CHAPTER VII: KNOWLEDGE BASE FOR TRANSBOUNDARY WATER ALLOCATION

SUMMARY:

This chapter discusses the need for and importance of a shared knowledge base (e.g. available water resources, water uses and needs) at the basin or aquifer level in relation to transboundary water allocation. It also considers means to gather that knowledge, including water resources assessment, water uses and needs assessment and transboundary impact assessments. In addition, it presents structured decision-making approaches and systems as tools for building management responses in a transboundary context.

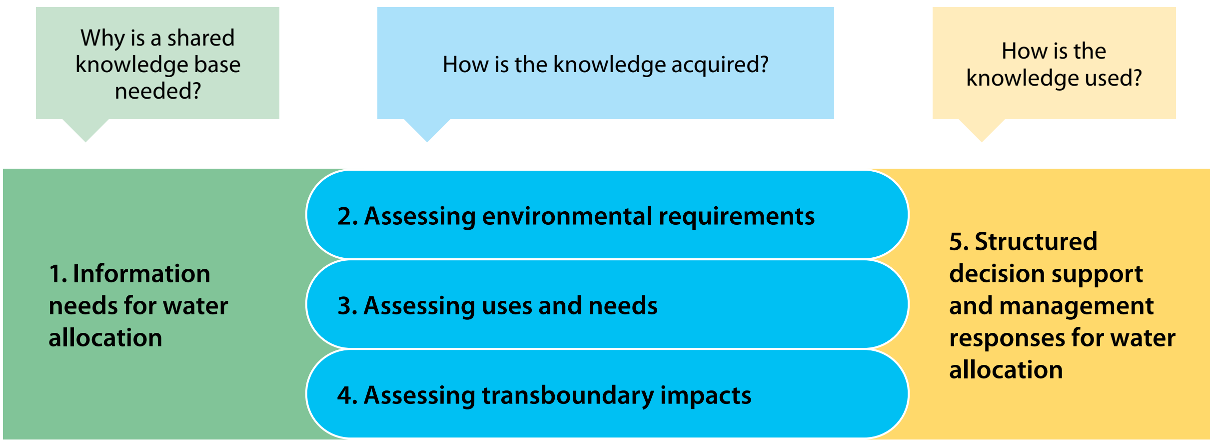
1. Information Needs for Water Allocation

a. Elements and importance of shared information and data harmonization

Water policy planning and implementation and functional water resources management are dependent on access to adequate data and information. In a transboundary context, the information should be shared by all riparian States in a commensurate manner to support decision-making and build trust. A robust shared knowledge base is a prerequisite for implementation of the Water Convention and can greatly contribute to the sustainable and equitable allocation of transboundary waters. This chapter presents the basic means through which to gather that knowledge, including water resources assessment, assessment of environmental requirements, water uses and needs assessment and assessment of transboundary impacts. In addition, the last section discusses structured decision-making and decision support systems (DSS) and how the shared knowledge contributes to management responses in the transboundary context. Figure 11 provides a general overview of the relations of these different elements and their sequencing in this chapter.

FIGURE 11

Sequencing of Chapter VII and the elements associated with a shared knowledge base in transboundary water allocation



Source: UNECE Water Convention secretariat, 2021.

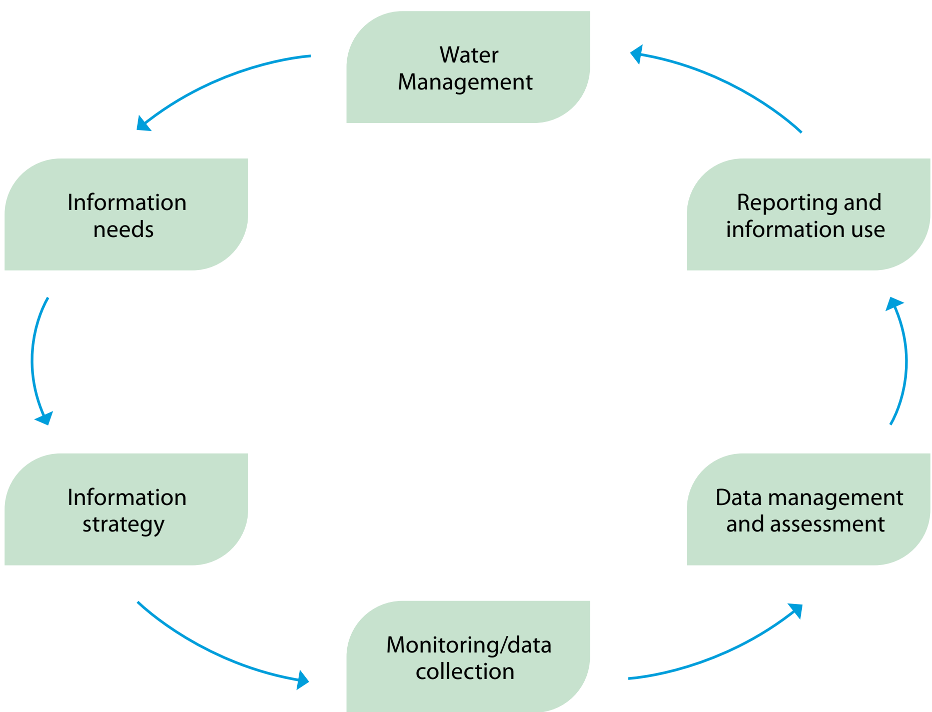
This chapter and Chapter VIII on operationalizing transboundary water allocation provide general ideal elements of the knowledge base for transboundary water allocation process. It should be emphasized that their actual application and sequencing is typically non-linear and their feasibility ultimately context specific and influenced by available resources and political priorities. On the other hand, selective information, knowledge and data-sharing may be subject to advancement of unilateral interests, to the detriment of all parties. This further highlights the importance of joint or coordinated assessment and monitoring systems as well as making data, information and indicators comparable in transboundary settings.

b. Joint monitoring and assessment of shared basins

A shared knowledge base at transboundary level requires harmonized and comparable monitoring and assessment methods and data management systems. These are best established in a form of systematic monitoring and assessment programmes that provide information for planning, decision-making and water management at all levels to both guide and complement the existing national-level practices. According to the Convention (Article 9) "the Riparian Parties shall establish and implement joint programmes for monitoring the conditions of transboundary waters, including floods and ice drifts, as well as transboundary impact". Transboundary monitoring and assessment ideally follows the monitoring cycle presented in Figure 12. Each step provides inputs for the following ones and at the end of the cycle the information needed is provided, for example, in the form of a report or a database. As more or different information needs emerge, when, for example, policies and targets change, the cycle starts again.[365]

FIGURE 12

The monitoring cycle in transboundary water management



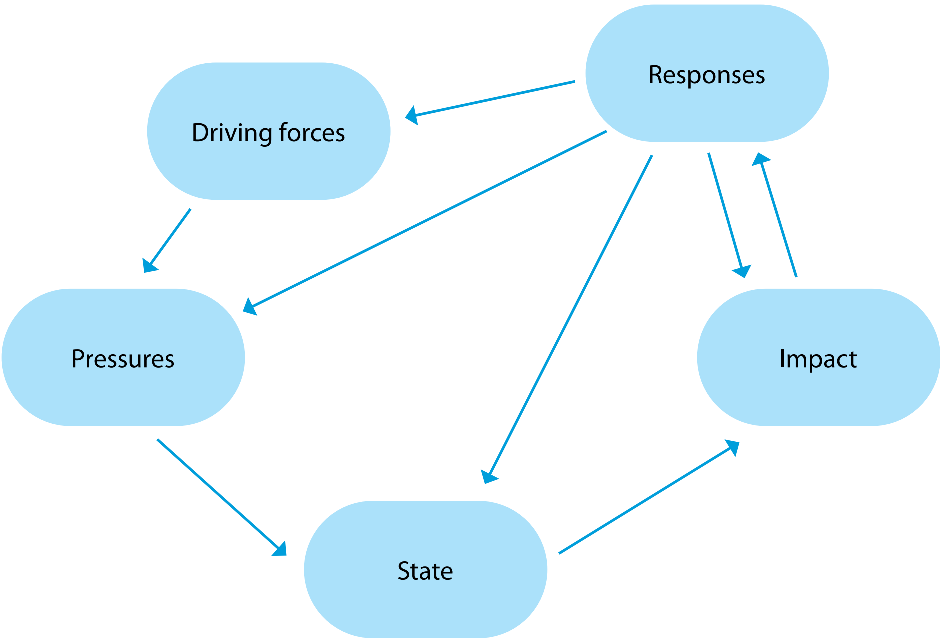
Source: UNECE, *Strategies for Monitoring and Assessment of Transboundary Rivers, Lakes and Groundwaters* (New York and Geneva, United Nations, 2006).

365 UNECE, *Strategies for Monitoring and Assessment of Transboundary Rivers, Lakes and Groundwaters* (2006).

As a first step in the monitoring cycle, the key information needs related to water allocation cover water availability, different water uses and functions, and the allocation needs. The information needs may be further defined using relevant frameworks, such as the Driving Forces–Pressures–State–Impact–Responses (DPSIR) framework[366] (Figure 13) and/or identified water management issues. The transboundary context and scale of the allocation affects the detail and level of information needed. Monitoring programmes typically consist of selection of parameters, locations, sampling frequencies, field measurements and laboratory analyses. The parameters, type of samples, sampling frequency and station location should reflect the information needs.

