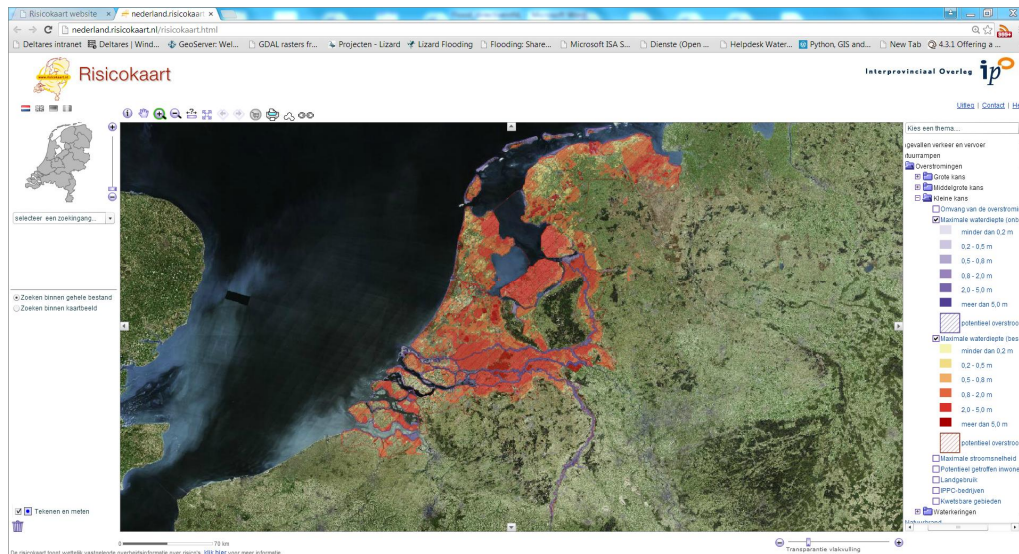


Figure 3: Examples of the Flood Hazard Map 'Maximum water depth' on the national website riscokaart.nl.

Guidance and a general handbook are available with detailed descriptions of functional and technical features of the data acquisition and on the (use of the) information systems.

3. FRMPs

The FRMPs (both nationally as internationally) make use of cartographic versions of the electronic data. A series of high-quality cartographic products is produced for insertion in the FRMPs. Some basic background layers, also needed for the electronic version, are centrally managed and stored as geographic data (shapefile) as well: e.g. FD-waterbodies, (incl. unique id and relevant attributes as type, manager and criterion to be included), embankments (incl. type, manager, design probability), protected vs. unprotected areas and basic simple topography. Plans do also include several summary / zonal statistics based on GIS-analysis of the different FHM and FRMs. Besides FRMPs there exists a detailed overview of applied types of interventions (with some localized examples) in order to mitigate or adapt to the floods and descriptions to what extent the data, maps and plans are internationally shared. The national and international portions are now available for formal public consultation and will be reported to Brussel before the 22nd of December 2015. The international portion of the Rhine will be supplemented with a new version of the Rhine-atlas, expected to be operational at the end of 2015.

3.2.3 Data used & needed

In the text above, the data used and needed are broadly described. In summary, the layers are:

- 1) Background layers, such as topography (water-land distinction), relevant waterbodies, flood protection infrastructure and protected vs. unprotected areas. Except the flood protection infrastructure, these are all polygon features which are assembled, where possible, on different spatial resolutions in order to use the data at its best at each zoom level within the portal.
- 2) Thematic layers like FHM and FRMs; build from thousands of individual local/regional simulation results (mainly ascii and geotiff files from hydraulic and GIS software of maximum water depth/ flow velocity and incremental files (overland flow

pattern through time)) and several national datasets for vulnerability/risk overlays (e.g. land use map, population maps and protected areas).

3.2.4 Gaps & possible improvements, Summary

Practically, local data resources are found sufficient for use in the Netherlands. Some general observations can be made on information gaps and the potential value of the application of earthH2Observe project datasets and models for the FD:

1. Cross-border information exchange was limited to some general discussions on statistical frequency analysis of own measured data; projection issues (xyz) were found problematic as well; the smaller the flow of a transboundary river, the less attention was paid to information exchange;
2. Coincidence of high discharges in different catchments or within catchment between main and regional rivers is often neglected in analysis;
3. A monitoring benchmark of system state (before/ after measurements) may be interesting to obtain through earthH2Observe, as the commission is primarily interested in monitoring the impacts of policy in order to mitigate the flood risk (in a 6-year reporting cycle). Earth observations of flood extents could help in monitoring the benefits from implemented flood mitigation measures;
4. In several transboundary river basins (outside the Netherlands) only less advanced models are available, while flood risks can be high and maps need to be provided under the EU Flood Directive. These countries / basins could probably be helped with good consistent transboundary benchmark models or data, although spatial resolutions may be too low;
5. Consistent data on land-water borders is often missing and difficult to assess. The definition of a flood in the directive is 'flooding of land which does not daily submerge.....' For the Netherlands it was very difficult to establish this base map – with daily submerged areas - on high resolution.
6. Consistent data at each zoom level (3-5 zoom levels are considered) is difficult to construct;
7. Groundwater flooding information is still lacking;
8. The methods to produce risk maps are probably largely divergent between European MSs; consistency in methods and data sources would be very good, although it is difficult to approach the level of quality, spatial resolution and detail of local information resources;
9. Benchmarking of historical floods may also be of interest for the MSs, research community and EU Commission, as these are also one of the requests to the MSs to describe the extent of historical floods (and flood prone areas).

4 GAP ANALYSIS: WATER ACCOUNTING

4.1 WATER ACCOUNTING: CONCEPT & FRAMEWORKS

Water Accounting provides a conceptual framework for organizing hydrological and economic information in a coherent and consistent manner. It is a systematic process of identifying, quantifying, reporting, assuring and publishing information about water in the form of an accounting book, considering inflows, outflows and changes in stocks. In this context water accounting facilitates the identification of water availability, and the benefits and costs associated with its use within the different economic sectors. This analytical information is potentially useful for planning, developing strategies and setting policy targets.

During the past 20 years, several initiatives have emerged towards the development of water accounting systems, with the purpose of combining hydrological and economic information in a format suitable for supporting policy and decision makers. The most common water accounting frameworks are summarized below:

- International Water Management Institute (IWMI) Water Accounting Framework [4]; [5]

The primary objective of the IWMI Water Accounting is to present concepts and definitions to account for water use, depletion and productivity, and is based on a water balance approach where, according to the mass conservation, the sum of inflows must equal the sum of outflows plus any change in storage. The spatial and temporal scales of analysis are flexible, and can differ from the root zone of an irrigated field to a river basin; and from a single season to several years. The IWMI Water Accounts classify domain inflows and outflows according to their uses and productivity as presented in Figure 4 below. The Gross Inflow to the system (from surface and subsurface sources, and from precipitation) is converted to Net Inflow expressed as changes in storage. A part of the Net Inflow is depleted (depletion is a use or removal of water from a water basin that renders it unavailable or unsuitable for further use) by four generic processes: evaporation, flows to sinks (e.g. the sea), pollution (quality degradation makes water unsuitable for certain uses), incorporation into a product (e.g. incorporation of irrigation water into biomass) [5]. The depletion can be beneficial (i.e. the depleted water provides input to produce a good) or non-beneficial (i.e. no benefit is derived, e.g. evaporation from fallow land, deep percolation into saline aquifers, etc.). The remaining Net Inflow (i.e. the non-depleted) becomes an Outflow, further classified as Committed (allocated for other uses, such as environmental flow, water rights, etc.) or Uncommitted. This Uncommitted water is available for a use within a basin or for export, but flows out due to lack of storage or operational measures. According to this framework, available water is the net inflow less the amount of committed water and less the non-utilizable uncommitted outflow. Using the IWMI Water Accounts different physically based utilization and water productivity indicators can be calculated, such as the depleted fraction, conveying information of the flow paths of water, the amount being depleted and the specific use that is depleting the water, the ratio and degree of beneficial use.

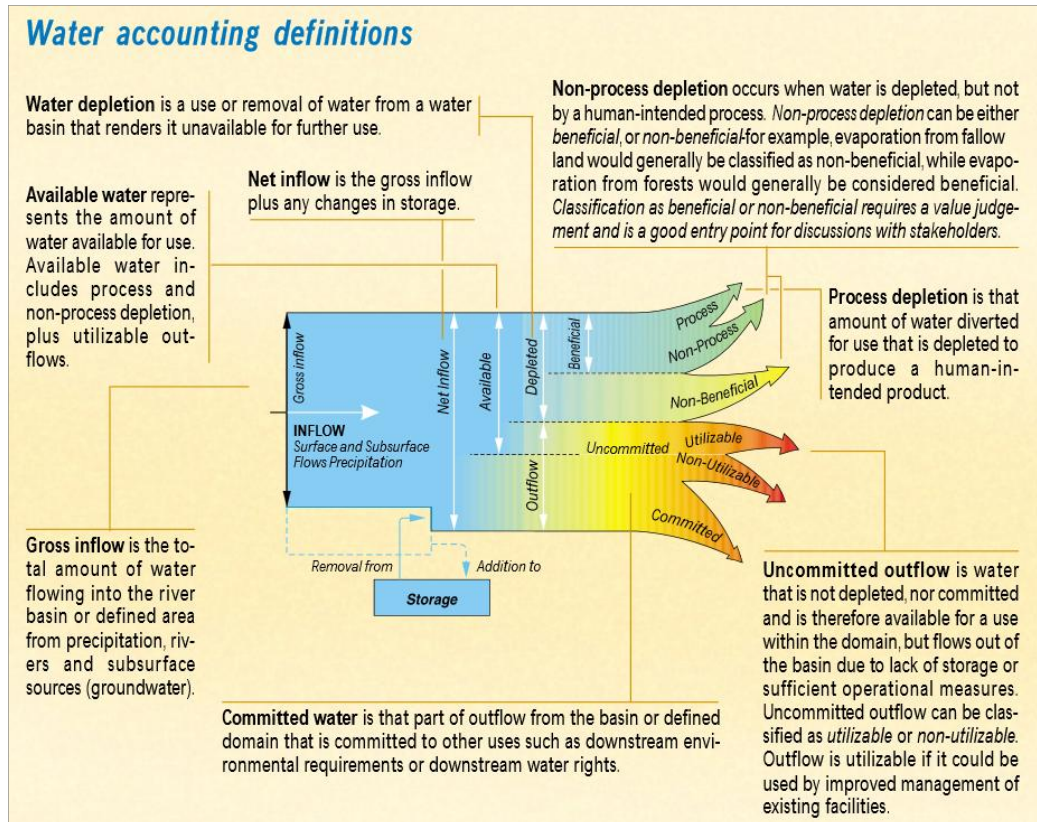


Figure 4: The IWM Water Accounting framework and definitions. Source: [6].

- United Nations Statistics Division (UNSD) System of Environmental-Economic Accounting for Water (SEEA) [7] [8] [9]

The SEEA was developed by the UNSD in collaboration with the London Group on Environmental Accounting and contributions from the Eurostat Task Force on Water Accounts, with the objective of standardizing concepts and methods in water accounting. The purpose of SEEA is to encourage countries to launch an IWRM approach through the establishment of an operational framework that integrates economic and hydrological information. Following the original Handbook of National Accounting "Integrated Environmental and Economic Accounting -2003" [8] (commonly referred to as SEEA-2003) which provided the opportunity to develop methodologies for water accounts, the UN Committee of Experts on Environmental-Economic Accounting (UNCEE) was established in 2005 with a main objective to elevate the system of environmental accounts to an international statistical standard and to advance the implementation of SEEA in all countries. The final draft of the SEEA has been established in 2007 to conform to the content and style of an international statistical standard, while a fictitious dataset has been developed to populate the standard tables [9], and has been further updated in 2012 [7]. The main argument for implementing the SEEA is that it provides the much-needed conceptual framework for organizing hydrological and economic information in support of Integrated Water Resource Management (IWRM), permitting a consistent analysis of the contribution of water to the economy and the impact of the economy on water resources, and should be thus adopted as the international standard for water statistics. The SEEA-2012 accounting framework considers the stocks, flows and exchange of flows between the

environment (i.e. water resources and the different components of the hydrological cycle) and the economy (i.e. water abstraction, use and return from/to the different NACE economic activities), and includes, as part of its standard presentation, information on the following [7]:

- Stocks and flows of water resources within the environment;
- Pressures imposed on the environment by the economy in terms of water abstraction and emissions added to wastewater and released into the environment or removed from wastewater;
- The supply of water and its use as an input in the production process and by households;
- The reuse of water within the economy;
- The costs of collection, purification, distribution and treatment of water, as well as the service charges paid by its users;
- The financing of these costs, that is, who is to pay for the water supply and sanitation services;
- The payment of permits for access to abstract water or to use it as a sink for the discharge of wastewater;
- The hydraulic stock in place, as well as investments in hydraulic infrastructure made during the accounting period.

SEEA also presents quality accounts (as yet at an experimental level), which describe water resources in terms of their quality, and proposes a set of indicators which can be derived from the accounting systems (rather than from individual sets of water statistics) and are useful to the policy makers.

The five main categories of water accounts are described below [7]:

1. Physical supply and use tables and emission accounts: the physical supply and use tables collect information on the volumes of water exchanged between the environment and the economy (abstractions and returns) and within the economy (supply and use within the economy). The emission tables collect information on the quantity of pollutants which have been added to or removed from the water (by treatment processes) during its use by economic activity and households.
2. Hybrid and economic accounts: these accounts combine the physical information of the water supply and use tables with monetary information (e.g. costs associated with water use and supply, such as water abstraction, purification, distribution, wastewater treatment, etc.). They also provide information on financing, i.e. the amount that users pay for the services of wastewater treatment, etc.
3. Asset accounts: these tables provide information on the water resources in physical terms (opening and closing stocks, changes in stocks due to precipitation, evapotranspiration, inflows, outflows, abstractions and returns) and link water availability to abstractions, facilitating thus the identification of pressures on the environment. The additional supplementary tables convey information on the flows of these volumes between the compartments of the hydrological cycle.
4. Quality accounts: these tables provide information on the stock of the water resources in terms of quality. They are still at an experimental level.
5. Valuation of water resources: these tables provide information on the valuation of water and water resources. In the case of water quality these are still at an experimental level.

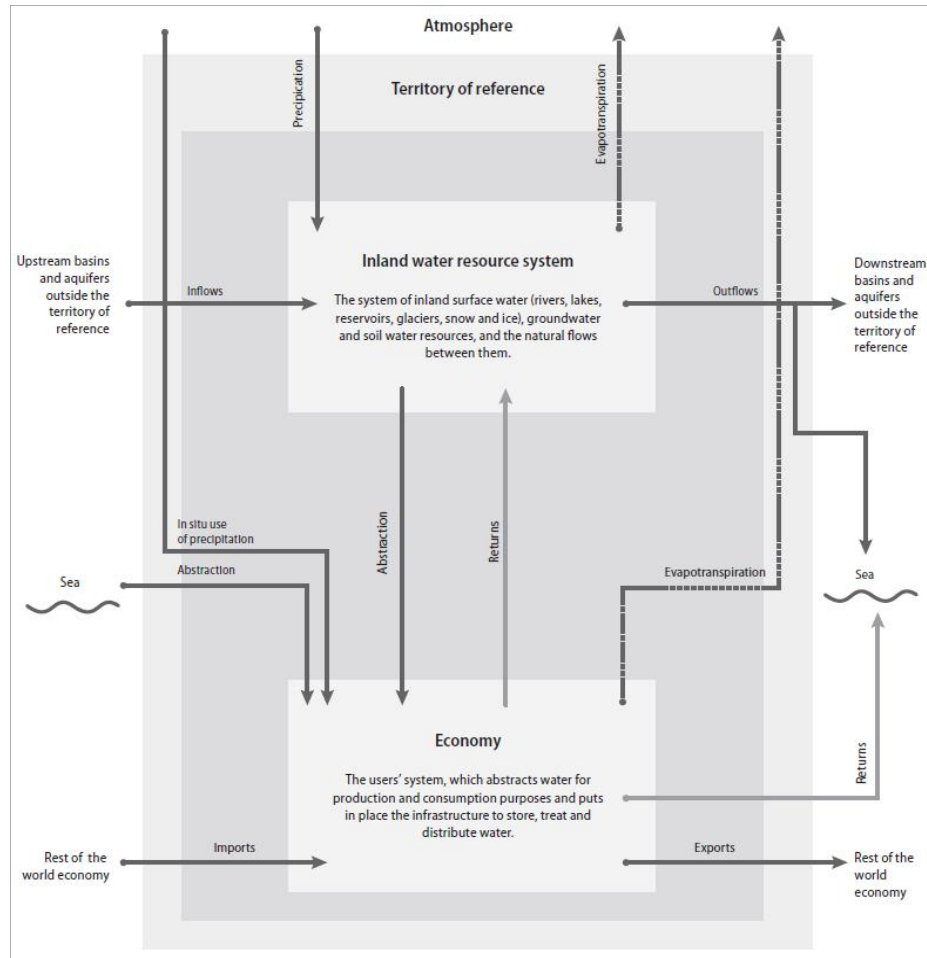


Figure 5: Main water flows between the inland water resource system and the economy captured by the SEEAW. Source: [7].

- The Australian Water Accounting Conceptual Framework (AWACF) and Standard (AWAS) [10]

Through the National Water Initiative (NWI), Australian, State and Territory governments have committed to achieving a national water accounting process to 'meet the information needs of different water systems in respect to planning, monitoring, trading, environmental management and on-farm management' [11]. The National Water Accounting Development project, which ran from 2007 to 2010, established the foundations of a national approach to water accounting. The project was funded by the Raising National Water Standards program administered by the National Water Commission. Key activities of this project included: a user requirements study, development of a Water Accounting Conceptual Framework ([WACF](#)), proposing a process for developing Australian Water Accounting Standards (AWAS) and drafting them ([AWAS1](#), [AWAS2](#)), proposing appropriate institutional arrangements for water accounting in Australia. In the Australian General Purpose Water Accounting Reports (GPWAR) the following information is included, varying according to the nature of the water reporting entity [10]: (a) Water Assets¹ and Water Liabilities² and their changes

¹ A water asset is water, or the rights or other claims to water, which the water reporting entity either holds, or for which the water reporting entity has management responsibilities, and from which an individual or

(information about the water resources attributable to a water reporting entity and about trades or other changes in rights or obligations relating to water); (b) Physical Water Flows (information about how the physical water resource and the rights to that resource have been sourced, managed, shared and used). Additional reporting elements include: Notes and Supplementary Schedules (narrative explanations of the material judgments and assumptions made and estimates used in preparing the statements, disclosures about the risks and uncertainties affecting water reporting entities, information relating to markets, etc.); Compliance and assurance (information about externally-imposed compliance requirements such as minimum passing flows, maximum diversion rates, water saving targets, water quality levels, etc.); Assumptions underlying the preparation and presentation; Accrual basis of water accounting (information about past transactions, transformations and events, unused water rights or obligations which continue to exist from one reporting period to the next).

