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Perspectives on the Establishment of Integrated Watershed Management in the Amudarya and Syrdarya River Basins

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Author's declaration

No portion of the work referred to in this thesis has been submitted in support of an application for another degree or qualification of this or any other university or other institute of learning.

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ABSTRACT OF THESIS submitted by:
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The given study examines the current state of Integrated Water Resource Management (IWRM) and Integrated Watershed Management (IWM) implementation in the Amudarya and Syrdarya river basins of Central Asia. The research establishes an analytical framework by exploring the interrelationships between IWRM and IWM concepts and explores their practical implications in the region. Findings reveal that while Central Asian countries have made significant efforts to improve water resource management at the national scale, there are still challenges due to political, legal, and financial discrepancies that hinder the effectiveness of institutions in performing management of the two main watersheds of the region.

The study identifies key issues, including the lack of clear water allocation principles, competing sectoral demands, and the prioritization of national interests over basin-wide needs. These factors contribute to the fragmentation of water management at both national and regional levels. The research emphasizes the importance of developing comprehensive basin management plans, strengthening institutional coordination, and promoting data sharing as the developing new region-specific principal grounds for integrated watershed management, which could bring clarity into the institutional structure and operational tasks at all levels.

Keywords: Integrated Water Resource Management, Integrated Watershed Management, Amudarya River Basin, Syrdarya River Basin, Central Asia, transboundary water management, regional cooperation, enabling environment, institutions, management

List of Figures

List of Abbreviations <optional>

ARB Amudarya river basin

ASBP Aral Sea Basin Program

BWC Basin Water Council

BWO Basin Water Organization

CA Central Asia

ESV Ecosystem service value

FAO Food and Agricultural Organization

GDP Gross Domestic Product

WR Water resources

IWM Integrated Watershed Management

IWMI International Water Management Institute

IWRM Integrated Water Resource Management

KAZ Kazakhstan

KGZ Kyrgyzstan

SRB Syrdarya river basin

TJ Tajikistan

TKM Turkmenistan

UN United Nations

UNDESA United Nations Department of Economic and Social Affairs

UNDRR United Nations Office for Disaster Risk Reduction

UZB Uzbekistan

WHO World Health Organization

WM Water management

WRM Water resource management

WUA Water User Association

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1. Introduction

The thesis examines the current state of Integrated Water Resource Management (IWRM) and Integrated Watershed Management (IWM) implementation in the Amudarya and Syrdarya river basins of Central Asia. Water management in this arid region has long been a critical issue, with competing demands between upstream and downstream countries creating tensions over water allocation and use. As climate change and population growth further strain water resources, there is an urgent need to adopt more holistic and sustainable approaches to managing these transboundary river systems (Xenarios et al. 2019).

The concepts of IWRM and IWM have emerged globally as frameworks for improving water governance and promoting more equitable and efficient resource use (Tarlock 2007). However, their practical implementation faces many challenges, particularly in complex transboundary contexts (Karthe, Chalov, and Borchardt 2015). This research aims to assess the progress, barriers, and opportunities for establishing IWM in the Amudarya and Syrdarya basins by analyzing the current institutional, policy, and management landscapes.

Drawing on a comprehensive literature review, stakeholder surveys, and analysis of recent policy developments, this study will evaluate the progress on the IWM establishment in Central Asia by identifying key gaps and areas for improvement, providing some insights and recommendations to support more integrated and sustainable water management.

The findings of this study have important implications for policymakers, water managers, and development partners working to address water security challenges in Central Asia. As water scarcity and environmental degradation continue to threaten livelihoods and ecosystems in the Aral Sea basin, advancing IWM offers a pathway toward more resilient and cooperative water governance. This thesis aims to contribute to that goal by offering a critical assessment of current approaches and outlining priorities for strengthening integrated water management in the region.

1.1. Background

Water management in the transboundary Amudarya and Syrdarya river basins has long been a critical issue for Central Asian countries. The collapse of the Soviet Union in 1991 fragmented previously integrated water management systems, creating new challenges for cooperation and equitable resource allocation between upstream and downstream nations. Existing research has documented the tensions arising from competing water demands for irrigation, hydropower generation, and environmental flows (Karthe, Chalov, and Borchardt 2015).

The concepts of IWRM and IWM have emerged globally as frameworks for improving water governance and promoting more sustainable resource use. However, their practical implementation in complex transboundary contexts remains controversial, with debates around the effectiveness of top-down versus bottom-up approaches and the role of international organizations in facilitating cooperation (Dukhovny, Sokolov, and Ziganshina 2015; Sehring and Ibatullin 2020).

The region heavily relies on agricultural production. Irrigation, being the main water withdrawal sector, makes water distribution a critical factor in national security for all countries, while energy production from hydropower entails patterns harmful downstream, adding a new variable to the transboundary water management equation (Saidmamatov, Sobirov, et al. 2024). Being the reflections of each other, Water and Land are highly interconnected and interdependent (Saidmamatov et al. 2023). Therefore, the issues of water quality or quantity, decreasing soil productivity, and land degradation cannot be addressed as mere symptoms but as signals of a systemic error. The deep transformational software are synonymous yet differing frameworks: Integrated Watershed Management (IWM) and Integrated Water Resource Management (IWRM).

While many studies have examined institutional arrangements for water management in Central Asia (Dukhovny and Schutter 2011a; Sehring 2009b; Sehring 2009a), there remains a significant gap in understanding how IWRM and IWM principles can be effectively operationalized, given the region's unique political, economic, and environmental constraints.

This research aims to address these gaps by revisiting the state of IWRM and IWM implementation in the Amudarya and Syrdarya basins. By analyzing their practical implications with a comprehensive assessment framework synergized from both concepts, this study will contribute to a revision of the challenges and opportunities for advancing integrated water management in Central Asia.

1.2. Research aims and objectives

The research question for the study is formulated in the same way as its title: "What are the perspectives on the establishment of Integrated Watershed management in the Amudarya (ARB) and Syrdarya river basins (SRB)?" To answer this question, the study outlines several subquestions: one on the theoretical framework (IWM) and the other on its application in the study area. Together, the processes of finding the answers to these make up the design of the study.

First, the research attempts to understand and discriminate between the definitions of IWM and IWRM and track the changes in approaches to water management, as well as IWM's development, compounds, criteria, conceptual and analytical frameworks.

Next, the study area is explored regarding the previous findings' guidance. This process could have theoretically proceeded independently, without the expectations brought by the international criteria; however, these elements are analyzed and compared, allowing for the systematization of existing problems within the universal frameworks, which makes up the answer to the main research question. This aim is divided into the following objectives:

1. Define watershed and watershed management and provide an outlook on the development of water management, highlighting milestones of paradigm shifts globally.
2. Collect and bring to a common denominator the information on the practical guidelines of the IWM and IWRM concepts, establish the interrelation between these concepts in theory.
3. Explain the IWM analytical framework and prepare a criterion basis for applying it to the situation in CA.
4. Explore the facts relevant to water management in Central Asia, focusing on the factors that are significant for national and transboundary water management in CA.
5. Describe the ARB and SRB as hydrological systems with human impacts and pressures.
6. Evaluate the national IWRM processes and discuss the facts relevant to the IWM establishment. Outline the problems in IWRM processes that hinder or help the IWM establishment in the river catchments.
7. Based on the regional context, elaborate on the modern issues that hinder the IWM in the Amudarya and Syrdarya river basins.

1.3. Research structure

The research consists of an Introduction, a Literature review, a Methodology, the main body of the research (4. Results), a Discussion, and a Conclusion. The Introduction explains the problem and its significance in the field. The literature review represents the preparatory knowledge necessary for the application of the IWM framework in the region: the first subchapter of the literature review represents the outputs from the exploration of the watershed and watershed management. The other subchapter concentrates the explanatory information on the study area, the ARB and SRB, as well as some factors that define or influence the IWM processes in Central Asia: socioeconomic, political, and ecological overview. Additionally, the literature review incorporates the Conceptual Framework and Analytical Frameworks of the study. The first one discloses IWM and IWRM concepts and their interrelations - all interpreted from the approaches suggested by the international institutions that deal with water management, mostly the United Nations (UN), Food and Agricultural Organization (FAO), and International Water Management Institute (IWMI), as well as the Scientific-Information Center of the Interstate Commission for Water Coordination (SIC ICWC) that shares its observations from the experience of Central Asia.

After that, the research applies the analytical structures identified in the Literature review to the field, providing data on IWRM and IWM implementation in CA in the form of a matrix with outlined problems within the IWRM thematic pillars, representing the study's results.

As the next step, that findings are compared to the etalons described in the Literature review, mainly IWRM criteria and IWM analytical elements, attempting to reduce the gap between the defacto-water management situation in the region with the framework understanding of IWM. The Discussion part navigates the research to a more narrowed-down, contextualized, and region-specific disclosure of the findings, noting the opinions of the water management professionals that are thought to suggest some logical vectors of improvement of IWRM components for IWM in the Amudarya and the Syrdarya river basins, while adding some commentaries on the potential principals for working out the solutions, which may not have been discussed in the literature, but represent the author's observations.

Lastly, the study concludes the main findings and again stresses the main stumbling blocks that need the attention of the related officials and professionals concerned, as well as the international experts providing the assistance on water management in the region.

2. Literature review

2.1. Conceptual Framework

2.1.1. Defining watershed management

"We each live in a watershed" (Vandas 2002)

There are many, yet not too differing definitions of the watershed, from simply *"the land area that drains water to a stream, river, lake or ocean"* (Vandsas 2002, 11), "*An Earth area, where surface stream (river) is formed, is called a catchment area or river basin*" (Dukhovny and Sokolov 2005, 33) to *"[…] watershed is not simply the hydrological unit but also socio-political-ecological entity which plays crucial role in determining food, social, and economical security and provides life support services to rural people*" (Wani and Garg 2009, 3), and also "*a hydrological response unit, a biophysical unit, and a holistic ecosystem in terms of the materials, energy, and information that flow through it"* (Wang et al. 2016, 2).

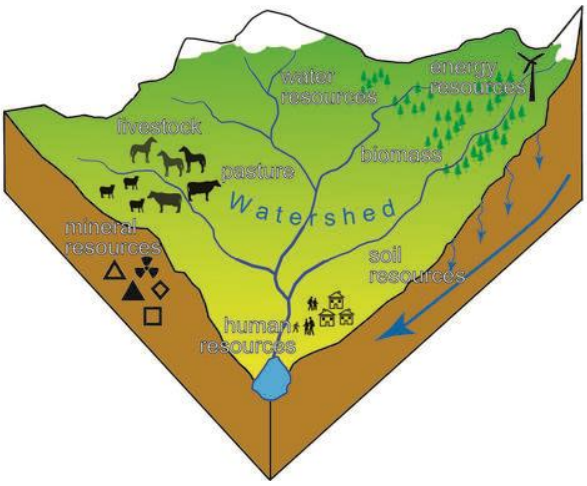

Figure 1. Schematic illustration of a Watershed. Source: Freie Universität Berlin, Image Credit: Ellen Leipner, Oktiabr Topbaev, 2015.

"Despite this long experience in water use and water management,

humans have failed to manage water well."

(Freie Universität Berlin on Heathcote 1998)

It became necessary to manage water and related domains holistically due to the integrated role the resource plays, given its multifaceted interrelations, impacts on ecosystems, and human dependency on drinking water.

Research on the evolution of water management shows that the knowledge of controlling water for various profits existed in most civilizations throughout human history. Historical manuscripts, such as those that captured controversies over water in Mesopotamia, the maintenance of irrigation canals in Babylon, or the script of the Atharva Veda from Ancient India, provide evidence of the active development of water management approaches (Wang et al. 2016).

The ability of humans to use water on a large scale in such a way that its quality remains the same, even though water management techniques have been known for a long time, is still doubted (Heathcote 2009). This became especially evident in the light of industrialization and the following two hundred years when the effects of the exponential growth of the global economy and population resulted in the degradation of natural resources and reduced supplies worldwide (2009).

Over the past hundred years, water consumption is estimated to have increased six times (Dukhovny and Sokolov 2005). Presently, one in three people has no access to safe water for drinking purposes (WHO 2023). Lack of sanitation and the effects of water-related natural disasters bring the deaths of millions of people annually; the growth of cities disturbs the water cycle, bringing the consequences of extreme water regimes, manifested in more frequent floods or droughts with significant human, material and financial losses (Pohl et al. 2017). Accelerated food production drove intensive water use for irrigation, which was assessed to destroy half of the river deltas and wetlands of previously rich water rivers by the beginning of the 21st century (Dukhovny and Sokolov 2005).

2.1.2. Development of water management concepts

With the rise of environmental consciousness, the need for reasonable resource use became evident to most systemically thinking individuals in the mid-20th century. During that period, though, the responsibility for the protection of nature was left to the national governments, with implementation through law enforcement and increased participation of populations and institutions (Wang et al. 2016). The early concepts of water management emerged in the 1950s and 1960s, excluding the rural development compound, which was resolved in the 1980s when the ecosystem concept emerged (2016). Therefore, one can speak of conceptualizing integrated water management as a holistic approach in the 80s.

FAO in 1987 defined water management as *"the process of developing and implementing a series of actions for the management of natural, agricultural, and human resources within a watershed to provide required and appropriate goods and services to society under the precondition that land and water resources are not negatively affected, <...> considering the prevailing socio-economic and institutional factors, within and beyond the watershed"* (Forch 2004, 120).

The Soil Conservation Society of America suggested understanding water management as *"integrated utilization, regulation and care of the water and land resources in a watershed with the aim of meeting predefined development goals*" (Forch 2004, 120).

In 1988, All India Soil and Land Use Survey and AFPRO Action for Food Production respectively described IWM as *"coherent development and utilization of the land and water resources within the natural boundaries of a watershed to deliver and produce in a sustainable manner from plant, animals and their products while ensuring a controlled and clean inflow of water into downstream communities"* and *"<...>.the attempt to optimally use the available natural resources in a watershed through technological and human* *development within one integrated program to improve the living standards of the local [population]"* (Forch 2004, 120).

Such a trend was explained by the enormous costs of depleted resources and degraded ecosystem services, topped with increased social inequity in many river basins worldwide (Tarlock 2007).

These developments opened the economic paradigm of water management, which started in the 1990s (Sehring 2009b). The Earth Summit in Rio de Janeiro and the Dublin Water conference recognized that mere commitment by national governments had not shown anticipated positive dynamics for socio-economic development, as well as the total freshwater water supplies (Rahaman 2012). Both international and domestic water laws supported the initial economic development plans pursued under a condition of water discrimination, namely semi-exclusive national rights to its storage and withdrawal, which encouraged unilateral national water resource management practices (Tarlock 2007).

The paradigm matured with the emergence of the Institutional vision of water management (Sehring 2009b). One of the examples that pushed towards the new vision of the place of water management is the notorious case of the Aral Sea, which is the study area of the given research. The 6th party in the transboundary resource in Central Asia, once the World's third largest lake, was systematically cut off from the waters inflow from the two rivers in favor of irrigated agriculture, resulting in one of the biggest ecological disasters (Dukhovny and Schutter 2011a). Not only did the local communities have to change their livelihoods completely, but all aquatic species were lost due to the dry-out (Yang et al. 2019).

Figure 2. Aral Sea shrinking. Sourse: NASA Earthdata, accessed April 29, 2024.

The echoes of the catastrophe are still nailed in the development agenda of the region's countries as continuing projects on revegetation of the site to at least protect the communities affected by the saline sandstorms rising with the strong winds from the bottom of the lake (Yang et al. 2019).

2.1.3. Development of the IWRM and IWM concepts

The vision of a river system as a freely exploited commodity persisted in many parts of the world in the 20th century, with consequences that the present generation has struggled or is now struggling to cope with. In contrast to that, IWRM emerged as a concept that rethinks water as an integral part of the ecosystem, a natural resource, and a social and economic good (Tarlock 2007). Consequently, it is important to understand that the trend towards the IWRM approach inevitably means a shift from centralized resource management to the hydrological levels where an ecosystem-based approach is concerned (Tarlock 2007).

The latter's main principle is integrating ecological protection and restoration with human needs (Wouters and Dukhovny 2007a). IWRM is a strategy that navigates human activities towards the protection and rehabilitation of water and the associated aquatic and terrestrial resources of a watershed while aiming to provide socio-economic development

(2007a). This is achieved through Integrated Watershed management (IWM) as a tool for decision-makers in land and water use.

After the Earth Summit in 1992, IWRM obtained solid international promotion (Wang et al. 2016). The notion of a river basin (catchment) being the most suitable unit to manage not only water but also local ecosystem-based sustainable development in general. With respect to that recommendation, regions worldwide inevitably faced a series of challenges and opportunities (Tarlock 2007).

The new thinking unavoidably forced one to look broader at the water resource operational planning to the Integrated Watershed management (IWM). Given the geophysical features of the river and their non-administrative being, Figure 3 could be a conceptual visualization of a perfect socio-economic development unit to manage from the ecological perspective. Therefore, IWM both gives one such vision and raises the question: “What if such an approach, which is best for ecosystems, could be not only compatible with socio-economic development, but also auspicious for that?”.

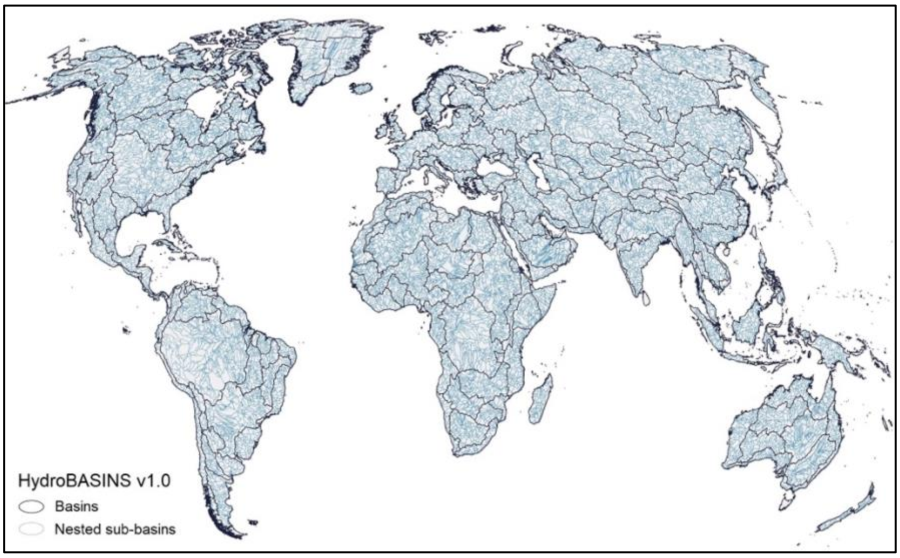

Figure 3. Hydrological Basins of the World. Source: HydroSHEDS (2013), accessed May 30, 2024.