FIGURE 13

DPSIR assessment framework



Source: UNECE, *Strategies for Monitoring and Assessment of Transboundary Rivers, Lakes and Groundwaters* (New York and Geneva, United Nations, 2006).

The next step on the monitoring cycle, information strategy, defines the best practical way to gather the data from different sources (e.g. from national monitoring systems, surveys, experts and statistics). The strategy guides the following steps related to monitoring/data collection, data management and assessment, and reporting and information use. The information strategy has to adapt with each cycle when targets or policies change. However, continuity in time series is important, and monitoring programmes should always aim to be long-term.[367]

366 Ibid. The DPSIR framework was originally developed by the European Environment Agency, see Edith Smeets and Rob Weterings, "Environmental indicators: typology and overview", Technical Report, No. 25 (Copenhagen, European Environment Agency, 1999).

367 UNECE, *Strategies for Monitoring and Assessment of Transboundary Rivers, Lakes and Groundwaters* (2006).

CASE STUDY 35: **Exchange of hydrological data in the Sava River Basin: diverse providers and users unified by a common policy and standards**

The Framework Agreement on the Sava River Basin (FASRB), in force since 2004, with Bosnia and Herzegovina, Croatia, Serbia and Slovenia as parties, integrates different aspects of water management. The FASRB contains an obligation to exchange information on the water regime of the Basin on a regular basis. Additionally, the Protocol on Flood Protection to the FASRB states that the parties shall ensure timely exchange of meteorological and hydrological data, analyses and information important for flood protection, in line with the agreed procedure. The International Sava River Basin Commission (ISRBC), the implementing body of the FASRB, has established, in phases, an advanced data exchange system (operational since 2015) through the Sava GIS Geoportal (www.savagis.org), which by design is compliant with World Meteorological Organization (WMO) regulations and standards as well as relevant European Union Directives. The Sava GIS Geoportal is a scalable and flexible tool for data visualization and management; it supports multilingual usage (English and the six official languages of the parties) and implements open source technologies. Web application for editing, loading and retrieving data and metadata allows registered users to view, visualize, share and retrieve geographic information and data sets. Sava GIS database enables collection of data from the 13 governmental data provider institutions, their uploading using tools and processes to harmonize the data, and storing in a central database.

As an integral part of Sava GIS, the ISRBC has also established the Hydrological Information System for the Sava River Basin—Sava HIS (www.savahis.org), taking into account the Policy on the Exchange of Hydrological and Meteorological Data and Information, prepared in close cooperation with WMO and signed in 2014 by relevant organizations of the parties and Montenegro (a fifth Basin State). As a WMO exchange standard is implemented, the Sava HIS system enables storage of water observations time series data and spatial information in a standard format and their sharing and publication via web service for further use. Sava HIS is currently collecting observed data from 310 hydrological and 220 meteorological gauges, and the number is increasing with recognition of the efficiency and benefits of the system.

When it comes to the following steps, the composition of the knowledge base for transboundary water allocation can vary depending on the allocation needs, but certain data elements are usually present (e.g. environmental requirements, water availability and water use). National monitoring systems usually gather the information used in transboundary basins. However, the key organizations harmonizing and distributing the information in the transboundary context are the joint bodies or other similar institutions; they should thus be involved in defining the information needs and can provide a framework for detailing various information and data-related issues.[368] To allow data harmonization and support water allocation, the riparian States should agree on comparable monitoring and reporting methodologies or follow international standards. UNECE provides guidelines about the monitoring and assessment of transboundary lakes,[369]

368 UNECE, *Capacity for Water Cooperation in Eastern Europe, Caucasus and Central Asia: River Basin Commissions and Other Institutions for Transboundary Water Cooperation* (New York and Geneva, United Nations, 2009).

369 UN/ECE Working Group on Monitoring & Assessment (WGMA), *Guidelines on Monitoring and Assessment of Transboundary and International Lakes: Part A: Strategy Document* (Helsinki, 2002); UNECE, *Guidelines on Monitoring and Assessment of Transboundary and International Lakes: Part B: Technical Guidelines* (Helsinki, Finnish Environment Institute, 2003). Both are available at https://unece.org/environment-policy/publications/guidelines-monitoring-and-assessment-transboundary-and.

groundwaters[370] and rivers.[371] The World Meteorological Organization (WMO) has developed a series of hydrometeorological guidelines and regulations.[372] In addition, for example, the World Hydrological Cycle Observing System (WHYCOS) project implemented by WMO provides international guidelines on how data could be shared.[373] WMO is also creating the infrastructure enabling easier discovery, access and exchange of data and information through the Hydrological Observing System (WHOS), a portal to facilitate access to already available online real-time and historical data.[374] Timely and effective data exchange is particularly crucial for flood management, and the application of international standards and relevant regional guidelines helps to ensure harmonization (see Case Study 35). Remote sensing is also an increasingly useful method of providing harmonized data for many parameters across borders.[375]

c. Integration of different forms of knowledge

Transboundary water resources management builds on a variety of knowledge forms, calling for active knowledge exchange between different actors, including the riparian governments, scientists and other key actors in the society.[376] The knowledge base for transboundary water allocation ideally builds on the joint monitoring and assessment systems as described above. The system design and data gathered are best built on various forms of knowledge available about the characteristics of the water resources and management issues, including best available scientific knowledge, but also relevant local and Indigenous knowledge. Local and Indigenous knowledge on water can provide invaluable inputs to both science and policy processes through the powers of observation of long periods and the recall of knowledge passed down from generation to generation. Besides knowledge on water resources, Indigenous approaches to water allocation and conflict management may also provide useful methods to international negotiation settings.[377] For further details on public and Indigenous participation in transboundary water allocation, see Chapter V, subsections 4a and 5c.

Bringing such different sources and even contradictory forms of knowledge together is not easy, especially in a transboundary allocation context. It therefore requires well-structured facilitation. Key conditions for effective science-policy interaction in transboundary water governance include:

- recognizing that science is a crucial but bounded input into water resource decision-making processes;
- establishing conditions for collaboration and shared commitment among actors;
- understanding the role that social learning between scientists, policymakers and non-State actors can have to address complex water issues;

370 UN/ECE Taskforce on Monitoring & Assessment, *Guidelines on Monitoring and Assessment of Transboundary Groundwater* (Lelystad, The Netherlands, RIZA, 2000).

371 UN/ECE Taskforce on Monitoring & Assessment, *Guidelines on Monitoring and Assessment of Transboundary Rivers: First Review of the 1996 Guidelines on Water-quality Monitoring and Assessment of Transboundary Rivers* (Lelystad, The Netherlands, Institute for Inland Water Management and Waste Water Treatment (RIZA), 2000).

372 A compilation can be found in ECE/MP.WAT/WG.2/2019/INF.1.

373 WMO, *WHYCOS Guidelines for Development, Implementation and Governance*. Hydrological Information Systems for Integrated Water Resources Management (Geneva, 2005).

374 For further information, see https://hydrohub.wmo.int/en/whos.

375 Water Global Practice, *New Avenues for Remote Sensing Applications for Water Management: A Range of Applications and the Lessons Learned from Implementation* (Washington, D.C., World Bank, 2019); J. Sheffield and others, "Satellite remote sensing for water resources management: potential for supporting sustainable development in data-poor regions", *Water Resources Research*, vol. 54, No. 12 (December 2018), p. 9724–9758; UNESCO, "Application of satellite remote sensing to support water resources management in Africa: results from the TIGER initiative", IHP-VII Technical Documents in Hydrology, No. 85 (Paris, 2020).

376 Anthony R. Turton and others, eds., *Governance as a Trialogue: Government-Society-Science in Transition* (Berlin, Springer, 2007).

377 Aaron T. Wolf, "Indigenous approaches to water conflict negotiations and implications for international waters", *International Negotiation: A Journal of Theory and Practice*, vol. 5, No. 2 (2000), p. 357–373.

- accepting that the collaborative production of knowledge about hydrological issues and associated socioeconomic changes and institutional responses is essential to build legitimate decision-making processes; and
- engaging boundary organizations and informal networks of scientists, policymakers, and civil society when appropriate.[378]

The Shared Vision Model of the International Joint Commission (IJC) between the United States and Canada exemplifies bringing together different forms of knowledge for water allocation decision-making. It involves key water managers, knowledgeable scientists and leaders and key stakeholders in each country to create a system model that connects science, public preferences and decision-making criteria in a transparent manner (see Case Study 38).

d. Scenarios and transboundary water allocation

Scenarios help planners and decision-makers understand how the future may unfold and what kinds of changes and uncertainties affect it. Scenarios are not forecasts or predictions; rather, they are a set of images or stories about possible futures. Scenarios should be coherent, internally consistent and plausible descriptions of the future state of the world, and—in the context of transboundary waters—they should preferably be jointly developed by all riparian States. Climate change scenarios[379] are among the most important scenarios for planning transboundary water allocation (see Chapter III, subsection 2c). Yet other types of scenarios may also play a central role in allocation development, including scenarios about water demand, economic development or demography.[380]

Several different scenario approaches have been used in transboundary water contexts to date.[381] They typically exemplify two types: exploratory or anticipatory.[382] Exploratory scenarios view the future based on known processes of change as well as extrapolations from the past, building on trend analyses (see Figure 14). This makes exploratory scenarios relatively easy to use but less sensitive to potential major transitions. Anticipatory scenarios, on the other hand, build on different visions for the future, establishing first the desired future state and then recognizing the steps that are needed to reach it from the present situation. Anticipatory scenarios are therefore often more strategic but also subjective, making them particularly suitable for broader policymaking and shared visioning. Overall, negotiations can benefit from an assessment of present and future water needs in the riparian States, including a detailed diagnosis of potential water allocation scenarios.