- Water Footprint Accounting [12] [13]

Water Footprinting (WF) has been introduced in 2002 [12] to measure the total annual volume of freshwater used to produce the goods and services consumed by any well-defined group of consumers. It has been developed as an accounting tool for water resources management, allowing the mapping of water uses within a defined system, the water consumption level to produce the goods and services consumed by the system, and their relationships to the available water resources. Water footprint assessments can be carried at different spatial scales, and be specific to different entities, such as a group of consumers, a group of products, a geographical unit (catchment, municipality, country, etc.), a household, a business, a corporation, etc., depending on the scope of analysis.

organization that is a water reporting entity, or a group of stakeholders of a physical water entity, derives future benefits. Changes in water assets are increases or decreases in the water reporting entity's water assets. Net water assets are the excess of the water assets of the water reporting entity after deducting all its water liabilities.

² A water liability is a present obligation of the water reporting entity, the discharge of which is expected to result in a decrease in the water reporting entity's water assets or an increase in another water liability. Changes in water liabilities are increases or decreases in the water reporting entity's water liabilities.



	Spatial explication	Temporal explication	Source of required data on water use	Typical use of the accounts
Level A	Global average	Annual	Available literature and databases on typical water consumption and pollution by product or process.	Awareness-raising; rough identification of components contributing most to the overall water footprint; development of global projections of water consumption.
Level B	National, regional or catchment- specific	Annual or monthly	As above, but use of nationally, regionally or catchment specific data.	Rough identification of spatial spreading and variability; knowledge base for hotspot identification and water allocation decisions.
Level C	Small catchment or field- specific	Monthly or daily	Empirical data or (if not directly measurable) best estimates on water consumption and pollution, specified by location and over the year.	Knowledge base for carrying out a water footprint sustainability assessment; formulation of a strategy to reduce water footprints and associated local impacts.
Note: The three levels can be distinguished for all forms of water footprint accounting (for example, product, national, corporate accounts).				

Figure 6: Spatiotemporal explication in water footprint accounting. Source: [13].

The water footprint of a catchment is defined as the total freshwater consumption and pollution within the boundaries of the catchment, and is the sum of the process water footprints of all processes taking place in the catchment. The water footprints, expressed in terms of water volume are divided into three separate components: the blue, green and grey, which can be expressed individually or as a sum.

Blue water is the volume of consumptive water use abstracted from surface and ground water resources. Green water is the volume of evaporative flows (found in soils rather than major bodies of water) used. Grey water is the theoretical volume of water needed to dilute pollutants discharged to water bodies to the extent that they do not exceed minimum regulatory standards. Water footprinting focuses on providing a method to measure water use and discharge (volume, location, timing) and does not explicitly aim to assess the status of watersheds or water-related impacts per se [14].



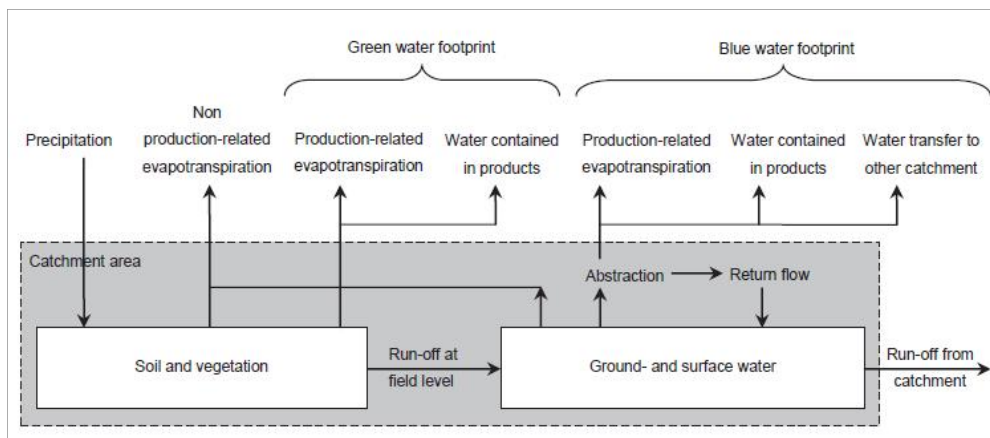


Figure 7: The green and blue water footprint in relation to the water balance of a catchment area. Source: [13].

- Water-use accounts of the Challenge Program on Water and Food (CPWF) [15], [16]

The water-use accounts framework of the Challenge Program on Water and Food (CPWF³) follow the concepts of the IWMI basin accounts and the Australian national accounts, but they are dynamic, with a monthly time step (as opposed to static accounts which provide a snapshot for a year) reflecting thus for seasonality and annual variability, and also link water movement to use. They provide monthly estimates of major water uses in a river basin. They can also examine dynamic effects such as climate change, land use change, changes to dam operation, etc. [16]. The use-accounts are compiled in Excel, and have been applied to several major river basins of the CPWF (Murray-Darling, Volta, Karkheh, Mekong, Limpopo; [15]). The water-use accounts look at the whole catchment, they are based on a simple conceptual mass balance model, and adopt a top-down model based on simple partitioning of rainfall into runoff and infiltration into a generalized surface store (i.e. they do not model the spatial distribution of hydrological processes and storages within the catchment).

The components of the water-use accounts (Figure 8) are described in [16] as follows: Starting with rainfall (and in some basins snowfall), the accounts track the partitioning of water into runoff, and evapotranspiration by rainfed vegetation. The runoff is tracked as it becomes flow down the rivers, with losses (such as evaporation and seepage) and gains (such as tributary inflows), storages in lakes and reservoirs, diversion for irrigation or other purposes, floods in lowland floodplains, and finally discharges to the sea. The account estimates the water use by the major irrigation industries and other uses. Total catchment evapotranspiration is estimated from potential evaporation and water supply from the surface store, and is partitioned between rain-fed and irrigated land uses based on the ratio of their areas. The rain-fed component of evapotranspiration is further partitioned between land uses/vegetation types (agriculture, forest/woodland, grassland, other) based on the ratio of their areas and using crop coefficients to scale their evapotranspiration relative to other land uses. Runoff flows into the rivers, with downstream flow is calculated by a simple water balance. Flow is stored in dams and other storages and, during high flows, in the

³ The Challenge Program on Water and Food (CPWF), an initiative of the Consultative Group on International Agricultural Research (CGIAR), is a multi-institutional research-for-development program that aims to increase water productivity for agriculture—that is, to change the way water is managed and used to improve food security and help meet international poverty eradication goals.

channels and floodplains. Water is lost from rivers (especially downstream sections in rivers in arid or semi-arid zones) by evaporation and seepage, or by the consumption as evapotranspiration of a proportion of flood discharge on to the floodplain. Water is diverted from the rivers mainly for use in irrigation, and unused water flows to the sea. The account is based on a monthly time step, which we consider adequate for our purpose. The account links known quantities in the water balance, such as rainfall and stream flow measured at gauging stations, with simple, physically plausible models, guided by the data.

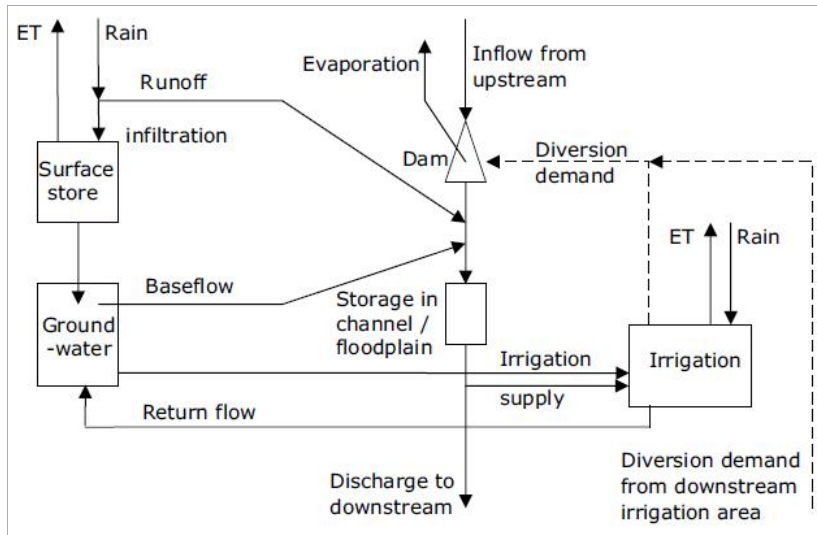


Figure 8: Conceptual model of the water-use accounts of a single catchment. Source: [16].

▪ Water Accounting Plus (WA+) [17] [18]

The Water Accounting Plus (WA+) framework builds on the combination of the systems and approaches from the IWMI [4] and from WaterWatch [19], and is based on the standard water balance approach⁴ with specific emphasis on the various water users. WA+ uses the IWMI WA principles of tracking water depletions rather than withdrawals, adopts the IWMI definition for water depletion, but considers more details in the processes and mechanisms. Depletion in WA+ includes evapotranspiration (ET) for every land use class (conserved, utilized, modified, managed) and flow to sinks, therefore, withdrawals and return flows are no longer necessary to be measured because the depletion can be obtained directly from satellite measurements [17].

WA+ explicitly recognizes the influence of land use on the water cycle, and thus groups land use under four classes (with common management characteristics) in order to better capture the interplays between land use, water balance, water use and water management [18]:

- Conserved land use (CLU): includes national parks and other protected areas
- Utilized land use (ULU): includes land with intensive ecosystem services
- Modified land use (MLU): includes land with human influences (e.g. cultivation of rain-fed crops, plantations and soil treatment, managed water use, etc.).

⁴ The basis of the WA+ water balance approach is that outflow from a certain area of interest (e.g. river basin) are explicitly related to the net inflow and depletion through measurable ET processes [17]

- Managed water use (MWU): where withdrawals are effectuated through man-made infrastructure (diversion dams, canals, ditches, pumping stations, gates, weirs, pipes, etc.)

The WA+ framework proposes four main accounting sheets: the Resource Base Sheet, the Evapotranspiration sheet, the Consumptive Use Sheet, the Productivity Sheet, and a set of relevant indicators to support water managers and policy makers. The four sheets, as presented in [18], are summarized below and illustrated in Figure 9 - Figure 12.

- The resource base sheet provides information on water volumes, looking at both water supply and water depletion processes.
- The evapotranspiration sheet presents information how the ET depleted water is broken down to beneficial and non-beneficial depletion.
- The productivity sheet shows links between water depletion and biomass production, carbon sequestration, crop production and water productivity.
- The withdrawal sheet contains information on water withdrawals and reuse, which is relevant for water allocation and management

WA+ is amenable to satellite data: satellite-derived estimates of land use, rainfall, evaporation, transpiration, interception and biomass production can be used in addition to measured basin outflow for building the WA+, and can thus minimize the data collection burden [20].

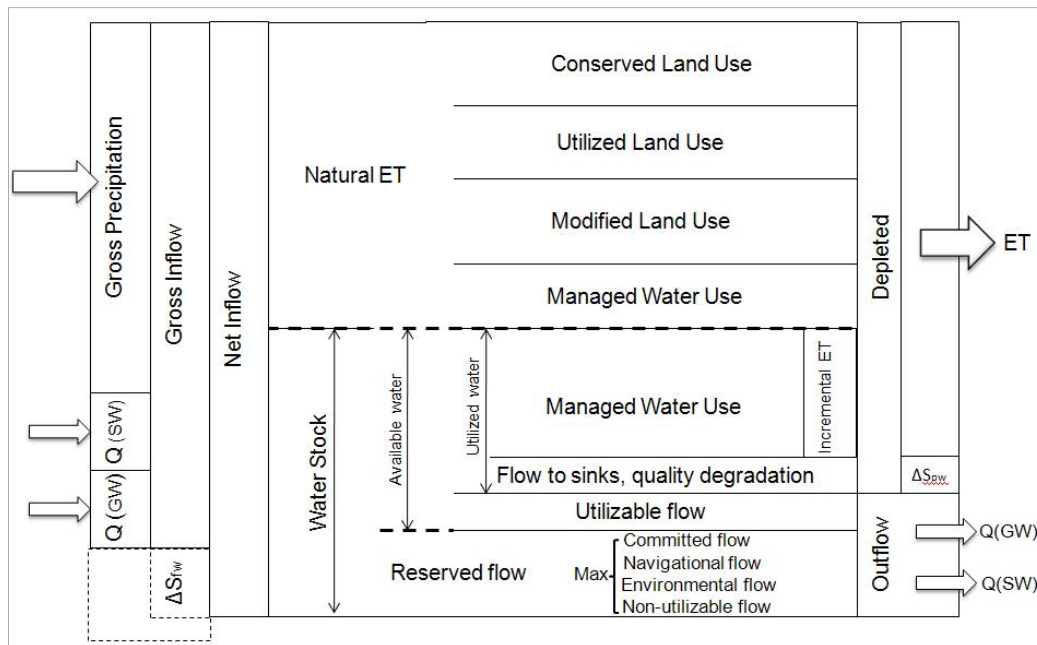


Figure 9: WA+ Resource Base Sheet (sw=surface water, gw=groundwater, dSfw=storage of fresh water, dSpw=storage of polluted water). Source: [21].

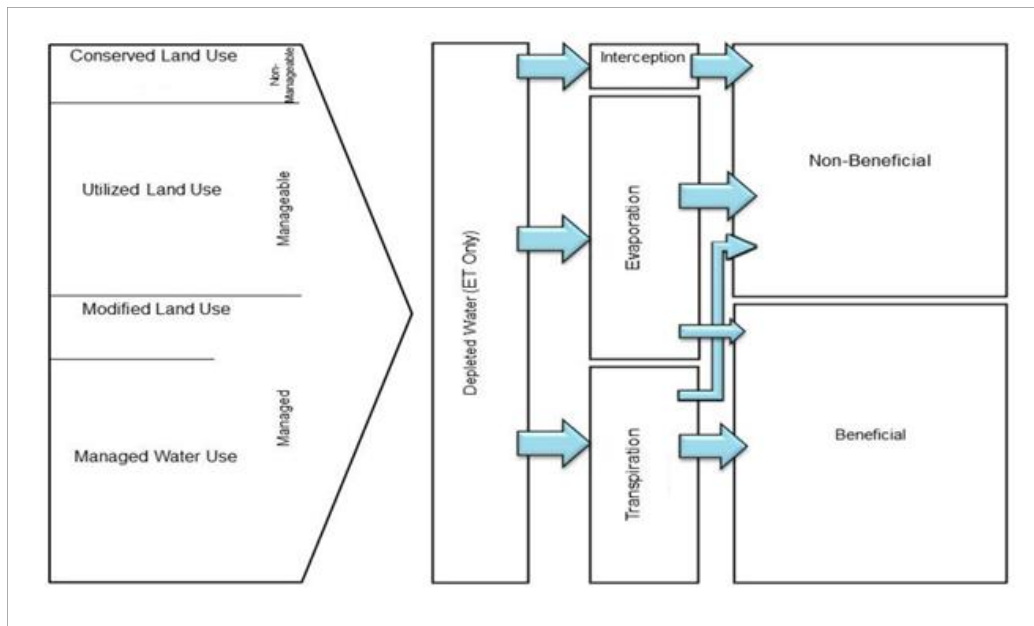


Figure 10: WA+ Evaporation Sheet. Source: [18].

		Biomass Production (kg/ha)	CO2 Sequestration (kg/ha)	Biomass Water Productivity (kg/m3)	Yield Equivalent (kg/ha)	Yield Eq. Water Productivity (kg/ha)
Conserved Land Use	Parks	xxx	xxx	xxx		
	Tropical Rainforest	xxx	xxx	xxx		
	Wetlands	xxx	xxx	xxx		
	Lakes					
	Others	xxx	xxx	xxx		
Utilized Land Use	Forests	xxx	xxx	xxx		
	Savanna	xxx	xxx	xxx		
	Deserts	xxx	xxx	xxx		
	Mountains	xxx	xxx	xxx		
	Others	xxx	xxx	xxx		
Modified Land Use	Plantation Trees	xxx	xxx	xxx	xxx	xxx
	Rainfed Pastures	xxx	xxx	xxx	xxx	xxx
	Rainfed Crops	xxx	xxx	xxx	xxx	xxx
	Others	xxx	xxx	xxx	xxx	xxx
Managed Water Use	Irrigated Crops	xxx	xxx	xxx	xxx	xxx
	Urban Areas					
	Others	xxx	xxx	xxx	xxx	xxx

Figure 11: WA+ Productivity Sheet. Source: [21].

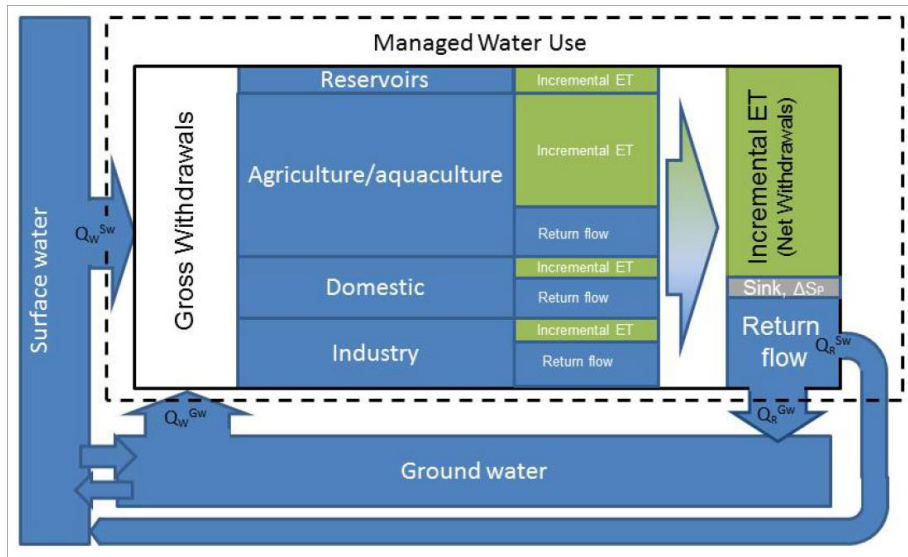


Figure 12: WA+ Withdrawal Sheet. Source: [17].