According to UN-Water data (UNEP-DHI Centre website, accessed May 23, 2024), around 58% of the world’s transboundary catchment areas have an operational arrangement for water cooperation. The global progress towards IWRM by country is depicted on Figure 4.

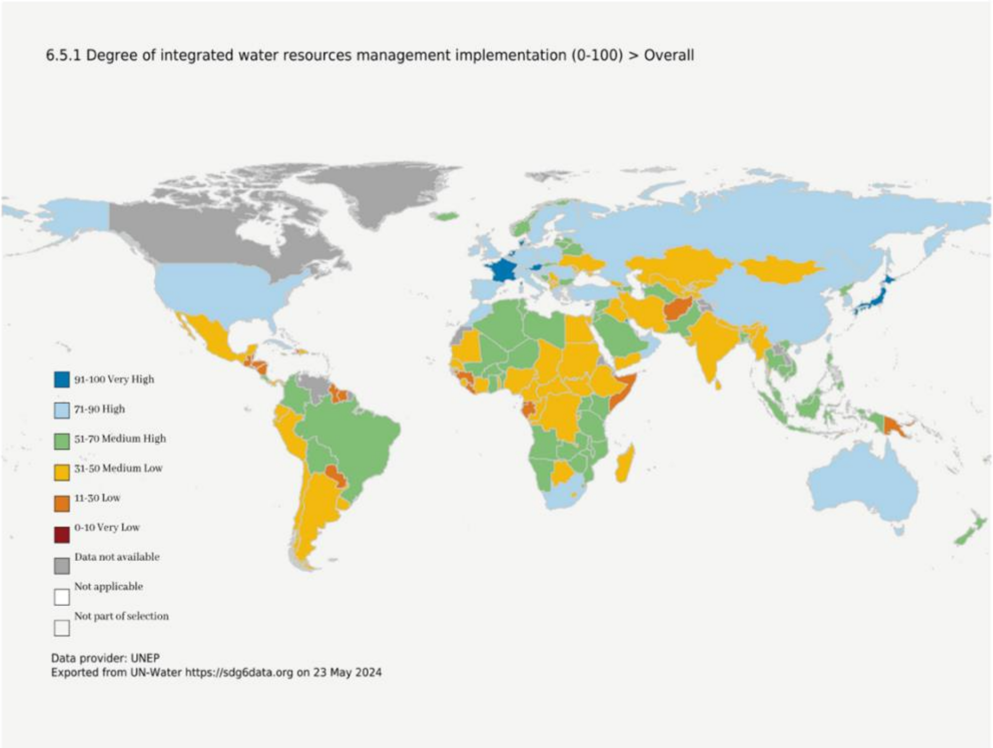

Figure 4. Degree of implementation of SDG 6.5.1. Source: UNEP-DHI Centre (Mix of 2018, 2020, 2022, 2023 data), accessed May 23, 2024.

2.1.4. Interrelations between IWM and IWRM

Behind the statistics, there are paths the world countries have been developing to apply IWRM principles to their national development goals by designing their own IWM complexes. As an instrument, IWM has proven to help achieve the objectives of other related frameworks and concepts, which may not necessarily comprise water management directly but are inevitably water-inclusive, like Sustainable Land Management, Land Degradation Neutrality, etc. (Tarlock 2007).

IWRM, manifested in IWM implementation in a river catchment, advocates for coherent development and management of water, land, and other natural resources for socio-economic well-being in an equitable manner that would allow for ecosystems' health (Dukhovny and Sokolov 2005).

To achieve that goal, WM must fall under several crucial principles (FAO 2006; Sokolov, Ziganshina, and Dukhovny 2014; V. Dukhovny 2021):

1. IWM takes place within the **hydrological borders of a river basin**.
2. **It comprises all kinds of water sources (surface, underground, return)** and considers relevant climatic characteristics (precipitation and evaporation).
3. The **basin** is seen as an **economic and socio-ecological management unit** where water and land are interdependent values. Therefore, land use is aligned with the ecosystem-based approach in the same manner.
4. Water supply for the **environment** is one of the parties' priorities, while environmental protection is placed at parity with consumptive use.
5. Water use is **coordinated** at the horizontal level - between all water users and sectors, and at the vertical level - within the hierarchy of water users.
6. **Public participation** at all stages of IWM is promoted. Equity or social justice are recognized as constraints in case of unreasonable water allocation.
7. I**nformation exchange, publicity, and transparency exist between subnational and international stakeholders**.
8. Water management cornerstones are water **conservation, rational usage**, **loss elimination, reduction, and minimization of wastewater.**

As seen from the world's practice, IWM as the process of coordinated development and management of watershed's water and land resources, is commonly manifested in the following practices:

- Attempts to institutionalize **river catchments** to simplify operations of a basin. The default approach relies on administrative, operational division and procedures that usually lack a natural science foundation, which might bring systemic damage to the ecosystem that, in turn, supports the socioeconomic development of the people. Obtaining a hydrological reference to the managed system is the core precondition of a sustainable water-land nexus (Wouters and Dukhovny 2007a);

- Moving from **sectoral** water management towards integrated **cross-sectoral** (horizontal) coordination of all kinds of water uses and organizations involved in watershed resources management, including coordination of hierarchical levels of water and other natural resource governance (P. Wouters and Dukhovny 2007b; Boas, Biermann, and Kanie 2016);
- Applying a **"top-down, bottom-up"** approach: Higher water management hierarchical structures establish water use limits (quotas) and support water users, whereas other levels form water requirements and participate in decision-making (Rafikov and Rahmatullaev 2016; Tarlock 2007). Moving away from the **command-administrative** method of water management towards a **corporative** one (Sehring 2015);
- Moving from water resources management towards **water demand management** (FAO 2006; Bekboloto and Jaloobayev 2007);

2.2. Analytical Framework

2.2.1. IWM Analytical Framework

Elaborating on the IWM system compounds, this framework can be divided into three analytical elements (Hufschmidt, 1984):

- IWM as a System of Management 1) ***measures*** and 2) implementation ***tools*** applied to a watershed through a set of 3) ***Institutional and organizational arrangements***.
- IWM as a set of linked ***activities*** for which specific ***management tasks*** are required.

- IWM as ***process*** involving separate but closely linked stages of planning and implementation.

As a ***System,*** IWM is manifested through (Hufschmidt 1984):

- Resource management ***actions*** which comprise land uses in a broad sense, on-site resource utilization and management practices, and off-site management practices.
- Implementation ***tools*** for carrying out the management measures through public and private actors.
- Finally, there must be a set of ***institutional arrangements*** that allows for and guides the implementation.

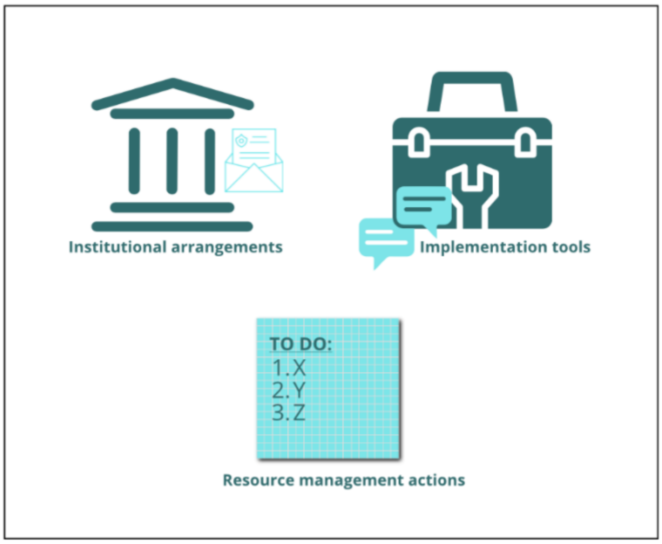

Figure 5. IWM as a System (adapted from FAO). Own compilation.

Looking into watershed management as a ***Process*** that includes a series of sequential steps such as planning, design, installation, operation, and maintenance, with the incorporation of feedback at each stage of the process. (Hufschmidt 1984).

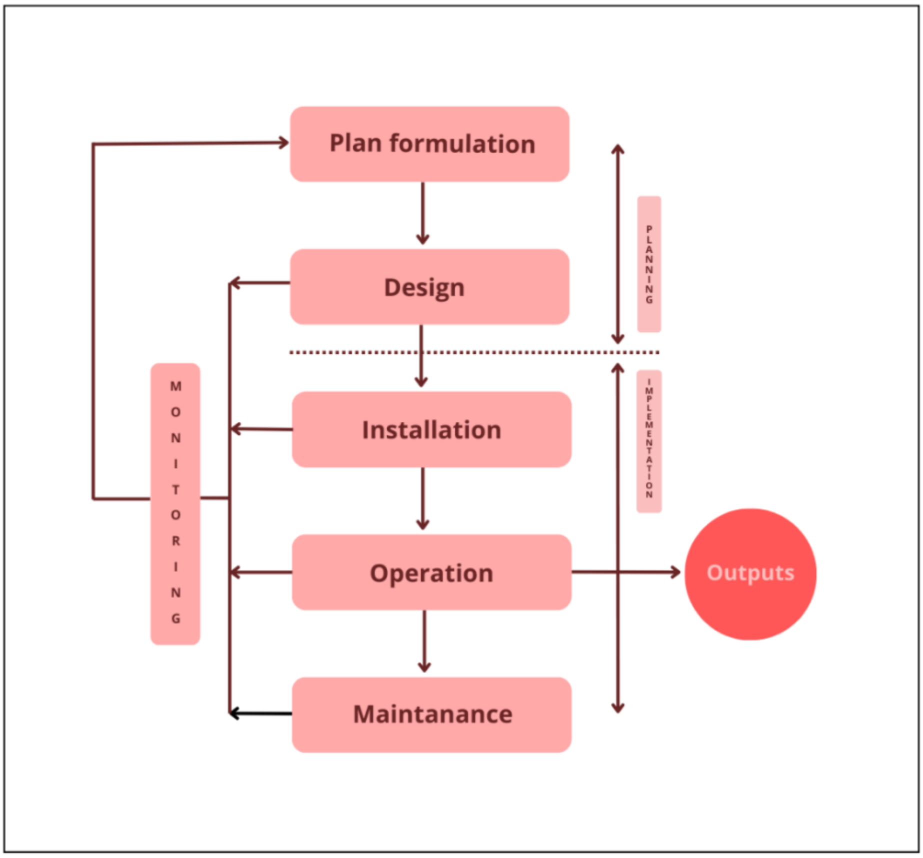

Figure 6. IWM is a process in stages. Own compilation, adapted from Hufschmidt 1984.

Starting with problem identification, a subject (or group of subjects) decides on a project or program plan to address it. By formulating a plan and assessing its feasibility, one makes the decision to implement the project. The next steps involve designing and implementing watershed resource utilization and management practices, followed by installing them, which often requires substantial financial, time, and effort investments. (Hufschmidt 1984; FAO 2006). Together, these steps make up a system comprising five stages, divided into inter-influencing planning and implementation phases and backed by incessant monitoring and evaluation (Figure 6).

As a set of management ***activities***, IWM can and should be subdivided into a number of specific steps that watershed management agencies or other actors must perform to produce the desired outputs and effects on the natural system (Hufschmidt 1984; FAO 2006).

These steps can be identified by analyzing watershed management as a set of linked activities for which specific management ***tasks*** are required (Hufschmidt 1984).

The **first** task is delineating the watershed boundaries. Water flows under the laws of physics, ignoring administrative division. As argued previously and supported by distinguished IWM experts, the morphology of a basin is a key factor in transitioning to management based on hydrogeographic principles that can meet the ecosystem's requirements (Dukhovny 2005).

Secondly, the area within the borders must be categorized into land use types and areas, possibly indicating land change dynamics. Naturally, each of these types can have various applications. (Hufschmidt 1984; FAO 2006). This step is possible with the use of remote sensing and geospatial analysis techniques, which too are being advanced and aligned with the UN criteria to assess land degradation, which is crucial to guide ecosystem restoration (Locke 2024). As an output, land use land cover change map products can be generated, disclosing potential pressures and impacts crucial for the IWM designers and decision-makers.

The next management ***activity*** calls giving a land-type use, as operational unit, **on-site resource utilization and management practices** which are masterminded accordingly to the issues present locally with reference to the bigger ecosystem, socio-economic, legal and institutional picture (Figure 7) (Hufschmidt 1984; FAO 2006).

As the last step, the methodology suggests minimizing the adverse effects of on-site land use activities in the downstream areas by implementing additional measures as a set of **off-site management practices** instream and along river stream borders (Figure 7) (Hufschmidt 1984).

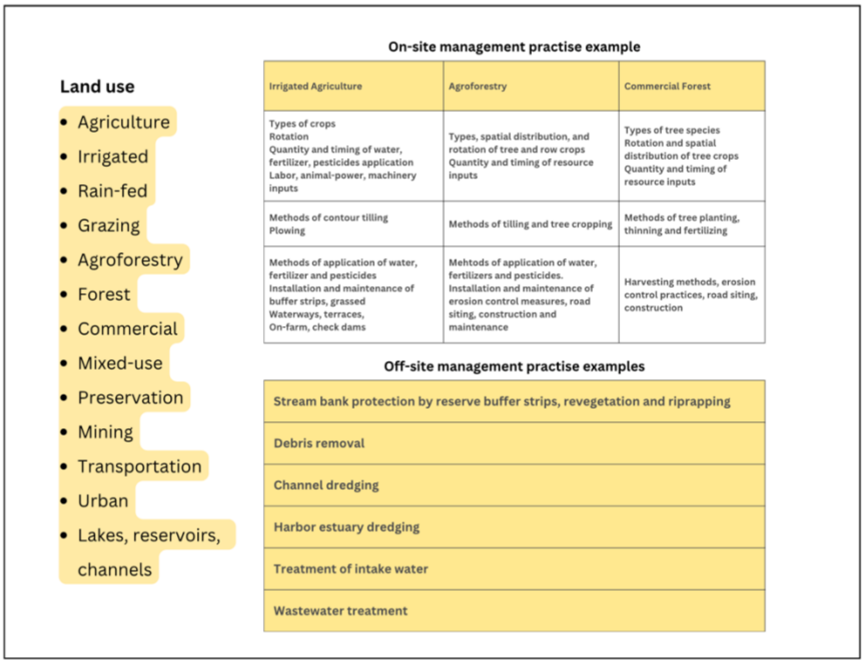

Figure 7. IWM as management activities (Own compilation, adapted from Hufschmidt 1984).

The three-component approach: system, activities, and process - allows for a voluminous vision of the elements that would need to be addressed for the implementation of the IWM framework in practice.

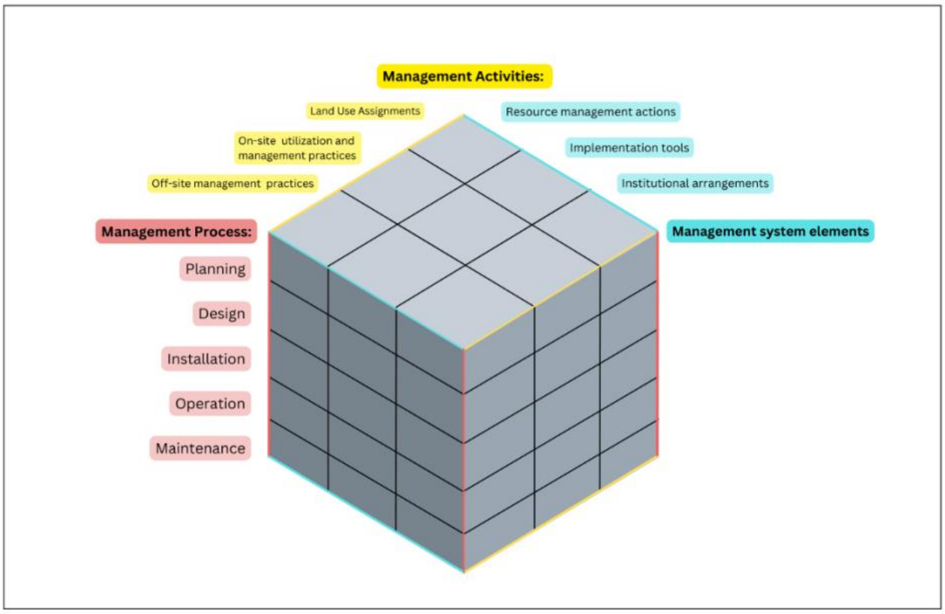

Figure 8. Three-dimensional IWM model (Own compilation, adapted from Hufschmidt 1984)

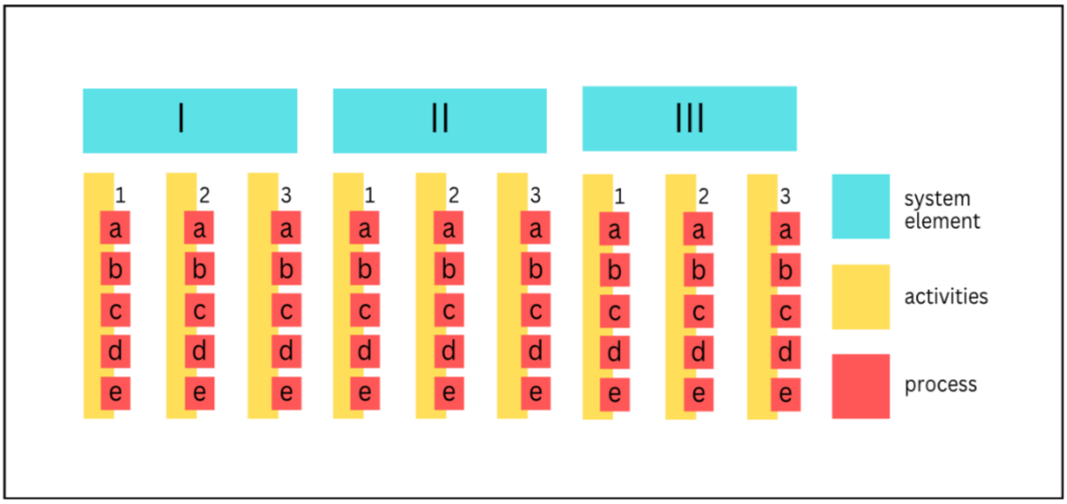

Figure 9. A 2-dimensional 3-component IWM model (Own compilation, adapted from Hufschmidt 1984).

As a linear scheme, to navigate throughout the IWM establishment process, example-wise, one can select:

- "I-1-a", which would navigate IWM at a stage of: "resource management action - delineating the watershed boundaries - planning";
- "II-1-a": "tools for carrying out the management measures - delineating the watershed boundaries – planning.
- "III-1-a": "institutional arrangements - delineating the watershed boundaries - planning";

This "slice" of the 3-dimensional IWM model describes the **System elements** needed for delineating watershed boundaries as a task within the IWM as an **activity** in the **planning stage**; one may need to address the delineation in resource management **action**, decide on the **tools,** and make clear the involvement of **institutional arrangements**.