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378 Derek Armitage and others, "Science–policy processes for transboundary water governance", *Ambio: A Journal of Environment and Society*, vol. 44 (2015), p. 353–366.

379 Intergovernmental Panel on Climate Change (IPCC), "Global warming of 1.5oC: an IPCC Special Report on the impacts of global warming of 1.5°C above pre-industrial levels and related global greenhouse gas emission pathways, in the context of strengthening the global response to the threat of climate change, sustainable development, and efforts to eradicate poverty", Valérie Masson-Delmotte and others, eds. (n.p., 2019).

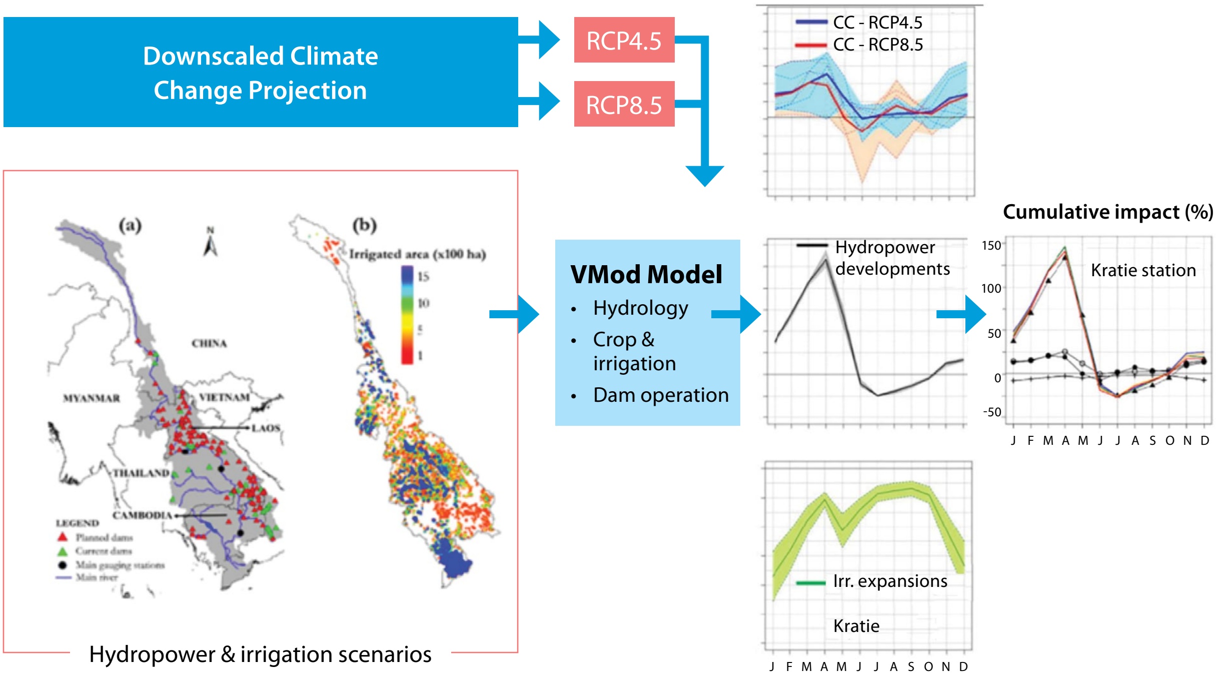
380 UNECE, *Guidance on Water and Adaptation to Climate Change* (2009).

381 See, for example, F. Farinosi and others, "An innovative approach to the assessment of hydro-political risk: a spatially explicit, data driven indicator of hydro-political issues", *Global Environmental Change*, vol. 52 (September 2018), p. 286–313; Angela Gorgoglione and others, "A new scenario-based framework for conflict resolution in water allocation in transboundary watersheds", *Water*, vol. 11, No. 6 (2019), 1174; Marko Keskinen and others, "Using scenarios for information integration and science-policy facilitation: case from the Tonle Sap Lake, Cambodia", in *Sustainable Futures in a Changing Climate: Proceedings of the Conference "Sustainable Futures in a Changing Climate", 11–12 June 2014, Helsinki, Finland*, Aino Hattaka and Jahmo Vehmas, eds. (Turku, Finland Futures Research Centre, 2015), p. 282–292; David Phillips and others, "Trans-boundary water cooperation as a tool for conflict prevention and for broader benefit-sharing", Global Development Studies, No. 4 (Stockholm, Ministry for Foreign Affairs, 2006).

382 Mohammed Mahmoud and others, "A formal framework for scenario development in support of environmental decision-making", *Environmental Modelling & Software*, vol. 24, No. 7 (July 2009), p. 798–808.

FIGURE 14

Example of climate change, irrigation and hydropower modelling in the Mekong as part of a scenario process



Source: Long P. Loang and others, "The Mekong's future flows under multiple drivers: how climate change, hydropower developments and irrigation expansions drive hydrological changes", *Science of The Total Environment*, vol. 649 (February 2019), p. 601–609.

e. Assessing available water resources

Assessing the quantity, quality and regime of available water resources for allocation

The riparian States and parties to a shared waterbody need a common understanding of the quantity, quality and regime of the available water resources for the purposes of allocation. Detailed guidelines about the monitoring and assessment of transboundary lakes,[383] groundwaters[384] and rivers[385] have been developed by UNECE. However, generally, the available water resources can be assessed with the following three main steps (as also presented in Chapter III):

1. **Delineating and agreeing on the basin and/or aquifer boundaries**, considering the biophysical and hydrological characteristics and administrative boundaries

Topographic data are essential for determining the surface drainage area and its boundaries, as well as in understanding the direction of flow. It is useful to build a complete and harmonized Geographic Information

383 UN/ECE Working Group on Monitoring & Assessment (WGMA), *Guidelines on Monitoring and Assessment of Transboundary and International Lakes: Part A: Strategy Document* (2002); UNECE, *Guidelines on Monitoring and Assessment of Transboundary and International Lakes: Part B: Technical Guidelines* (2003).

384 UN/ECE Taskforce on Monitoring & Assessment, *Guidelines on Monitoring and Assessment of Transboundary Groundwater* (2000).

385 UN/ECE Taskforce on Monitoring & Assessment, *Guidelines on Monitoring and Assessment of Transboundary Rivers: First Review* (2000).

System (GIS) base map of the shared waterbody. Satellite data may be further used for defining the basin characteristics. If appropriate, additional layers of data (e.g. Lidar data) may be added to define floodway, floodplain and other relevant watercourse or aquifer information. For characterization of transboundary aquifer systems, including the boundaries, information about the geology and hydrogeology is necessary. While this can entail dealing with significant challenges and uncertainties, there is continuous progress in terms of mapping transboundary aquifers, from local to global levels, which can ultimately assist the data baselines for allocation.[386]

2. Assessing the surface and groundwater availability and quality, taking into account inter- and intraannual variability, with hydrological and geohydrological analyses utilizing commensurate methods and data

For water resources assessment, that is, the determination of the sources, extent, dependability and quality of water resources for their utilization and control, the World Meteorological Organization (WMO) provides helpful technical material.[387] Frequent or continuous water level and river discharge measurements lay the foundation for river basin management and water resources assessments.[388] Long-term, time series observations from stream gauges and piezometer levels can provide a sound basis for assessing variability and change in the interconnected surface water and groundwater resources over time. Water quality and sediment quality assessments and surveys give insight into the functioning of the aquatic ecosystem, and the point and non-point pollution sources and toxicity of pollutants in water bodies, which might affect the quality of the water available for allocation.

There are several universally applicable parameters for water quality. The indicators for SDG target 6.3.2 on the quality of inland waters include core physico-chemical water-quality parameters of dissolved oxygen, electrical conductivity, total oxidized nitrogen, nitrate, orthophosphate and pH, with their associated target values. SDG indicator 6.3.2 is also directly linked to indicator 6.3.1 on wastewater treatment and to target 6.1 on access to safe drinking water and target 6.6 on water-related ecosystems.[389] Other key parameters of water quality include, among others, physical characteristics of water system, salinity and other mineral composition, suspended solids and presence of specific pollutants, preferably reflecting the influence of anthropogenic pressures and impacts.[390] A water quality classification system for waters is provided, for example, by the European Union Water Framework Directive (2000/60/EC). European surface waters are classified based on their ecological status to five classes, from low to high quality, and groundwater by their quantitative status. In addition, both surface and groundwaters are classified by their chemical status.

Remote sensing is an increasingly applicable means by which to gather near real-time data on certain aspects of water resources and their quality. It can complement costly in-situ measurements. Advances in cloud storage and computing, connectivity and cheaper satellites make this data source increasingly competitive.[391]

386 IGRAC, "Transboundary aquifers of the world map", 2015.

387 WMO, "Technical material for water resources assessment", Technical Report Series, No. 2 (Geneva, 2012); WMO, "Guide to hydrological practice: volume I: hydrology – from measurement to hydrological information", WMO No. 168 (Geneva, 2020); WMO, "Manual on stream gauging: volume II: computation of discharge", WMO No. 1044 (Geneva, 2010).

388 UN/ECE Taskforce on Monitoring & Assessment, *Guidelines on Monitoring and Assessment of Transboundary Rivers: First Review* (2000).

389 UNEP, *Progress on Ambient Water Quality: Piloting the Monitoring Methodology and Initial Findings for SDG Indicator 6.3.2* (n.p., 2018).