Different accounting frameworks have been presented in this section, having commonalities, but also differences among them, either in concepts, or in definitions, or in the scale of implementation. The underlying basis across all frameworks is that they try to convey hydrological and economic information, linking water availability (or supply) to water use and its value. There is a growing interest from policy-makers and water managers to look into (and possibly adopt) water accounting as a tool to support proper water allocation, and efficient use of water resources, yet none of the frameworks has been widely adopted as an accepted standard. Most of the case studies are also conducted outside Europe (e.g. Nile, Mekong, Indus, Volta, Ganges, Limpopo, Karkheh, Niger, Kirindi Oya, Bhakra, Okavango, Murray-Darling, Yellow River, etc.). In [21] the following reasons for this lack of uptake have been identified:

- The increased complexity of some of the frameworks makes them unsuitable for use as a supporting tool
- Most frameworks are location specific rather than universally applicable.
- Input data requirements are often too intense, and the data are not readily available, or require long-term expensive monitoring activities.
- In many frameworks only abstracted water is considered, which in some areas this volume represents only a fraction of the entire water resources and water use.
- The focus on interventions and management options is limited, and the presented results do not always differentiate between managed, manageable and non-manageable water flows which are of importance to water managers.

Adding to the above reasons, it is also to be noticed that the existence of an abundance of WA frameworks confuses itself the water managers, since their definitions are not harmonized and their concepts are not harmonized. To some extent, these frameworks are also very generic, whereas water management is a case specific issue. It is thus questionable if they can provide much more than a type of “hotspot analysis” and an awareness level overview of the inputs and outputs of the investigated system, as opposed to being able to support management and policy decisions. As quoted in [21] “a framework providing numbers where it is unclear how and where interventions are possible, remain to a large extent a more academic exercise rather than a solid base to explore options to improve water resources management”.

4.2 QUICK REVIEW OF THE WATER ACCOUNTING DEVELOPMENTS IN EUROPE

The development of Water Accounts in Europe, at national and/or river basin scale and at the pan-European scale, has picked-up during the latest years, probably led by the increased demand for information about the economic value of water and the wider economic consequences of water policy and management. This information demand has been boosted by the European Water Framework Directive (WFD) which explicitly acknowledges the important role of economics in water policy and management. National level and pan-European level developments in building water accounts are presented in the next sections.

4.2.1 Development of Water Accounts at the National level

At the national level, interest in environmental accounts has been generated within environmental institutes and ministries which use this data for environmental-economic analysis and policy development. Existing initiatives in European countries are presented below:

The Dutch water accounts

In the beginning of the 1990s, Statistics Netherlands extended their National Accounting Matrix (NAM) with a 'satellite account', which includes the environmental pressures related to the production of goods and services. This resulted in the National Accounting Matrix including Environmental Accounts (NAMEA) [22], which is published annually by Statistics Netherlands. Following a pilot project in 1997, the Dutch system of environmental accounts was extended in 2002 with the National Accounting Matrix including Water Accounts (NAMWA). NAMWA is a further specification of NAMEA for water, using the same basic structure as the NAMEA [23].

In order to increase the usefulness of NAMWA for water policy and management, and offer opportunities to analyse the trade-offs between environmental goals and the economic interests involved, the data and information were further disaggregated from the administrative national level to the level of river basins where actual decision-making in the context of the WFD takes place. This resulted in the river basin NAMWA (NAMWARB), which links the economic activities in the seven WFD river basins in the Netherlands (Meuse, Scheldt, Ems and the Rhine split up in 4 sub-basins: Rhine-North, Rhine-West, Rhine-East and Rhine- Centre) to their corresponding water use over the period 1996-2000 [24], [25].

The structure of NAMWA consists of three types of accounts (either monetary or physical ones) [24]:

- An economic account (accounts #1-10, all in millions of euros).
- A water extraction and discharge account (account #11 and #13, in millions of cubic meters).
- An emission account (account numbers #12 and #14, in kilograms).

The accounts #11-14 are physical accounts: the accounts #11 (water extraction and discharge) and #12 (emission of substances) represent the flows. The account #13 for water extraction and discharge describes changes in stocks, while the account number #14 for emissions describes the contribution of various substances to 'environmental themes' such as eutrophication or the dispersion of heavy metals in water.

By linking information about the physical pressures exerted on the water system by economic agents and the associated economic interests, NAMWA enables policy makers and water managers at national and river basin scale in a consistent way to assess the necessary measures to reduce these pressures and meet the environmental objectives in the Water Framework Directive (WFD) in an integrated way [23]. The Institute for inland water management and wastewater treatment (RIZA) uses the water accounts for making the reports regarding to the WFD. The Dutch water accounts are published annually by Statistics Netherlands. Statistics Netherlands is extending the system of environmental accounts based on the System of Environmental and Economic Accounting (SEEA). New work will be undertaken with regard to material flow accounts (MFA). The monetary accounts will be extended with the inclusion of environmental subsidies, emission trade and the environmental goods and services sector.

4.2.2 Development of Water Accounts at the European level

The implementation of the WFD has increased policy and decision-maker demand for integrated hydro-economic information at the level of river basins [26]. Further policy needs [27]; [28], etc.) have further increased the demand for water quantity related data and assessments of various categories (water availability, supply and use, economic data, etc.) that are validated and consistent, capable for integration, comparable across the EU, and harmonised in terms of definitions. A special focus is been thus placed on the geographical boundaries of the data and the respective unit of common reference. To this extend, the SEEAW (of Environmental-Economic Accounting for Water) has the potential to provide a framework for the coherent organisation of the information related to the water balance and the development and extraction of relevant indicators, at the appropriate time and spatial scale, which are at the heart of high-level policy assessments and communication. In light of these developments, and further recognizing the needs stemming from (a) the implementation of the WFD which has increased the demand for integrated hydro-economic information at the RBD level, and (b) the policy relevant communications on the importance of assessing the water stress, efficiency and water balance across the EU regions, different EU initiatives have emerged towards the development of physical water accounts at the EU level.

4.2.2.1 The European Environment Agency (EEA) initiative (EEA, 2013)

The EEA (supported by a DG ENV service contract 2011-2012) engaged into developing pan-European Physical Water Accounts under the ECRINS georeference system⁵. The EEA approach focused on the development of water balances in line with the SEEAW tables on “Asset Accounts” (Figure 13) and “Physical Supply and Use” (Figure 14, Figure 15), at the monthly resolution and using the Functional Elementary Catchment (FEC⁶) as

⁵ ECRINS v.1, developed by the EEA, is a fully connected system of watersheds called FECs (Functional Elementary Catchments) with rivers stretches, lakes & reservoirs, monitoring stations (quality and quantity) and dams. The system is derived from the JRC CCM2.1. Compared to the CCM, the ECRINS system offers a smaller number of elementary catchments with 181,071 FECs (with an average size of ~ 62 km²) instead of more than 2,000,000 elementary catchments within the CCM. The latest ECRINS v1.0 allows the aggregation of FECs at several levels (sub-basins, basin, River Basin District-RBD in line with the WFD, NUTS2, NUTS0). ECRINS v1 data sets are fully and publicly available and downloadable from the EEA website: <http://www.eea.europa.eu/publications/eea-catchments-and-rivers-network> (EEA, 2012. EEA Catchments and Rivers Network System – ECRINS v1.1. Rationales, building and improving for widening uses to Water Accounts and WISE applications, EEA Technical Report No 7/2012, European Environment Agency).

⁶ The functional elementary catchment (FEC) is the elementary area of land, participating to a river catchment, for which rainfall and evaporation are computed; by extension, both values are broken down per land-use category if required. The functional elementary catchment is the host for soil water

the minimum hydrological spatial unit of the analysis. The EEA concept was based on the belief that the production of detailed water balances can facilitate the in-depth understanding of the relevant exploitation of water resources, not just for the purpose of identifying water stress in scarce areas, but for further understanding how efficiently water is used, what are possible territorial dependencies, and how water and the economy interact. The EEA WA intended to also serve additional purposes and address multiple challenges, such as to [29]:

- Check the overall effectiveness of the approach, identify methodological and conceptual issues with regards to the input/output tables, and communicate these findings to the SEEAW task force, thus contributing to the refinement of the methodology.
- Assess the appropriateness of the existing data collection systems and propose improvements, with the hope that many data gaps and methodological imperfections will be ironed out in the future.
- Foster the EU policy needs for a full-scale implementation of water balances at the appropriate spatial and temporal resolution.
- Allow the building of a comprehensive database that can be used in turn to reinforce the production of various relevant indicators, such as the Water Exploitation Plus (WEI+⁷).
- Support the wider work on E-flows by providing a consistent river reference system (ECRINS) populated with long time-series data that could allow analysis at river segment level between the hydrological conditions and the water body status.
- Target the integration of the Physical Water Accounts under the wider frame of Environmental Accounting to support other important environmental issues, as well as holistic assessments of ecosystems' integrity and sustainability.

⁷ The Water Exploitation Index Plus (WEI+) has been developed by the CIS Expert Group on Water Scarcity and Drought (EG WSD) as an improvement to the traditional Water Exploitation Index (WEI = the ratio of annual freshwater abstractions over the long-term annual average freshwater availability). WEI+ proposed a more disaggregated spatial scale (i.e. river basin) and temporal resolution (i.e. monthly) and further incorporates returned water in the calculation. Details of the WEI+ formula are available in: Faergemann, H. (2012). [Update on Water Scarcity and Droughts indicator development](#), May 2012, presented to the WD Meeting, 4-5 June 2012, Denmark.

Asset accounts (millions of cubic metres)							
	EA.131. Surface water				EA.132 Groundwater	EA.133 Soil water	Total
	EA.1311 Artificial reservoirs	EA.1312 Lakes	EA.1313 Rivers	EA.1314 Snow, ice and glaciers			
1. Opening stocks	1 500	2 700	5 000	0	100 000	500	109 700
Increases in stocks							
2. Returns	300	0	53		315	0	669
3. Precipitation	124	246	50			23 015	23 435
4. Inflows	1 054	339	20 137		437	0	21 967
4.a. From upstream territories			17 650				17 650
4.b. From other resources in the territory	1 054	339	2 487	0	437	0	4 317
Decreases in stocks							
5. Abstraction	280	20	141		476	50	967
6. Evaporation/actual evapotranspiration	80	215	54			21 125	21 474
7. Outflows	1 000	100	20 773	0	87	1 787	23 747
7.a. To downstream territories			9 430				9 430
7.b. To the sea			10 000				10 000
7.c. To other resources in the territory	1 000	100	1 343	0	87	1 787	4 317
8. Other changes in volume							0
9. Closing stocks	1 618	2 950	4 272		100 189	553	109 583

Matrix of flows between water resources (millions of cubic metres)							
	EA.131. Surface water				EA.132 Groundwater	EA.133 Soil water	Outflows to other resources in the territory
	EA.1311 Artificial reservoirs	EA.1312 Lakes	EA.1313 Rivers	EA.1314 Snow, ice and glaciers			
EA.1311. Artificial reservoirs			1 000				1 000
EA.1312. Lakes			100				100
EA.1313. Rivers	1 000	293			50		1 343
EA.1314. Snow, ice and glaciers							0
EA.132. Groundwater			87				87
EA.133. Soil water	54	46	1 300		387		1 787
Inflows from other resources in the territory	1 054	339	2 487	0	437	0	4 317

Figure 13: SEEAW "Asset Accounts main" and supplementary tables. Source: [7].

A. Physical use table (physical units)		Industries (by ISIC category)							Households	Rest of the world	Total
		1-3	5-33, 41-43	35	36	37	38, 39, 45-99	Total			
From the environment	1. Total abstraction (= 1.a + 1.b = 1.i + 1.ii)										
	1.a. Abstraction for own use										
	1.b. Abstraction for distribution										
	1.i. From inland water resources:										
	1.i.1. Surface water										
	1.i.2. Groundwater										
	1.i.3. Soil water										
	1.ii. Collection of precipitation										
	1.iii. Abstraction from the sea										
Within the economy	2. Use of water received from other economic units of which:										
	2.a. Reused water										
	2.b. Wastewater to sewerage										
3. Total use of water (= 1 + 2)											

A. Physical use table (millions of cubic metres)	
From the environment	1. Total abstraction (= 1.a + 1.b = 1.i + 1.ii)
	1.a. Abstraction for own use
	Hydroelectric power generation
	Irrigation water
	Mine water
	Urban run-off
	Cooling water
	Other
	1.b. Abstraction for distribution
	1.i. From inland water resources:
	1.i.1. Surface water
	1.i.2. Groundwater
	1.i.3. Soil water
	1.ii. Collection of precipitation
	1.iii. Abstraction from the sea
Within the economy	2. Use of water received from other economic units of which:
	2.a. Reused water
	2.b. Wastewater to sewerage
	2.c. Desalinated water
3. Total use of water (= 1 + 2)	

Figure 14: SEEAW “Physical Use” main and supplementary tables. Source: [7].

		Industries (by ISIC category)							Households	Rest of the world	Total
		1-3	5-33, 41-43	35	36	37	38, 39, 45-99	Total			
B. Physical supply table (physical units)											
Within the economy	4. Supply of water to other economic units										
	of which:										
	4.a. Reused water										
	4.b. Wastewater to sewerage										
Into the environment	5. Total returns (= 5.a + 5.b)										
	5.a. To inland water resources										
	5.a.1. Surface water										
	5.a.2. Groundwater										
	5.a.3. Soil water										
	5.b. To other sources (e.g., sea water)										
	6. Total supply of water (= 4 + 5)										
	7. Consumption (= 3 - 6)										

B. Physical supply table (millions of cubic metres)			
Within the economy	4. Supply of water to other economic units	Into the environment	5. Total returns (= 5.a + 5.b)
	of which:		Hydroelectric power generation
	4.a. Reused water		Irrigation water
	4.b. Wastewater to sewerage		Mine water
4.c. Desalinated water	Urban run-off		
	Cooling water		
	Losses in distribution because of leakages		
	Treated wastewater		
	Other		
	5.a. To inland water resources (= 5.a.1 + 5.a.2 + 5.a.3)		
	5.a.1. Surface water		
	5.a.2. Groundwater		
	5.a.3. Soil water		
	5.b. To other sources (e.g., sea water)		
	6. Total supply of water (= 4 + 5)		
	7. Consumption (= 3 - 6)		
	of which:		
	7.a. Losses in distribution not because of leakages		

Figure 15: SEEAW “Physical Supply” main and supplementary tables. Source: [7].

The EEA Physical Water Accounting is a consolidation and exploitation of heterogeneous data sets along with computational and semi-modelling techniques to bridge the necessary data gaps and achieve the production of water balances at the catchment scale and monthly resolution for an 8-year period on average [30]. The computation area covers the catchments included in the EU-27, plus the areas necessary for connecting these catchments. For example, Serbia and Croatia are not part of the EU-27; however, since the Danube flows in these countries from and to EU-27 countries, relevant areas of these non-EU countries have been considered in the computations as well. By contrast, because of the lack of resources and difficulties in obtaining data, the Turkish catchments have not been considered, despite falling inside the EEA area.

The prerequisite to implement the EEA Physical Water Accounts (the asset accounts in particular) is the existence of an appropriate hydrographical reference system. For this purpose, the ECRINS has been used as a georeference system, allowing the regular production of the WA at the relevant time and scale resolutions and their integration into a wider continental water assessment system. The application used to integrate the EEA WA is the NOPOLU2 System, developed in MS Access. NOPOLU2 consists of several modules and routines that manage data and implement the various proxy calculations and modelling components.

In the EEA implementation, the focus of water accounting is on the interactions between water resources and the economy, where the economy is considered the system that abstracts water for consumption and production activities, and puts in place the

infrastructure to mobilise, store, treat, distribute and return water to the environment. The various components are briefly described below [29]: Inflows and outflows are considered only between other territories of reference or between the sea and atmosphere (i.e. exchange of flows within the compartments of the same territory of reference has not been represented). The atmosphere is considered as one indiscriminate compartment from which rainfall is provided to the appropriate statistical unit of the territory of reference (i.e. FEC) and from which evaporation subtracts resources. At the moment, stocks are just a fraction of annual flows, while the water asset accounts implemented do not apportion aquifers into statistical units (this is postponed until a reasonably accurate map of aquifers is related to the surface water system). Finally, information relative to the matrix of transfers of water within the economy (i.e. exchange on flows between economic units) is found purely in the economic sector and is not addressed in the current implementation. The main data used for the calibration of the physical system are the streamflow data, collected through the WISE-SoE#3 and an additional ad-hoc collection.

Using the EEA Physical Water Accounts a calculation of the Water Exploitation Index Plus (WEI+) has been also carried out. The results have been normalized in a 0-1 (nWEI) and relevant percentiles (50%, 90%, etc.) have been calculated in order to demonstrate average annual vs. monthly conditions [30]. For example, the 90% nWEI indicates the frequent peak pressure on the resource, showing the probability of a peak to occur in one month over 10 based on the 8-yr data. The 90% is used to accommodate the monthly representation of the index, which also makes the WA application more flexible as the percentile values can be adjusted depending on the needs of the assessment.

A final output of the EEA Physical Water Accounts application was the identification of important gaps in the availability of key data, necessary for the production of water balances in Europe, which confirms the evidence that a regular targeted dataflow needs to be established and maintained for that purpose.