It is fair to admit that these details of an IWM analytical framework may not be of great importance for the implementation. Still, such division could provide a basis to guide or track this process by setting questions such as (e.g.): "What resource management actions, tools for carrying out the management measures, and institutional arrangements are needed for delineating a basin at different stages?"

2.2.2. Interrelation of IWM analytical framework and IWRM conceptual framework

Exploring the recommendations of leading water management institutions on IWRM, as they are inherently interconnected, one should note that the International Water Management Institute (IWMI) suggests three pillars through which those principles should be integrated nationally and/or regionally: **policy, institutions**, and **management** (IWMI accessed May 3). In the same way, SDG 6.5.1 "By 2030, implement integrated water resources management at all levels, including through transboundary cooperation as appropriate," accounts for the same pillars, except for the ***Finance,*** which is outlined separately, unlike the IWMI's ***Policy,*** which embeds both national plans and the funding allocated to implement those at the help of ***Institutions*** and the adequate ***Management*** performed (UN-Water 2024). IWMI suggests a list of criteria which greatly correlates with the UN's IWRM assessment for SDG 6.5.1 (CA-Water 2024).

ENABLING ENVIRONMENT	INSTITUTIONS	MANAGEMENT
National water resources policy	National institutions leading IWRM	Water availability monitoring
National water resources law(s)	Cross-sectoral coordination	Sustainable and efficient use management
National IWRM plans	Public participation	Pollution control
Sub-national WR policies	Private sector participation in WRM	Water ecosystem & biodiversity management
Basin/aquifer management plans	Developing IWRM capacity	Management of water-related disasters
Transboundary WRM agreements	Basin/aquifer level organizations	Basin management instruments
Sub-national WR regulations	Public participation in WRM - local	Aquifer management instruments
National budget for WR infrastructure	Participation of vulnerable groups	Data and information sharing within country
National budget for IWRM elements	Gender mainstreaming in WRM	Transboundary data and information sharing
Sub-national/basin budgets for WR infrastructure	Transboundary WRM organisational frameworks	
Revenues raised for IWRM elements	Sub-national authorities for IWRM	
Financing transboundary cooperation		
Sub-national/basin budgets for IWRM elements		

Figure 10. UN assessment criteria for SDG 6.5.1 "By 2030, implement integrated water resources management at all levels, including through transboundary cooperation as appropriate".

A THE ENABLING ENVIRONMENT 3
A1 POLICIES – Setting goals for water use, protection and conservation 3
A1.1 Preparation of a national water resources policy 3
A1.2 Policies with relation to water resources 4
A2 LEGISLATIVE FRAMEWORK – Water policy translated into law 5
A2.1 Water rights 5
Although many legal systems allow perpetual rights, time-bound concessions might be preferred for the same reason. 6
A2.2 Legislation for water quality 6
A2.3 Reform of existing legislation 6
A3 FINANCING AND INCENTIVE STRUCTURES – Financial resources to meet water needs 7
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Figure 11. IWMI criteria for IWRM assessment (own compilation, adapted from IWMI).

To investigate the correlation between IWM and IWRM, all three IWRM elements from the IWMI can be compared with FAO's IWM ***System elements*** and partial ***Management actions***. As IWM is a down-to-practice set of efforts, unlike the IWRM concept, it also includes IWM as a ***Process.***

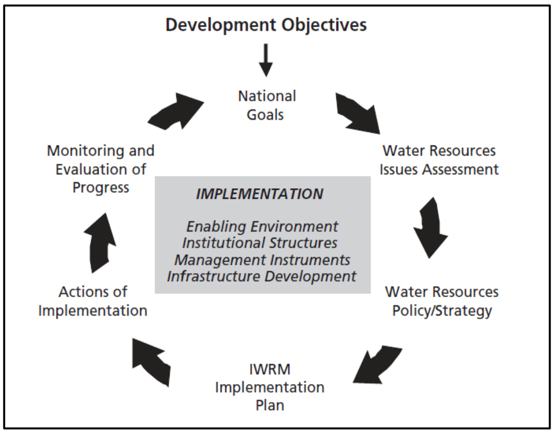

Figure 12. Stages in IWRM planning and implementation. Source: UN-Water.

Within the UN Decade for Water framework, there are commonalities with UNDESA's vision for implementing IWRM with FAO and IWMI, depicted in a cyclic scheme (Figure 12). As highlighted, the entry point is represented as IWRM-aware policymaking which shapes ongoing national development plans. This step corresponds to the FAO's IWM framework's ***System element*** *dimension*: ***Institutional Arrangement***, followed by a ***Management tool*** (Figure 5. IWM as a System, FAO) of ***"Water resources Issues assessment"*** **(**Figure 12).

The combination of these two by UNDESA with reference to FAO's ***Institutional Arrangement*** and ***Management tool*** brings further to review of the updated objectives, which later translated into an IWM **plan** (Figure 6), divided into IWM management **tasks** within ***"Actions of Implementation"*** (Figure 7: "*land use assignments"*, "*on-site-"* and "*off-site activities"*). The latter step generally accounts for the ***Management Activities*** slice of the cube (Figure 8). Finally, outputs are produced, and the systemic effects are evaluated. The overall assessment adjusts the plan and the whole cycle repeatedly (Figure 6: *"Monitoring"*).

In conclusion to the literature review, these findings allow for distinguishing two relationship lines between the IWRM and IWM.

The study estimates IWRM as a broader concept, as it embodies the will of the pursuit of a wise water-centered and ecosystem-based approach towards sustainable development that does not compromise socio-economic growth. To achieve that, IWM is being as a prerequisite as well as a tool to ensure the conceptual context of IWRM.

At the same time, it is interesting to note that IWM has two facets: regional and subnational. Watershed is sometimes fairly compared with a leaf (Swiss Developemt Agency, IWMI 2008) (Figure 13): in that relation, IWM can be understood as a set of practices that are aligned with IWRM at a particular location of a watershed, and, at the same time, one can look at the watershed in its boundaries, - which highlights the necessity of Institutionalization of a river catchment by the riparian countries, improving national IWRM and project the same standards to the regional scale, where transboundary cooperation and diplomacy serve the main IWM tools.

Figure 13. Photograph of a leaf, analogous to the river system within its catchment. Source: Wikipedia Commons. Link: https://commons.wikimedia.org/wiki/File:Leaf_1_web.jpg.

It is safe to assume that judging by the efficiency of IWM and the degree of its implementation in a country or, due to the catchment's non-administrative nature, - region, one can speak of the state of IWRM and vice-versa.

In fact, the analysis of the IWM may occasionally be slightly broader since more ***Management actions*** on various ***IWM stages*** might be concerned.

In addition to that, while IWRM focuses on principles for national governments to manage water in the described way while setting the eyes on the implementation of those at a basin-scale, where usually other countries are a part of the basin operations, various other related ***System elements'*** challenges arise, such as a non-hydrological approach to managing water, internationally uncoordinated basin operations due to the lack of basin's institutionalization amidst unwelcoming legal environmental and overarching sectoral assignments of the parties concerned (Dukhovny and Sokolov 2005).

2.2.3. The levels of analysis for IWM establishment in the ARB and the SRB

Diagnostics of the problems of the establishment of IWM in transboundary river basins regarding Central Asia should proceed on the three-level basis illustrated in Figure 14: Global (encompassing International Water Law and its Enforcement), regional, and national, including subnational compounds. Levels-wise, IWM incorporates regional level (Transboundary cooperation) and national IWRM complexes.

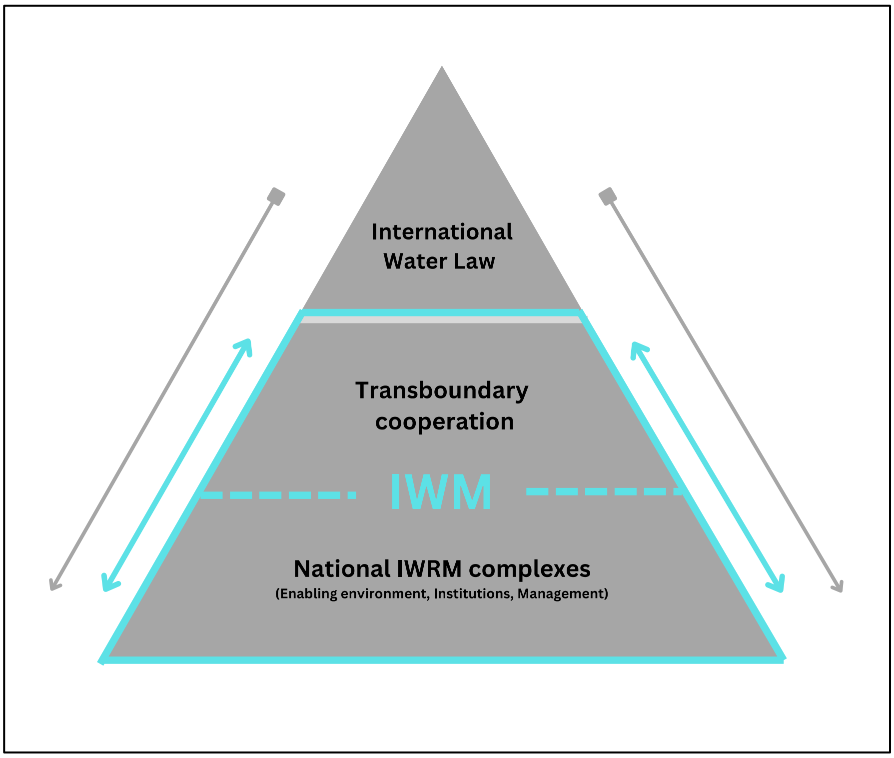

Figure 14. Three levels for IWM process analysis. Own compilation.

Looking into the global scale or the top section of the Pyramid (Figure 25), the UN Convention has not been fully implemented because it lacks practical showcasing support by the leading states. In other words, as many critics put it, the UN Water Convention has been ignored (Tarlock 2007; Dukhovny and Schutter 2011a; Rahaman 2012). The International Water Law, which governs the use and management of transboundary water resources, faces several issues (Rahaman 2012). These challenges are not reflected in the following study's outputs as it does not directly refer to IWM establishment in the Syrdarya and the Amudarya river basins but still serve as an important top component for understanding the water management trends worldwide, including CA. The issues with IWRM and IWM on a global scale can be broadly categorized into legal, political, and practical dimensions.

Regarding the legal aspects, the following shortcomings can be pointed out:

1. Fragmentation of Legal Frameworks: there is no single, comprehensive international treaty that governs all aspects of transboundary water resources. Instead, there are multiple conventions and agreements, like the UN Water Convention and the 1992 Helsinki Convention. This fragmentation leads to inconsistencies and conflicts between different legal instruments, national water codes, and rules for the use of transboundary waters (Rahaman 2012; Sehring et al. 2021b).

2. Ambiguity and Interpretations: Many provisions in international water law are open to interpretation. Terms like "equitable and reasonable use" and "no significant harm" are subjective and can be interpreted differently by different states, leading to disputes. Consequently, there is no universal model for National Water codes and rules for the use of transboundary waters (Tarlock 2007).

3. Lack of Binding Enforcement Mechanisms: International water law often lacks strong enforcement mechanisms. Compliance is largely dependent on states' goodwill, and there are limited means to compel states to adhere to their obligations or to resolve disputes effectively (Tarlock 2007; Bulkeley et al. 2014).

Policy-wise, IWRM is somewhat limited due to the range of frequently observed tendencies:

1. Sovereignty Concerns: States are often reluctant to cede control over their water resources to international bodies or agreements, viewing it as an infringement on their sovereignty. This has diminished the development and implementation of effective

transboundary water management policies (Tarlock 2007; Bulkeley et al. 2014; Xenarios et al. 2019).

2. Power Asymmetries: In many transboundary water basins, there are significant power imbalances between upstream and downstream countries. Upstream countries may have more control over the water flow, which can lead to conflicts and difficulties in reaching equitable agreements (Tarlock 2007; G. Wang et al. 2016).

3. Geopolitical Tensions: Water resources are often located in politically sensitive regions, like Central Asia. Existing geopolitical tensions can exacerbate disputes over water use and management, making cooperation even more complex (Dukhovny and Schutter 2011b; Y. Wang et al. 2023).

As for the Management side, there are some technical and climate-related factors:

1. Data and Information Sharing: Effective management of transboundary water resources requires accurate and timely data (De Keyser et al. 2023). However, states may be unwilling to share data due to security concerns or mistrust, leading to gaps in information that can hinder cooperative management efforts (Hejnowicz et al. 2022).

2. Infrastructure and Development: Differences in the level of infrastructure development between countries sharing a watercourse exacerbate probability of conflicts (Sehring et al. 2019). For example, the construction of dams or diversion projects by one country can significantly impact water availability and quality for downstream countries (Jalilov, Amer, and Ward 2013; Sehring et al. 2019).

3. Climate Change: Climate change is commonly seen to be altering precipitation patterns, river flows, and the availability of water resources (Yang et al. 2019). This adds an additional layer of complexity to the management of transboundary waters, as historical data may no longer be reliable predictors of future conditions (Yang et al. 2019; Bulkeley et al. 2014).

Addressing these issues requires a combination of strengthening legal frameworks, fostering political will for cooperation, and improving practical mechanisms for data sharing and joint management. Among the strong yet promising opinions are transferring water security issues to the jurisdiction of the UN Security Council, preparing procedures to clarify the provisions of the Convention on the Protection and Use of Transboundary Watercourses and International Lakes (Water Convention), and widespread assistance to their IWRM processes and options for support in mediating transboundary water conflicts (Dukhovny and Schutter 2011b).

2.2.4. Matrix for IWM analysis

Considering the descending background influence of International Water law on IWM, the research suggests the following approach to investigating IWM in the ARB and SRB, having reviewed the analytical and conceptual frameworks (Figure 15).

	IWM System elements			**IWM activities**		
	Institutional arrangement	Management tool	Management action	Land Use Tasks	On-site	Off-site
IWRM Pillar	***ENABLING ENVIRONMENT***					
Component	*Policy*					
Problem	XYZ					
	Is it about Institutions?	Is it about the tools?	Is it about the executive capacity?	Is it about the sectoral discrepancies and land reclamation?	Is it about on-farm / on-site practices?	Is it about the technical sustenance and operation of the hydrological system?
Component	*Legislation*					
Problem	XYZ					
	?	?	?	?	?	?
Component	*Finance*					
Problem	XYZ					
	?	?	?	?	?	?
IWRM pillar	***INSTITUTIONS***					
Problem	XYZ					
	?	?	?	?	?	?
IWRM pillar	***MANAGEMENT***					
Problem	XYZ					
	?	?	?	?	?	?

Figure 15. Suggested approach for the analysis of IWM establishment.

The overview of the IWM and the IWRM frameworks has allowed for designing the matrix, which will allow for visual and systemic reference to a concrete IWRM pillar or IWM element while discussing problems as outputs for the research on IWM establishment in the ARB and SRB.

Summarizing the overview of the elements of the conceptual and analytical frameworks, one can understand that with the shift of the water management paradigm and the development of the IWRM concept, the countries that share one of the few river basins embarked on their journeys to establish IWM. More than half of the countries have developed some arrangements for Transboundary basin management. In contrast, the statistics on water quality and quantity, ecosystems, and the status of water as a socio-economic good worldwide still vary. The case for Central Asia started off from an ecological disaster and teaches a lesson about the consequences of systemic resource management errors. Given the region's poverty at some areas of the ARB and the SRB and fragile socio-economic situation (UNDRR 2021), many people directly depend on water supplies to support their livelihoods. The water management is still far from perfect in terms of the timely delivery of the water to the users and its quality, not speaking of the "add-ins" the "Integrated" water management incorporates, like a top-down approach, extremely exotic to Central Asia's path-dependent development design or public participation, stakeholder engagements, which is limited due to the lack of socio-economic development and water rights, etc.

2.3. Study area

2.3.1. Geophysical, hydrological, ecological features and requirements of the Amudarya and the Syrdarya river basins

In continuation of the notorious example, this section focuses on the Amudarya and Syrdarya rivers in the present times.

The Syrdarya is the second largest and first longest river in Central Asia. Its length is 3019 km, and its basin area is 219 thousand km^2. (Kulmatov, Adilov, and Khasanov 2020) The Syrdarya is formed on the territory of the Kyrgyz Republic from the source of Naryn and the Kara Darya River, which are fed by glaciers and snow of the Central Tien Shan mountains. The water regime is characterized by spring-summer floods, with the swarm beginning in April. The highest flow occurs in June. Flowing through Uzbekistan and Tajikistan it reaches the Aral Sea on the territory of Kazakhstan (CA-Water 2024).

The Amudarya is the largest river in Central Asia. Taking its origin from Pyanj, it stretches 2540 km, forming a basin area of 309 thousand km^2. The river starts at the point where the Pyanj merges with The Vakhsh River. In the middle reaches, three large rivers flow into the Amudarya: Kafirnigan, Surkhandarya, Sherabad and Kunduz (CA-Water accessed May 3, 2024). River feeding mainly consists of meltwater, so maximum flow rates are observed in summer and the smallest in January-February. Such seasonality of water distribution of runoff is favorable for using river water for irrigation. Flowing across the plain, the Amudarya loses most of its flow to evaporation, infiltration, and irrigation. In terms of turbidity, the Amudarya is the front-runner in Central Asia as well as in the world (Asarin, Kravtsova, and Mikhailov 2010).

The value of the average long-term runoff is accepted: for rivers of the Syrdarya basin 36 km^3/year; for rivers of the Amudarya basin – 79 km^3/year. Therefore, the total average long-term resources of surface (river) waters in the Aral Sea basin seas are 116.483 km^3/year (Asarin, Kravtsova, and Mikhailov 2010) .