390 UNEP (2016).

391 Water Global Practice (2019). See also, generally, EU Copernicus Programme (www.copernicus.eu/en), particularly the European Drought Observatory (www.copernicus.eu/en/european-drought-observatory) and the Copernicus Climate Change Service (https://climate.copernicus.eu/).

When assessing the available volume of water, existing and potential augmentation of water resources is important to incorporate into the overall estimates. The augmentation can be achieved by, for example, desalination, reuse of water or managed aquifer recharge to augment groundwater resources. Such options entail trade-offs, which need to be carefully assessed. For example, recharging an aquifer from a surface watercourse reduces flow in that watercourse. Consequences of unintended allocation are equally important to consider: besides the formal processes of allocation, water shares, even large volumes, may also be gained via indirect action or inaction, for example, as a result of land use changes.[392] The role of timing has been underexplored and underutilized in most water allocation plans and arrangements to date. However, available water resources are not fixed in time, but vary inter-annually and seasonally. Understanding of flow regimes, inter-annual and seasonal variability and exceptional situations, i.e. floods and droughts, is therefore important to take into account in water resources assessments. Failures in understanding or allocating water for inter-annual variability often cause basin water management disagreements (see also Chapter III, section 2).[393]

3. **Estimating allocable water in different seasons and in different scenarios**, based on the previous steps

Relevant trend analysis may be calculated for both water quality and flow data as well as relevant statistical parameters (averages, medium, percentiles, etc). The historical flow data can be utilized to extend the period of record and climate change as projections allow.

Addressing diverging understandings

Common definitions, as well as exchanging data available, help to establish a shared understanding of the situation. Establishing a joint monitoring and assessment system with representation of officials, water experts and key stakeholders from the different States, as previously described, helps ameliorate potential disagreements and diverging understandings on the status and availability of allocable water resources. If disagreements threaten cooperation on the shared waterbody, joint bodies have a key role to play in dispute resolution. For further details on dispute prevention and resolution, see Chapter VIII, section 11.

Modelling of water resources

Allocable water may be estimated based on hydrological observations as described above. However, the observations can be complemented or estimated with hydrological models, i.e. rainfall run-off models[394] and more detailed three-dimensional integrated dynamic hydrological models considering both surface water and groundwater.[395] Hydrological modelling may enable spatially or temporally more extended hydrological data compared with observations, and also estimation of the future state of water resources. Models are also used with flood forecasting and travel-time calculations regarding industrial accidents and other flow spillages.[396]

Hydrological models can be classified as empirical models, conceptual models and physically based models. The models need several inputs, the two most important being rainfall data and drainage area.[397] Usually, hydrological data is needed for calibration, and poor or lacking observations set restrictions on the model choice and usefulness of the models. The models can incorporate different scenarios and are a vital part

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392 Virginia Hooper and Bruce Lankford, "Unintended water allocation: gaining share from indirect action and inaction", in *The Oxford Handbook of Water Politics and Policy*, Ken Conca and Erika Weinthal, eds. (Oxford, Oxford University Press, 2018).

393 Speed and others (2013).

394 Ibid.

395 Stefan Kollet and others, "The integrated hydrologic model intercomparison project, IH-MIP2: a second set of benchmark results to diagnose integrated hydrology and feedbacks", *Water Resources Research*, vol. 53, No. 1 (January 2017), p. 867–890.

396 UN/ECE Taskforce on Monitoring & Assessment, *Guidelines on Monitoring and Assessment of Transboundary Rivers: First Review* (2000).

397 K. Devi Gayathri, B. P. Ganasri and G. S. Dwarakish, "A review on hydrological models", paper presented at the International Conference on Water Resources, Coastal and Ocean Engineering (ICWRCOE 2015), *Aquatic Procedia*, vol. 4 (2015), p. 1001–1007.

of impact assessments and decision support systems (DSS), as described later in this chapter. Models do, however, have uncertainties and these should be always presented with the results. A basic understanding of the model being used helps understanding and coping with particular uncertainty. Global hydrological models can also help assess water resources and water use scenarios. The Inter-Sectoral Impact Model Intercomparison Project (ISIMIP) provides climate-impact simulations, based on scientifically and politically relevant historical and future scenarios. Climate change impact assessments should always be based on several models and climate forcing data, which ISIMIP can provide.[398]

Understanding long-term trends

Monitoring programmes should aim to be long-term, even when the issue at hand might not require it. Long-term time series data points are essential when trying to detect possible long-term trends in water levels, discharges and pollutant concentrations. All significant trends should be taken into consideration when agreeing on the water allocations. Models also require long-term data series for calibration. Climate change impacts are also more evident and more accurate to predict with long-term time series. The riparian countries or joint bodies may develop common scenarios and models to have a joint understanding of the effects of climate change on the shared basin, as also discussed in section 1.4 above. WMO provides a tool (Dynamic Water Resources Assessment Tool) for water resources managers and policymakers to assist with long-term planning and water resources assessment. The tool helps, for example, to assess land use changes and the impacts on water availability with different scenarios, including climate change.[399]

2. Assessing Environmental Requirements

a. Understanding water-related ecosystems and their contribution to livelihoods, development and economy

Sustainable water allocation should be based on knowledge about the river basin and aquifer flows and their interconnections to sustain ecosystem health. Environmental flow assessments are needed to build the scientific evidence for the choice of flow regimes required to meet ecological objectives. Flow assessments should evaluate how ecology, economic costs and benefits across sectors and social equity respond to alternative flow scenarios. They should include assessment of the contribution of biodiversity and ecosystem goods and services to livelihoods and poverty reduction.[400] As presented in Chapter III, section 3, a widely accepted definition of environmental flows comes from The Brisbane Declaration and Global Action Agenda on Environmental Flows (2018), which defines environmental flows as "[t]he quantity, timing, and quality of water flows required to sustain freshwater and estuarine ecosystems and the human livelihoods and well-being that depend on these ecosystems."[401]

b. Different approaches to assessing environmental flows

There are more than 200 methods that have been applied in assessing environmental flows to date.[402] The simplest hydrology-based methodology (setting minimum flow levels) can be complemented with variability needs (flows mimicking seasonal natural flow variability) or, in the most holistic approaches, the aim is to take care of all aspects, including social and developmental. Properly implemented, environmental flows can help sustain and generate livelihoods, create economic value, preserve rivers, share benefits of

398 ISIMIP, "The Inter-Sectoral Impact Model Intercomparison Project" (n.d.).

399 WMO, "Dynamic Water Resources Assessment Tool" (2021).

400 Speed and others (2013).

401 Arthington and others (2018).

402 See, for example, WMO, "Guidance on environmental flows: integrating e-flow science with fluvial geomorphology to maintain ecosystem services", WMO No. 1235 (Geneva, 2019).

basin development more equitably, and generally contribute to the sustainable management of rivers.[403] Existing methods differ in input information requirements, types of ecosystems they are designed for, time needed for their application and the level of confidence in the final estimates. No single environmental flow assessment technique suits all social, economic, hydrological and ecological contexts within a country. A comparison of different environmental flow (e-flow) assessment methods is presented in Table 9.

TABLE 9

Comparison of the three general categories of e-flows estimation methodologies

Methodology category	General purpose	Scale	Duration of assessment (months)	Relative costs	Relative frequency of use
Hydrological	Examination of historic flow data to find flow levels that naturally occur in a river and can be considered "safe" thresholds for flow abstraction	Whole rivers, applicable for regional assessments	1-6	€	+++
Hydraulic-Habitat	Examination of change in the amount of physical habitat for a selected set of target species or communities as a function of discharge	Applied at a study site / river segment scale, upscaling to whole river basin based on the assumption of "representative" site conditions	6-18	€€	++
Holistic	Examination of flows in an expert opinion workshop leading to recommendation of flows for all components of the river ecosystem, including societal and recreational uses	Whole rivers, applicable for regional or river specific scales	12-36	€€ - €€€	+ (increasing)

Source: European Union, "Ecological flows in the implementation of the Water Framework Directive", CIS Guidance document No. 31, Technical Report, No. 2015 - 086 (Luxembourg, Office for Official Publications of the European Union, 2015), adapted from Tommi Linnansaari and others, "Review of approaches and methods to assess environmental flows across Canada and internationally", Canadian Science Advisory Secretariat, Research Document, 2012/039 (n.p., Fisheries and Oceans Canada, 2012).

Note: Explanation of symbols pertaining to "relative costs" (€ = low cost; €€ = medium cost; €€€ = high cost) and "relative frequency of use" (+ = low frequency; ++ = medium frequency; +++ = high frequency).

c. Assessing and incorporating environmental flows into SDG indicator 6.4.2, including groundwater

The Food and Agriculture Organization of the United Nations (FAO) and partners provide guidance on assessing and incorporating environmental flows into SDG indicator 6.4.2 on water scarcity.[404] The guidance, accompanied by an interactive online tool,[405] helps Member States set goals for environmental flows and for reporting on required SDGs. Importantly in the context of conjunctive surface and groundwater allocation,

403 Dharmadhikary (2017).

404 Chris Dickens and others, *Incorporating Environmental Flows into "Water Stress" Indicator 6.4.2: Guidelines for a Minimum Standard Method for Global Reporting* (Rome, FAO, 2019).