4.2.2.2 The EU Commission initiatives

The EC DG Env supported the development of Water Accounts with four initiatives:

- A service contract supporting the elaboration of the EEA Physical Water Accounts/Physical Water Balances at sub-catchment level with monthly resolution.
- Development of hydro-economic modelling by the JRC.
- 10 Grants for pilot projects to develop and implement water accounts at the river basin scale under the 2011 and 2012-13 Calls for Proposals concerning preparatory action on development of prevention activities to halt desertification in Europe.
- Development of water scarcity and drought indicators within the CIS Expert Group on Water Scarcity and Drought (EG WSD), and more specifically the WEI+ which builds on the components of the water balance (supported by the EEA and the MSs).

A service contract for the elaboration of physical water balances at sub-catchment level with monthly resolution, for developing water accounts based on UN SEEAW methodology, was carried out by Pöyry and Vito Consultants for DG Environment (<http://ec.europa.eu/environment/water/blueprint/balances.htm>), in order to support the work of the EEA. The work was joined with the EEA activities described in the previous section. The project demonstrated the benefits of building a consistent framework for physical water accounts at EU level with a high degree of geographical, temporal and sectoral accuracy. It further allowed the checking of the WEI+⁷ agreed by the Water Directors, and the improvement of water resource indicators. However, the project also highlighted important gaps in the availability of key data and confirms the need to design a more cost-effective process for reporting as well as the need for

statistics for the assessment of quantitative water resources. In addition, it demonstrated the need for further interaction between modelled and reported data. Four main reports are available presenting the project outcomes, namely: the reference system and the datasets [31], the methodologies to calculate water supply and use [32], the water accounts system and the results [33], and the user guide to the application [34]. The outcome of the process was discussed in the meeting of Water Directors in November 2012, following a technical workshop⁸ that took place on 7/9/2012 with experts nominated by Member States and SCG stakeholders. The main conclusions of this meeting are the following [35]:

- There was no fundamental disagreement to the generic approach followed by DG ENV and the EEA. Nevertheless, a more active involvement of MS in technical details (such as the delineation of sub-catchment so that they correspond to management units) was required.
- The problems identified by the participants relate to concrete datasets and could be solved by bilateral coordination with the member states and sectoral experts to clarify the interpretation of the used data and to look for a way forward for concrete contributions from Member States or stakeholders covering missing data. Uncertainties remain very high and it is not clear to what extent these uncertainties have an influence on the results.
- There were therefore concerns expressed on the potential publication of maps, in particular on the Water Exploitation Index (WEI / WEI+), due to the lack of a large amount of data and the unclear interpretation of the used data.
- Finally, a better coordination with the work undertaken in the context of the CIS should be established, more specifically on the calculation of the WEI+, and the forthcoming analysis and agreement upon the thresholds of the WEI+ and development of complementary indicators.

A modelling environment (hydro-economic modelling) has been developed by the JRC in the context of the Blueprint Impact Assessment to assess the effects of water retention measures, water savings measures, and nutrient reduction measures on several hydro-chemical indicators, such as the Water Exploitation Index, Environmental Flow indicators, N and P concentrations in rivers, the 50-year return period river discharge as an indicator for flooding, and economic losses due to water scarcity for the agricultural sector, the manufacturing-industry sector, the energy-production sector and the domestic sector [36]. This modelling environment consisted of linking several existing pan-European models: the agricultural CAPRI model, the LUMP land use model, the LISFLOOD water quantity model, the EPIC water quality model, the LISQUAL combined water quantity-quality and hydro-economic model, and a multi-criteria optimization routine. Simulations have been carried out to assess (among other policy relevant issues) the effects of various measures on several hydro-chemical indicators, including the Water Exploitation Index.

Water Balances have been calculated within this modelling environment at a 5x5 km grid, using the LISFLOOD water quantity model. Results can be aggregated at the WaterRegions level (these are 1246 smaller European sub-regions) or the MacroRegions level (these are 21 large European regions, with no water transfers between them, consisting of one or several entire river basins). LISFLOOD is a GIS-based spatially-distributed hydrological rainfall-runoff model developed at the JRC. It includes

⁸ The minutes of the "Ad-hoc expert meeting on EU physical water balances, 07/09/2012" are available at:

<http://ec.europa.eu/environment/water/blueprint/pdf/Minutes%20water%20accounts%20meeting%207-9-2012.pdf>

a one-dimensional hydrodynamic channel routing model and is currently used at the JRC for simulating water resources in Europe and Africa. Driven by meteorological forcing data (precipitation, temperature, potential evapotranspiration, and evaporation rates for open water and bare soil surfaces), LISFLOOD calculates a complete water balance at a daily time step and every grid-cell. Processes simulated for each grid cell include snowmelt, soil freezing, surface runoff, infiltration into the soil, preferential flow, re-distribution of soil moisture within the soil profile, drainage of water to the groundwater system, groundwater storage, and groundwater base flow. Runoff produced for every grid cell is routed through the river network using a kinematic wave approach. Satisfactory results can be obtained in basins of a few hundred km² up to the size of the entire Danube basin. A limiting factor is the availability of good, accurate and homogenous input data for the entire pan-European, for example soil data or measured discharge data. Human influences (e.g. dams, reservoirs, polders, irrigation) also are difficult to quantify [36].

Water abstraction, demand and consumption have also been modelled within the JRC modelling environment as follows [36]: Average monthly irrigation water needs have been derived using the JRC EPIC model [37]. Irrigation water use and abstraction were calculated taking into account irrigation water needs, and irrigation efficiency. It is assumed that 5% of the 'not-efficiently' used irrigation water (the difference between abstraction and crop use) is lost (evaporated), while 95% of that part is return flow. Industrial water abstractions are estimated based on Eurostat and similar data sources using the 100m land use data to downscale, and considering consumptive use and potential reuse of water. The consumptive water use in industry (i.e. water not returned due to evaporation during cooling) was assumed to be about 15%, while a water reuse fraction controls the percentage of water reuse under different scenarios. Energy water withdrawals (for cooling during electricity production) were attributed almost exclusively to thermal power stations. Country-level data were used and disaggregated using the number of thermal power stations per 5km pixel extracted from the European Pollutant Release and Transfer Register (E-PRTR) database. In case data were not available the water withdrawals were disaggregated to the Corine refined industry class. Household water abstractions are estimated based on Eurostat and similar data sources, using the 100m land use data to downscale. Consumptive water use in households is assumed at 0.20 cubic metres per capita per day, while leakage was considered based on actual reported values. It was further assumed that 5% of the 'leaked' water is lost (evaporated), while 95% of that part is return flow. Livestock water abstractions are estimated based on Eurostat and similar data sources, using the 100m land use data and actual temperature data to downscale. Consumptive water use is estimated to be about 15%.

Concluding remarks of the policy relevance of this modelling work are summarized below [35]: The study shows that this modelling software environment can technically deliver optimum scenario combinations of packages of measures that improve various water quantity (and water quality) indicators, but that additional work is needed before final conclusions can be made about using the tool. With regard to the modelling of water balances at sub-catchment scale, it seems there is a trade-off between homogeneity of the results at EU level and accuracy at local scale. This needs to be taken into account when using results and drawing policy conclusion at e.g. national or river basin scale. Conceptually speaking, such a model which integrates water quantity, quality and economic aspects is very interesting to elaborate River Basin Management Plans. However, the model, at this stage of development, is not able to capture all the water-related specific issues in each basin, including those that affect water planning, for which river basin authorities may have other tools that better suit their policy needs, including the implementation of the WFD. The modelling framework, if sufficiently

populated and validated, could be used by a Member State or a trans-boundary coordination body, in a subsidiary way, and as a tool to explore some aspects of objective setting relating to combinations of measures.

The general objective of the pilot projects of the DG ENV Preparatory Action on development of prevention activities to halt desertification in Europe Halting desertification in Europe is to investigate and build water balances at the local level. The pilot initiatives should supplement the work on complementing EU water resource balances with local data, as well as demonstrate the potential of management, technological and economic measures for improving water management with a view to halting desertification in Europe and decreasing vulnerability to water scarcity and droughts. From 2011 onwards 10 grants have been awarded for implementing activities in the following 12 pilot river basins: Tiber⁹ (Italy), Mulde⁹ (Germany), Ali-Efenti⁹ (Greece), Vit⁹ (Bulgaria), Guadiana^{10,11} (Spain), Jucar¹² (Spain), Segura¹³ (Spain), Duero¹⁴ (Spain/Portugal), Arno¹⁵ (Italy), Guadalquivir¹⁶ (Spain), Andalusian Mediterranean Basins¹⁷ (Spain), Tagus¹⁸ (Spain/Portugal). The specific objectives of these pilots are to:

- Develop water balances in the selected river basin(s) following a methodology consistent with the building of the European water resource balances at EU level and the SEEAW framework.
- Test innovative solutions for gathering and integrating the data needed for the water balance (e.g. river discharge monitoring).
- Test at local/regional/transboundary scale the integration of water balances in the river basin management planning.
- Identify management, technological and economic measures applied in the selected river basin(s), which encourage optimal water management and avoid unsustainable water use.
- Propose, based on the identified water saving potentials in the selected river basin, sector specific and river basin specific water efficiency targets, water re-use targets and targets related to ecosystems and their services, land-use and adaptation to climate change allowing to preserve and/or restore the natural water balance.

The pilot projects (not all of them are currently completed) attempted to use the SEEAW framework and fill in the requested data with respect to the “asset accounts” and the “physical supply and use” from existing national database and sources. The exercise was proven very challenging, while for the purpose of developing EU water balances and

⁹ Assessment of Water Balances and Optimization based Target setting across EU River Basins (ABOT), www.abot.it

¹⁰ System of economic and environmental accounts for water in Guadiana River Basin (GuaSEEAW), <http://iderm.imida.es/guaseeaw/>

¹¹ New developments in Water Accounts Implementation in Guadiana river basin (GuaSEEAW+)

¹² Halting Desertification in the Jucar River Basin (HALT-JUCAR-DES), <http://evren.es/halt-jucar/>

¹³ Accounting System for the Segura River and Transfers (ASSET), <http://www.assetwater.eu/>

¹⁴ Duero River Basin: Water resources, water accounts and target sustainability indices (DURERO), http://138.100.137.130/durero_project_2014/

¹⁵ Pilot Arno Water accounts (PAWA), <http://pawa.emwis.net/>

¹⁶ System of Water Accounting in the Guadalquivir River Basin (SYWAG)

¹⁷ Water accounting in a multi-catchment district (WAMCD)

¹⁸ Water balances in the Tagus River Basin (PROTAGUS), http://evren.es/wp-content/uploads/2014/12/PROTAGUS_WEB_30122014_VINCULOS.pdf

capturing the quantitative status of the water resources the tables were in some case found too detailed, some of the requested information was practically not policy relevant, and some impossible to obtain without the set-up and outputs of detailed water management models. For example, the opening stock for EA 1313 Rivers can hardly be measured; defining the precipitation that falls over the rivers is a detail that will not bring much knowledge to a policy process; while the exchange of flows between soil – surface bodies - groundwater requires the output of detailed hydrological models [38]. An additional disadvantage of the methodology lies in the fact that it tries to integrate information available at the administrative level (i.e. water use) with information available at the hydrological level assuming that this is feasible a priori through the reporting of statistics. The truth is, that to correctly integrate this information, a detailed water management model needs to have been applied first to obtain consistent results considering the location of abstractions, water users and returns. All in all, the SEEAW has a simplistic and not adequately elaborated view of how water balance is defined in a physical system, how the interactions among the water compartments evolve in time, how important is the integration of the exact location of the abstraction and returns, etc. and the fact that the exchanges of flows between the compartments of the water cycle cannot be simply obtained via reported statistics.

DG ENV supported the development of the Water Exploitation Index (WEI+7) undertaken by the CIS Expert Group on Water Scarcity and Drought (EG WSD). The WEI+ is an indicator that reflects the pressure that freshwater abstraction exerts on the water resources of a particular territory and is calculated from the components of the water balance. Traditionally the WEI has been defined as “the ratio of annual total water abstraction over the available long-term freshwater resources” and calculated at the country level and annual scale. A review and upgrade of the index (WEI+) has been developed with the purpose of better capturing the balance between renewable water resources and water consumption, in order to assess the prevailing water stress conditions in a region. The WEI+ aims mainly at redefining the actual water exploitation, since it incorporates returns from water uses and effective management, tackling as well issues of temporal and spatial scaling. Alternative formulas have been tested within the EG WSD in pilot areas in Austria, Belgium, Czech Republic (Morava RB), Finland (Paimionjoki RB), France (Voulzie RB), Germany (Havel-Spree RB), Hungary (Kettos and Kapos RB), Italy (Arno and Po RB), Slovakia (Bodva RB), Spain (Segura RB) and the United Kingdom (RBDs in England & Wales), and resulted in the formulation of the suggested expression of the WEI+, which has been endorsed by the Water Directors in May 2012 (Faergemann, 2012 [39]). The EG WSD has agreed that the WEI+ would be calculated at the sub-basin, river basin or river basin district scale, formulated in these terms:

$$WEI+ = (Abstractions - Returns) / Renewable Water Resources \quad [Eq. 1]$$

In some basins, water scarcity is reflected only when calculating the indicator at the monthly WEI+ but not necessarily captured by the annual WEI+. It is recognized that the monthly index level best represents seasonal shortages that may not be revealed in the annual scale, while the annual WEI+ may be enough where the absence of water scarcity problems is evident. Given that the application of the index on a monthly basis in some cases requires considerable effort in data acquisition, the TWG has recommended a two-step approach: In a first step the WEI+ at annual scale would be applied. Where appropriate and if data are available, WEI+ at monthly scale should be calculated either for every month or in the worst month where water scarcity situations could be expected. In any case, if the problem of data acquisition is adequately solved by the outputs of water balance models the monthly basis would be adopted as the general approach.

For the calculation of the denominator “Renewable Water Resources (RWR)” two alternative approaches have been proposed in order to suit more cases subject to different data availability, which are aligned with the water balance equation. The hydrological balance equation, as applied in pristine basin unaffected by human interventions, has been used as a starting point. Thus:

$$ExIn + P - Eta - \Delta S = Qnat$$

Where: *ExIn* is the External Inflow, *P* is the Precipitation, *Eta* is the Actual Evapotranspiration, ΔS is the Change in Storage, *Qnat* is the Natural Outflow

Both sides of the above equation may be identified with “Renewable Water Resources”, and thus the 2 alternative approaches for calculating RWR are:

Option 1. $RWR = ExIn + P - Eta - \Delta S$

Option 2. $RWR = Qnat$

Consequently, when applied in basins with human alterations, the observed outflow does not in fact equal RWR. For option 2, a flow re-naturalization is thus necessary. This correction can be made by restoring the consumption (abstractions – returns) and flow alteration linked with management, which may be approached by adding the variation in artificial storage:

Option 1. $RWR = ExIn + P - Eta - \Delta Snat$

Option 2. $RWR = Outflow + (Abstraction - Return) - \Delta Sart$

It has been identified by the TWG that both approaches present certain limitations. There are practical difficulties in incorporating the variation of natural storage ($\Delta Snat$) in Option 1. In case this is neglected, the ($P-Eta$) at the monthly scale can render negative values. The calculation of the $\Delta Snat$ most often requires hydrological modelling and is not a parameter to be obtained for measurements as such. With regards to Option 2, the outflow should consider both surface and groundwater. In case of systems that are not groundwater dominated, one could assume that the surface outflow (i.e. streamflow at the outlet), which in fact includes baseflow, is representative enough. Yet, it is to be emphasized that in the case of non-pristine sites, where water abstraction is influencing the system, the observed streamflow does not represent the RWR. The necessary in these cases “naturalization” of the streamflow is a challenging process, especially in complex system of reservoirs and on the monthly basis. In case that a part of the water stored in the artificial reservoirs comes from a transfer (as opposed to generated within the territory of reference) or from a desalination plant, then the $\Delta Sart$ needs to be carefully considered and corrected for the effect of these alternative water resources (i.e. water transfers, desalination). Both approaches present the limitation of not separating between surface water and groundwater resources, which is very relevant and should be explored at a later stage. Environmental Flows should be conceptually considered in the WEI+. At the moment, due to the absence of a harmonized and comparable method of calculation, *Eflows* are left out of the WEI+ formula itself, and should be considered instead in the definition of the relevant thresholds. The elaboration of new thresholds for the WEI+ has not been finalized.

4.2.2.3 The Eurostat initiative

Eurostat has indicated to give high priority to the further development of the environmental accounts and the water accounts under the SEEAW methodology. Complimentary to their regular reporting through the OECD/Eurostat Joint Questionnaire on Inland Waters [40], a Regional Environmental Data Collection (REQ)

requesting water statistics at the River Basin District and sub-units level (according to the WFD) has been launched as a pilot exercise in 2010 (initiated upon the request of the European Commission's Directorate-General for Regional and Urban Policy). An improved more extensive version was released in the second half of 2012. Grants have also been given to ESS members to implement pilot projects for water statistics at the river basins/ river basin district level. The following activities have been identified (Forester, 2010 [41]):

- Regional aggregation (REQ 2012): NUTS and RBD
- Data link into WISE (water.europa.eu)
- International coordination and harmonization
- Alignment with water accounting (SEEA-water)
- Quality improvement / Enhanced EU country commitment
- Development of compulsory reporting

4.3 LINKS BETWEEN WATER ACCOUNTS AND THE EU COMMUNICATIONS “WATER SCARCITY & DROUGHTS” AND “BLUEPRINT”

The asset accounts of the SEEA describes the inland water resource system in terms of stocks and flows, providing information on the stocks of water resources at the beginning and end of the accounting period and the changes therein. These changes are described in terms of flows brought about by the economy (as abstractions) and by natural processes (exchange of flows within the hydrological cycle). Asset accounts can therefore be thought of as a formalised description, in accounting terms, of the hydrological water balance. The physical supply and use accounts of the SEEA describe the interactions between water resources and the economy by presenting the allocation of the abstracted water to each economic sector (volume, source), the exchange on flows between economic units and the returns to the environment.

The information from the asset and physical supply and use accounts can feed different indicators which are relevant for assessing water availability, water exploitation, etc., and thus support the relevant policy requests of the EU Communications “Water Scarcity and Droughts [27]” and “Blueprint to Safeguard Europe's Water Resources [28]”.