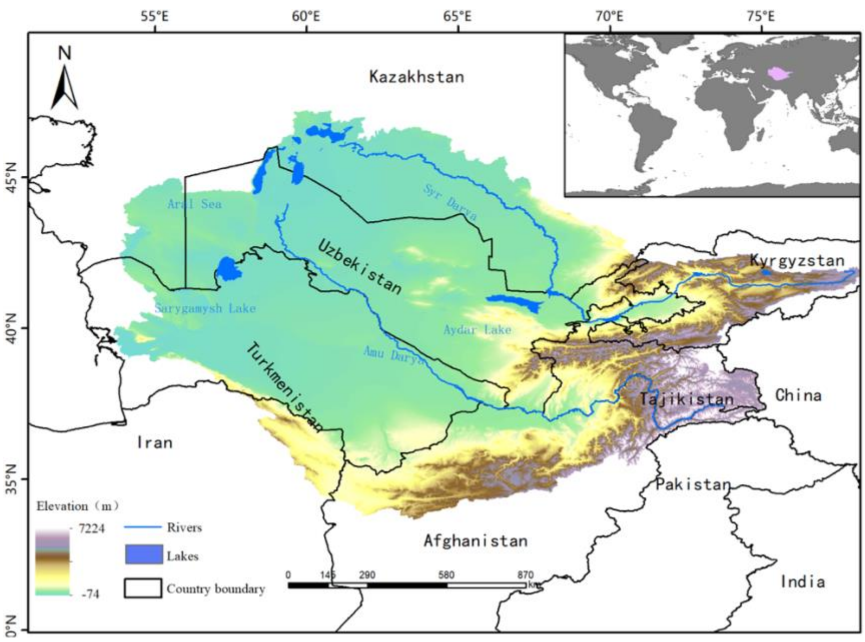

Figure 16. Map of the study area, the Amudarya and the Syrdarya forming the Aral Sea basin. Source: Chen et al 2021.

One of the features of the region is the division of its territory into several main areas: new zones of surface runoff, zones of runoff formation, recharge areas in mountainous areas, zones of transit and dispersion of runoff, and the deltas (Karthe 2018). Usually, there are no significant anthropogenic changes in the runoff formation zone, but due to the construction of large dams and reservoirs on the border of this zone, the flow regime in the lower reaches does change (Karthe 2018).

The natural flow of rivers is defined by gravity and the rotation of the Earth; however, due to anthropologic advancements, river systems are being modified. The operational part of water management is extremely complex. In simple words, it is a system of dams, canals, and reservoirs that serve all the required water demands of the users and pose a task to manage it well for both rivers' and water users' well-being (Norkobil 2019; Nasrulin 2019).

In the zone of transit and dispersion, flow, and all hydrological, the cycle changes because of the interaction between water and land. The action is characterized by the intake of water from rivers for irrigated areas and the discharge return flow with salts and agricultural chemicals into rivers (Karthe 2018; Wang et al. 2023). The latter is notorious for water and land fertilizer-, pesticide-, and herbicide pollution, increasing soil salinity and damaging the groundwater to a debatable yet allegedly wide extent (Liu et al. 2021). Irrigated agriculture is the primary water user in the Syrdarya basin, consuming about 80-85% of the water resources (Musina et al. 2023; Abdullaev and Molden 2004). The basin has a vast irrigation network, but inefficiencies and losses in water delivery are significant, with up to 30-50% of water withdrawals lost (Rau et al. 2023; Di and Nasrulin 2019). The Amudarya basin also heavily relies on irrigated agriculture, with a complex irrigation system that includes numerous canals, pumping stations, and reservoirs (Rysbekov 2023). The basin's irrigated area is approximately 3.8-4.0 million hectares, with significant water losses due to inefficient irrigation practices (Sorokin and Sorokin 2023).

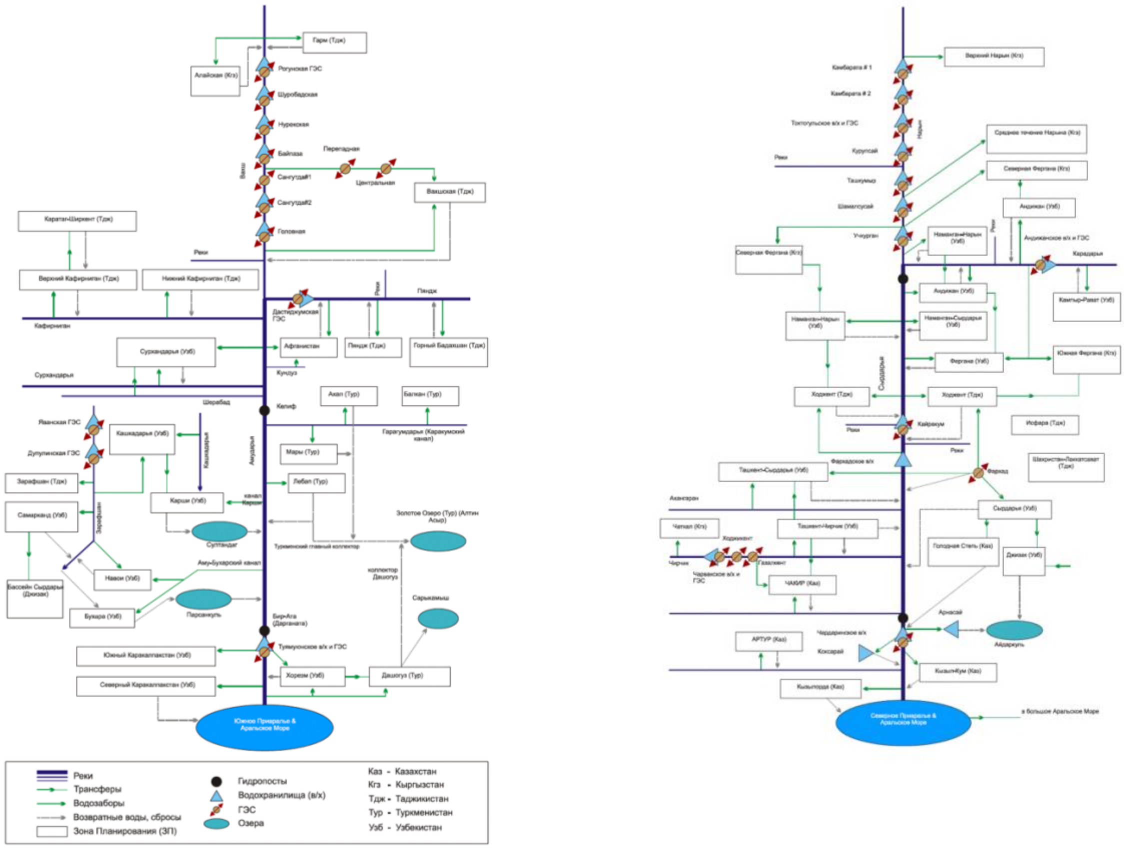

Figure 17. The schemes of the ARB (left) and the SRB (right) water networks (Rivers Transfers, Water intakes, Hydroposts, Reservoirs (water reservoirs), HPPs, Return waters, discharges, Lakes, Planning Zones).

The distribution of issues which usually arise due to agriculture and chemical pollution in the two basins, can be assessed accordingly to the spatiotemporal estimated by Hirwa, Sayidjakhon, and Khasanov (2021) (Figure 18). Deterioration of the quality of water and the environment is manifested in registered soil degradation, water logging, and land salinization (Saidmamatov et al. 2024; Saidmamatov et al. 2023; Rau et al. 2023). Along with the agricultural pollution, the area encompassed by the SRB is notorious for hazardous waste pollution (radioactive and industrial) as well as improper sewage and communal waste management practices (Bekturganov et al. 2016; Liu et al. 2021). The pollutants' historical distribution is depicted on Figure 19 (GRID-Arendal, UNEP, and Zoï Environment Network 2017).

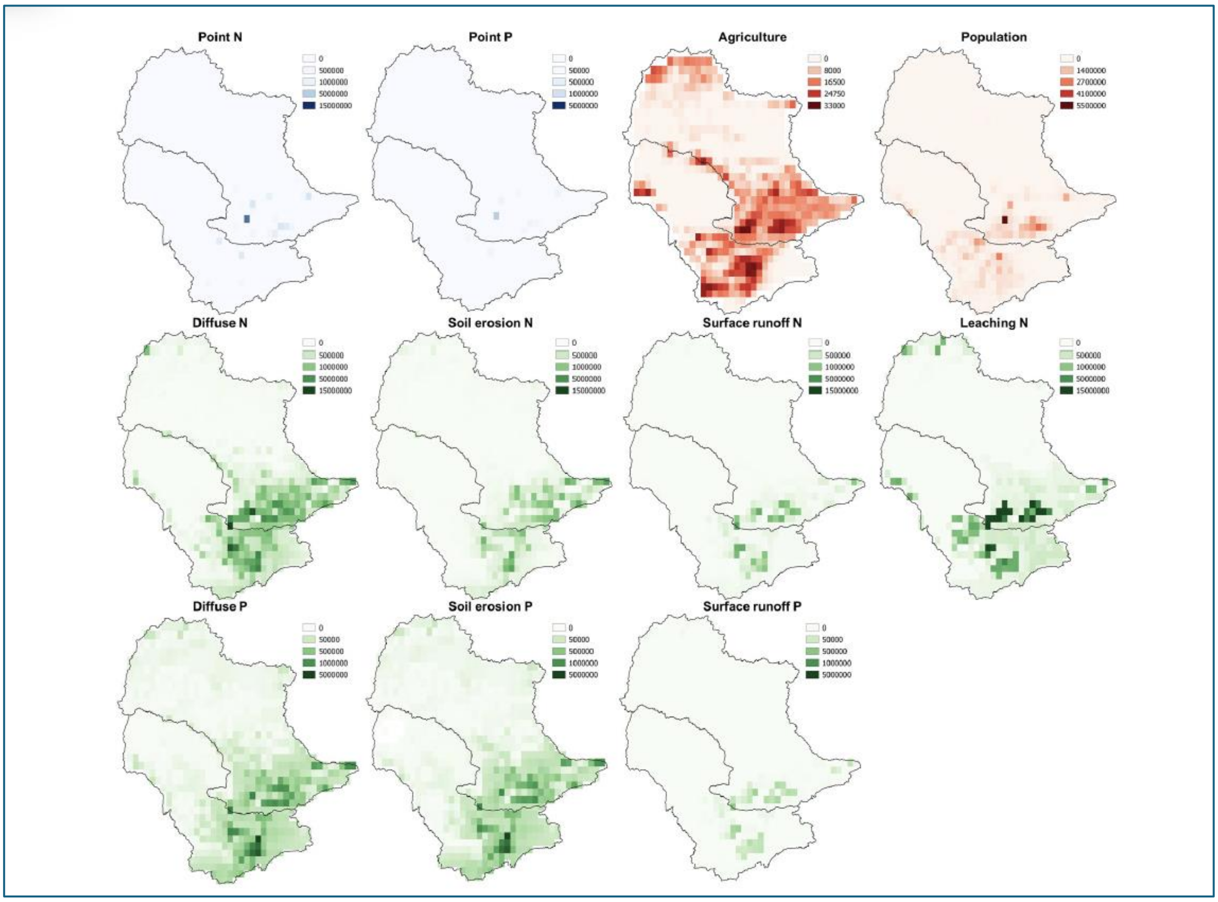

Figure 18. Agriculture-related issues in the Syrdarya and the Amudarya river basins. Source: Hirwa and Sayidjakhon, Khasanov (2021).

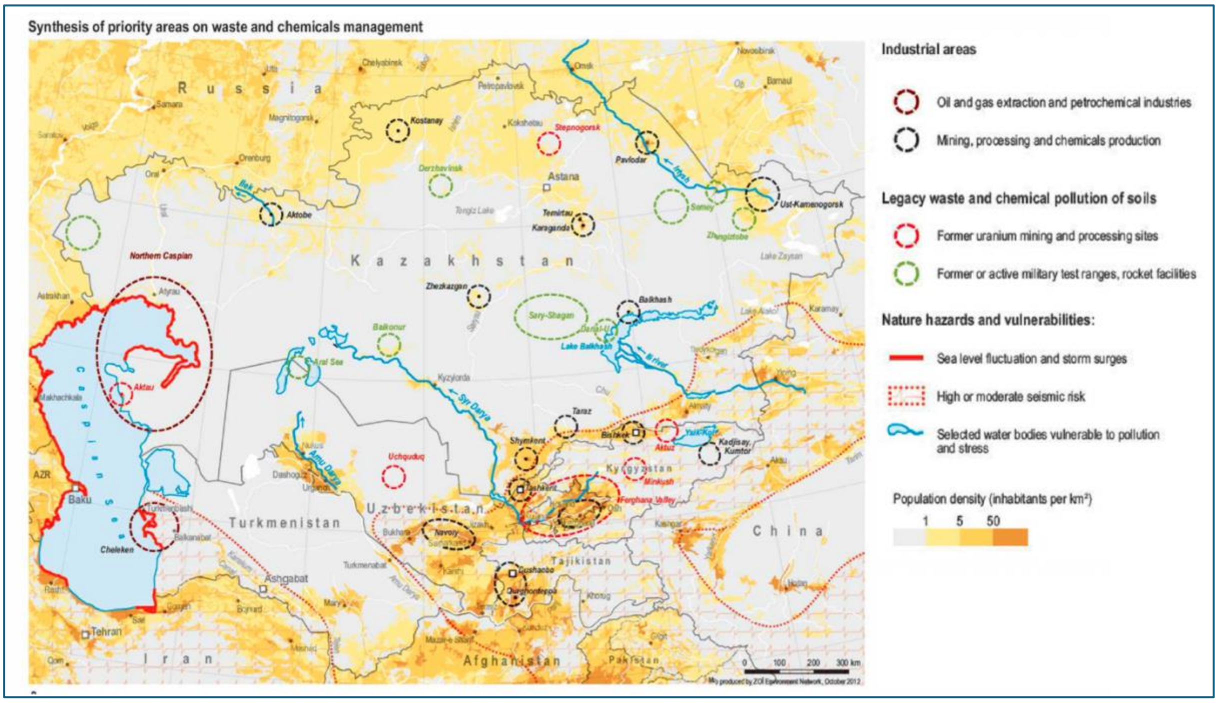

Figure 19. Visualization of Priority areas on waste and chemicals management. Source: GRID-Arendal, 2016, 2013 data.

Currently, the total volume of water resources available for use varies between 114 and 117 km^3 in the entire Aral Sea basin, considering return waters and all water waste, which in terms of the 2022 population was 2380 m3/person per year (ESCAP 2022).

Country	River Basin		Total Aral Sea Basin	
	Syrdarya	Amudarya	km^3	%
Kazakhstan	2.516	—	2.516	2.2
Kyrgyzstan	27.542	1.654	29.196	25.2
Tajikistan	1.005	58.732	59.737	51.5
Turkmenistan	—	1.405	1.405	1.2
Uzbekistan	5.562	6.791	12.353	10.6
Afghanistan and Iran	—	10.814	10.814	9.3
Total Aral Sea basin	36.625	79.396	116.021	100

Figure 20. Surface water resources in the Aral Sea basin (mean annual runoff, km^3/year). Source: CA-Water, accessed May 20, 2024.

The patterns of water withdrawals are tightly interconnected with each country's interest in water resource withdrawal (Figure 20, Figure 21, Figure 22). Being mostly covered by the SRB, Uzbekistan holds the biggest share of the river's resource intake, mostly for agricultural needs, which is evenly distributed throughout the year. Tajikistan increases the volumes in the spring and summer seasons, while Kazakhstan, combining both hydropower and agricultural sectors in its south, accelerates water withdrawals in February-March, July-August, and December. Kyrgyzstan has a comparatively small share in withdrawals, mostly due to the mountainous landscapes, which have little area of cultivated land, and is rather known for the HPPs exploitation for energy production at the Naryn-Syrdarya cascade (Khamidov 2007a).

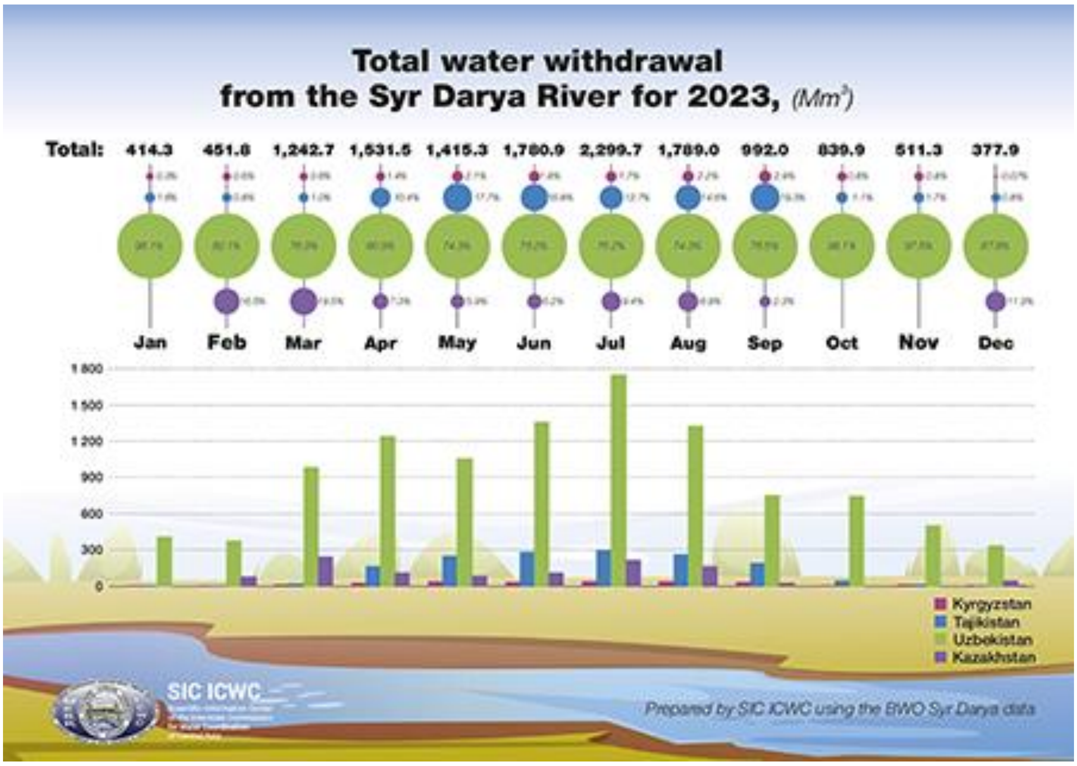

Figure 21. Total Water withdrawals from the Syrdarya River for 2023. Source: Ca-Water.info.

The three-party utilization of the Amudarya water resources is equally balanced, with larger water allocations for Turkmenistan.