405 Available at http://eflows.iwmi.org/.

the tool specifically assesses limits to groundwater abstraction in perennial river systems in order not to affect critical base flows for environmental flows.[406]

d. Environmental flows in a transboundary context: challenges in scope and effectiveness

Seven key challenges that can constrain the scope and effectiveness of environmental flow assessments and allocations in international river basins have been identified by Dharmadhikary (2017):

1. Stakeholder participation: In the case of international rivers, negotiations or discussions are mainly between governments and therefore can prevent or eliminate the role of local communities in environmental flows assessments.
2. Deliberations have to contend with the diversity of cultures, languages and governance systems across boundaries, and need to reconcile differences in national priorities and in national situations.
3. Environmental flows objectives are a societal and therefore a political choice. They often end up being reduced to a governmental choice even in purely domestic river basins; in transboundary rivers, this risk is much higher.
4. The sharing and verification of data is more difficult, especially for riparian communities.
5. In transboundary rivers, considerations of sovereign control can create difficulty for managing the river basin as a unit, creating problems in environmental flows assessments and implementation.
6. Often, the required multilateral legal and institutional frameworks are absent, and are not easy to create and sustain.
7. Ensuring that the downstream States use environmental flows only for the environmental purposes for which they were released is a big challenge.

Notably, this view is primarily from a surface water/river perspective and does not include considerations of the role of groundwater resources. As highlighted above, there is a critical need for increased conjunctive management of transboundary surface water and groundwater resources.[407]

CASE STUDY 36: **E-flows knowledge base and capacity-building via stakeholder engagement in the Pungwe, Buzi and Save River Basins**[408]

The transboundary Pungwe, Buzi and Save River Basins are shared between Zimbabwe and Mozambique in Southern Africa. Mozambique and Zimbabwe signed the Pungwe Basin Water Sharing Agreement in 2016 to institutionalize transboundary water management in the Pungwe Basin. Draft Agreements that were in place for the Buzi and Save Basin are similar to that of the Pungwe Basin. Article 9 of the Pungwe Water Sharing Agreement concerns "Protection, Preservation and Conservation of the Environment". It includes interim environmental flow recommendations pending detailed studies. On 29 July 2019, both Governments signed the Agreement on Co-operation on the Development, Management and Sustainable Utilization of the Water Resources of the Buzi Watercourse. Cooperation in these basins is driven by water resources development and management projects that require the

406 The baseline assessment for this part of the work is documented in Sood and others (2017).

407 Lautze and others (2018).

408 Dominic Mazvimavi, "Working with stakeholders linking environmental flows to transboundary governance in the Pungwe, Buzi & Save River basins", presented at the Global Workshop on Water Allocation, Geneva, 16 October 2017.

two countries to cooperate as stipulated in the Revised Protocol on Shared Watercourses in the Southern African Development Community (SADC), which was signed in 2000.[409]

In the absence of a bilateral institution that will be responsible for the Agreement's implementation, the International Union for Conservation of Nature (IUCN) and Waternet developed a pilot project that aimed to increase stakeholder engagement and build capacity and a knowledge base utilizing innovative communication technology methods for environmental flow recommendations. Three phases were adopted. The first phase involved developing the awareness of policymakers and water resources managers about socioeconomic and ecological benefits from, and principles of integrating environmental flows in, transboundary water resources management (November/December 2015). The second phase involved demonstrating procedures for environmental flow assessment in a selected pilot river basin (July 2016). Finally, a learning-by-doing process was implemented, facilitating and guiding stakeholders and multidisciplinary country teams to jointly develop recommendations on environmental flows (August 2017–April 2018).

In the learning-by-doing phase, first, the Revue subbasin of the Buzi River Basin was selected to pilot the capacity-building approach. This was followed by the formation of multidisciplinary country teams in Mozambique and Zimbabwe along with the identification of key stakeholders to participate throughout the process. There was country-level and transboundary stakeholder participation in river basin situation analysis (identification of river-related ecosystems services and potential effects of river flow modifications on these services). Country teams jointly selected indicators for determining biophysical and socioeconomic responses to potential river flow modifications. Each country team collected data for selected indicators, and potential flow modifications. Country teams jointly evaluated biophysical and socioeconomic responses to potential river basin developments. Finally, country teams jointly recommended environmental flows for achieving agreed desirable levels of the provision of ecosystem services. The outcome was that the country teams jointly submitted environmental flow recommendations to policymakers responsible for transboundary management of the Revue subbasin. The country teams jointly presented policy recommendations for implementation of environmental flows.

A further idea to come out of the process was the possibility of developing an interactive mobile phone/ web-based application for participatory environmental flow assessment. This would involve uploading data and information- sharing by country teams in Mozambique and Zimbabwe.

The pilot project in this context was initiated by IUCN and Waternet based on an assessment of clear opportunities and favourable conditions for transboundary cooperation in implementing environmental flows by Mozambique and Zimbabwe. Most importantly, there was a long history of excellent bilateral collaboration in all the sectors between both States. There was also explicit commitment from both States to improve bilateral cooperation through implementation of transboundary water sharing agreements, and specifically to determine and implement environmental flow provisions of the bilateral agreements. Additional favourable conditions for cooperation and strong stakeholder engagement involved the States' demand for developing capacity for planning and managing environmental flows and a shared commitment to stakeholder participation in IWRM.

409 Smart Water Magazine, "Mozambique and Zimbabwe sign agreement to enhance water cooperation in the Buzi Watercourse", 12 September 2019.

3. Assessing Uses and Needs

a. Determining sectoral water uses and needs

Changes in different water uses and needs are usually the main driver for water allocation and reallocation. Water uses are typically divided into domestic, agricultural and industrial, and water used for energy production, hydropower generation having the most central role in altering and regulating transboundary flows. Assessments of water requirements for environmental flows are discussed in detail in section 2 above. In addition, in-steam water uses like navigation can set boundary conditions for water abstraction and altering flows (see Chapter III, section 2).

Besides the quantity of water needed for different uses, its quality and timing of use or release are important to consider. Quality is especially critical for domestic and certain industrial uses that typically require purification before abstraction, whereby purification costs rise with decreasing quality of the source water. In addition to alterations in flows, ecosystems are sensitive to alterations in nutrients, sedimentation and pollutant concentrations (see Chapter III, subsection 4c). When it comes to timing, irrigation needs vary considerably between seasons, and ecosystems may be especially sensitive to flow alterations from hydropower at certain times of the year, for example.

An additional factor to consider when determining water needs and allocations is the possibilities for improved efficiency and productivity in different sectors and for different water uses. Especially in water-scarce contexts, allocations in a national context should be informed by the relative efficiency of different water uses, which in turn has ramifications for transboundary allocation.[410] Ultimately, as water resources available for allocation are becoming increasingly limited, balancing different water uses and needs and clarifying their priority is one of the key tasks in the allocation process. Different approaches and mechanisms are discussed in detail in Chapter II, section 3, Chapter III, and Chapter VI, section 3.

b. Methods for water use assessments

There are a few general approaches on how to assess water use:[411]

- **Monitored observed use**, which is usually reliable for large urban, industrial or irrigation schemes. Mass balance modelling can also be utilized.
- **Registered authorized use**, based on records via licensing, permitting or billing.
- **Estimation**, via proxies like irrigated area or number of households.

Water footprint assessments provide one option for the assessment of sectoral, basin-level or national water use.[412] Return flow estimation is especially important in a transboundary context, when assessing how much water is allocable downstream. Return flows can be assessed with the same approaches as water use in general. The starting point for the assessment of water uses and needs is usually national data collection and management systems. They typically suffer from inconsistencies and gaps, however, making transboundary data-sharing also challenging. Data on groundwater use is especially limited. In the absence of complete data sets, FAO Aquastat[413] and global hydrological models[414] can help with making initial estimates, and developing harmonized water-use assessment systems is important to prioritize in the transboundary cooperation. In addition to existing water uses and needs, it is important to also assess potential and future

410 Speed and others (2013).

411 Ibid.

412 Arjen Y. Hoekstra and others, *The Water Footprint Assessment Manual: Setting the Global Standard* (London, Earthscan, 2011); Arjen Y. Hoekstra and Mesfin M. Mekonnen, "The water footprint of humanity", *Proceedings of the National Academy of Sciences*, vol. 109, No. 9 (February 2012), p. 3232–3237.

413 FAO, Aquastat.

414 ISIMIP, "The Inter-Sectoral Impact Model Intercomparison Project".

needs. Historical time series data sets can help to estimate future uses, but the analyses should be then set into the overall context of the regional development, taking into account socioeconomic, environmental and climatic factors, as described in Chapter III and subsections 1 and 2 above.

c. Sharing information on sectoral water uses

Common approaches between and among riparian countries on sharing information on sectoral water uses are essential for determining equitable and reasonable water allocation, as well as avoiding significant harm, and help in identifying possibilities for water-food-energy-ecosystem nexus solutions[415] and benefit-sharing[416] (see also Chapter IV). Joint nexus assessments help to deal with the complexities of analysing several interconnected sectors with their associated stakeholders. The Transboundary Nexus Assessment Methodology (TBNA) developed by UNECE enables stakeholders to identify positive and negative linkages, benefits and trade-offs between/among relevant sectors in different climatic and socioeconomic scenarios (see Chapter IV, subsection 2c). The nexus linkages are first identified and mapped qualitatively in a participatory process involving experts and officials. Then the linkages that have been deemed "high priority" are quantified, utilizing available data and tools, including modelling. The nexus methodology further assists in identifying means for coherent integration of sectors and their needs.[417]

4. Assessing Transboundary Impacts

a. How to assess transboundary impacts of water allocation

Impact assessment is an essential part of the planning and decision-making processes related to any large projects, programmes or other initiatives, including those for or affecting transboundary water allocation. The aim of an impact assessment is to identify and evaluate the likely key effects (i.e. impacts) that the planned initiative is likely to have, along with the possible measures to prevent, reduce, mitigate and control adverse effects and to enhance positive effects. To do so, an impact assessment typically considers a set of alternative options for the planned initiative. To ensure its effectiveness, the assessment should also be carried out at an early stage of planning. Several tools exist for impact assessment, each with differing thematic and/or methodological emphasis. The most widely used tools are environmental impact assessment (EIA) and strategic environmental assessment (SEA). While both tools focus on the environment, their present-day use may also consider related societal impacts (e.g. health, economic, social, cultural and gender). Similarly, EIA and SEA may be complemented by other relevant impact assessment approaches, including those capturing also the broader impacts of the planned initiatives (e.g. social impact assessment or cultural impact assessment[418]), as well as approaches with a specific focus, for example on water (e.g. hydrological impact assessment, cumulative impact assessment). Furthermore, assessment of benefits provides an important alternative angle for identifying synergies in transboundary contexts (for further details, see Chapter IV).