More specifically, the EU Communication on WS&D aims to address the increasing impacts of water scarcity and droughts in the EU, to ensure the long-term protection and the sustainability of available water resources, and to promote sustainable water uses. In achieving these objectives, a good overview of the balance between availability and demand (in the broader sense, i.e. including abstractions, uses etc.), at the correct temporal and spatial scales is essential for sound water management. Furthermore, the Communication discusses the necessity to improve the relevant knowledge and data collection, and proposes the presentation of an annual European assessment based on agreed indicators and data provided by MSs and stakeholders to the EC or to the European Environment Agency (EEA), and the full exploitation of the Global Monitoring for Environment and Security (GMES) services for the delivery of space-based data and monitoring tools in support to water policy objectives.

Along the same lines, the Blueprint identified the need to implement actions that could greatly improve quantitative water management and water efficiency in Europe, thereby also contributing to water quality objectives. The development of water accounts at river basin and sub-catchment level are suggested as a tool to support water managers since they can convey information on how much water flows in and out of a river basin and how much water can realistically be expected to be available before allocation takes



place: “Water accounts fill a gap by bringing together knowledge that so far was only available in a scattered and piecemeal manner. If widely implemented, they could go a long way towards helping to solve water scarcity problems, e.g. by better analysing structural and episodic categories of water stress and providing better insights for water resource indicators. Water accounts are closely linked to the identification of ecological flow as they should ensure that the needs of nature are respected and that water balances within a river basin stay within sustainable limits”. The Blueprint also identifies the need to improve water use efficiency, and thus suggests the definition of water efficiency targets (for the main water using sectors) by the river basin authorities, especially in the areas facing (or projected to face) water stress.

It is thus evident, that the development of Physical Water Accounts (assets accounts, physical supply and use accounts) coincides with the recent policy objectives. It has to be noticed that the EU Communications and the CIS Process, when referring to water accounts they basically consider the development of physical water balances, and related indicators, which capture the balance between water availability, abstraction and use in order to identify water stress, water resources over-exploitation, etc. leading to unsustainable conditions.

4.4 THE USE OF WATER ACCOUNTS TO SUPPORT WATER MANAGEMENT IN EUROPE

In the EU policy agenda there is a strong need to elaborate sound assessments of water resources that would accurately depict European diversity and possibly identify issues which call for targeted actions. The development of water resources assessment frameworks focusing on water balances or asset accounts (which use hydrological information), or incorporating additional elements and economic information related to water using concepts (physical supply and use accounts, hybrid and economic accounts), have been identified as a useful tool for guiding water policy and management at different decision making scales, in particular with regard to the quantitative management and efficient allocation of water resources. More specifically, the production of detailed water balances can facilitate the in-depth understanding of the relevant exploitation of water resources, not just for the purpose of identifying water stress in scarce areas, but for further understanding how efficiently water is used, what are possible territorial dependencies, and how water and the economy interact. The Water Accounts can provide a framework for the coherent organisation of this needed for information and the development and extraction of relevant indicators, at the appropriate time and spatial scale, which are at the heart of high-level policy assessments and communication. In the longer term it can be expected that more integrated environmental, social and economic accounting will provide the basis for new top-level indicators.

Following the recommendations of the EU Communication “Blueprint to Safeguard Europe’s Water Resources [28]” a [Working Group on Water Accounts](#) (WG WA) has been set within the CIS process with the purpose to draft a “Guidance Document on Water Balances for supporting water management and the implementation of the WFD” to be presented to the EU Water Directors (currently under drafting by the WG WA). The main objective of this Guidance is to support the development and use of water balances at the river basin and/or catchment scales, as pre-requisite to sound and sustainable quantitative management of water resources. In the medium term, the application of water balances will support integrated water resources management and decision-making at the local scale, improve water allocation schemas and the definition of policy targets, and the drafting and adoption of sustainable measures. It will

contribute to the achievement of the environmental objectives of the EU Water Framework Directive (WFD) and the wider socio-economic benefit.

It is important to clarify here the terms “water balances” and “water accounts” as they are used interchangeably within the EU water policy communications and document:

- ‘Water Balance’ is defined as the numerical calculation accounting for the inputs to, outputs from, and changes in the volume of water in the various components of the hydrological cycle, within a specified hydrological unit and during a specified time unit, occurring both naturally and as a result of the human induced water abstractions and returns, and is based on mass conservation (WG WA, Guidance Document on Water Balances for supporting water management and the implementation of the WFD, Draft v.4.0, 11/03/2015). In this context, category 3 of the SEEAW ‘Asset Accounts’ (which measure stocks and their changes due to natural causes, such as precipitation, evapotranspiration, etc., and human activities, linking thus water abstraction and return to the availability of water in the environment) are aligned with the concept and components of the ‘Water Balance’, although some discrepancies might exist in the definitions and in the scales of application of both frameworks.
- ‘Water Accounting’ integrates physical (hydrological) and economic information related to water consumption and use, to achieve equitable and transparent water governance for all water users and a sustainable water balance between water availability, demand and supply. Standard water accounting frameworks have been developed by various organizations, as presented in the previous Chapter 1, and include additional components and accounts which go beyond the water balances.

The benefits for the river basin managers of developing and applying water balances have been identified within the WG WA and addressed in the Guidance Document (draft v.4.0, 11/03/2015) as follows:

- Better understand whether water resources are “at quantitative risk” – or not!
- Contribute to the development of a common EU-wide knowledge with coherent and comparable data, harmonized definitions and common understanding of the relevant assessments.
- Have a good overview of the spatial and temporal variability of water resources, under current and future (scenario building) conditions in order to design, identify or bridge the gaps of appropriate allocation schemas.
- Provide a common platform for building a “shared understanding” of issues between stakeholders and different water users, as all are represented by one or more components of the water balance.
- Identify “where best to target efforts” (be it identifying areas where action is needed due to existing or future water stress, reducing abstraction from a given use, focusing on runoff, increase storage, etc.) when selecting measures for improving the quantitative state of water resources.
- Have a solid base for additional water resources assessment and management at various scales: runoff estimation, groundwater recharge potential, nitrates mass balance, water-energy nexus, e-flows and Good Ecological Status (GES) determination, input to real-time analysis, operation and forecasting.
- Provide a coherent framework for combining and structuring water-related hydrological and socioeconomic information on climate, water resources in different compartments, water uses (abstraction, discharge...), etc.
- Facilitate the identification of priority “data gaps”.
- Facilitate reporting (EC, EEA, Eurostat).



- Provide sounder arguments as part of communication & awareness raising.

At the EU level, having systematic water balances at the catchment and river basin scales, will bring additional benefits by:

- Enhancing Europe-wide (comparable) knowledge on the state and quantitative management of water resources (based on data held by the MS). This will in turn facilitate and contribute to on-going and future Pan-European initiatives such as: (1) the mapping Europe-wide state of water resources by DG Environment as contribution to the evaluation of the effectiveness of current water policies; (2) the development of water balances by the European Environment Agency (EEA) as input to the State of the Environment report; and (3) hydro-economic modelling by the Joint Research Center (JRC) of Ispra for carrying out in particular *ex-ante* assessments of possible (future) water policy scenarios.
- Facilitating MS WFD reporting to the European Commission on the quantitative state of groundwater resources and the abstraction pressures on the surface and groundwater bodies, and the preparation of MS responses to the EEA (WISE-SoE#3 [42]) and Eurostat (JQ on Inland Waters and REQ) water-related questionnaires on water resources availability, abstraction and use;
- Promoting MS assessment of water resources and follow-up the results of the hydro-economic modelling by the DG Joint Research Center (JRC) for carrying out in particular *ex-ante* assessments of possible (future) water policy scenarios.

It has been identified that Water Balances can be further extended and complemented with additional information linked to water quality or economics (i.e. elements of the water accounts) and bring in additional added value in supporting more efficient and optimal water management decisions:

- Support the identification of pressures and impacts related to the water uses for economic activities, and the selection of measures that will improve the quantitative state of water resources and achieve a set objective (e.g. the equilibrium between water demand and water supply, a set ecological river discharge or a set objective for replenishing aquifers). In this direction, support the drafting of the WFD Programmes of Measures (PoMs).
- Support target setting by evaluating the soundness of current water abstraction rates and water allocation schemas, especially in water stressed areas. The targets can relate to water saving, acceptable withdrawal rates, etc.
- Support climate change adaptation, by investigating the direct and indirect impacts of climate change 9and/or land use change) scenarios on the water balance components.
- Support water resource efficiency targets, by looking at productivity rates and identifying options that optimize water use per unit of economic output.
- Support the integration of water quantity and quality issues by expanding the water balances to account for water quality (e.g. nutrients in rivers and their relation to low flows).
- Support the evaluation of the economic importance of water availability and the marginal values of water uses for a given area, the dependence on water-intensive sectors, the cost-effectiveness analysis in the selection of suitable response measures, etc., by expanding the water balances and integrating economic information.

4.5 DATA REQUIREMENTS FOR THE DEVELOPMENT OF WATER BALANCES AND THE EEA WATER ACCOUNTING FRAMEWORK

4.5.1 Data requirements for developing Water Balances at the catchment level

The first step in developing water balances requires the assessment of the freshwater resources, accomplished through the quantification of the components of the hydrological cycle. The (natural) hydrological balance equation is based on the principles of conservation of mass in a closed system: any change in the water content of a given soil volume during a specified period must equal the difference between the amount of water added to the soil volume and the amount of water withdrawn from it (WG WA, Guidance Document on Water Balances, Draft v.4.0, 11/03/2015). In its simplest form, the hydrological balance of a catchment is described by the equation:

$$IN = OUT \pm \Delta S \quad [Eq. 2]$$

In more details, looking at the functioning of the hydrological cycle and the dynamics of its different components (Figure 16) during a given time period, (P) reaches the soil surface and the vegetation where water can be intercepted and evaporate directly (Ei) or stored (ΔS). Water can also infiltrate in the soil or directly run off (Rs) if the amount of rainfall exceeds the infiltration rate capacity (rainfall excess). The water infiltrated in the soil goes to the unsaturated zone (dSu/dt) and recharges the ground water ($dSgw/dt$). Groundwater (Rgw) and unsaturated zone water ($Rsub$) can also contribute to river flows as subsurface runoff. The vegetation roots absorb water that is transported to the stomata of the vegetation leaves, where it goes back to the atmosphere as transpiration (Et). Water can also evaporate directly from the soil or from the river (Es). The capillary rise brings water on the soil and then water evaporates. These elements and their inter-relations lead to the following formulation of equation 2:

$$P + ExIn = Rs + Rsub + Rgw + Es + Ei + Et \pm \Delta S \quad [Eq. 3]$$

Where:

P : Precipitation [hm^3 / time unit]

R : Runoff (s : surface, sub : subsurface, gw : groundwater) [hm^3 / time unit]

E : Evaporation (s : surface, i : interception, t : transpiration) [hm^3 / time unit]

ΔS : Change in storage over time [hm^3 / time unit]

$ExIn$: External Inflow is the total volume of actual flow of rivers and groundwater entering the hydrological unit of analysis from neighbouring territories/other units [hm^3 / time unit]

*Note: $1hm^3 = 1 \text{ million } m^3$

In some cases, there might be some amount of water that is lost from the hydrological unit due to naturally occurring groundwater outflow to neighbouring systems or to the sea (i.e. outflows from the groundwater bodies which do not contribute to the baseflow but feed neighbouring systems or discharge directly to the sea). This is common in karstic systems, coastal areas, islands, etc. This amount should be then incorporated in

Eq. 3 as a sink and added on the right side of the hydrological balance equation, but it is usually difficult to estimate.

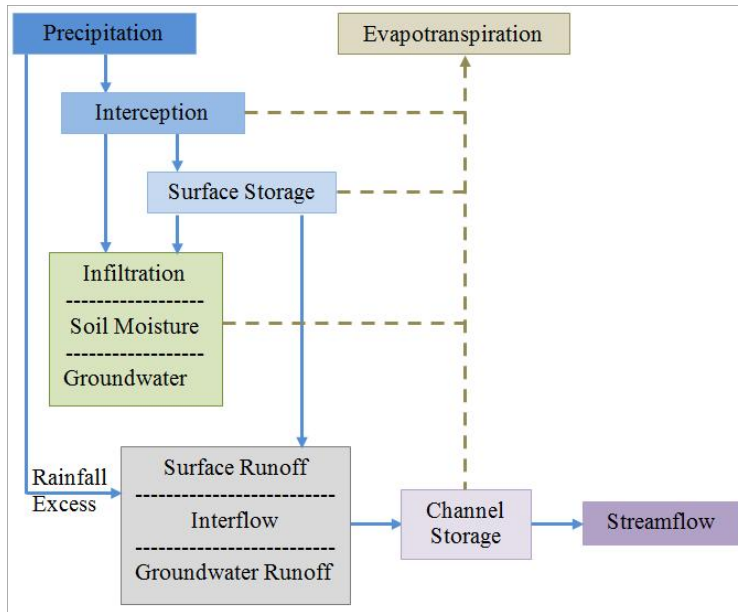


Figure 16: Representation of the hydrological cycle [43].

The flows and storages described previously (Eq. 3) are due to natural phenomenon. Human activities can influence components of the hydrological balance equation, by removing (abstractions for water supply or water transfers) or adding (returns from various users or water transfers) certain amounts of water at certain time steps. Land use changes induced by human activities can also have significant influence in the processes of soils storage, infiltration and runoff. Water Balances (also known as Water Budgets) capture the equilibrium between inputs and outputs as modified by the human intervention. In general, water balance is described by the following equation (as proposed by the WG WA, Guidance Document on Water Balances, Draft v.4.0, 11/03/2015), building on the basic input-output components of the natural hydrological balance (Eq. 2 and 3):

$$INPUTS = OUTPUTS \pm \Delta S \quad [Eq. 4]$$

Where:

$$INPUTS = P + ExIn + RET$$

$$OUTPUTS = Eta + Outflow + ABS$$

P = Precipitation [hm^3 / time unit]

$ExIn$ = External Inflow is the total volume of actual flow of rivers and groundwater entering the hydrological unit of analysis from neighbouring territories/ other units [hm^3 / time unit].

RET = Returned water is the volume of abstracted water that is discharged to the fresh water resources of the hydrological unit either before use (as losses) or after use (as treated or non-treated effluent). It includes water that was directly discharged from a user (e.g. domestic, industrial etc. including cooling water, mining), and water lost from the waste water collection system (as overflow or leakage). Artificial groundwater recharge

with source water generated within (abstracted from) the hydrological unit is also considered as returned water for the current calculation purpose. Discharges to the sea are excluded [hm³/ time unit].

Note: We can further break down Returned water into 2 components: R1 is the amount that is released in-situ and returned in the system within the time unit and is practically a reduction in the abstraction part, while R2 is the volume that is returned in the system at a next time step or ex-situ (e.g. urban wastewater) and is practically an addition on the resources part. Cooling water can fall under R1 or R2 depending on the type of industry and case).

ETa = Actual Evapotranspiration [hm³/ time unit]

Outflow = The total volume of actual outflow of rivers and groundwater into the sea plus actual outflow into neighbouring territories (outside the hydrological unit of analysis) [hm³/ time unit] .Note: Environmental Flow-EF and other Water Requirements-WR as defined e.g. by treaties are a part of the Outflow)

ABS = The total volume abstracted from the system, from surface and groundwater resources, intended for any use (consumptive, non-consumptive, transfer-exported water etc.)

ΔS = Change in Storage (both in surface water and groundwater as a lumped sum)

**Water transfers, exported or imported water, are included in Eq. 4 as part of returns and abstractions respectively.*

As with Eq. 3 above, the Eq. 4 can be further refined reflecting the various components of the hydrological cycle for both the physical parameters (e.g. inflow can be surface or subsurface, evapotranspiration could be from surface or interception or transpiration, storage can be surface or subsurface, etc.) and the anthropogenic induced activities (abstraction can be separated to surface and groundwater, returned water before use¹⁹ or after use²⁰, etc.).

The customization of Eq. 4 depends on the objectives and on the scale of the analysis. It is unlikely that all the refined parameters are needed or are of equal importance in all analyses (i.e. some are of low importance or even negligible), and this relates of course to the selected boundaries of the unit of analysis. Data availability is also a relevant issue here (i.e. monitoring networks are not designed to measures all sub-parameters of the hydrological balance but are usually designed according to specific situations taking into account the hydrological and geological background). For example, in a small well-defined catchment (where its boundaries also correspond to groundwater divides), where surface outflow occurs via a main river outlet and groundwater feeds the river system, then outflow can simply be represented by the streamflow and baseflow. In

¹⁹ Water abstracted from any freshwater source and returned into a freshwater recipient *before use* refers to the volume of water lost during transport through leakage between a point of abstraction and a point of use, and/or between a water supplier/distributor. Discharges to the sea are excluded. Evapotranspiration losses, or water which occurs during mining or construction activities is not included (EEA – ETC/ICM, 2013. [WISE-SoE Water Quantity, Data Manual, v3.1](#)).

²⁰ Water abstracted from any freshwater source and returned into a freshwater recipient *after use* refers to the total volume of water discharged after use as treated effluent or as non-treated into freshwaters. Cooling water is included. Discharges to the sea are excluded. Treated effluent: effluent that has undergone treatment through UWWTP or other WWTP. Non-treated effluent: Effluent that has not undergone any wastewater treatment and was returned to the water body. It includes water that was directly discharged from a user (e.g. domestic, industrial etc., including cooling water, mining), and water lost from the waste water collection system (as overflow or leakage) (EEA – ETC/ICM, 2013. [WISE-SoE Water Quantity, Data Manual, v3.1](#)).

other cases, groundwater discharge can be estimated as the groundwater recharge depending on the time step and the characteristics of the aquifer.

Water balances can be expanded and complemented with additional water quantity parameters that are relevant to water accounting and water management, such as water use per economic sector, alternative water supplies (desalination, reuse), water demands, conveyance efficiency and losses, or economic information on the main water users (e.g. yields, income generated, etc.). The relevance of including or excluding specific components will depend on the key questions that need to be addressed with regards to the quantitative management of water resources, and also on the importance of quantitative water management issues for a given river basin.

The following data are thus required for the development of basic water balances at the catchment level:

Table 6: Data required for the development of basic water balances at the catchment scale (all units in hm³/time unit).