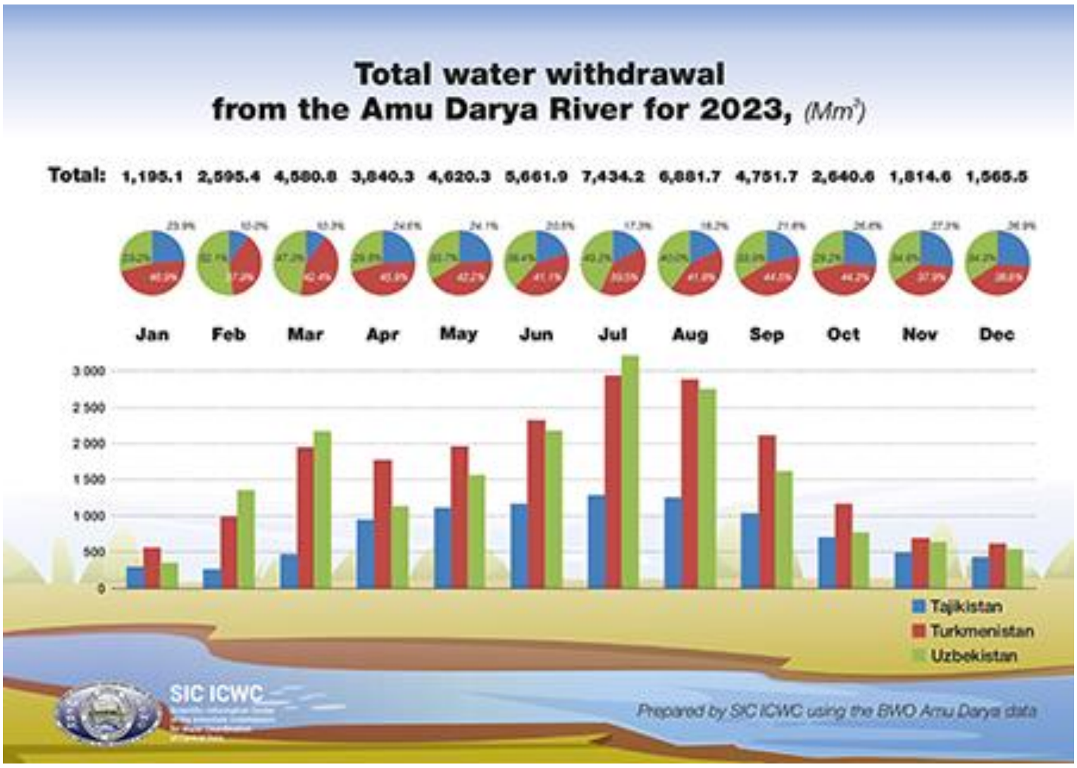

Figure 22.Total Water withdrawals from the Amudarya river for 2023. Source: Ca-Water.info.

As a common sense, the best ecological precondition to IWM is to save water resources. Among the measures to increase the volume of available water in the ARB and SRB are:

- clarification of channel flow losses in the bed of the rivers through complex hydrological studies with the participation of hydrometeorological national services and water management organizations of all countries in the basin and the creation of automated monitoring systems at all gauging stations and water intakes (Bekboloto and Jaloobayev 2007)
- return to a multi-year irrigation regime for regulating river flow or construction of additional reservoirs for seasonal regulation, compensating for average annual losses of 3.5 km^3 per year (for the SRB) (Conrad, Kaiser, and Lamers 2016; Asarin, Kravtsova, and Mikhailov 2010);
- completion of the creation of an automated accounting and control system (SCADA) (Sharda, Dogra, and Dhyani 2012; Dukhovny and Schutter 2011b);
- improvement of return water management (Chen et al. 2021; Wang et al. 2021; GRID-Arendal, UNEP, and Zoï Environment Network 2016).
- improving coordination of the work of all major water users, using water resources of two main transboundary rivers (hydropower, public water supply, irrigated agriculture, and industry) (Nazirov 2007; Mirzaev 2022; Dukhovny 2021).

Along with the improvement of technological-institutional capacity, one should also highlight some ecological requirements for the sustainability of watershed operations:

- Ensuring a consistent water flow in bodies of water, such as lakes, is essential, especially when the only water source is a collector-drainage network. It is particularly important to maintain this flow during the growing season. (Makhmudova, Djuraev, and Khushvaktov 2021; Asarin, Kravtsova, and

Mikhailov 2010; Wouters, Dukhovny, and Allan 2007; Khamidov 2007b; IWMI 2024);

- To ensure optimal conditions for fish farming, it's crucial to maintain water salinity at levels below 5 g/l, particularly during the spring and summer months when spawning, hatching, and young fish growth take place from April to June in the lakes. (Wang et al. 2023; IWMI 2024);
- Keeping the water depth in lakes at a minimum of 1.5 meters during winter. (Wang et al. 2023; IWMI 2024);
- Preventing a sharp drop in water levels during spawning and hatching, and sharp rise in winter (Wang et al. 2023; IWMI 2024);
- Keeping available shallow water zones to maintain conditions for the growth of reeds (Wang et al. 2023; IWMI 2024).
- Long-term preservation of water areas of lakes, which form the hydro-biological regime of reservoirs and sustain food for fish, bird, and animal species (Wang et al. 2023).

As stated earlier, one of the cornerstones of IWM is managing water in relation to land. A peer-reviewed study (Chen et al. 2021) analyzes spatiotemporal changes, trade-offs, and synergistic relationships in ecosystem services provided by the Aral Sea basin, which is formed by the two studied river systems. The outputs partially reflect the ecosystem response to the anthropogenic influence. Those impacts go in hand with the Land Use and Land Cover (LULC) changes in the basin and are assumed to have caused significant ecosystem transformations during the 1995–2025 period (Figure 23). This has been evaluated in a loss of 22.87 billion USD worth of ecosystem service values (ESVs). The study indicates that most of these lost ESVs stem from converting water bodies to bare land areas (2021).

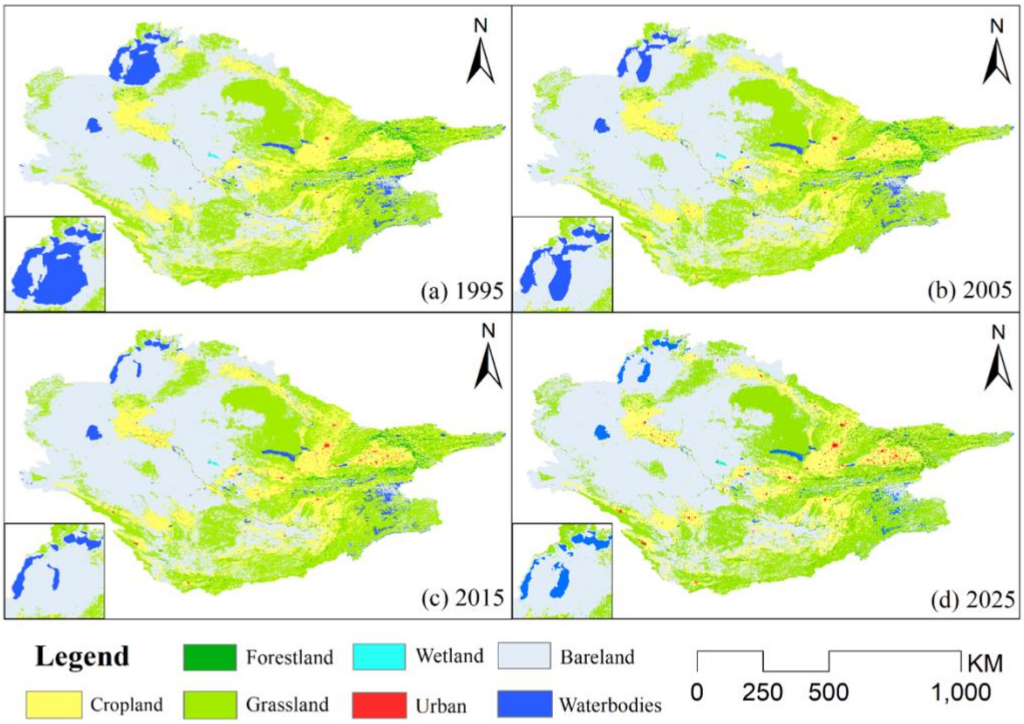

Figure 23. Land Use and Land Cover change Map of the Aral Sea basin. Source: Chen et al, 2021.

These highlights allow for some reasoning about the regional context of ecosystem dynamics and the importance of water. The findings elucidate that the main concerns for decision-makers should be **balancing cultivated and urban land areas**, encouraging **grassland expansion**, and preventing land cover change from grassland or bare land to cultivated land to **prevent water losses** or the consumption of **extra water** (2021).

In conclusion, the geophysical, hydrological, and ecological features of the Amudarya and Syrdarya river basins underscore the complexity and significance of these water systems in Central Asia. The Syrdarya, being the longest river in the region, and the Amudarya, the largest by volume, both play crucial roles in supporting the agricultural, industrial, and domestic water needs of the surrounding countries. However, the extensive use of these rivers for irrigation, coupled with inefficient water management practices, has led to significant water losses and environmental degradation, including soil salinization and pollution.

The seasonal variability in water flow, driven by snowmelt and glacial contributions, presents both opportunities and challenges for water resource management. The peak flows in summer align well with irrigation demands, but the low flows in winter necessitate careful planning and storage solutions to ensure year-round water availability.

Addressing these challenges requires a multifaceted approach that includes improving irrigation efficiency, enhancing coordination among water users, and implementing advanced monitoring and management systems. By adopting IWM practices and focusing on sustainable land use, the region can better balance the needs of its ecosystems and human populations, ensuring the long-term health and productivity of the Amudarya and Syrdarya river basins.

2.3.2. Factors that influence water management in the ARB and SRB

An overview of the national and regional context is of particular importance to provide an overview of the IWM establishment in the basins that cover these areas (Figure 24).

Figure 24. Political Map of the Aral Sea Basin (ASB). Source: CA-Water.info, accessed May 17, 2024.

This background is built up not only from hydrological features, but also from a sum of interconnected and mutually influencing factors reflected in Figure 25, namely, socio-economic and political aspects. Some of them directly or indirectly shape the changing balance of water resources availability and water requirements at different speeds.

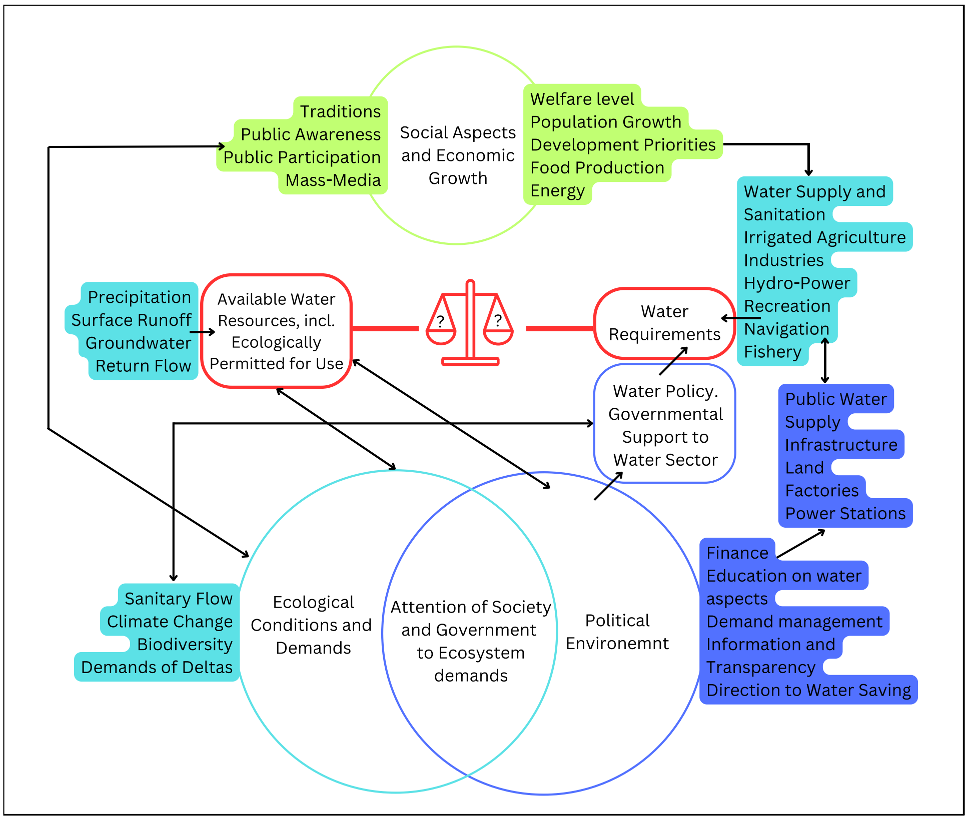

Figure 25. Factors that influence water management in CA (own compilation, adapted from Dukhovny and Shutter 2011)

As the research attempts to analyze the IWM in ARB and SRB, this section will look into some of the socio-economic aspects and elaborate on the trends in the industry water requirements.

2.3.2.1. Historical and Traditional features of water management in Central Asia

Due to the arid climate and the importance of agriculture, Central Asia has a long history of irrigation and water management dating back centuries (Sehring 2009b). Traditional practices made efficient use of scarce water resources and adapted to the difficult conditions created by aridity (2009b). Over centuries, slopes were terraced into small, level basins irrigated by flooding, often bordered by trees (Sehring 2009b). In ancient times, the integration of irrigation with desert rangelands was a key component of water management strategies in the region's oases. Farmers combined rainfed agriculture with livestock keeping, giving irrigated lands periodic rest (Dukhovny and Schutter 2011a).

Customary institutions and practices included the position of "mirab" or "murab" - a water master responsible for fair distribution – it has existed since the 18th century to mediate water disputes between villages (Dukhovny and Schutter 2011a). Villagers cooperated to clean springs and rationalized water distribution through agreed irrigation schedules, especially during shortages. In mountain villages of Kyrgyzstan and Tajikistan, irrigation was timed for cooler parts of the day to reduce evaporation (Sehring 2009b). Some traditional water management systems like qanats (underground tunnels), khooshab (micro-catchments) and bandsar (small dams) are still used effectively in parts of the region where they are well-adapted to local conditions. However, integrating these indigenous practices with modern technologies remains a challenge (Dukhovny and Schutter 2011a).

A popular opinion reasonably highlights that during the Soviet period, many indigenous practices were replaced by a centralized, production-oriented system, which led to the expansion of cotton cultivation, increasing water use, loss of soil fertility, and fewer land areas for food crops (Sehring 2009b). Construction of large-scale infrastructure like the Karakkum Canal in Turkmenistan diverted substantial flows from rivers, impacting downstream areas (Asarin, Kravtsova, and Mikhailov 2010).

Alternative points of view stress the positive aspects of centralized management, such as the presence of integrated water development projects which have been present since the 1950s, such as the Master Plan for Integrated Water Use and Conservation in the Aral Sea Basin and Master Plans for Integrated Water Use and Conservation in the Amudarya and Syrdarya river basins (Dukhovny and Schutter 2011a; IWMI 2024 #178). The program served as a basis for international water sharing in the region. The planning system included the components are prototypical to the general water management methodologies, yet with less sophisticated legal and institutional components and ecological awareness. The plans were based on a forecast of water resource availability, which allowed us to predict water demand and estimate water balances. The system included flood control measures and water distribution regarding the hydropower and agriculture sectors (2011a). The water use for these two sectors was incorporated into the development strategy, which included milestones and timeframes for water- and infrastructure-related management activities (Dukhovny and Schutter 2011a).

Although these plans were coordinated with the representative bodies of all five countries, their performance was not tracked or evaluated (IWMI , accessed NMay 32024). The less supportive of the Soviet water management system opinion points out that from the 1950s on, the water resources of Central Asian rivers, mainly Syrdarya and Amudarya, have been utilized in economic processes for a relatively short period of just 20-30 years (Sehring 2009b). It was evaluated that by the mid-1980s, available water resources had already been overused by 50% (Ryabtsev 2007). In time, this practice resulted in adverse effects and the occurrence of the Aral Sea disaster, which is nearly impossible to deny.

2.3.2.2. Post-Soviet Regional Cooperation on Basin Management

The collapse of the Soviet Union in 1991 led to significant challenges in water management across Central Asia, particularly in the Syrdarya River basin (Asarin, Kravtsova, and Mikhailov 2010). This event marked a turning point that reshaped the region’s approach to water resources and created a complex web of political, economic, and environmental issues that persist to this day.

The states which had just gained independence had to develop their own water policies and management approaches after the dissolution of the centralized Soviet system. This transition was challenging as the countries were not well-prepared for it (Sehring 2009a).

The tensions arose between upstream countries like Kyrgyzstan and downstream countries like Kazakhstan and Uzbekistan over water allocation and reservoir operations (2009a). Kyrgyzstan, facing fuel shortages, began demanding compensation in fuel and electricity for water releases from its reservoirs like Toktogul (Sehring 2015). Annual barter agreements were established starting in 1995 where downstream countries would provide fuel and electricity to Kyrgyzstan in exchange for water releases for irrigation (2015). However, these agreements often faced implementation problems due to pricing disputes, payment failures, and the linkage of water prices to gas prices (Dukhovny and Schutter 2011a). The Kyrgyz Republic, at times, reduced water releases to downstream countries to get more compensation. It also tried to charge higher prices for electricity generated in summer months which the other countries refused to pay. This created instability in the irrigation water supply. The close linkage of water releases to barter supplies of fuel or (and) electricity in 1998 created a lot of uncertainty in the operation of reservoirs and hydropower stations, which was underpinned in the regional agreements (2011a). Commercial pricing demands by Kyrgyzstan led to delays in annual agreement protocols. This became particularly evident when the country inflated its commercial price requirements, causing objections from other agreement participants and leading to annual delays in signing protocols by 5-6 months in the 2000s (Dukhovny and Schutter 2011a).

According to numerous sources (Dukhovny and Schutter 2011a; Patricia Wouters, Dukhovny, and Allan 2007), the ongoing confrontation between upstream and downstream countries has been mainly evolving around the attempts to link water releases with purchases of fuel and electricity. This approach seems fundamentally problematic, as it commodifies water, which is inherently at odds with the principle that water is not a commercial good in accordance with international conventions and human rights principles. Foreign researchers show interest in the region’s water management problems, implementing numerous projects, including theoretical studies aimed at finding compromise solutions (WECOOP 2023). These attempts are manifested in pilot studies, but the establishment of that agreements seem very fat from the basin scale, which IWM demands (Mirzaev 2022).

2.3.2.3. Trends in Agriculture and Energy in Central Asia

Agriculture plays a pivotal role in the economies of Central Asian countries, contributing significantly to their Gross Domestic Product (GDP) and employing a substantial portion of their labor force. In Kazakhstan, the agricultural sector is a cornerstone of the economy, accounting for approximately 10% of the GDP and employing around 20% of the workforce (World Bank 2019). The country has embarked on several strategic initiatives to boost agricultural productivity and sustainability, such as the "Concept for the Development of the Agro-Industrial Complex for 2021-2030" and the "National Project on the Development of Agro-Industrial Complex for 2021-2025" (FAO 2020).

Similarly, agriculture is a vital sector for Kyrgyzstan, contributing over 30% to the GDP and employing a significant portion of the population (FAO 2020). Despite facing challenges like outdated infrastructure and inefficient practices, efforts are underway to modernize the sector. In Tajikistan, agriculture is crucial, contributing nearly 20% to the GDP and employing 61% of the workforce (ADB 2022). However, the sector grapples with limited arable land and significant challenges, including climate change and infrastructure deficits 29 (2022).