415 UNECE, *Reconciling Resource Uses in Transboundary Basins* (2015).

416 UNECE, *Policy Guidance Note on the Benefits of Transboundary Water Cooperation* (2015).

417 UNECE, *Methodology for Assessing the Water-Food-Energy-Ecosystems Nexus* (2018).

418 Adriana Partal and Kim Dunphy, "Cultural impact assessment: a systematic literature review of current methods and practice around the world", *Impact Assessment and Project Appraisal*, vol. 34, No. 1 (2016), p. 1–13.

CASE STUDY 37: Assessments of cumulative transboundary impacts in the Lower Mekong River Basin

The Mekong River Commission (MRC) considered the development of water infrastructure, especially large-scale hydropower and irrigation, on the transboundary Mekong River mainstream as one of the most important strategic issues facing the Lower Mekong River Basin. As a result, the MRC Member States (Cambodia, Laos, Thailand and Viet Nam) commissioned a strategic environmental assessment (SEA) of planned mainstream dams to assist them in working together and to make the best decisions for the Basin. The SEA began in May 2009 and was completed 16 months later. The SEA complemented the 2010 MRC Basin Development Programme's Scenario Assessment of the countries' planned projects in hydropower and irrigation. The strategic decision at the time concerned whether and how best to construct hydropower dams across the Mekong River—a development that would have far-reaching economic, social and environmental implications, both positive and potentially adverse.

Twelve hydropower schemes had been proposed on the lower reaches of the Mekong mainstream. The SEA sought to identify the potential opportunities and risks, as well as the contribution of these proposed projects to regional development and the most appropriate mainstream Mekong hydropower development strategies. In particular, the SEA focused on regional distribution of costs and benefits with respect to economic development, social equity and environmental protection. The SEA, as well as the Basin Development Programme Assessment, provides the scientific basis for countries' discussion on benefits and trade-offs of planned developments, and contributed to the preparation of, and agreement on, the Basin Development Strategy for Mekong River Basin for 2016–2020.

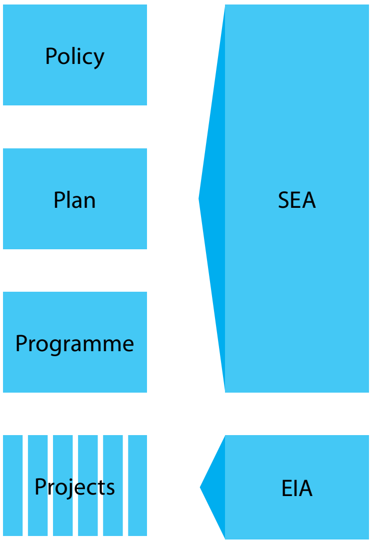
To close more knowledge gaps and include more planned water and related development sectors, the MRC released the Study on the Sustainable Management and Development of the Mekong (the Council Study) in 2017. The findings from the Council Study have been used by countries in debating the impacts of planned projects on water level, flows and quality, including fisheries and sediment, during the prior consultation process for mainstream dams. The strengthened knowledge of the MRC contributed to the preparation of, and agreement on, the latest Basin Development Strategy 2021–2030, which calls for more proactive regional planning to come up with new joint and basin-wide investment projects with multiple benefits, including flood management, drought relief, energy, navigation and environmental protection.

While EIA focuses on the environmental impacts of a single project, typically maintaining a rather technical focus, SEA addresses wider aspects of development, focusing on a broader set of environmental impacts of plans, programmes, policies and legislation covering a set of related projects (Figure 15). EIA is therefore particularly strong for detailed discussion on a clearly defined project(s), while SEA facilitates discussion about cumulative impacts and broader, more fundamental issues, such as what kinds of projects (and where) would best achieve the desired development with minimal adverse effects.[419] Although SEA can be considered a more appropriate tool in the context of general water allocation negotiations within a river basin, at best, any development with likely significant adverse transboundary impact makes use of both tools, with SEA focusing on broader aspects of development and EIA then providing a more detailed view on the impacts of the projects that are identified, based on the SEA process. In this context, future plans/programmes, as well as planned projects with likely significant adverse transboundary impacts, should be shared with the affected countries as soon as reasonably possible in accordance with the principles of prior notification and consultation.

419 UNECE, *Protocol on Strategic Environmental Assessment to the Convention on Environmental Impact Assessment in a Transboundary Context* (New York and Geneva, United Nations, 2017).

FIGURE 15

Simplified visualization of the main emphasis for environmental impact assessment (EIA) and strategic environmental assessment (SEA) and their key characteristics



SEA	EIA
The perspective is strategic and long-term	The perspective is on the execution and in the short/medium term
The process is cyclical and continuous	The process is discrete, motivated by concrete intervention proposals
The aim is to help build a desirable, jointly agreed plan for future developments	The project to be assessed has to be known and described at a relatively detailed level
There is a large amount of uncertainty and the data is typically scarce and of varying quantity	The focus is relatively clear, and data typically rather well available or can be collected
Follow-up performed through the development of policies, plans, programmes and projects	Follow-up performed through the implementation of the selected option for a project
Putting the strategy into practice depends on the implementation of more detailed plans	Projects requiring an EIA are executed (or not), once their environmental feasibility is guaranteed

Source: Marko Keskinen and Matti Kummu, *Impact Assessment in the Mekong: Review of Strategic Environmental Assessment (SEA) and Cumulative Impact Assessment (CIA)* (Aalto, Finland, Aalto University, Water and Development Research Group, 2010) (modified).

As a general recommendation in transboundary contexts, it is important to define the methods and scale of the assessments together with the different parties, taking into account five key dimensions relevant for carrying out the assessment: geographic scope; sectoral mandate; level of integration; likelihood of compliance; and capacity to implement.[420]

b. Legal requirements regarding transboundary impacts of allocation

International law has several different frameworks with related substantive and procedural requirements for EIA, SEA and the prevention, reduction and mitigation of transboundary impacts that may be applicable to water allocation, depending on the context. According to the Water Convention, States need to ensure that EIA and other means of assessment are applied to prevent, control and reduce transboundary impact (Art. 3.1h).[421] For this purpose, one of the tasks of joint bodies is to participate in the implementation of an EIA relating to transboundary waters (Art. 9.2j). States must also carry out joint or coordinated assessments of the conditions of transboundary waters and the effectiveness of measures taken for the prevention, control and reduction of transboundary impact (Art. 11.3). A joint exercise at the regional level resulted in the Second Assessment of Transboundary Rivers, Lakes and Groundwaters.[422] In the Watercourses Convention, EIA is linked to notification concerning planned measures with possible adverse effects upon other riparian States. Accordingly, such notification must be accompanied by available technical data and information, including the results of any EIA (Art. 12).[423] The Draft Articles on the Law of Transboundary Aquifers include a similar provision in relation to transboundary aquifers or aquifer systems (Art. 15.2).

420 Christina Leb and others, *Promoting Development in Shared River Basins: Tools for Enhancing Transboundary Basin Management* (Washington, D.C., World Bank, 2018).

421 See UNECE, *Guide to Implementing the Water Convention* (2013), p. 53–55.

422 UNECE, *Second Assessment of Transboundary Rivers, Lakes and Groundwaters* (2011).

423 See Rieu-Clarke, Moynihan and Magsig (2012), p. 142.

Transboundary EIAs and SEAs can be relatively complex processes, as the riparian States may have differing institutional settings and differing views regarding the process. In addition to the United Nations global water conventions, the UNECE Convention on Environmental Impact Assessment in a Transboundary Context (Espoo Convention) requires transboundary EIA and provides step-by-step procedural requirements, including for early notification, preparation of EIA documentation, consultations with authorities, public participation and taking into account their result in the final decision regarding the planned activity.[424] Accordingly, a State under whose jurisdiction a proposed activity is envisaged to take place must ensure that a transboundary EIA is undertaken prior to a decision to authorize or undertake a proposed activity listed in Appendix I that is likely to cause a significant adverse transboundary impact (Art. 2.3). Moreover, the International Court of Justice stated in *Pulp Mills on the River Uruguay (Argentina vs. Uruguay)* (Judgment of 20 April 2010) that EIA "may be considered a requirement under general international law". In this regard, States need to undertake EIA "where there is a risk that the proposed industrial activity may have a significant adverse impact in a transboundary context, in particular, on a shared resource". Furthermore, the Court observed that "due diligence, and the duty of vigilance and prevention which it implies, would not be considered to have been exercised, if a party planning works liable to affect the regime of the river or the quality of its waters did not undertake EIA on the potential effects of such works" (para. 204).[425]

Appendix I of the Espoo Convention covers the following projects that can be relevant to transboundary water allocation:

- large dams and reservoirs;
- groundwater abstraction activities or artificial groundwater recharge schemes (annual volume of water 10 million m^3 or more);
- transfer of water resources between river basins (over 100 million m^3/year if the transfer aims at preventing water shortages; or over 5 per cent of the 2,000 million m^3/year flow); and
- wastewater treatment plants (capacity exceeding 150,000 population equivalent).