INPUTS	OUTPUTS	CHANGES IN STORAGE	LAND USE & SOIL INFORMATION (to support the calculation of evapotranspiration)
Precipitation (rainfall and snowmelt where applicable)	Actual Evapotranspiration	Changes in snowpack (where relevant)	Land cover
External Inflow (surface and groundwater)	Outflow (surface and groundwater into the sea and/or neighbouring territories) <i>*Outflow is usually approximated by measuring the river streamflow at the outlet of the catchment</i>	Changes in storage in natural reservoirs and/or water levels	Soil map
Returned water (location and volume)	Surface water Abstractions (location and volume)	Changes in storage in artificial reservoirs, and/or water levels, inflows/outflows	Crops (type and location)
Groundwater Recharge (necessary for intermediate calculations where applicable)	Groundwater Abstractions (location and volume)	Changes in groundwater storage, and/or groundwater table levels	Soil moisture Soil capacity
			Climate data (air temperature, humidity, wind speed, solar radiation)

4.5.2 Data requirements of the EEA Water Accounting Framework

The development of the EEA Water Accounting Framework requires more or less the same data input (as presented in Table 6) since aligned with the water balance equation, with some additions due to the necessary modelling routines used to surrogate unavailable data, or to aggregate/disaggregate at the FEC level, and to comply with the SEEAW methodology. The later include: opening and closing stocks, river discharge at different locations within the catchment, water use and returns per sector, water



abstraction per sector, water transfers (volume, source and recipient of water imports and exports).

To compile the EEA Physical Water Account a wide data collection of heterogeneous datasets (in terms of spatiotemporal scales and sources) along with computational and semi-modelling techniques to bridge the necessary data gaps and achieve the production of the necessary parameters, making use of the Nopolu2 system infrastructure, was necessary. In the following section the data used so far for the development of the EEA WA are presented, along with their limitations and further requirements, as extracted from the EEA Technical Report on the WA results and lessons (EEA, 2013 [30]) and its Annexes:

Climatic data:

Climate data are essential to the water balances production. Meteorological events are the primary source of water and should be broken down in their flows and allocated per location to populate the corresponding values of the SEEAW water assets accounts table. Several sources of information were mobilized during the development of physical water accounts at the EEA level. During the first implementation, data were generated from the ATEAM²¹ grid which provided densely reallocated data (10' × 10', i.e. about 8km x 16km resolution, yielding several data per FEC) with limited parameters, but at a monthly time period, making the actual evapotranspiration more than uncertain. The ATEAM source had to be abandoned despite its high spatial granularity, because no computation beyond the year 2000 was scheduled and because of the inappropriate time resolution. In a second improvement, the MARS²² data sets provided by the JRC were used. The MARS data have daily time resolution, and in theory comprise all required parameters (even though snow is often not populated), but they are based on a 25x25 km grid. And disaggregation to FECs and aggregation on time (a 5-day period and monthly) was needed. It was concluded that higher spatial resolutions and more accurate coverage than that provided by MARS were needed, while the actual evaporation pre-computed in the MARS datasets could not be controlled (since soil components taken into account by the authors of MARS were unknown) and MARS data availability could not be secured on the long time for data ownership issues. For the above reasons, additional data sources were mobilized (while MARS daily wind speed, global radiation and relative humidity data were used as secondary source), namely the E-OBS (version 5) gridded meteorological data of the ENSEMBLES²³ project, and a full process of building a monthly climatic database and distributing it at the FEC level has been developed by the EEA so that both precipitation (as rainfall and as snow) and

²¹ Advanced Terrestrial Ecosystem Analysis and Modelling (ATEAM, 2013) is a Fifth Framework Programme (FP5) project that produced, among others, a monthly set of data gridded across Europe of key climatic variables at the monthly resolution. <http://www.pik-potsdam.de/ateam/>. Monitoring Agricultural Resources (MARS) (JRC, 2013) is a unit mission of the JRC supporting agricultural resources at large (<http://mars.jrc.ec.europa.eu/mars/About-us/AGRI4CAST/Data-distribution> MARS, under certain conditions, allows access and downloading of daily reconstructed climatic data over coarse grids, across Europe and its neighbours (not checked out of the EEA widest area of concern).

²² Monitoring Agricultural Resources (MARS) (JRC, 2013) is a unit mission of the JRC supporting agricultural resources at large (<http://mars.jrc.ec.europa.eu/mars/About-us/AGRI4CAST/Data-distribution>). MARS, under certain conditions, allows access and downloading of daily reconstructed climatic data over coarse grids, across Europe and its neighbours (not checked out of the EEA widest area of concern).

²³ The ENSEMBLES project (contract number GOCE-CT-2003-505539) is supported by the European Commission's 6th Framework Programme as a 5 year Integrated Project from 2004-2009 under the Thematic Sub-Priority "Global Change and Ecosystems". <http://www.ensembles-eu.org/>

evaporation from different surfaces (potentially applied to liquid areas and actual evapotranspiration from vegetation) could be obtained to populated SEEA cells. The collection of the E-OBS data was primarily carried out by the Royal Netherlands Meteorological Institute (KNMI), which also hosts the European Climate Assessment and Data set (ECA&D), based on daily observations that were compiled for precipitation, and minimum, maximum and mean surface temperature covering the time period 1950 to 2011 (version 5). E-OBS version 5 uses around 2,500 stations across Europe; however, stations are unevenly distributed, with the highest density in west and central Europe and the lowest density in the east part. Station data have been interpolated into 25-km grid using universal kriging.

Both evaporation and evapotranspiration values are computed by modelling, since they are not monitored, nor provided in the source Ensembles datasets. Such modelling requires information on soil capacities that has been collected separately and processed. The evapotranspiration estimate is not a straightforward calculation. The process involves first computing potential (ET_p), then turning it into actual (ET_a) evapotranspiration based on the equation $ET_a = k_s * k_c * ET_p$, where k_s and k_c are respectively stress factors and crop coefficients. Crop coefficients were estimated from the grouping of the 44 original classes of the 2006 CLC into 10 different groups for the purpose of this modelling study. The crop coefficients (values obtained by FAO [44]) were used to convert reference evapotranspiration into potential evapotranspiration ($ET_{pot} = k_c * ET_{ref}$). The hydrological soil properties (namely point of saturation, field capacity, and wilting point) have been retrieved primarily from the JRC European Soil Database (ESDB v.2.0²⁴), combined with the FAO soil map of the Harmonized World Soil Database (HWSD [45]), to produce a homogenized map of soil texture and organic matters, prepared earlier by the EEA ETC/LUSI, and finally completed for the modelling purposes of the current water accounts application.

River discharge data:

River discharge is the touchstone of the water balance and a key component of the Input / Output tables. The WISE-SoE streamflow data were used (where available) and an ad-hoc collection of daily discharge data at all possible stations situated on ECRINS main drains or in as many places as possible in all upstream catchments was launched. MSs were explicitly requested to provide a comprehensive list of gauging (hydrometrical) stations with their coordinates and daily stream flows for at least the 10 past years at those stations meeting criteria above. Data mining from MSs' official websites was also undertaken to supplement the data delivered by the MSs in an effort to minimize data gaps. At the end 7,442 streamflow stations have been listed. Yet, only 61% of them have discharge data attached to them, with time series of various lengths ranging between 1900 and 2011. The possibility to cooperate with the GRDC (Global Runoff Data Center) in order to share daily flows over European countries as been pursued and unfortunately failed due to WMO Members' restriction rules being applied by the GRDC.

The collected river discharge data present time gaps (i.e. when data have not been recorded for a while and the time series are interrupted) and spatial gaps (because some countries would not or could not provide enough data or because some sub-basins are not sufficiently instrumented). To mitigate such cases an attempt was made to reconstruct the missing data. Thus, reconstructions of the monthly average productivities (i.e. specific discharge measured in lt/sec/km²) were carried out with two different methods using probabilistic complements from stations located nearby. Ultimately, over a total number of 7,442 stations 4,852 stations (65%) are documented

²⁴ http://eusoils.jrc.ec.europa.eu/ESDB_Archive/ESDB/index.htm

(already known or filled for some time gaps) and 2,590 stations (35%) were reconstructed using the Experimental Probabilistic Hypersurface (EPH) method for spatial gaps. The regional allocation of these stations is as follows:

Continental: 1,759 stations (1,484 (84 %) documented and 275 (16 %) reconstructed);
Atlantic: 2,646 stations (1,415 (53 %) documented and 1,231 (47 %) reconstructed);
Mediterranean: 1,763 stations (899 (51 %) documented and 864 (49 %) reconstructed);
Arctic: 626 stations (516 (82 %) documented and 110 (28 %) reconstructed);
Alpine: 648 stations (538 (83 %) documented and 110 (17 %) reconstructed).

To compute the discharge at each and every ECRINS river segment (which represents the statistical unit of the application), the data from the aforementioned stations along the main drains are extrapolated. This function is carried out with the Nopolu System2 hydrological algorithm: discharge is extended up to the source of river, and considers the affluent as well as reservoirs.

Reservoir and Lake (levels, change in storage) data:

Lakes are part of the ECRINS reference system, and are polygon features related to FECs and to river segments. Dams are also part of the ECRINS, and are point features in relation to a lake and placed on a river segment. ECRINS v.1 release comprises about 72,000 lakes. The main current data source for dams is the European Lakes and Reservoirs database (ELDRED2) of the International Commission on Large Dams (ICOLD). The EEA integrated the 2003 catalogue of large dams, but no formalisation of updates was put in place. This was due to different factors, one of them being the lack of dam positioning in ICOLD (mitigated by the development of DAMPOS²⁵ that took much longer to populate than envisaged, as there were cooperation issues with the national ICOLD contact point). Article 13 reporting under the WFD was also used as a source, as well as Wikipedia information and web-sources.

Groundwater data:

In the absence of reference systems, no groundwater data were mobilized for the EEA water accounts exercise. The assumptions were that groundwater is an indefinite recipient and source of water. In other words, there is no processing of limits for groundwater recharge, and no limit for abstraction. The water asset accounts according to the SEEAW do not allocate direct recharge from precipitation into the groundwater, but rather suggest that this is routed through the soil. In other words, soil serves as a “bucket” for the effective precipitation that falls in a particular area and then water is routed from the soil to the surface or groundwater systems. To assess the exchanges from soil water to groundwater a simple partitioning rule is implemented based on the SUGAR coefficient. SUGAR is an innovative index which indicates whether water falling on a particular zone mostly contributes to groundwater recharge (i.e. infiltrating areas) or to discharge to surface water. Being the outcome of a European research project FOOTPRINT²⁶ the SUGAR index is been compiled for the whole of Europe and is

²⁵ Dam Positioning (DAMPOS), a web facility based on Google Earth open-source tools, allows users to collect dam coordinates by clicking a dam on its observed position. DAMPOS is harvested by the Eldred2 administrator and update rights are given to experts on request.

²⁶ Functional Tool for Pesticide Risk assessment and management (FOOTPRINT) is a research project funded by the European Commission as part of its Sixth Framework Programme for Research and Technological Development (FP6). The project aims at developing computer tools to evaluate and reduce the risk of pesticides impacting on water resources in the EU (both surface water and groundwater). The SUGAR index is a necessary intermediate developed for this purpose.

distributed in the form of national data sets on the projects' website (http://www.eu-footprint.org/FOOTPRINT_SUGAR_downloads.html).

Inflow and Outflow data:

In the EEA Water Accounts both the inflows from upstream territories and from other water resource categories within the territory are populated with values pulled from scenario libraries. Similarly, the outflows (to other water resources within the territory, or to other territories/countries, and/or to the sea) are also populated based on values extracted from respective scenario libraries.

Inflows and outflows in surface water categories are calculated from the linearized flow values per stretch obtained with the Nopolu resources module and for a specified time range. The selection can be itself saved as a scenario to combine with other data categories' scenarios for the final consolidation. Inflows and outflows are processed together (for consistency reasons, since they come from the same data source: outflow from upstream is inflow for downstream, and this is why it is so important to process within a fully topological hydrological reference system).

Opening and Closing Stocks data:

The concept of a stock of water is related to the quantity of surface and groundwater in a territory of reference measured at a specific point in time (beginning and end of the accounting period). The common practice in the EEA WA system is to set all values of opening stocks to zero. After the calculation of closing stocks the opening stocks are updated based on the values of the closing stocks.

Water Abstraction, Return flow, and Water Use Data:

Water uses for the domestic, industrial and agricultural sectors have been based on proxy calculations and coefficients, and following a stratified statistics approach.

To calculate urban water use, population data were multiplied by an average water consumption per capita/per day. This rate was obtained from Eurostat data at the country level. The population data were obtained from the urban audit (Eurostat), the UMZ (Urban Morphological Zones), derived from CLC by ETC/LUSI and from LandScan 2010, for each strata: large, medium and small cities. The volumes of returned water have been estimated with data from the UWWT Directive. For the abstractions, statistics of water abstraction and use at country level from Eurostat were used to model the relevant volumes (relevant technical coefficients at country level were calculated and then apply at the FEC level). The calculation of industrial water uses was based on data from the European Pollutant Release and Transfer Register (E-PRTR) database, which provides data concerning emissions and waste from 28,000 facilities across Europe (IPPC installations). However, there is no information on volume of either activities or water use, and thus formulas have been developed to relate emissions information to activity and/or water use for the main water-consuming industries by reviewing the best available information from BREFS published by the JRC-IPTS and using water use coefficients related to currently published volume activities. Irrigation water use volumes were assessed by JRC and the agriculture abstraction information is based on data sets obtained from JRC, compiled and set in the Nopolu System2 (a common efficiency rate of 65% was assumed).

4.6 GAPS & POSSIBLE IMPROVEMENTS

Climatic data:



The E-OBS data meet the constraints of being both technically and freely available, yet the following limitations/issues have been recognized by the developers of the EEA WA application:

- The source meteorological data is extremely odd in many countries. The current density of source data is also relatively low compared to the WA requirements. The final weighted data quality scoring is only 19.8%, with well-covered countries/areas being Ireland, Germany, the Netherlands, Northern Italy, Slovenia, Southern Scandinavia (Denmark excluded).
- The final grid omits many coastal catchments. The source gridded data (25 km grid) has to undergo a complex process of modelling and post-processing to become a calculable source for the accounts and disaggregated at the necessary FEC level. This introduces some uncertainties on one hand, and on the other hand maintenance and updating of the WA can be jeopardized if this process is not routinely secure (from a technical and resources point of view).

The calculation of Eta presents some uncertainties. In some cases Eta values were greater than precipitation values for winter months. Calibration and validation, as well as modelling improvements underpinned by solid data are needed. The computation of land cover and soil characteristics at the gridded level should be revised to incorporate NDVI.

River discharge data:

The following limitations/issues have been recognized by the developer of the EEA WA application:

- The current WISE-SoE data on river discharge are not sufficient to support the necessary calculations for the production of WA. They present spatial gaps (limited spatial coverage) and the length of the time series is often limited. The GRDC data were not available for this application due to WMO Members' restriction rules. An ad-hoc data collection and data web-mining can improve the coverage, yet as this process is not systematic the updating is problematic.
- Even with the ad-hoc data collection the data availability did not improve to the desirable level, so reconstruction of missing data has been performed, based on monthly average productivities (i.e. specific discharge measured in lt/sec/km²). An overall quality analysis showed that in some cases the reconstruction is acceptable while in other cases is totally erratic and unusable.
- Erroneous values and outliers have been detected, as well as cases of wrong station coordinates. The erroneous values may also be associated with the reporting units (lt/sec vs. m³/sec)
- Discharge is extrapolated between stations along the main drains of ECRINS to populate each and every ECRINS segment with a monthly value. This is carried out with the Noplu2 system hydrological algorithm: discharge is extended up to the source of river, and considers the affluent as well as reservoirs. This process though can introduce uncertainties

Reservoir and Lake (levels, change in storage) data:

The following limitations/issues have been recognized by the developer of the EEA WA application:

Some countries (e.g. Spain and Portugal) provide online services of the reservoir variations in reserve. This information is contrastingly becoming more hidden in other countries. In fact, where the reservoir (generally a dam) is operated for energy generation, some degree of commercial secrecy is applied, and prevents the provision of



such data, even on a retrospective scale. However, regulation reservoirs (for low-flow enhancement for example) are reported in 'hydrological bulletins', albeit not systematically recorded.

Groundwater data:

The following limitations/issues have been recognized by the developer of the EEA WA application:

In the absence of reference systems, no groundwater data were mobilized for the EEA water accounts exercise.

Exchange from soil water to groundwater is assessed via a simple rule, using the SUGAR scenarios, used for splitting the water flow from water soil between rivers and groundwater and the time modulations of monthly exchanges. The SUGAR scenarios have been constructed from the source SUGAR index raster, by simply overlaying and then populating the FEC with the weighted average of the intersecting index (based on areas). Each month, the run-off at the FEC level (from meteorological data) is apportioned between surface water and groundwater by application of the SUGAR coefficient. This broad-brush approach can introduce uncertainties with regard to the actual groundwater recharge.

Regarding the transfers between surface and groundwater, without a detailed modelling process between groundwater and surface water being available, only simple solution for assessing exchanges between resources can be implemented.

Inflow and Outflow data:

The following limitations/issues have been recognized by the developer of the EEA WA application:

In the EEA Water Accounts both the inflows (from upstream territories and from other water resource categories within the territory) and outflows (to other water resources within the territory, or to other territories/countries, and/or to the sea) are populated with values pulled from scenario libraries. Inflows and outflows in surface water categories are calculated from the linearized flow values per stretch obtained with the Noplu resources module and for a specified time range.

Opening and Closing Stocks data:

The following limitations/issues have been recognized by the developer of the EEA WA application:

The common practice in the EEA WA system is to set all values of opening stocks to zero. After the calculation of closing stocks the opening stocks are updated based on the values of the closing stocks.

Water Abstraction, Return flow, and Water Use Data:

The current Noplu System2 does not contain a function for creating time series of water use data. These data are calculated based on proxies and coefficients, which represent a standard average values for the period 2000-2012.

Water abstractions and returns are based on the water use data. It would be highly valuable to have disaggregated data on water abstraction and returns (also per source) along with information on their location. The information on the exact location of the abstraction is highly missing.