In Turkmenistan, agriculture is a significant sector, employing nearly half of the workforce and contributing around 8% to the GDP. Due to the arid climate, the sector is heavily reliant on irrigation, which presents serious challenges, but also motivation for innovation in water management (World Bank 2021b).

The energy sector in Central Asia is marked by a transition towards renewable energy sources, driven by the need to reduce reliance on fossil fuels and address environmental concerns (O. Saidmamatov et al. 2023). Kazakhstan seems to be the front-runner of this transition, with 146 operational renewable energy facilities (Times 2024). The government aims to increase the share of non-hydropower renewable energy to 15% by 2030 and 50% by 2050 in the electricity mix (IEA 2022). However, challenges such as outdated infrastructure, low electricity tariffs, and the dominance of coal-fired generation impede progress towards emission reduction targets. To modernize the power sector and attract investments, Kazakhstan is implementing energy subsidy reforms, including incentive-based tariff regulation and provisions for social protection (IEA 2022).

Kyrgyzstan still heavily relies on hydropower, which accounts for over 90% of its electricity generation (FAO 2020). The country faces challenges due to aging infrastructure and limited diversification. Approximately 60% of the transmission and distribution network is past its useful life and needs replacement (ADB 2021). To diversify its energy sources, the government is prioritizing the construction of small hydropower plants and exploring solar and wind potential. Efforts are also underway to improve energy efficiency, integrate renewable sources into the grid, and enhance regional cooperation for energy security (ADB 2021).

Tajikistan’s energy sector is dominated by hydropower, but the country faces supply shocks and frequent power outages due to aging infrastructure and limited diversification (World Bank 2020b). The Nurek hydroelectric plant, which supplies around 50% of Tajikistan's electricity, is undergoing rehabilitation with support from international financial institutions (2020). The Rogun hydropower plant, constructed in 2019, is CA’s largest power plant but faces financial and other transboundary challenges (2020).

Turkmenistan's energy sector is primarily focused on its abundant hydrocarbon resources, but the country is exploring renewable energy potential. Turkmenistan is rich in critical raw materials like lithium, iron, and copper, which are essential for renewable energy technologies (UNDP 2021). The government aims to address climate change, enhance environmental sustainability, and promote green growth through regional cooperation. However, challenges include the lack of comprehensive data on reserves, regulatory frameworks for non-hydrocarbon mining, and the need for donor assistance (World Bank 2021b).

Uzbekistan is actively pursuing a transition towards renewable energy sources to reduce its heavy reliance on natural gas. The government aims to increase the share of renewable energy in power generation to 25% by 2030, prioritizing solar and wind projects (M.o.E.o.t.R.o. Uzbekistan 2020). Challenges include the need for energy storage systems, modernization of distribution networks, and improving energy efficiency (Ministry of Energy of Uzbekistan, 2021).

While CA countries face numerous challenges, they share common priorities such as economic diversification, energy security, and sustainability, following global trends (Qin et al. 2022). Regional cooperation, investment in renewable energy sources, and modernization of infrastructure are crucial for achieving their energy transition goals and destress hydropower where possible.

2.3.2.4. Population and demographics

As of early 2024, the total population of CA surpassed 79 million, with an average annual increase of 1 million people in the last decade (World Bank 2021a).

Uzbekistan has the largest population at 35.6 million, followed by Kazakhstan (19.8 million), Tajikistan (10.4 million), Kyrgyzstan (6,79 million), and Turkmenistan (6.59 million) (World Bank 2022a).

Despite challenges like low living standards and high mortality, the region's population has grown by 60% since the collapse of the USSR, adding nearly 30 million people. According to UN data, the population is projected to exceed 100 million by 2050. By 2100, the median projection is 101 million, with an 80% uncertainty range of 72-133 million (UNDESA 2022)

CA has one of the world's youngest populations with an average age of 27.6. Around a third of the population is under age 15 (World Bank 2021a). Such demographic presents opportunities but also challenges if countries fail to create sufficient jobs and meet growing needs. Rural poverty is driving migration to urban areas ill-equipped to handle the influx, fueling social tensions, with depopulation of rural areas poses another challenge (World Bank 2020a; IOM 2021).

2.3.2.5. Public awareness and participation in water management

The urgency of efficiently using and protecting water resources has been increasing globally due to population growth and the rise in industrial and agricultural production, including the expansion of irrigated agriculture. During the 1990s and 2000s, public involvement in water management issues was minimal in CA. This was due to several factors (Ryabtsev 2007):

1. Countries in the region had recently gained independence and were focused on identifying development models, leading to insufficient attention to establishing civil societies.

2. Citizens, accustomed to totalitarian regimes, were not prepared to actively participate in water resource management and environmental issues.

3. There was a lack of trained professionals who could understand and address water and environmental issues at the public level.

Since then, the situation has improved significantly (Ryabtsev 2007). Numerous non-governmental organizations (NGOs) have emerged, focusing on the water sector, raising public awareness, and interacting with governmental agencies in water resource management and regulation (Ryabtsev 2007). These NGOs have become a real force capable of influencing local, basin, and regional regulations (WECOOP 2023). Public participation in regional water resource management varies, involving NGOs, movements, and parties with different political goals (WECOOP 2023). This participation includes activities such as workshops, conferences, public hearings, media statements, tree planting, garden creation, and cleaning water protection zones (Sehring et al. 2019). The main goal of these activities is to draw governmental attention to the importance of efficient water resource use and protection (Sehring et al. 2019).

Additionally, public organizations play a crucial role in educating civil society and the younger generation about environmental issues, fostering a responsible attitude towards water and the environment (UNECE 2011). The establishment of the Regional Ecological Center of Central Asia (REC CA) has significantly contributed to uniting NGO efforts to improve the ecological situation in the Aral Sea Basin. For instance, in 2002, REC CA reviewed over 250 proposals from regional NGOs, funding projects that stimulated public participation in addressing vital regional problems (Yoshida 2022).

Summarizing the main factors that influence the balance between water requirements and water availability in the context of IWM establishment, the major relevant components observed in relation to Figure 25 are:

- Growing food demands because of population growth (Hamidov et al. 2022).
- The unevenness of socio-economic development in the basins, medium-low public participation, and generally sporadic environmental awareness (Ryabtsev 2007; Xiaolei Wang, Zhang, et al. 2023; Itayi, Mohan, and Saito 2021).
- Instability in financing of operation and development (Hejnowicz et al. 2022).
- Low income, declining employment opportunities, poverty, and natural disasters (UNDRR 2021).
- Agriculture and other subsectors, particularly hydropower, are experiencing growing competition, with some prospects for each sector's technological improvement in terms of resource efficiency (reduced water losses, energy supply diversification, reduced electricity consumption) (Nazirov 2007; Qin et al. 2022; O. Saidmamatov et al. 2023).
- Uneven access to safe drinking water and sanitation, especiallu in the areas with high hazard, vulnerability and the lack of coping capacity (Yapiyev et al. 2021; UNDRR 2021).
- Inadequate or worn infrastructure (Sehring et al. 2019).

In conclusion, the water management landscape in Central Asia has undergone significant transformations shaped by historical practices, geopolitical shifts, and evolving socio-economic needs. The region's long-standing tradition of water management, dating back centuries, demonstrates the importance of adapting to arid conditions and efficiently utilizing scarce water resources. However, the transition from Soviet-era centralized management to independent state policies has created complex challenges in water allocation and regional cooperation.

The post-Soviet era has been marked by tensions between upstream and downstream countries, particularly in the SRB, where water releases have been linked to energy exchanges, leading to instability in irrigation water supply. This commodification of water resources contradicts international conventions and human rights principles, highlighting the need for a more sustainable and equitable approach to transboundary water management.

Agriculture remains a crucial sector for CA economies, contributing significantly to GDP and employment. However, the sector faces challenges such as outdated infrastructure, inefficient practices, and the impacts of climate change. Simultaneously, the energy sector is transitioning towards renewable sources, with countries setting ambitious targets for its diversification and sustainability.

The region's growing population, projected to exceed 100 million by 2050, adds pressure to already strained water resources and infrastructure. This demographic trend underscores the urgency of IWM establishment that can balance the needs of agriculture, energy production, and urban development while preserving ecological systems.

Public awareness and participation in water management have improved since the 1990s, with the emergence of NGOs and increased civil society engagement. This growing involvement presents an opportunity to foster a more inclusive and sustainable approach to WRM in CA.

CA is facing water management challenges that can be addressed through enhanced regional cooperation, investment in sustainable technologies, and the integration of traditional knowledge with modern practices. By prioritizing these aspects, it increases the changes that the region will succeed in working towards achieving water security, economic stability, and environmental sustainability in the face of ongoing climate change and population growth.

2.3.3. Basin governance of the ARB and SRB in CA

Exploring the institutional settings that deal with IWM in the ARB and SRB, the study found the following organizational outlay (Figure 26).

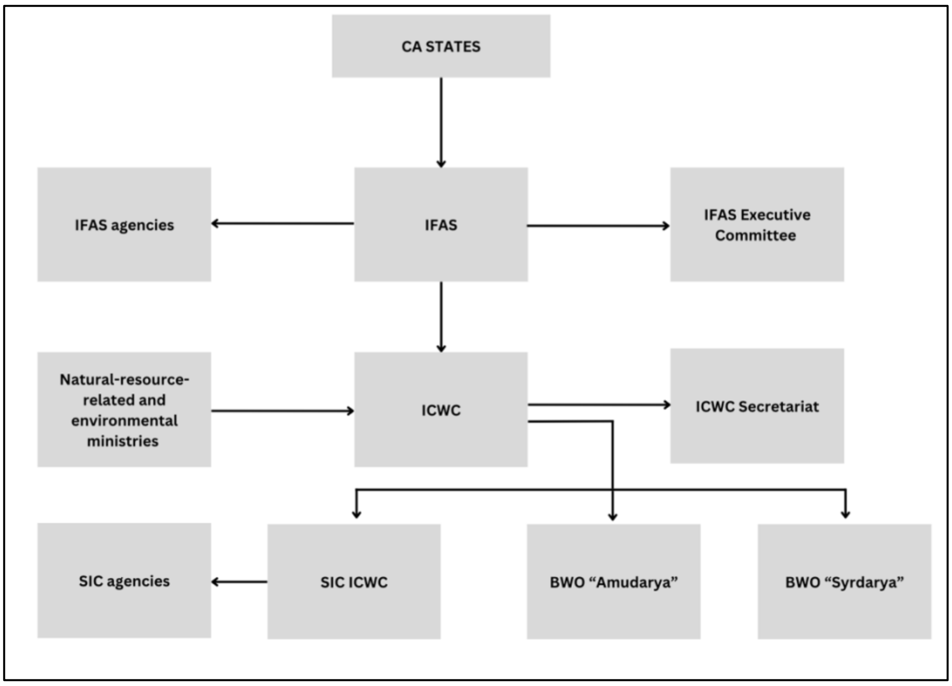

Figure 26. Structure of interstate water resources management in Amudarya and Syrdarya river basins (Own compilation, adapted from Dukhovny 2007), validated from CA-Water.info (accessed May 1, 2024).

The initiators of the IWM process in the region are recognized as the national of the states of Central Asia.

The International Fund for Saving the Aral Sea (IFAS) is the top basin-scale Institution that manages water resources in Central Asia and coordinated efforts to mitigate the impacts of the Aral Sea crisis and improve regional socio-economic conditions (Sokolov, Ziganshina, and Dukhovny 2014).

Established in 1993, IFAS facilitates dialogue and joint decision-making on water management involving bodies like the Interstate Commission for Water Coordination (ICWC). It secures funding and technical support from international organizations like the FAO, GEF, UNDP, UNECE, etc. (ICWC 2023) and develops agreements on water allocation, ensures fair distribution among countries, and provides training programs to enhance regional water management capacity (UNECE 2011).

However, political disagreements and financial constraints limit IFAS' effectiveness (V.A. Dukhovny and Schutter 2011b). Future efforts aim to enhance regional cooperation, promote sustainable development, and secure more international funding (Sehring et al. 2019).

Functions-wise, one can discover the following interrelations between the bodies involved in governance, finance, management, and information sharing relevant to the establishment of the IWM process.

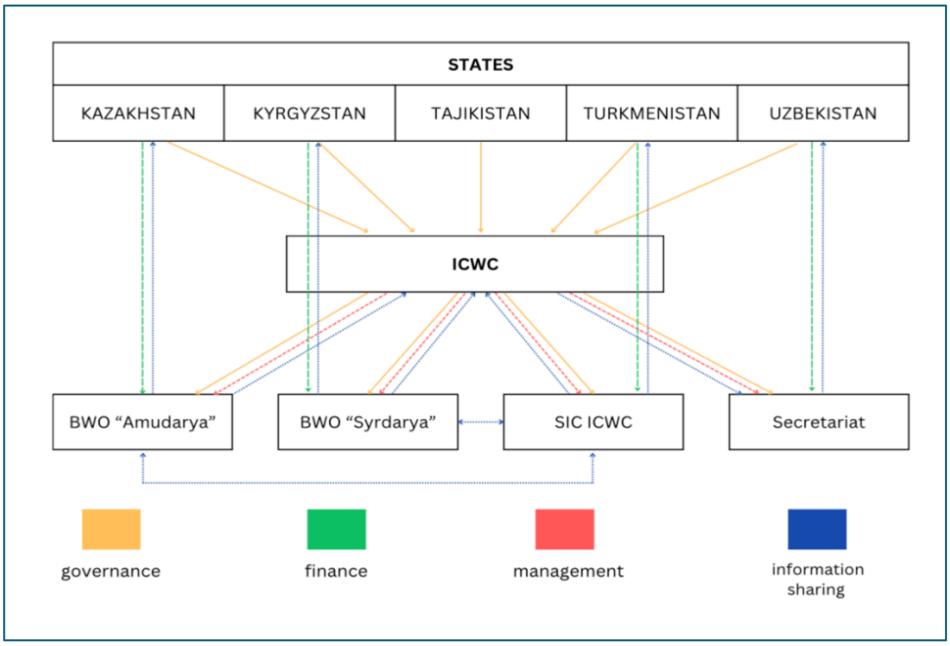

Figure 27. Functions and interrelations of Water Management Institutions in Central Asia. (Own compilation, adapted from Dukhovny and de Shutter 2007)

According to the Agreement of 9 April 1999, ICWC was included in the IFAS system, and its executive bodies were endowed with privileges and immunities previously granted only to the central structural units of IFAS (V. Dukhovny 2007). The ICWC operates as a regional body under IFAS, tasked with the joint management, rational use, and protection of water resources in the Aral Sea basin. This subordination is further confirmed by the regulatory documents that align ICWC's activities with the decisions of the IFAS Board (Hunink 2021).

Established in 1992 by Kazakhstan, Kyrgyzstan, Tajikistan, Turkmenistan, and Uzbekistan, ICWC operates under the principles of equity, equality, and consensus. Key Functions and Responsibilities of ICWC include formulating and implementing regional policies for efficient water use and protection and addressing social, economic, and environmental needs – separately or in collaboration with the Interstate Commission on Sustainable Development (ICSD) (ICWC 2023). It oversees the allocation of water from shared sources, ensuring compliance with annual withdrawal limits and managing the operation of large interstate reservoirs (Djalalov 2007).

Through its Scientific Information Center (SIC), ICWC supports research, information dissemination, and capacity building to enhance water conservation and management practices (Nazirov 2007)

Despite its efforts, ICWC faces challenges such as political disagreements and limited authority, which hinder its ability to enforce decisions and develop universally acceptable solutions (V.A. Dukhovny and Schutter 2011b; Sehring, ter Horst, and Said 2023).

The ICWC operates through its executive bodies, which include the Basin Water Organizations (BWOs) for Amudarya and Syrdarya (Figure 27). These BWOs are responsible for the operational management and distribution of water resources within their respective river basins, adhering to the limits and guidelines set by the ICWC (BWO "Amudarya" Statute 1992; BWO "Syrdarya" Statute 1992).

BWO Amudarya manages water resources in the Amudarya River basin, ensuring the timely and reliable delivery of water to users according to the agreed limits. It also oversees the provision of sanitary and environmental flows to the Aral Sea. The BWO Amudarya's activities are guided by the ICWC's decisions, agreements, and protocols, and it operates under the legal frameworks of the member states locally. The organization is financed by subsidies from Uzbekistan, Tajikistan, and Turkmenistan, and it maintains an independent balance, juridical rights, and bank accounts (1992a).

Similarly, BWO Syrdarya is tasked with managing water resources in the Syrdarya river basin. It ensures the timely provision of water to consumers, operates water-intakes, hydropower facilities, and reservoirs, and implements measures to improve the ecological situation. BWO Syrdarya also plans water-intake limits, manages interstate reservoirs, and controls water quality. It operates under the legislation of the ICWC member states and is financed by interested ICWC members (1992b).

The BWOs function as the “operational arms” of the ICWC, executing its decisions and ensuring compliance with water allocation limits. They provide critical data and feedback to the ICWC, which uses this information to make informed decisions on water management policies. The BWOs also collaborate with other ICWC bodies, such as the Scientific Information Center (SIC) and the Secretariat, to support research, training, and international cooperation efforts (1992a, 1992b).

The cornerstone principles articulated in the regional agreements that guide the work of these bodies correspond to the International Water law (Figure 28).

Principles	Almaty Agreement (1992)	ICWC Statute (2008)	BWO “Amudarya” (1992)	BWO “Syrdarya” (1992)
Reasonable and equitable use	Preamble, Art. 1,2,10	Art. 1,5,2.1,2.2	Art. 1.3, 2.1	Art. 1.3, 2.1
Not to cause significant harm	Art. 3,4	Art. 1.4, 2.3, 2.4, 4.1, 4.2, 5.5	Art. 1.3, 2.2, 2.5, 2.7, 3.8	Art. 1.3, 2.2, 2.5, 2.7, 3.8
Cooperation and information exchange	Art. 5,7,8,9,10	Art. 2.7, 2.10, 2.11, 2.13, 2.16, 4.2, 5.1, 5.6, 5.7, 5.8	Art. 2.3, 2.4, 2.5, 2.6, 3.3, 3.5	Art. 2.3, 2.4, 2.5, 2.6, 3.3, 3.5
Notification, consultation	Art. 7,8,9,10,11	Art. 2.17, 4.1, 4.2, 4.4	Art. 3.2, 3.3	Art. 3.2, 3.3
Peaceful settlememt of disputes	Art. 8,9,10,11,13	Art. 2.17, 4.1, 4.2, 4.4	Art. 2.1, 3.1, 3.2	Art. 2.1, 3.1, 3.2

Figure 28. Transboundary agreements on IWRM in CA. Adapted from Rahaman 2012 (own compilation).