Accordingly, a party of origin should notify potentially affected parties if a significant adverse transboundary impact from those activities is "likely" or cannot be excluded.[426] Ultimately, a transboundary EIA is only undertaken if an affected party responds positively to the notification.

According to the Espoo Convention, EIA shall, as a minimum requirement, be undertaken at the project level. In addition, States must endeavour to apply the principles of EIA to policies, plans and programmes (Art. 2.7). However, the Protocol on Strategic Environmental Assessment specifically requires that States must ensure that SEA at a national level is carried out for certain plans and programmes, including water management plans and programmes, that set the framework for future development consent for projects that require EIA (Art. 4.2) and are likely to have significant environmental, including health, effects. Annex I and II of the Protocol specifically list the water-related projects that might be covered by plans/programmes, some of which are directly relevant to water allocation in a transboundary context, including, among others:

- large dams and reservoirs (Annex I, Art. 11);
- groundwater abstraction activities in cases where the annual volume of water to be abstracted amounts to 10 million m^3 or more (Annex I, Art. 12);
- water management projects for agriculture, including irrigation and land drainage projects (Annex II, Art. 3);

424 UNECE, "Environmental assessment" (n.d.).

425 See McIntyre (2011), p. 124–144.

426 "Likely" is the terminology used in the Convention, including Appendix I, which is interpreted by the Espoo Convention's Implementation Committee to mean "cannot be excluded". See, for example, UNECE, Findings and recommendations of the Implementation Committee on compliance by the United Kingdom of Great Britain and Northern Ireland with its obligations under the Convention in respect of the Hinkley Point C nuclear power plant (ECE/MP.EIA/2019/14).

- works for the transfer of water resources between river basins ((Annex II, Art. 78).[427]

Article 10 of the Protocol provides for transboundary consultations on the plans and programmes and a related SEA report. The notification is required where a party of origin considers that the implementation of a plan or a programme is likely to have a significant transboundary effect or where the party likely to be significantly affected so requires. Similarly to the Convention, the Protocol sets requirements for carrying out an SEA, including for screening (identification of whether an SEA is required), scoping (identification of the scope of the SEA, i.e. what issues will it cover), preparation of an environmental report, public participation, and consultation with national environmental and health authorities and potentially affected parties, taking the results of SEA and all consultation into account in the final decision regarding the plan or a programmme.

In sum, transboundary water allocation may be subject to several substantive and procedural obligations related to EIA and SEA under a variety of frameworks in international law, depending on the specific context. Customary international law requires EIA when a planned activity, such as industrial works or an infrastructure project, may have a significant adverse impact in a transboundary context.[428] The United Nations global water conventions also contain certain EIA obligations for States parties and the duty to take all appropriate measures to prevent transboundary harm, which may be applicable to allocation processes and/or outcomes. Furthermore, the UNECE Espoo Convention and SEA Protocol require that assessments are extended across borders when a planned activity may cause significant adverse transboundary impacts or a plan or programme sets the framework for such an activity. Therefore, States may need to consider using EIA or SEA as tools or supporting procedures during their transboundary water allocation negotiations and planning processes. It is therefore strongly recommended to follow the guidelines that the Espoo Convention and UNECE documents provide on how best to carry them out.[429]

5. Structured Decision Support and Management Responses for Water Allocation

a. Knowledge base, structured decision support and decision support systems

The previous sections have introduced the key aspects needed to establish a knowledge base on water allocation for a specific transboundary context—assessment of water resources, environmental requirements, water uses and needs, and transboundary impacts. Such a knowledge base is required to make well-informed decisions regarding water resources management and related water allocation. Water allocation in a transboundary context typically concerns a variety of actors, all with differing interests and needs. Different kinds of decision-support approaches and methods can be used to make the best possible use of the variety of views, as well as the different forms of information available throughout the decision cycle and structured decision-making processes (Figure 16).[430] Two practical methods and tools that are increasingly applied for structured decision-making in a transboundary context are presented here:

- multi-criteria decision analysis (MCDA);
- decision support systems (DSS).

427 For the full lists of water-related projects that might be covered by plans/programmes, refer to Annex I and II of the Protocol.

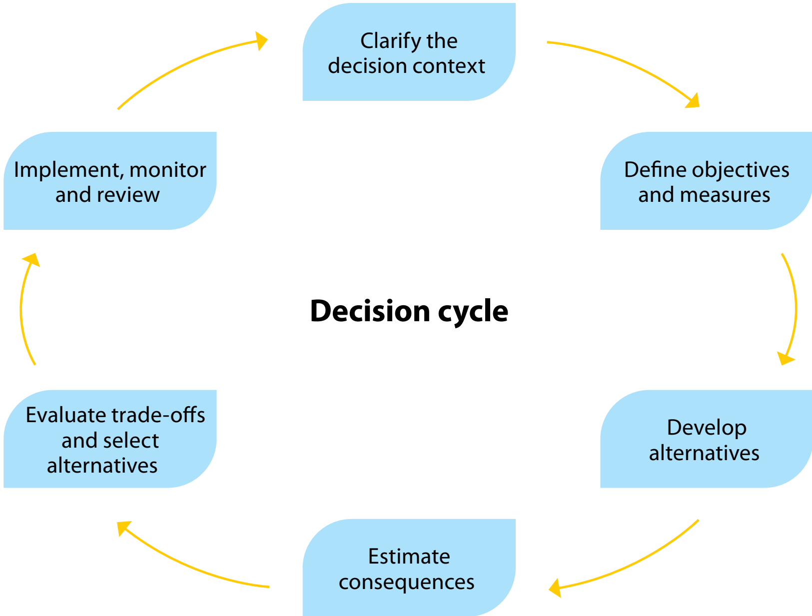
428 Ibid.

429 UNECE, "Introduction: Guidance on the practical application of the Espoo Convention" (n.d.); UNECE, *Guidance on the Practical Application of the Espoo Convention* (n.p., United Nations, 2006).

430 Robin Gregory and others, *Structured Decision Making: A Practical Guide to Environmental Management Choices* (Chichester, United Kingdom, Wiley-Blackwell, 2012).

FIGURE 16

Decision cycle



Source: Robin Gregory and others, *Structured Decision Making: A Practical Guide to Environmental Management Choices* (Chichester, United Kingdom, Wiley-Blackwell, 2012).

b. Multi-criteria decision analysis in transboundary water allocation

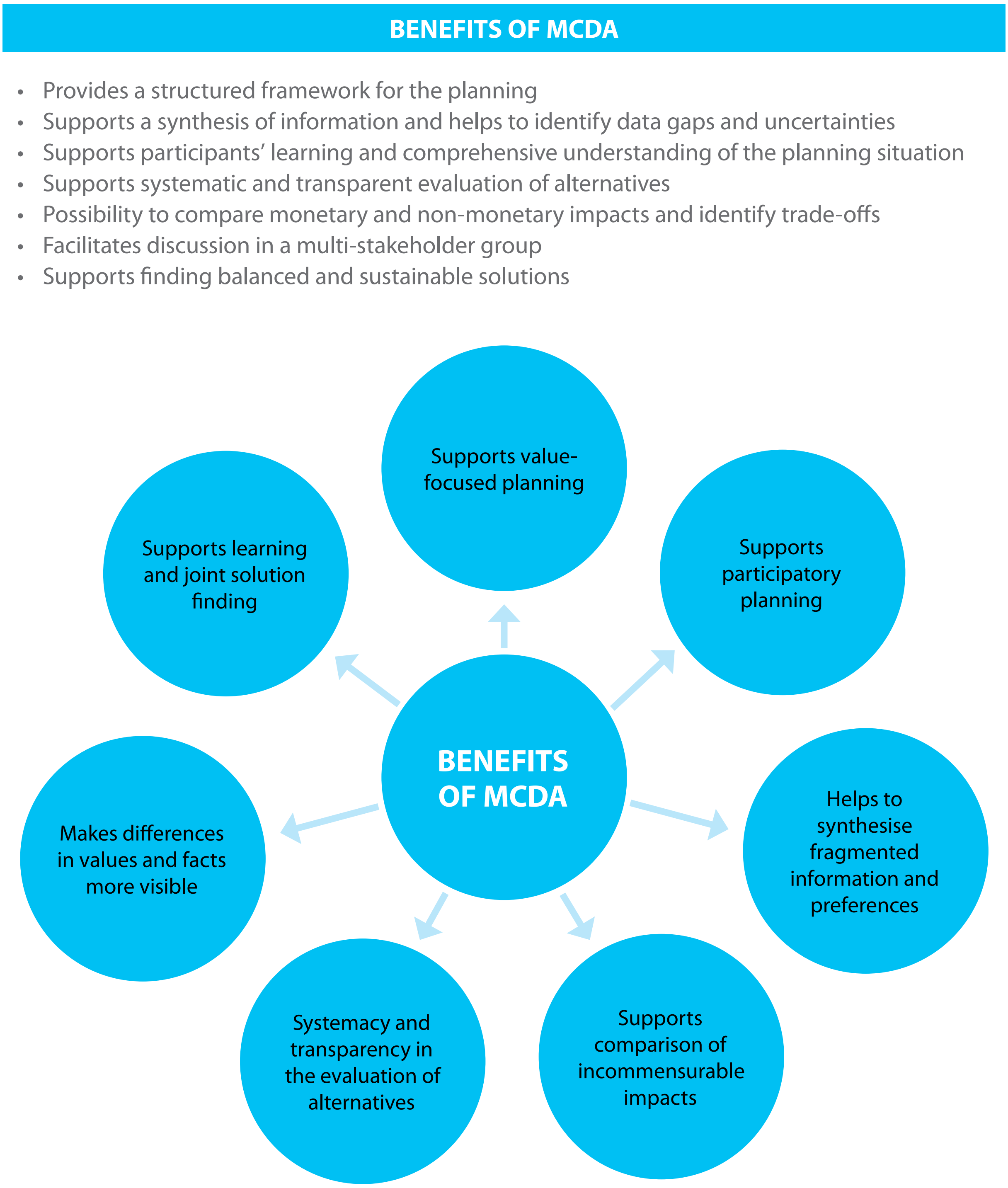
Multi-criteria decision analysis (MCDA) is a general term for systematic approaches that support the analysis of multiple alternatives in complex problems involving different objectives, intangible and incommensurable impacts and uncertainties.[431] They are especially useful when evaluating trade-offs and selecting alternatives (Figure 17). MCDA methods aim at improving the quality of decisions by providing an overall view of the pros and cons of the different alternatives. The main phases of MCDA are: 1) identification of objectives; 2) structuring them into a form of hierarchy; 3) developing alternatives; 4) assessing their performance with regard to objectives; and 5) collecting preference information. The potential benefits of MCDA are presented in Figure 17. The MCDA process and its application are presented in Chapter VIII.