With regard to the domestic water use disaggregated data would be beneficial, and data on water transfers are very important. On industrial water use, there is no clear relationship between the 'agglomeration' used in the UWWTP for reporting of sewage and domestic entities, such as 'cities'. Clarification on this point is essential to simplify the use of data and avoid difficult, time-consuming and poor guessing.

Statistical data on industrial production levels are hard to come by because of confidentiality issues. Eurostat provides mainly production information in terms of the value and not the quantity. However, there is no information on volume of either activities or water use, and thus formulas have been developed to relate emissions information to activity and/or water use for the main water-consuming. The concerns with the latter approach are that ranges can be wide, there are broad assumptions on technology used, and there are major problems in finding activity data on production levels. It is fully acknowledged that this approach may be questioned. It is for the time being the only one feasible and capable of providing values that can be entered into the SEEA processing.

Regarding irrigation water use (and abstraction) since many irrigation activities are driven by the weather, disaggregated values at the monthly level are needed. Currently, such time-disaggregated data are significantly erroneous, whereas available and more accurate information is seemingly lumped and averaged.

Table 7: Data required for the development of basic water balances at the catchment²⁷.

Parameter	Data origin			Data sources currently used	Data Gaps, Quality issues and Uncertainty
	Monitoring	Modelling	Statistics		
Reference System				1km grid of LEAC ECRINS River Network	The Land and Ecosystem Account (LEAC) is the standard Inspire-based kilometric grid to which all continental data sets refer. The ECRINS represents the river network in a GIS system. This reference layer needs some further improvements.
Rainfall	***	***		E-OBS v.5 (ENSEMBLES project), hosted by the Royal Netherlands Meteorological Institute MARS Database of the Joint Research Center (JRC)	Unevenly distributed data, interpolation was necessary to fill gaps. Disaggregation from the 25x25 km grid level to the FEC level (Functional Elementary Catchment) was necessary, yet this process has introduced some uncertainty. MARS data (JRC): fine time density but insufficient spatial density, with restricted accessibility; odd quality for the accounts (oriented to agriculture in plains); no longer used by the EEA from 2010. ENSEMBLES E-OBS dataset, obtained via the European Climate Assessment and Data (ECA&D) Database: fine time density and acceptable spatial density (with some noticeable exceptions, which could be improved); odd quality (depending on the Ensembles data set); Time series are updated regularly every six months.
Land Cover and Soil				Corine Land Cover 2006 and ESDB v.2. of the JRC	The data are not covering the EU territory for the year 2006, thus gaps were filled with the 2000 database.
Evapotranspiration	*	***		Computed from daily data taking into account the soil capacity and characteristics. Climate and soil input	Due to the non-availability of these data the actual evapotranspiration (Eta) values were modeled and calculated. Values where Eta was greater than Precipitation in winter months resulted in some cases.

²⁷ This table has been compiled based on the following sources: [61], [30], [29], [62].



				data were retrieved from CORINE, FAO and JRC information.	Calibration of the resulting values is necessary to reduce uncertainty and errors.
Evaporation resulting from irrigation	*	**	**	JRC data	
River Discharge	***	*		EEA WISE-SoE#3 data reporting Ad-hoc data collection (from member states' organizations, agencies, etc. and from web-mining)	Data coverage is not sufficient; time-series length is often limited. Modeled data were used to fill-in gaps where possible. Errors have been detected (and corrected when possible) (e.g. errors regarding the exact location of a station). River discharge data are an important element of calculation and calibration of the WA (especially regarding the outflows), and is thus absolutely necessary to have a good coverage of reliable streamflow data.
Groundwater recharge	*	**		SUGAR project coefficients	In the absence of reference systems, no groundwater data were mobilised for this water accounts exercise. The assumptions were that groundwater is an indefinite recipient and source of water. In other words, this means that there is no processing of limits for groundwater recharge, and no limit for abstraction.
Levels of reservoirs				ELDRED-2 ²⁸ Dam Database, WFD Art. 13 reporting, Wikipedia information	Large uncertainty of the input data linked to the fact that non-official sources of information were mobilized.
Abstraction and returns	**	*	***	Returns: UWWT Directive Abstractions: Eurostat Joint Questionnaire on Inland Water (JQ IW), calculated water use data, adjusted with coefficients	Water abstractions and returns are based on the water use data, adjusted by coefficients and ESTAT country level data, and present uncertainties. It would be highly valuable to have spatially and temporally disaggregated data on water abstraction and returns (also per source) along with information on their location. The information on the exact location of the abstraction is highly missing. Water transfer data (exports, imports) are also very much needed here and unfortunately very limited.
Water use by sector	*	**	***	Domestic: Eurostat Joint Questionnaire on Inland Water (JQ IW), Eurostat Urban Audit, UMZ (Urban Morphological Zones) derived from CLC by ETC/LUSI, LandScan	The current Noplu System2 does not contain a function for creating time series of water use data. These data are calculated based on proxies and coefficients, which represent a standard average values for the period 2000-2012. Uncertainties relate with the proxy methods and

²⁸ELDRED2 database of dams is maintained by the EEA and comprises about 5000 dams fully connected to rivers / FECs / lakes. This source serves as the identification of reservoirs. The ancillary table of large dams and their relationships with lakes and with river segments is available from EEA.



				2010 Industrial: EPRT, Eurostat Agriculture: JRC data	formulas used to calculate water uses from surrogate data.
Losses, leakage,	*	*	**	Eurostat Joint Questionnaire on Inland Water (JQ IW)	The calculation are based on some coefficients, high uncertainties
Exchanges between sectors, supply	*		***		Not assessed



5 GAP ANALYSIS: COMMUNICATION ON WATER SCARCITY AND DROUGHTS (COM(2007) 414 FINAL) [27]

5.1 EBRO BASIN

This document presents a gap analysis regarding the Commission's Communication on Water Scarcity and Droughts in the Ebro Basin (COM/2007/0414 final). This communication, and its follow-up documents, aim at addressing the increasing impacts of water scarcity and droughts in the EU, ensuring the long-term protection of available water resources, a sustainable water availability across Europe, and promoting sustainable water uses.

The Ebro river basin is the largest Mediterranean river of the Iberian Peninsula. Due to its Mediterranean climate, droughts are an important risk in the basin and the intensity and frequency of droughts may increase due to Climate Change. Furthermore, water scarcity is also a problem due to the human pressures on the system. The Ebro is one of the most regulated river basins in the world with 108 big dams. Its water exploitation index (WEI) is higher than most European rivers but lower than other basins in the Iberian Peninsula, its consumptive use of water being more than 34% of the average long term renewable resources of the basin [46]. Today, the primary objective of water management in the basin is reconciling economic growth with the protection and improvement of the water resources which are critical in sustaining economic welfare in the long term. Through different policies, the water resources management of the river basin has transitioned towards an integrated approach, making a real contribution to sustainable development [46]. European policies have been influential in this transition.

5.1.1 Overview

The Spanish Government, through the Ministry of Agriculture, Food and Environment (MAGRAMA), is the national authority for the management of water resources in Spain. Agriculture, the environment and land-use planning also fall in its area of responsibility. The Ministry performs this function through the Directorate General of Water. Basin authorities are responsible for water planning and management at the basin level. In the case of basins completely included in an autonomous community (region) all the powers have been transferred to the concerned region. In interregional basins, such as the Ebro (it partially or totally covers nine regions: Aragon, Catalonia, Navarre, Castile and León, La Rioja, Basque Country, Castile-La Mancha, Valencian Community, and Cantabria), the corresponding Hydrographic Confederation (*Confederación Hidrográfica*) is the basin authority. An interesting aspect of these Confederations is that stakeholders are involved in the decision making process. Regional governments also have some involvement as they have a role in the application of national laws related to agriculture, the environment and land-use planning. Finally, city councils are responsible for urban supply, water treatment and sewage, but regions are also involved when the infrastructures have scales larger than a city. Thus, MAGRAMA and the Ebro Hydrographic Confederation (CHE) are the main institutions responsible for the application of the Communication on Water Scarcity and Droughts (CWSD) in the Ebro basin. Regional governments and city councils have some involvement, but that is of lesser importance.

There is no specific law related to the CWSD, as the Communication is a set of policy recommendations, not an applicable law. Thus, in this document we discuss the state of implementation of laws which are related to the objectives of the CWSD. Some of these laws are previous to the publication of the CWSD. The transposition of the Water Framework Directive, was done four years before the publication of the CWSD. The last relevant plan approved was the Hydrological Plan of the Ebro river basin, in 2014. The CWSD mainly reinforced the drought related activities at the basin (M. A. García Vera (CHE), personal communication).

The main law related to the topics included in the CWSD is the Water Law (*Ley de Aguas*). Other relevant policies are the National Hydrological Plan and the Hydrological and Drought Plans of each basin.

The transposition of EU Water Framework Directive 2000/60/CE was done by means of the law 62/2003 of the 30th of December 2003. This law, which affected several topics, included the modification of the Water Law [47].

The current National Hydrological Plan was approved in 2001 [48] and was modified in 2002, 2004 and 2005. The main objectives of the plan are to coordinate the different basin plans, to provide solutions to the different alternatives that the basins plans offer, the planning and regulation of water transfers between basins, and the delimitation, characterization and regulation of groundwater bodies that are shared by different basins.

Each basin has its own hydrological plan. These plans aim at achieving good ecological status of water bodies, while meeting water demands for regional and sector development, increasing the availability of resources, protecting water quality, economizing water use, and making allocations that are consistent with environmental flows that support ecosystems [49]. In Spain, the approval of the basin plans, which was required by the Directive, was delayed. In fact, to date, the approval of some plans is still pending. The current Ebro Basin Plan (2010-2015) was approved in 2014 and published on the Official Bulletin of the State in March 2014 (bulletin number 52). Work has already started to prepare the plan for the next period (2015-2021). The current basin plan included several new measures. The measures that represent a larger investment are those related to the modernization of irrigation systems (which includes changing flood irrigation to drip and sprinkler systems), and building storage facilities [49].

The normative framework for drought management in Spain involves two approaches. On the one hand the revised text of the Water Law offers a reactive approach, enabling the Government to take the necessary measures to overcome exceptional situations of water scarcity or drought. On the other hand the National Hydrological Plan introduces a preventive approach to drought management [50], [51].

According to article 27 of the National Hydrological Plan (Law 10/2001, 5th July), Basin Authorities had to elaborate drought management plans within two years of the publication of the law. The same article determines that the Ministry of the Environment would establish a drought indicator system for the early detection and classification of drought events in interregional river basins. This indicator system should serve as a reference to formally declare drought and trigger the basin drought management plans. The third section of this article establishes that public administrations that are responsible for urban water supply to cities of 20.000 or more inhabitants had to implement a drought emergency plan in accordance with the basin drought management plans within the next four years.

The required indicator system [51], [52] was developed by the Ministry of the Environment in 2006 and drought management plans for the interregional basins were approved by [53].

The main aim of the drought management plans is to mitigate environmental, social and economic impacts of drought. To achieve this objective drought management plans should define forecast and early detection systems; establish thresholds to characterise drought severity; define mitigation measures, and ensure transparency and public participation in the elaboration of the plan. Within these plans basin authorities have developed hydrological drought indicator systems to detect drought events, classify their severity and contribute to water management decision making in the basin. Measurement networks associated to these indicators systems include information such as reservoir levels, aquifer levels, water flow, rainfall data and snow quantity. Indicators classify drought situation in four categories: "normal", "pre-alert", "alert" and "emergency". This allows defining specific mitigation measures associated to each of the severity levels and implementing them progressively according to the indicator thresholds.

The CHE, in its Plan of Action for Drought Situations [54] defines a set of indicators to detect situations of hydrological drought in the Ebro basin and evaluate the degree of severity. The main indicators included are based on observed variables, namely water stored in reservoirs, three-month water flow and monthly precipitation. Additionally, head levels in aquifers, snow quantity and wetland levels are considered. For each area in the basin, the most representative indicators and appropriate thresholds have been selected. In the areas in which the flow is regulated by dams, water stored in reservoirs is considered the most robust indicator, but other variables such as water flow, snow or head levels in aquifers may also be taken into account. For areas with a natural or an almost natural flow regime, the three-month water flow measured at representative stations is selected as the main indicator.

At the national level, the National Drought Observatory [55] (*Observatorio Nacional de la Sequía*, ONS) aims at bringing together all the national institutions with competencies in the water sector, such as basin authorities and regional and local authorities, and constituting a centre for drought knowledge, planning, mitigation and monitoring. The ONS publishes regular reports about drought conditions in the interregional basins and monthly maps of the drought indicator values. The data used is often provided by the basin authorities. The ONS is integrated with other similar initiatives at the national and the international scales, such as the European Drought Observatory (EDO).

Concerning water pricing and efficiency, which is one of the topics of the CWSD, at present there are no plans for water pricing as a tool to improve water use efficient [49]. When some investments are done with help of the EU, the EU can impose conditions to those investments. Water prices might be affected by taxes and tariffs imposed by the basin authorities or by regional and local authorities. These costs of using water are local and dependent on the existing infrastructure. Concerning agriculture, water fees and tariffs for irrigation can be waived in many cases. Water saving campaigns have been quite successful in Spain, causing a reduction of the water used per person and day [56]. The Spanish Government has approved legislation forcing all concessionaires to install metering devices, although the legislation is currently only being implemented in pilot areas.

A sound drought management policy is essential in Spain, due to its climate. Thus, the drought management system in Spain, and the Ebro basin, is quite advanced. However, improvements are still necessary. According to [49] new drought prediction systems,

a better knowledge of the relationship between climate and drought, and of the impacts of climate change and droughts on human activities and ecosystems, together with and improvement of our knowledge on drought management practises, water efficiency and the development of new water sources, are very important to improve the management of droughts in the Ebro river basin.

5.1.2 Implementation process

There is not a single law, policy or plan that applies the CWSD to the Ebro river basin, as the CWSD is not a law that must be transposed to the national systems. The application of its policies has been done by means of several laws and plans which were deployed in a period that started in 2001, six years before the publication of the CWSD, and ended in 2014. All the policies are already set up.

The Spanish Parliament is responsible for the approval of the different laws that are required to apply the CWSD. The Spanish Government, mainly through the MAGRAMA, has the responsibility of supervising and coordinating its implementation at the national scale. The basin authorities are responsible for the policies in their basins. In the case of the Ebro, CHE is the basin authority. The regions are involved in the application of several laws related to agriculture, the environment and land planning. Also, city councils are responsible for water supply, treatment and sewage, but the regions take care of these in many areas. Thus, the responsibility mainly lies on MAGRAMA and CHE, with some involvement of the regions and the city councils.

- National Hydrological Plan. This was approved in 2001, and modified several times thereafter. Among many other subjects, it introduced a prevention strategy for drought.
- Transposition of the Water Framework Directive. It was done in 2003, with the approval of the Water Law.
- Ebro Basin Hydrological Plan. The basin plan was approved in 2014, with a five year delay. A new plan will be prepared for the next period (2015-2021).
- Ebro Basin Drought Plan. The drought plan of the Ebro basin was approved in 2007, the same year the CWSD was published, this way the Ebro basin was advanced in the application of these policies, at least concerning drought. The CWSD presents Spain as an example of good practices. The approval of this plan was a requirement of the National Hydrological Plan.

For the Ebro river basin the main legislative apparatus is already set-up. The policies described in the CWSD are being applied, especially in the area of drought risk management. For the other policy options mentioned in the CWSD, there are varying degrees of implementation.

5.1.3 Data used & needed

The CWSD is related mainly to drought, water scarcity and water resources. Thus any data that can give information on the state of the water resources, the evolution of drought or water uses is relevant to adhere to the policy requirements of the CWSD.

The Ebro basin is a data-rich basin, thus the basin managers have abundant in-situ data that can be used to adhere to the CWSD. These in-situ data, which are provided by the Automatic System of Hydrological Information (SAIH), include meteorological data, river flow measurements, dam levels, piezo-metric levels, snow gauges, water extraction by the main irrigation systems, etc. Concerning water extraction, there is a degree of extraction from non-declared wells, but the extractions done in sensitive

areas are well accounted for. CORINE land cover data is used to obtain information on irrigated surface.

Snow information is received through the national program ERHIN [57]. Within this program in-situ measurements of snow depth and density (from snow poles and automatic measurements), remote sensing derived data of area covered by snow (from MODIS and NOAA-AVHRR) and model outputs (from the ASTER model) are acquired and reported.

Concerning hydrological modelling, the CHE developed a comprehensive Flood Control Decision Support System [58]. This tool is used for short term river flow prediction and also to support reservoir management, as it is able to simulate different water release strategies. Additionally, for longer term studies, such as those included in the White Paper of Water in Spain [59], the SIMPA model has often been used [60]. SIMPA was developed by CEDEX, a civil engineering agency which belongs to MAGRAMA. It was designed to analyse spatial and temporal hydrological variables and to simulate hydrological processes based on them. The included models to simulate water resources, floods and water quality. Concerning water resources, it is a distributed conceptual model at the monthly time step. It simulates natural flows and it does not include reservoirs or other infrastructures.

5.1.4 Gaps & possible improvements

Data required vs. data available

Table 8 lists the main data needed in order to apply the CWSD. The table shows that the Ebro river basin is a data rich basin with few gaps. In fact, in general, more than gaps, we should talk about areas of possible improvement.

Table 8: Main data needed in order to apply the CWSD.

Data type	Is this data used by the basin managers ?	Is there enough data in terms of frequency, resolution and scope?	Data source.	Comments.
In-situ data				
Meteorological data.	Yes.	Yes.	CHE and AEMET.	Very dense network.
River flow	Yes.	Yes.	CHE.	Very dense network.
Dam levels.	Yes.	Yes.	CHE.	
Irrigation related extractions.	Yes.	Yes.	CHE, irrigators.	Some pumping wells are not declared.
Other extractions.	Yes.	Yes.	CHE, users.	