The system of water management in CA looks the following way (Figure 29) and is subject to the governance and management of the above-illustrated institutional architecture.

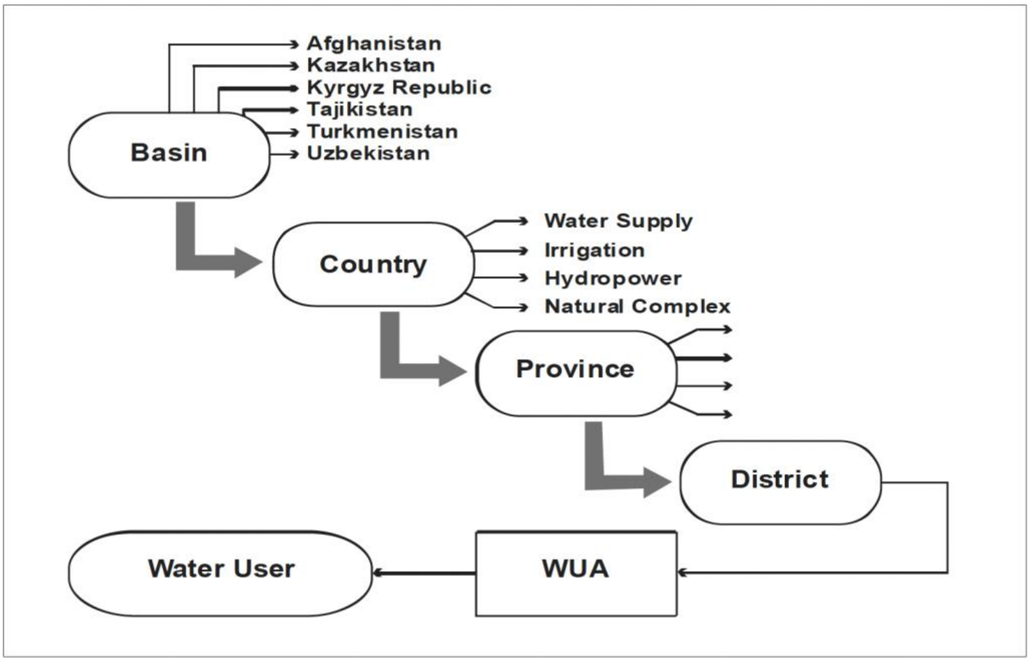

Figure 29. The levels of Water management in Central Asia. Source: Dukhovny 2007.

Those structures — the hierarchical levels of water management in CA (Figure 26), the Structure of interstate water resources management (Figure 27), and the functional compound of the IWM process (Figure 29) — together form the complexity that the Asian Development Bank in 2003 referred to as "*do not fix the pipes; fix the institutions that fix the pipes*." (Sehring 2009b, 18).

To conclude this subchapter on the institutional settings for Integrated Water Management (IWM) in the Amudarya and Syrdarya River Basins (ARB and SRB), one can summarize the key findings and implications as follows:

The literature review has revealed a complex, multi-layered institutional framework for managing transboundary water resources in Central Asia. At the apex of this structure is the International Fund for Saving the Aral Sea (IFAS), which serves as the primary basin-scale institution coordinating efforts to address the Aral Sea crisis and improve regional water management. Under IFAS, the Interstate Commission for Water Coordination (ICWC) plays a crucial role in formulating and implementing regional water policies, allocating water resources, and overseeing the operation of major interstate reservoirs.

The operational management of water resources is carried out by the Basin Water Organizations (BWOs) for Amudarya and Syrdarya, which function as the executive bodies of the ICWC. These organizations are responsible for the day-to-day distribution of water resources within their respective basins, adhering to the limits and guidelines set by the ICWC.

While this institutional framework provides a foundation for transboundary water management, it faces several challenges:

1. Political disagreements and financial constraints limit the effectiveness of IFAS and ICWC.
2. The ICWC's authority is limited, hindering its ability to enforce decisions and develop universally acceptable solutions.
3. The complex interplay between regional and national interests often complicates decision-making processes.

The study also highlights the importance of aligning water management practices with international water law principles, as reflected in the regional agreements guiding these institutions' work. However, the implementation of these principles remains challenging due to the competing interests of the riparian states.

In conclusion, while Central Asia has established a comprehensive institutional architecture for transboundary water management, significant work remains to be done to overcome existing challenges and fully realize these institutions' potential.

Summarizing the information on the study area, one should recognize the difficulties of water allocation in the transboundary river basins, and the variety of the socio-economic, political and demographic factors that co-define water consumption and land reclamation. Besides that, the basins experience various kinds of pollution arising from the agriculture and mining sectors, as well as radioactive and other waste mismanagement. Unlikely to that, the alternative scenario could help to stop the negative influence on the health of living beings and water availability. The best sustainable option for future IWM management according to ecosystem needs is to save water, encourage wetland transitions, mitigate impacts of existing pollutants, undertake basin-scale clean-up measures by engineering and biological methods, establish irrigation wastewater treatment practices, and properly manage waste. Additionally regulating the levels of the water with appropriate mineralization in the water bodies for animal species for its life sustenance.

Within the socioeconomic and political factors, many features upset the balance of human Water Requirements and natural Water availability. CA does have a set of proper Institutional architecture, the performance of which the study is going to disclose in the further sections. Given the pending era of hydrographization of the basins and the management based on hydrological principles in CA, many sustainable opportunities are being delayed.

3. Methodology

3.1 Data Collection

This study employed a qualitative research approach, relying primarily on document analysis and literature review to gather data on integrated watershed management (IWM) and integrated water resources management (IWRM) in the Amudarya River Basin (ARB) and Syrdarya River Basin (SRB) of Central Asia.

The data collection process began by investigating the architecture and knowledge repositories of key regional water management bodies. Relevant data portals explored included the Scientific-Information Center of the Interstate Commission for Water Coordination (SIC ICWC), the CA-Water.info Portal, and online repositories of international organizations active in the region such as the World Bank, UNECE, UNDESA, UNDRR, and FAO. Access to some practical basin-level data required special institutional permissions and financial provisions, which limited the incorporation of certain sources.

Key publications and reports were purposively selected for analysis based on their relevance to IWM and IWRM in the ARB and SRB. Particular attention was given to works by prominent regional experts such as Victor Dukhovny, former head of SIC ICWC, and Jenniver Sehring, a leading researcher on water management institutions and politics in Central Asia. Selection aimed to capture authoritative sources reflecting scientific consensus and diverse perspectives.

Empirical data was obtained from national agencies' submissions to the UN-Water survey on SDG indicator 6.5.1 for IWRM implementation as of 2023. This publicly available data was accessed from the relevant government bodies in Kazakhstan, Kyrgyzstan, Tajikistan, Turkmenistan, and Uzbekistan. Together with the literature review, it has allowed for collecting the data on 1) The state-of-the-art environmental issues in the ARB, SRB, and

Central Asia broadly; 2) Frameworks for IWM and IWRM; 3) In-depth examination of IWM and IWRM experiences specific to Central Asia.

For each stage, searches were conducted in academic databases (e.g. Google Scholar, Web of Science), organizational knowledge repositories, and reference lists of key publications. Search terms included relevant keywords such as “Integrated water resources management”, “Integrated watershed management”, “Amudarya”, “Syrdarya”, “Water in Central Asia”, etc. Sources were analyzed and synthesized to extract relevant data, identify themes, and develop a comprehensive understanding of the topics.

3.2. Data Analysis

To analyze the collected qualitative data, an analytical framework was developed by combining elements of the IWMI IWRM assessment toolbox, UN IWRM implementation criteria, and Hufschmidt's 3-dimensional IWM model (1984). The resulting matrix captured IWRM and IWM concepts along dimensions of System, Activities, and Process.

Using this framework, practical water management problems identified through the literature and empirical data were categorized and contextualized at different levels (regional, national, basin) and management aspects. The analysis aimed to structure the complex web of issues affecting IWM and IWRM in the ARB and SRB.

3.3. Limitations

This study faced several limitations. First, the complexity of water resource management and the diversity of approaches in the region challenged neat categorization. The research scope was necessarily bounded according to the analytical framework developed; after the elements were disclosed, the study sought analogous patterns in the study area. Secondly, heavy reliance on SIC ICWC publications, while reflecting their authority, may have resulted in biased representation of perspectives. Efforts were made to include various sources to balance the opinions and discuss the results voluminously. Third, Victor

Dukhovny's passing in 2021 has impacted the availability of updated field-level observations from SIC ICWC in recent years. Empirical data from UN surveys helped fill some gaps, but on-the-ground details may be lacking.

Finally, the study does not deeply examine Afghanistan's role in ARB management. While this is a limitation, the focus on post-Soviet Central Asian republics still provides valuable insights into the institutional context.

Despite the constraints, the combination of purposive document analysis, comprehensive literature review, and structured qualitative data analysis allowed for a meaningful examination of IWM and IWRM issues in the ARB and SRB at a level appropriate for the study's scope and aims. The transparent description of methods also supports the evaluation of the research's strengths and boundaries.

4. Results

4.1. IWM in the ARB and SRB

4.1.1. National IWRM complexes

Even though IWRM national complexes stand further from the International Water Law on IWM, the study sees the need to address them before the Transboundary cooperation (Figure 14). Alternatively, this level can be seen as a foundation, setting the defacto rules for interaction at the basin level (Figure 14, “IWM”). These two IWM levels – Transboundary cooperation and IWRM complexes - mutually influence one another: this feature is stressed with the arrows along the sides of the pyramid: top-down for the International Water Law as the highest standard-setting Institution, and the second set of arrows reveals the nature of administrative realities applied to the basin management.

To understand the role of the by-level approach in the analysis of the IWM establishment in CA, here one must look at how the countries of the basin address basin management according to the features of the area of the catchment as well as the socio-economic factors that shape the balance between water requirements and supply (2.3. Study area), which later, as a matter subject to diplomatic regulation, is raised at the negotiating table to decide on watershed management at the basic-scale. The agreements developed within the Transboundary cooperation level then adjust the IWRM complexes of the countries. This approach may not be universal, correct, or ethical, but it is relevant to the description of the dynamics of IWM in CA.

As the UN data submitted by the national authorities of all countries show (Kazakhstan 2024; Tajikistan 2023a, 2023b; Kazakhstan 2023a, 2023b; Information 2023; Z. 2023; Ministry of Natural resources Ecology and Technical Supervision of Kyrgyz Republic 2023; Ecology and Technical Supervision of Kyrgyzstan Ministry of Natural Resources 2023a; Ecology and Technical Supervision of Kyrgyzstan Ministry of Natural Resources 2023b;

Uzbekistan 2023a; Turkmenistan 2023;. Uzbekistan 2023b) at the world-scale comparison, Central Asia is in the *medium-high* and *medium* sections of the IWRM implementation spectrum (Figure 30).

Figure 30. National iwrm evaluation (EN – enabling environment, I– institutions, M - management). UN-Water (2023 data), accessed June 4, 2024. Own compilation.

If the statistics are not broken down into the criteria evaluation, the Enabling environment and Institutions show generally worse results than Management (Figure 31).

ENABLING ENVIRONMENT	KAZ	KGZ	TJ	TKM	UZB
National water resources policy	40	60	70	70	60
National water resources law(s)	20	60	70	70	40
National IWRM plans	20	30	60	70	40
Sub-national WR policies	40	10	60	70	40
Basin/aquifer management plans	20	20	60	60	30
Transboundary WRM agreements	80	80	70	80	70
Sub-national WR regulations	40	10	40	60	30
National budget for WR infrastructure	40	60	-	70	50
National budget for IWRM elements	40	20	-	70	40
Sub-national/basin budgets for WR infrastructure	20	10	-	70	40
Revenues raised for IWRM elements	40	30	-	60	30
Financing transboundary cooperation	100	30	-	20	50
Sub-national/basin budgets for IWRM elements	20	20	-	-	30

INSTITUTIONS	KAZ	KGZ	TJ	TKM	UZB
National institutions leading IWRM	40	40	70	60	70
Cross-sectoral coordination	70	40	60	60	60
Public participation	80	60	40	40	60
Private sector participation in WRM	100	10	40	80	50
Developing IWRM capacity	50	40	60	50	60
Basin/aquifer level organizations	20	30	50	80	60
Public participation in WRM - local	80	30	40	20	60
Participation of vulnerable groups	60	20	10	10	40
Gender mainstreaming in WRM	10	30	40	40	50
Transboundary WRM organisational frameworks	100	70	70	80	70
Sub-national authorities for IWRM	20	40	50	80	40

MANAGEMENT	KAZ	KGZ	TJ	TKM	UZB
Water availability monitoring	70	30	60	70	70
Sustainable and efficient use management	60	60	60	60	60
Pollution control	50	60	50	50	60
Water ecosystem & biodiversity management	60	60	50	60	60
Management of water-related disasters	70	40	60	70	70
Basin management instruments	60	40	60	60	60
Aquifer management instruments	60	40	50	60	60
Data and information sharing within country	80	50	50	80	70
Transboundary data and information sharing	80	40	50	80	50

No data | Very low (0, 10) | Low (20, 30) | Medium-low (40, 50) | Medium-high (60, 70) | High (80, 90) | Very high (100)

Figure 31. SDG 6.5.1 in CA. Source: UN-Water (2023 data), accessed June 4, 2024. Own compilation.

Applying some reasonable skepticism to the data collected from nationally submitted surveys, one can still see and rely on the overall IWRM situations in each country.

Exploring the enabling environments reveals that subnational water resource policies, regulations, and budgets in Kyrgyzstan for 2023, together with the *Management pillar* on a regional scale, are still “very low”.

The survey submitted by Turkmenistan shows a medium-high rating for the criteria available, except for the transboundary cooperation financing.

Given its economic and political settings, Tajikistan lacks much information on Finance and may lack data-gathering capacity. Considering the provided data, the country is in the medium section of the IWRM establishment spectrum.

Uzbekistan and Kazakhstan show mixed results in *Policy* and *Finance* performance (*Enabling environment*).

It is also worthy of noting how countries define “*Basin/Aquifer organizations*”, which are certainly one of the essential criteria for the given research. Kazakhstan and Kyrgyzstan give the lowest evaluation for cooperation; Tajikistan has a medium-low appraisal, while Uzbekistan has a medium rate; Turkmenistan surprisingly has evaluated it highly positive. By that, parties mean the work of the Basin Water Organizations (BWOs), which the research will discuss later.

Interestingly, Kazakhstan has the highest possible ranking for transboundary cooperation financing, regardless of relatively low adjustments for the national and other IWRM criteria. The country actively collaborates with international agencies, which allows for extensive data gathering on a national level, as many national IWRM reports are being published. Among all CA countries, Kazakhstan submitted only one IWRM Action Plan for the Global Water Partnership in April 2019 with goals for 2020, 2025 and 2030 (Kazakhstan 2019). Despite that, in sharing the impressions on National IWRM Plans, the distinguished ministry assessed it as *low*. This can be explained either by the incompleteness of the tasks or by the challenges faced with the 2020 tasks, which should have been fulfilled by now.

Generally, the estimation of the transboundary agreements is medium-high. Agreeably, the analysts note that the existing legal basis for transboundary cooperation is established and may be considered sufficient. However, because of a number of issues, including the lack of political will in the region and parochial interests, deviations occur (Sehring et al. 2021b). A similar logic applies to the national legislation, which apparently may be lacking flexibility compared to the basin management plans, occasionally being violated in favor of alternative profitable opportunities, supported by national sovereignty right (Nazirov 2007; Ruziev and Prikhodko 2007; Sehring and Ibatullin 2020).

Another tendency elucidates the struggles with water allocation for the Syrdarya river basin. As one can see, Kazakhstan, Kyrgyzstan, and Uzbekistan have hardly any basin management plans, whereas Turkmenistan and Tajikistan seem to be having a less troublesome transboundary cooperation in the Amudarya river basin. Similarly, Finance-wise, not all participants are ready to allocate sufficient funds for the basin infrastructure. Within their parts of the basin, the budgets also seem tight.

Speaking of the Amudarya basin, Tajikistan lacks some data on the *Enabling environment*, but the assessment by Turkmenistan is medium-high, except for finance for transboundary cooperation and the missing data on their national budget for operation and maintenance of the part of the Amudarya system on their territory.

From the surveys, one can observe that most CA countries estimate their national water management performance *beyond medium* (on the global scale), whereas the IWM-related indicators*, "Basin level organizations,"* seem to be evaluated as of much lower efficiency. Financing for the transboundary cooperation is low as well, except for Kazakhstan's inputs, as the most economically developed country in the region. Sub-national/basin budgets for IWRM elements are low for each country that represented the data, even the Kazakh Republic.

Having discussed the most outstanding correlation between the Enabling environment and partial Institutions, one can focus on public participation, engagement of the private sector, and Gender issues. What most countries share is weak sub-national water authorities. This criterion defines the grassroots level of implementation of on-site and off-site IWM activities, as well as the IWM principle of equitable water distribution and bottom-up water management approach. Weak "lows" of the hierarchy may testify to the weak water rights as well. Indeed, public participation by the vulnerable groups – which usually with worse sanitation and access to water – is extremely low, especially in the Amudarya river basin (Tajikistan, Turkmenistan).

Interestingly, sub-national authorities for IWRM in the Kazakh Republic are evaluated as *Low*, but public participation, including vulnerable groups, is generally higher than in the rest of the surveys. However, the one and only *"Very Low"* for Kazakhstan is Gender mainstreaming in water resource management. The latter indicator, though, does not exceed *Medium-Low* for the region as of 2023.

It is striking that Kazakhstan has given a very confident evaluation of the Private sector's success in water resource management. In contrast, the Syrdarya upstream, Kyrgyzstan, has the lowest possible ranking for that indicator. Surprisingly that Turkmenistan has high evaluations of their private sector engagement in water resource management.

The Management pillar, which is slightly fewer *"Lows"* and *"Medium Lows",* still has some efficiency degreasing patterns: pollution control and transboundary information sharing for the Amudarya basin, and comparative lower indicators for nearly all criteria from Kyrgyzstan's side: first of all, the standing-out Water availability monitoring, and then the *"Medium Lows"* for *Management of water-related disasters, Basin management instruments,* *Aquifer management instruments, Data and information sharing within and outside the country.* As the research now states that most issues deal with basin Institutions, Finance for Transboundary and Local Basin infrastructure, and Basin Action Plans and Organizations, it is important to proceed to more concrete observations found in the relevant sources.

4.1.2. IWM establishment in the ARB and the SRB: situation analysis

As the previous findings show, CA does have the conceptual basis for IWM's *System elements* provided by the organizational framework for basin-level cooperation. While the form appears legitimate, its content and practical outputs still need improvement.