MCDA can be applied to help stakeholder involvement by collecting, structuring, integrating and analysing information from different sources. A collaborative MCDA-based process applied optimally should result in all involved parties learning from each other. Consequently, this can open up assessment and allocation processes by highlighting the diversity of opinions, conflicting interests, ignored uncertainties and new options. One of the strengths of MCDA is its ability to combine information from different sources and highlight the importance of values in decision-making. The role of facts is often overemphasized compared with that of values. Typically, the ranking of alternatives depends very much on the value placed on different criteria. An exception is a case where one alternative outperforms other alternatives with respect to all, or almost all, criteria. The number and range of MCDA applications is very large, but there are relatively few cases related to transboundary waters. Table 10 summarizes six examples of applications of MCDA in a transboundary context.

431 Valerie Belton and Theodor J. Stewart, *Multiple Criteria Decision Analysis: An Integrated Approach* (Dordrecht, Springer Science + Business Media, 2002).

FIGURE 17

Potential benefits of multi-criteria decision analysis



Source: Finnish Environment Institute, 2021.

TABLE 10

Examples of multi-criteria decision analysis applied in transboundary water systems

Source	Countries/water system	Topic	Methods	Criteria and weights
Avarideh and others (2017)[432]	Iraq and Iran, Sirwan–Diyala River	Determining water share allocation to riparian countries	Weighted sum, pairwise comparison	32 indicators used, 3 different weight scenarios for factors (main criteria)
Dombrowsky and others (2010)[433]	Israel, Palestinian Authority, Kidron/ Wadi Nar Basin	Comparison of wastewater management alternatives	Cost-benefit and multi-criteria analyses	6 selected physical-institutional management options; MCDA is not described in detail in the paper
Gorgoglione and others (2019)[434]	Brazil–Uruguay, Cuareim/Quaraí catchment	Exploring policy options in a water-sharing conflict	MCDA (PROMETHEE), scenario analysis	10 criteria covering environmental and socioeconomic aspects
Kapetas and others (2019)[435]	Greece, Republic of North Macedonia, Axios Delta	Sociotechnical evaluation of intervention options for improving water budget	DPSIR and multi-criteria analysis	3 criteria used: impact, cost, ease of implementation, 5 intervention options
Quba'a and others (2017)[436]	Israel, Jordan, Lebanon, Palestinian Authority, Syria, Turkey, Jordan River Basin	Comparative assessment of joint water development initiatives	MCDA (Simple Additive Weighting)	8 criteria, 8 weight scenarios, sensitivity analysis for criteria weight was performed
Srdjevic and Srdjevic (2014)[437]	Serbia, Romania, Djerdap I reservoir, Danube	Allocation of reservoir storage for main reservoir uses	Analytic Hierarchy Process	5 criteria used, 6 alternatives (main reservoir uses)

Source: Finnish Environment Institute, 2021.

c. Decision support systems

Many types of the knowledge and data described in the previous sections of this chapter can be used as inputs in a decision support system (DSS). Usually, a DSS refers to a computer-based system to support complex decision-making processes in a specific domain.[438] A DSS can combine databases, data and information

432 Faribah Avarideh, Jalal Attari and Ali Moridi, "Modelling equitable and reasonable water sharing in transboundary rivers: the case of Sirwan-Diyala River", *Water Resources Management*, vol. 31 (2017), p. 1191–1207.

433 Ines Dombrowsky and others, "How widely applicable is river basin management? An analysis of wastewater management in an arid transboundary case", *Environmental Management*, vol. 45, No. 5 (May 2010), p. 1112–1126.

434 Gorgoglione and others (2019).

435 Leon Kapetas and others, "Water allocation and governance in multi-stakeholder environments: insight from Axios Delta, Greece", *Science of The Total Environment*, vol. 695 (December 2019), 133831.

436 Rola Quba'a and others, "Comparative assessment of joint water development initiatives in the Jordan River Basin", *International Journal of River Basin Management*, vol. 15, No. 1 (2017), p. 115–131.

437 Zorica Srdjevic and Bojan Srdjevic, "Modelling multicriteria decision making process for sharing benefits from the reservoir at Serbia-Romania border", *Water Resources Management*, vol. 28 (2014), p. 4001–4018.

438 Carlo Giupponi, "D9.4/9.5: Using modern decision support systems for evidence based policy making in IWRM in developing countries: coordinating European Water Research for Poverty Reduction – SPLASH" (n.p., 2011).

management, simulation models, socioeconomic evaluation tools, decision analysis techniques, (GIS) and user interfaces in an informative way. A DSS in the water management sector is often tailored for a particular case and can integrate different generic components, tools, methods and existing software packages, depending on the river basin characteristics and the decision-making process at hand.

A significant benefit of a DSS is that it can facilitate communication between stakeholders and riparian countries by providing an efficient platform for sharing information and supporting discussion about potential decisions and their implications.[439] Hence, a DSS can provide greater transparency in the decision-making processes, which is a crucial component for transboundary water allocation. While a DSS can assist in decision-making, it does not replace well-trained, skilled managers and experts, and cooperative processes.[440] A DSS can be intended to be used on different time horizons. It can be used in long-range strategic planning and decision-making as well as analysing scenarios (e.g. hydro-climatic change, demand development, different policies and management plans).[441] On the other hand, a DSS can also be used for operational purposes in day-to-day allocation decisions, as well as in data- and information-sharing. Moreover, models included in a DSS represent different temporal and spatial scales and provide input to each other.[442]

To avoid an undesirable situation where an expensive system remains unused, an overall requirement is that the development of a DSS is based on a real need. A common feature of a successful DSS is that it is developed in close collaboration with end users, to ensure that it meets the requirements and to foster trust and commitment in the system.[443] If deployed as part of a transboundary water allocation framework, riparian States must therefore together acknowledge the validity of the DSS to inform the decision-making process.[444]

d. Management responses for water allocation

After the knowledge base has been built and different alternatives for transboundary water allocation have been evaluated, with the potential help of tools such as MCDA and DSS, described above, the knowledge of the best options feeds forward to management and institutional-level responses. The management responses typically take their form in allocation arrangements, agreements and their national implementation, as described in detail in Chapter VIII on operationalizing transboundary allocation and elsewhere in this Handbook. As described in the decision cycle (Figure 16), management responses and their impact on the original allocation issue require continuous monitoring and evaluation. If the impact is not desired, the information needs and associated knowledge and data and the decisions should be adapted accordingly. The DPSIR framework (Figure 13) and management cycle (Figure 12) presented in this chapter help with iterating the information needs. Some impacts can be assessed through monitoring the outcomes. Some decisions linked to projects, programmes or policies, for example, can be assessed with impact evaluations.[445]

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439 Peter C. von der Ohe and others, "Monitoring programmes, multiple stress analysis and decision support for river basin management", in *Risk-Informed Management of European River Basins*, Jos Brils and others, eds., The Handbook of Environmental Chemistry, vol. 29 (Berlin, Springer, 2014).

440 GWP and INBO, *A Handbook for Integrated Water Resources Management in Basins* (Stockholm; Paris, 2009).

441 Ibid.

442 Aris P. Georgakakos, "Decision support systems for integrated water resources management with an application to the Nile Basin", in *Topics on System Analysis and Integrated Water Resources Management*, Andrea Castelletti and Rodolfo Soncini Sessa, eds. (Amsterdam, Elsevier Science, 2007), p. 99–116.

443 Henrik Nygård and others, "Decision-support tools used in the Baltic Sea area: performance and end-user preferences", *Environmental Management*, vol. 66 (2020), p. 1024–1038.

444 GWP, "The role of decision support systems and models in integrated river basin management", Technical Focus Paper (Stockholm, 2013).

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