Piezometers.	Yes.	Yes.	CHE.	
Snow height and density.	Yes.	Yes.	CHE, MAGRAMA (ERHIN)	Snow poles and automatic snow gauges (12)
Remote sensing				
Snow cover.	Yes.	Yes.	MAGRAMA (ERHIN)	From MODIS and NOAA-AVHRR images
Soil moisture.	No.	--	--	Satellite soil moisture data is not used to monitor drought.
Vegetation state.	No.	--	--	Satellite vegetation condition data is not used to monitor drought.
Land use	Yes.	Yes.	EEA	CORINE Land Cover
Models				
River flow (naturalized or real).	Yes.	Yes, but improvements are possible.	CHE, CEDEX.	Flood Control Decision Support System and SIMPA. The existing tools are very good, but research could provide improvements.
Groundwater.	Yes (with conceptual model).	Monthly data.	CEDEX	SIMPA
Soil moisture.	Yes (with conceptual model).	Monthly data.	CEDEX	SIMPA.
Snow.	Yes (with conceptual model).	Daily data.	ERHIN	ASTER.
Real Evapotranspiration.	Yes (with conceptual model).	Monthly data.	CEDEX	SIMPA.
Climate scenarios.				Diverse sources. More impact studies on water resources are desirable.
Other				
Drought indices.	Yes.	Yes..	CHE, MAGRAMA.	Spanish Drought Indicator System. The WEI+ indicator

				is reported to the EU.
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Missing data

The current automatic observation system (SAIH) is quite comprehensive. Thus, there are no clear gaps in the data gathering system. Of course, some improvements would be useful, such as an increase in the number of rain and snow gauges on the mountain areas of the basin.

Current operational use of remote sensing data is mostly limited to the ERHIN program. Within this program images from passive sensors (MODIS and NOAA-AVHRR) are used to acquire information about the surface covered by snow. Snow density and depth data is obtained through in-situ measurement campaigns and 12 automatic snow gauges. To complement this data, the use of remote sensing data to obtain spatially continuous information of snow density and depth could be explored. Remotely sensed soil moisture and vegetation data are not used. These data might be useful for drought monitoring.

Concerning modelling tools, the models available are performant and sophisticated. Thus, the gaps are not obvious. However, the Flood Control Decision Support System is very adequate for short term management, but not for long term studies. For long term planning, the conceptual and distributed SIMPA model has been successful, but it has some limitations, such as the monthly time step and the lack of hydraulic infrastructure, such as dams. A more comprehensive distributed and physically based model, which would include the main infrastructures and that would be able to perform long term water resources simulations of the basin, including climate change impact studies, would complement the existing tools. A high resolution land-surface analysis system, which would assimilate remote sensed data in model runs, would also be useful for agricultural and hydrological drought monitoring. Seasonal forecasting of drought would also be interesting, but the current state of the art cannot provide such forecasts, as it is known not have sufficient skill in this geographical area. Better data on the future of drought in a changed climate is also needed. Filling these gaps requires advances in research and development.

Frequency- data available but higher frequency required

The automatic observation system of the Ebro Basin (SAIH) obtains data with sub-hourly frequencies, thus no improvements are needed. Concerning models, the monthly time-step of SIMPA is limited for some applications.

Scale- data available but the scale is not detailed enough

The coverage and resolution of existing tools is good. In-situ data is abundant, even though some more rain and snow gauges in areas with pronounced relief would be welcomed. The current models and remote sensing products used have sufficient resolution.

5.1.5 Summary

The Ebro is a data rich basin, thus there are no clear gaps in the current uses of data in order to apply the CWSD. However, a more comprehensive approach through water resources modelling and the integration of remote sensing information could contribute to long term planning as well as to improved monitoring and prediction of drought. In order to fill these gaps, research is necessary in land-surface modelling, hydrological modelling, data assimilation, seasonal prediction and the impacts of climate change.

6 REFERENCES

- [1] "Directive 2007/60/EC of the European Parliament and of the Council of 23 October 2007 on the assessment and management of flood risks," Official Journal of the European Union, no. L 288/27, p. L 288/27, 6 11 2007.
- [2] MoE, "Report of the Ministry of Environment of the Czech Republic and of the Ministry of Agriculture of the Czech Republic: Preliminary Flood Risk Assessment in Czech Republic," 2011.
- [3] Ministerie van Verkeer en Waterstaat, 2007. Hydraulische Randvoorwaarden Primaire Waterkeringen voor de derde toetsronde 2006-2011. Pp.272 ISBN: 978-90-369-5761-8.
- [4] D. Molden, Accounting for water use and productivity. SWIM Paper 1. Colombo, Sri Lanka: International Irrigation Management Institute, 1997.
- [5] D. Molden and R. Sakthivadivel, Water accounting to assess use and productivity of water. Water Resources Development, 15: 55-71, 1999.
- [6] International Water Management Institute. Water Accounting for Integrated Water Resources Management. Colombo, Sri Lanka, n.d..
- [7] United Nations Statistics Division (UNSD): Department of Economic and Social Affairs. System of Environmental-Economic Accounting for Water, ST/ESA/STAT/SER.F/100, New York, 2012.
- [8] United Nations Statistics Division (UNSD). Handbook of National Accounting: Integrated Environmental and Economic Accounting: An Operational Manual, Series F, No. 78, Rev. 1 (United Nations publication, Sales No. E.00. XVII.17), 2003.
- [9] United Nations Statistics Division (UNSD). System of Environmental-Economic Accounting for Water. Final Draft, March 2007.
- [10] Water Accounting Standards Board. Water Accounting Conceptual Framework for the Preparation and Presentation of General Purpose Water Accounting Reports, Commonwealth of Australia, Canberra, 2009.
- [11] Commonwealth of Australia, Bureau of Meteorology. Accounting for Australia's water. 2012.
- [12] A. Hoekstra, Virtual water trade: Proceedings of the International Expert Meeting on Virtual Water Trade, 12-13 December 2002, Value of Water Research Report Series No 12, UNESCO-IHE, Delft, Netherlands. 2003.
- [13] A. Hoekstra, S. Chapagain, M. Aldaya and M. Mekonnen, Water Footprint Network, 2011.
- [14] J. Morrison and P. Schulte, Corporate Water Accounting. An Analysis of Methods and Tools for Measuring Water Use and its Impact, United Nations Environmental Programme, United Nations Global Compact, Pacific Institute, 2010..
- [15] M. Kirby, M. Mainuddin, M. D. Ahmad, P. Marchand and L. Zhang, Water use account spreadsheets with examples of some major river basins. Paper presented at the 9th International River Symposium, September 3-6 2006 in Brisbane, Australia, 2006.
- [16] M. Kirby, M. Mainuddin and J. Eastham, Water-use accounts in CPWF basins: Model concepts and description. CPWF Working Paper: Basin Focal Project series, BFP01. Colombo, Sri Lanka: The CGIARR Challenge Program on Water and Food. 21 pp, 2010.

- [17] Karimi, P., Bastiaanssen, W. G. M., Molden, D. 2013a: Water Accounting Plus (WA+) – a water accounting procedure for complex river basins based on satellite measurements, *Hydrol. Earth Syst. Sci.*, 17, 2459–2472, doi: 10.5194/hess-17-2459-2013.
- [18] Karimi, P., Bastiaanssen, W. G. M., Molden, D., Cheema M.J.M. 2013b. Basin-wide water accounting based on remote sensing data: an application for the Indus Basin. *Hydrol. Earth Syst. Sci.*, 17, 2473–2486, doi:10.5194/hess-17-2473-2013.
- [19] Bastiaanssen, W.G.M. 2009. Water accounts: de nieuwegeneratiewaterbeheercontroleurs. Intreerede Technische Universiteit Delft.
- [20] P. Karimi, D. Molden, W. Bastiaanssen and X. Cai, Water accounting to assess use and productivity of water: evolution of a concept and new frontiers. In: Godfrey, J. M.; Chalmers, K. (Eds.). *Water accounting: international approaches to policy and decision-making*. Cheltenham, UK: Edward Elgar. pp 76-88., 2012.
- [21] Droogers, P., Simons, G., Bastiaanssen, W. (2011). *Water Accounting Plus (WA+) in the Okavango River Basin. Coping with Water Scarcity – Developing National Water Audits Africa*. WaterWatch , FAO.
- [22] De Haan, M. and Keuning, S.J. (1996). Taking the environment into account: the NAMEA approach. *Review of income and wealth*, Series 42, Number 2, 1996.
- [23] Schenau, S., Delahaye, R., Edens, B., Van Geloof, I., Graveland, C., Van Rossum, M. 2010. *The Dutch environmental accounts: present status and future developments*. Statistics Netherlands, Department of National Accounts, The Hague, NL, 2010.
- [24] Van der Veeren, R., Brouwer, R., Schenau, S., Van der Stegen, R. 2004. *NAMWA: A new integrated river basin information system*. RIZA Report, Ministerie van Verkeer en Waterstaat, Centraal Bureau voor de Statistiek, 2004.
- [25] R. Brouwer, S. Schenau and R. Van der Veeren, Scale issues in an integrated hydro-economic river basin accounting system. In: *Environmental Valuation in Developed Countries: case studies*, edited by David Pearce. Published by: Edward Elgar Publishing Limited UK and Edward Elgar Publishing, Inc. USA, 2006.
- [26] S. Schenau and M. Ten Ham, *Water Accounts and the Water Framework Directive*. Statistics Netherlands (CBS), Department of National Accounts. Voorburg, The Netherlands. Presented in: Preliminary Meeting of the UN Committee on Environmental-Economic Accounting, New York, 29-31, 2005.
- [27] COM/2007/414 final: Communication from the Commission to the European Parliament and the Council- Addressing the challenge of water scarcity and droughts in the European Union, {SEC(2007)993} {SEC(2007) 996}.
- [28] European Commission (EC). Communication from the Commission to the European parliament, the Council, the European Economic and Social Committee and the Committee of the Regions “A Blueprint to Safeguard Europe's Water Resources” (COM(2012) 0673 final), 2012a.
- [29] Kossida M., Mimikou, M. 2013. Internal Report on the water accounts work and the data flows. ETC/ICM Report for the EEA, Task 1.4.1.d, Deliverable 1, October 2013.
- [30] European Environment Agency (EEA). 2013. Results and lessons from implementing the Water Assets Accounts in the EEA area. EEA Technical Report No 7/2013, May 22, 2013, Copenhagen.
- [31] European Commission (EC), DG Environment. 2012b. Preparatory Action - Development of Prevention Activities to halt desertification in Europe - Service

- Contract to contribute to the building of Water and Ecosystem accounts at EU level, Final Report 1 - Reference system and Resources datasets, v.3., June 2012. Prepared by Poyry and Vito Consultants.
- [32] European Commission (EC), DG Environment. 2012c. Preparatory Action - Development of Prevention Activities to halt desertification in Europe - Service Contract to contribute to the building of Water and Ecosystem accounts at EU level, Final Report 2 – Uses and supply, v.3., June 2012. Prepared by Poyry and Vito Consultants.
- [33] European Commission (EC), DG Environment. 2012d. Preparatory Action - Development of Prevention Activities to halt desertification in Europe - Service Contract to contribute to the building of Water and Ecosystem accounts at EU level, Final Report 3 – Water Accounts system and results, v.3., June 2012. Prepared by Poyry and Vito Consultants.
- [34] European Commission (EC), DG Environment. 2012e. Preparatory Action - Development of Prevention Activities to halt desertification in Europe - Service Contract to contribute to the building of Water and Ecosystem accounts at EU level, Final Report 4 – Water Accounts system User Guide, v.3., June 2012. Prepared by Poyry and Vito Consultants.
- [35] Delsalle, J. 2012. Discussion document on Knowledge Base on Water Resources as follow up of the Blueprint. Note presented to the Water Directors, 20 November 2012, Brussels.
- [36] A. De Roo, P. Burek, A. Gentile, A. Udias, F. Bouraoui, A. Aloe, A. Bianchi, A. La Notte, O. Kuik, J. Elorza Tenreiro, I. Vandecasteele, S. Mubareka, C. Baranzelli, M. Van Der Perk, C. Lavallo and G. Bidoglio, A multi-criteria optimisation of scenarios for the protection of water resources in Europe: Support to the EU Blueprint to Safeguard Europe's Waters. European Commission JRC, Institute for Environment and Sustainability. JRC75919, ISBN 978-92-79-27025-3, 2012.
- [37] Wriedt, G., Van Der Veld, M., Aloe, A., Bouraoui, F. 2008. Water Requirements for Irrigation in the European Union. EUR 23453 EN. Luxembourg (Luxembourg): OPOCE.
- [38] M. Kossida, et. al. Report on the water balances, following the standard SEEAW format. ABOT project Deliverable D.C2. ABOT "Assessment of water Balances and Optimisation based Target setting across EU River Basins" Preparatory Action on development of prevention, activities. Preparatory Action on development of prevention activities to halt desertification in Europe Halting desertification in Europe- 2011, DG ENV, 2012.
- [39] Faergemann, H. 2012. Update on Water Scarcity and Droughts indicator development, May 2012, presented to the WD Meeting, 4-5 June 2012, Denmark.
- [40] Nagy, M., Lenz, K., Windhofer, G., Fürst, J., Fribourg-Blanc, B. 2008. Data Collection Manual for the OECD/Eurostat Joint Questionnaire on Inland Waters, v.2.2., September 2008, Eurostat.
- [41] Forster, J. 2010. Official European Water Statistics: State of play and future challenges, Official European Water Statistics - OECD Workshop Zaragoza, 26/04/2010.
- [42] The new code for Water quantity reporting is WISE SoE#3 (<http://rod.eionet.europa.eu/obligations/184>). See also: <http://forum.eionet.europa.eu/nrc-eionet-freshwater/library/wise-soe-reporting-2013/water-quantity-reporting-2013>.
- [43] Adopted from: Raudkivi, A.J. 1979. Hydrology: An Advanced Introduction to Hydrological Processes and Modelling. Oxford [u.a.]: Pergamon Press. ISBN 0-08-

024261-8.

- [44] Food and Agricultural Organisation (FAO). The crop coefficient values were obtained from Allen, R. G., Pereira, L. S., Raes, D. and Smith, M., 1998, Crop evapotranspiration - Guidelines for computing crop water requirements, FAO, Rome.
- [45] FAO/IIASA/ISRIC/ISS-CAS/JRC, 2009, Harmonized World Soil Database (version 1.1), FAO, Rome, and IIASA, Luxemburg.
- [46] M. Omedas, R. Galvan and C. M. Gomez, "Water planning towards a green economy in the Ebro River Basin," in UN-Water International Conference. Water in the Green Economy in Practice: Towards Rio020, Zaragoza (Spain), 2011.
- [47] RLD 1/2001, of July 20th: Royal Legislative Decree 1/2001, of July 20th, in which the revised text of the Water Law is approved., BOE num. 176, Reference: BOE-A-2001-14276, July 24th 2001.
- [48] L 10/2001, of July 5th: Law 10/2001, of July 5th, on the National Hydrological Plan. BOE num. 161, July 6th 2001. Reference: BOE-A-2001-13042.
- [49] M. García-Vera and R. Galván-Plaza, Water Scarcity and Drought Management in the Ebro Basin, in Drought in Arid and Semi-Arid Regions, edited by L. M. G. Kurt Schwabe, Jose Albiac, Jeffery D. Connor, Rashid M. Hassan, pp. 409–424, Springer Netherlands, 2013, era, M. Á. and Galván-Plaza, R.: Water Scarcity and Drought Management in the Ebro Basin, in Drought in Arid and Semi-Arid Regions, edited by L. M. G. Kurt Schwabe, Jose Albiac, Jeffery D. Connor, Rashid M. Hassan, pp. 409–424, Springer Netherlands, 2013.
- [50] MAGRAMA, "Legislación estatal relacionada con la sequía (National legislation in relation with drought)," [Online]. Available: http://www.magrama.gob.es/es/agua/legislacion/Observatorio_Nacional_Sequia_2_legislacion.aspx.
- [51] T. Estrela and E. Vargas, "Drought Management Plans in the European Union".The Case of Spain, Water Resour. Manag., 26(6), 1537-1553, doi: 10.1007/s11269-011-9971-2, 2012.
- [52] V. Arqued Esquí, L. Martínez Cortina and J. Ureta Maeso, "La gestión del riesgo de sequía, in III Jornadas de Ingeniería del Agua,," La protección contra los riesgos hídricos, Valencia (Spain), p. 20, 2013.
- [53] MO MAM/698/2007: Ministerial order MAM/698/2007, of March 21st, in which Special Action Plans for Drought Situations are approved in the framework of inter-regional Basin Hydrologic Plans. BOE num. 71, March 23rd 2007, pp. 12820 a 12821, Reference: BOE-A-2007-6228.
- [54] CHE, "Plan Especial de Actuación en Situaciones de Alerta y Eventual Sequía en la Cuenca Hidrográfica del Ebro (Drought management plan for the Ebro basin)," p. 327, 14 March 2007.
- [55] MAGRAMA, "Observatorio Nacional de la sequía (National Drought Observatory)," [Online]. Available: <http://www.magrama.gob.es/es/agua/temas/observatorio-nacional-de-la-sequia>.
- [56] B. Werner and R. Collins, "Towards efficient use of water resources in Europe, European Environment Agency," 2012.
- [57] MAGRAMA, "ERHIN Programme - Evaluación de recursos hídricos procedentes de la innivación," [Online]. Available: <http://www.magrama.gob.es/es/agua/temas/evaluacion-de-los-recursos-hidricos/erhin>.

- [58] R. Romeo García, A. Linares Sáez, E. García Saleté and L. López García, "Reservoir Management in Real Time Flood Forecasting and Decision Support in the Ebro River Basin Flood Control Decision Support System of the Ebro," in International Conference on Innovation Advances and Implementation of Flood Forecasting Technology, Tromso, Norway, 2005.
- [59] Ministerio de Medio Ambiente, Libro Blanco del Agua en Espana, 2000.
- [60] J. Álvarez, A. Sánchez, L. Quintas, T. Tk, R. Hat and L. Compilers, "SIMPA, a GRASS based tool for Hydrological Studies,," in Proceedings of the FOSS/GRASS Users Conference, Bangkok, Thailand, 12-14 September, 2004.
- [61] European Environment Agency (EEA). 2012. Water Accounts: summary of the results so far, 26/10/2012, Note presented to the SCG Meeting, 07-08 November 2012, Brussels.
- [62] Weber, J.L., Crouzet, P. 2009. Implementation of SEEA Water in Europe - the EEA Approach. Fourth Meeting of the UN Committee of Experts on Environmental-Economic Accounting (UNCEEA), New York, 24-26 June 2009.