As discussed earlier, the region began rebuilding from chaos in 1991 and managed to establish organizational and conceptual frameworks in just one year, from 1992 to 1993, and the developments in national IWRM complexes have been taken every year since, including the help of international donors. However, despite overcoming challenges such as independent development, economic and political crises, and strong path dependency in water governance, there is limited room for open, horizontal transboundary water cooperation.

One recent testament to that is the failed ASBP-3 (Aral Sea Basin Program 3) for the period 2011-2015, which encompassed actions to improve basin management for both the ARB and SRB.

"Unfortunately, to this day there is no in-depth analysis of the results of the three programs (ASBPs) under IFAS. However, we can safely say that over the past 25 years, the provisions of the «Concept for Solving the Aral Sea Problems» of 1993 have practically become obsolete. Much has been done by countries to mitigate the consequences of the Aral Sea disaster, the socio-economic conditions in the countries of the region have changed, and the water management situation in the region has radically changed. In the Aral basin, like nowhere else in the world, the effects of climate change are being observed." (IFAS Agency, accessed June 7, 2024)

With the launch of ASBP-4 in 2021, more political promises have taken place, such as the Decision of the Board on the results of participation at the 9th World Water Forum and 2nd

World High-level Conference on the International Decade for Action "Water for Development", 2018-2028; The decision of the Board on the introduction of modern water metering and monitoring equipment resources in the Amudarya and Syrdarya river basins (from November 28, 2022); The decision of the Board on the implementation of the Project for modernization of hydrometeorological services in Central Asia (from 22 February 2022); Decision of the Board on the progress of implementation of ASBP-4 (from November 28, 2022); Investment Program for the Aral Sea Basin (IPBAM); Action Program for Assistance to Countries of the Aral Sea Basin (ASBA) (IFAS Agency 2022). In addition to the IFAS decisions, there are other practical bilateral developments related to water resources in Central Asia. In 2021, Tajikistan and Uzbekistan signed a new Agreement on joint management of the water resources of the Syrdarya River (CA-Water 2022). In 2022, Kazakhstan and Uzbekistan agreed on the joint construction of a reservoir on the Syrdarya River (CA-Water 2022). In 2023, Kyrgyzstan and Tajikistan began negotiations on a new agreement on the distribution of water resources of the Amudarya River (ICWC 2023).

These decisions are in line with the launch of the large-scale development framework by the FAO and GEF - "Interconnection of Water and Land Resources of Central Asia (CAWLN) for Ecosystem Restoration, Improved Management of Natural Resources, and Increased Sustainability," which has numerous projects that target or help IWM in the ARB and SRB (Alimzhanov 2024).

The research for the practical situation is captured in the matrix developed according to the intersection of IWM and IWRM analytical frameworks (Figure 32) from the literature and the national IWRM surveys.

	IWM System elements			IWM activities		
	Institutional arrangement	Management tool	Management action	Land Use Tasks	On-site	Off-site
IWRM pillar	***ENABLING ENVIRONMENT***					
Component	***Policy***					
Problem	Lack of clear water policy					
	(Nazirov 2007; Djanibekov, van Assche, and Valentinov 2016; V.A. Dukhovny and Schutter 2011b; Rafikov and Rahmatullaev 2016; Xenarios et al. 2019; K. 2022)					

	x	x	x	x		
Problem	The water rights are not determined by indicators of the quantity and quality of water resources					
	(Ermek and Zhakupova 2023; Han et al. 2022; Musina et al. 2023)					
	x	x	x	x	x	x
Problem	Discrepancies between policy and the legislative frameworks					
	(Ermek and Zhakupova 2023; Han et al. 2022; Musina et al. 2023)					
		x	x	x		
Problem	Fixed agricultural products and Water prices					
	(Jaloobayev 2007; *Benjamin Pohl* et al. 2017; Han et al. 2022)					
		x		x	x	x
Problem	Actual financial cost of water services is not certain Services-Payment relations in water use are not established					
	(Jaloobayev 2007; *Benjamin Pohl* et al. 2017; Han et al. 2022)					
	x	x			x	
Problem	Competition over water resources between sectors: hydropower, irrigation, water supply and nature conservation.					
	(Nazirov 2007; Sokolov, Ziganshina, and Dukhovny 2014; Qin et al. 2022)					
	x			x	x	x
Problem	Distinguishing between national sovereignty and regional obligations					
	(V.A. Dukhovny and Schutter 2011b; Bird 2021; Sehring, ter Horst, and Said 2023)					
	x					
Problem	Development of regional and national criteria water allocation in the region					
	(Tuchin 2007; Jaloobayev 2007; Djalalov 2007; Sehring, ter Horst, and Said 2023)					
	x	x	x	x	x	x
Component	***Legislation***					
Problem	Strict top-down procedures of water management					
	(Sehring 2009a; Xenarios et al. 2019; Sehring et al. 2021a)					
	x				x	
Problem	Lack of an established mechanism for the examination of interstate projects					
	(V.A. Dukhovny and Schutter 2011b; Sehring et al. 2019)					
	x	x	x	x	x	x
Problem	Fragility of the current water laws					
	(Rahaman 2012; Sehring et al. 2021b)					
	x		x	x	x	
Component	***Finance***					
Problem	Water organizations and users are lacking incentives to increase water productivity					
	(Ishpulatov 2023; Ministry of Natural resources Ecology and Technical Supervision of Kyrgyz Republic 2023; V. Dukhovny 2021)					
	x					
Problem	Partial agreement on allocation of funds for maintaining structures at transboundary watercourses					
	(Sehring et al. 2019; Sorokin and Sorokin 2023)					
						x
Problem	Weakness in the functioning of the financial mechanisms					
	(Sorokin and Sorokin 2023)					
	x				x	
IWRM pillar	***INSTITUTIONS***					
Problem	Lack of coordination between executive bodies (water supply for the remote areas, for industries, and other consumers)					
	(*Kazakhstan* 2024; Ministry of Natural resources Ecology and Technical Supervision of Kyrgyz Republic 2023; O. et al. 2020)					
	x	x	x		x	
Problem	Administrative approach to water management (room for "parochial egotism")					
	(V. Dukhovny 2021; Sokolov 2021; Sehring, Horst, and Said 2023)					
	x		x	x	x	x
Problem	Lack of representation in decision-making					
	(Ryabtsev 2007; Sehring, Horst, and Said 2023; Sehring, Horst, and Zwarteveen 2022)					
	x				x	
Problem	The work of the ICWC is not of a prime ministers' level					
	(Sokolov, Ziganshina, and Dukhovny 2014; Dukhovny and Schutter 2011a)					
	x					
Problem	Lack of accountability in front of the water consumers					
	(Sehring 2009a; V. Dukhovny 2021)					
	x			x	x	
Problem	Lack of coordination of hierarchic levels jeopardizes success of Institutional efficiency					

	(Qin et al. 2022; V. Dukhovny 2021; Sehring et al. 2019)					
Problem	The existing forms of water users organizations lack defacto recognition and resourcefulness, non-coordination (legal and economic) of water users weakens “the bottoms” of the water management hierarchy					
	(Mirzaev 2022; Sehring et al. 2021b)					
	x	x	x	x	x	x
IWRM pillar	***MANAGEMENT***					
Component	*Technical and technological aspects*					
Problem	Unsustainable water management practices					
	(Rau et al. 2023; Xiaolei Wang, Zhang, et al. 2023)					
			x	x	x	x
Problem	Actual water operations are not properly tracked due to imperfect infrastructure, equipment, and water metering services					
	(Jalilov, Amer, and Ward 2018; Bekturganov et al. 2016)					
			x		x	x
Problem	Uneven distribution of automation, efficient control, and communication means					
	(ICWC 2023; O. Saidmamatov et al. 2023)					
			x		x	x
Problem	Water allocation issues (downstreams experience lack of water supply, stability and equitability: water losses In the system due to evaporation from the canals)					
	(ICWC 2023; O. Saidmamatov et al. 2023)					
				x	x	x
Problem	Lack of common account of surface and ground water use as well as return flow utilization					
	(Rau et al. 2023)					
					x	
Problem	Lack of attention to water pollution and harmful impacts and environmental issues in general					
	(ICWC 2023; O. Saidmamatov et al. 2023)					
	x			x	x	x
Problem	Lack of regular reporting to national governments, no regional standard on subnational watershed management reporting and criteria, data localized and updated partially					
	(Mirzaev 2022)					
	x	x	x	x	x	x
Problem	Partial dissatisfaction with Hydrometeorological forecast services					
	(Mirzaev 2022)					
		x			x	
Problem	Imperfections in riverbeds maintenance and flood discharges					
	(Rysbekov 2023; Sorokin and Sorokin 2023; Rakhmatov et al. 2020)					
						x
Problem	Strengthening activities within the framework of accepted agreements, especially grassroot level					
	(V. Dukhovny 2021)					
	x	x	x	x	x	x
Problem	Lack of information on water resources or it does not meet the requirements					
	(Sehring et al. 2019; Mirzaev 2022)					
		x			x	x

Figure 32. Matrix of the IWM process in Central Asia[1] (Own compilation).

As one can note, the *Institutional arrangement* element of the IWM (Figure 32, column 1) is widely affected by the listed IWRM shortcomings and hinders the IWM establishment in the ARB and the SRB.

In the Enabling environment, ***Policy, Legislation***, and ***Finance*** show the listed problems, which are logically assumed to be influencing the other two IWRM pillars: both *Institutions* and *Management*, - which are basically **the embodiment of IWM’s System elements** (the work carried out by the institutions organized by the countries similarly to their own IWRM

[1] “x” stands for “the presence of this problem in the IWRM pillar hinders the corresponding structural element of IWM (the Amudarya and Syrdarya RBs)”

processes), and, to a lesser extent, giver the initial step Central Asia takes towards integrated basin-scale water management, **IWM's Management elements** (what the water bodies agreed on and what they do for IWM).

From the institutional outlay in the Literature review, it is obvious that the Institutionalization of the Basins is manifested in the existence of the BWOs and the ministerial cooperation at the ICWC platforms. However, thanks to the UN data on IWRM, the research has obtained the mosaic of all the pillars of IWRM for each country in CA for 2023, which confirms the findings from the empirical data and the relevant literature that the practical outputs for IWM are not clearly articulated. Suppose the evaluation of the perspectives on the concept's establishment takes the theoretical standards, incorporating the principles of the basin management described in 2.3. In that case, one can speak of the region being at the designing stage at present (Figure 6. IWM is a process in stages. Own compilation, adapted from Hufschmidt 1984.). This finding can be leveraged by the **lack** of hydrographization of the basins, bottom-up approach, cross-sectoral coordination, hydrological approach (recognition of a basin as a socio-economic and ecological unit), equitability of water allocation, water treatment regulation, as well as basin-wide public participation, information exchange, publicity, and transparency between subnational and international stakeholders. Having disclosed the research results, the study next elaborates on the details and reasons that have shaped the backgrounds that let the outlined problems within the matrix exist.

5. Discussion

5.1. Countries within the basin or each country's basin?

The empirical data overview of the ICWC analytics and the publications by the water management professionals in Central Asia have provided many insights into the peculiarities that challenge IWM in the Amudarya and Syrdarya river basins. However, the root of the problem is evident in the sectoral and administrative nature of water management, some legal and policy discrepancies, and consequently malfunctioning institutional frameworks for basin-scale cooperative management. Therefore, one can outline the first and main issue that challenges both *System elements* and *Management Actions* within the IWM of the ARB and SRB is **water allocation** and the guidelines on **its use and return**.

Given the ARB and SRB's complex hydromorphology, the ICWC and the BWOs experience difficulties with fair water distribution between the national socio-economic and regional ecological systems. The water rights of the basins' countries are not clearly outlined (Figure 32), except for quantitative water quotas determined by each country's sectoral demands. These quotas are agreed upon according to water forecasts by the hydrometeorological services that collaborate with the two basin institutions (Sokolov 2021).

As a technical issue, it manifests in problems with comprehensive indicators that could progressively estimate the quantity and quality of water resources. Those factors are discussed by Tuchin (2007) who stressed the paramount importance of annual water planning, operational planning, and operational control as prerequisites for watershed management. The theoretical (perfect) scheme is illustrated below (Figure 33).

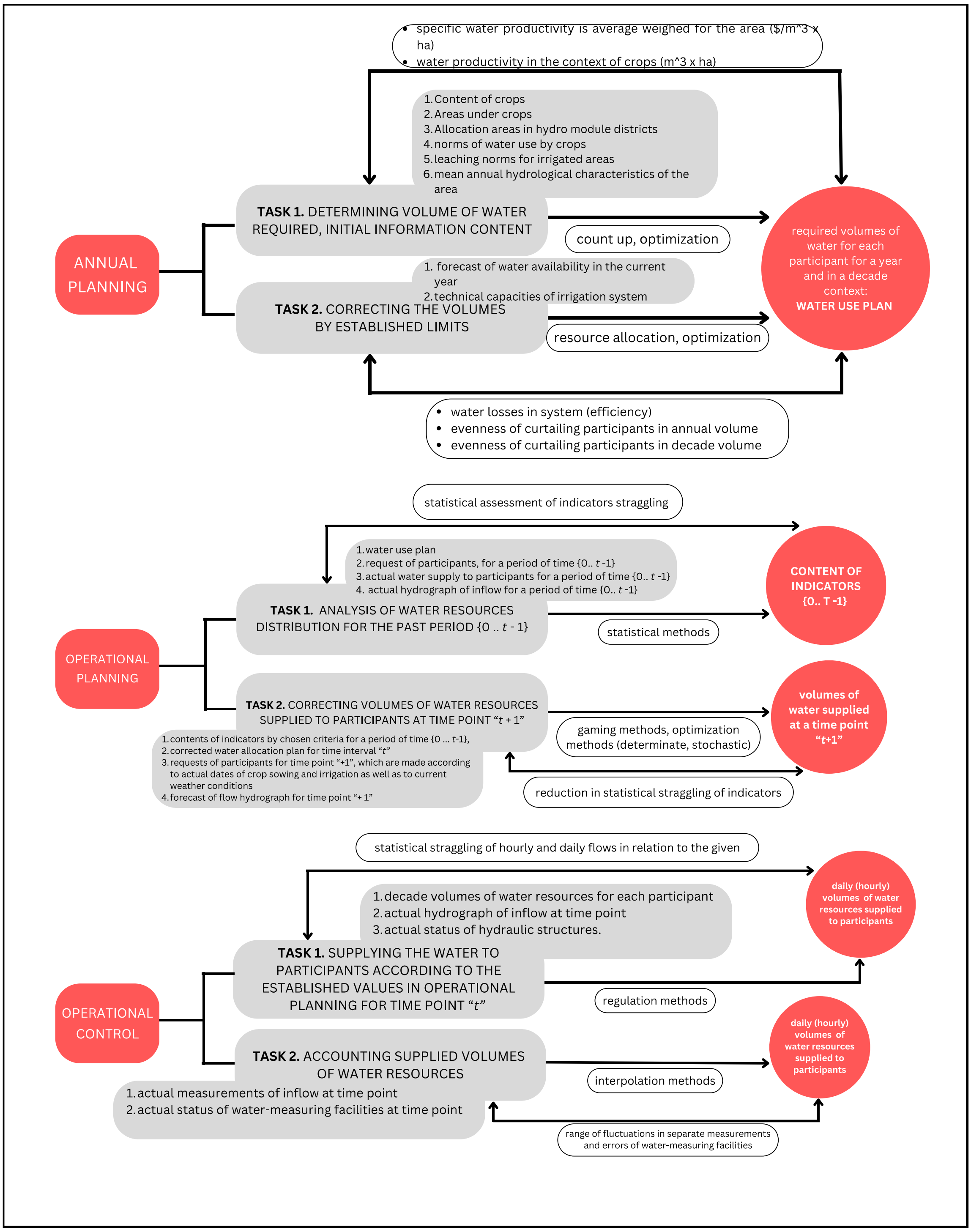

Figure 33. Main stages in Water Allocation in CA. Adapted from Tuchin 2007 (Own compilation).

The provisions of the basin water plan with improved strategies should and must be agreed upon by the heads of the states; at present times, this role is given to the sectoral representatives of the ICWC and then to the BWOs (Dukhovny and Schutter 2011a; Sorokin and Sorokin 2023). The working groups negotiate, attempting to balance the interests of one's party and the existing agreements, which have **room for maneuvers, given the abstract formulations in the legal frameworks**, which are common not only for the region but also for world practice. The practical **principles of the distribution of water resources and seasonal river flow regimes** are not underpinned in any basin agreement, regardless of the conceptual basis (Figure 28). Many experts agree that the water allocation principles should and must be clearly stated in the **basin agreements and protocols** (Dukhovny and Schutter 2011a; Dukhovny 2021).

After the BWOs, the next level of water management in CA includes large irrigation systems (LIS) and separate canals (LSC), which are subordinate to its management and are responsible for water transfers and distribution to various Water User Associations (WUAs) and private farms (Figure 29) (IWMI 2024; Dukhovny and Schutter 2011a). The subsequent hierarchy level is WUA, which is an independent water management unit that **regulates water intake limits and controls water supply within the context of canals and administrative areas**. At the lowest level, separate private farms are recognized, where factors such as crop patterns, soil salinity conditions, irrigation techniques, the technical condition of on-farm irrigation and collector-drainage networks, and best irrigation and **wastewater treatment practices** are considered (Rakhmatov et al. 2020). At the lower levels of public participation, the involvement of the local communities becomes very important. As one can see, the 2023 survey gives insights into those agendas, and one can see it is still far from perfect (Figure 31).

Fulfilling the strategic and tactical goals on the distribution of water among the users (in this context, the riparian countries) in **yearly, monthly, decade,** and **daily contexts** (Figure 33) at **each lower level** should follow a **control strategy** set at "a higher hierarchy level, except its own effectiveness criteria", given the fact the described levels have different tasks and infrastructures (Tuchin 2007). Both plans and infrastructures seem either Low- or

Medium-low, especially for the Syrdarya, and medium-high for the Amudarya management, but finance-wise, half of the information on the latter basin is missing for 2023.

On the right side of Figure 35, one can see the ascending box with *indicators*, emphasizing the need for the IWM principle, the "bottom-up" approach, the water demand management, and the **water-saving approach in agriculture, strong grassroots levels as aa well as local sub-basin authorities,** which too is not of high performance at present (Figure 31. SDG 6.5.1 in CA. Source: UN-Water (2023 data), accessed June 4, 2024. Own compilation.). Efforts should be made to minimize "free artist decision-making" (Tuchin 2007, 66), which has proven to be consequently damaging for all parties in the IWM process (2007). While Basin Action plans are not developed, the socio-economic development and ecosystems' integrity are constantly not secured.

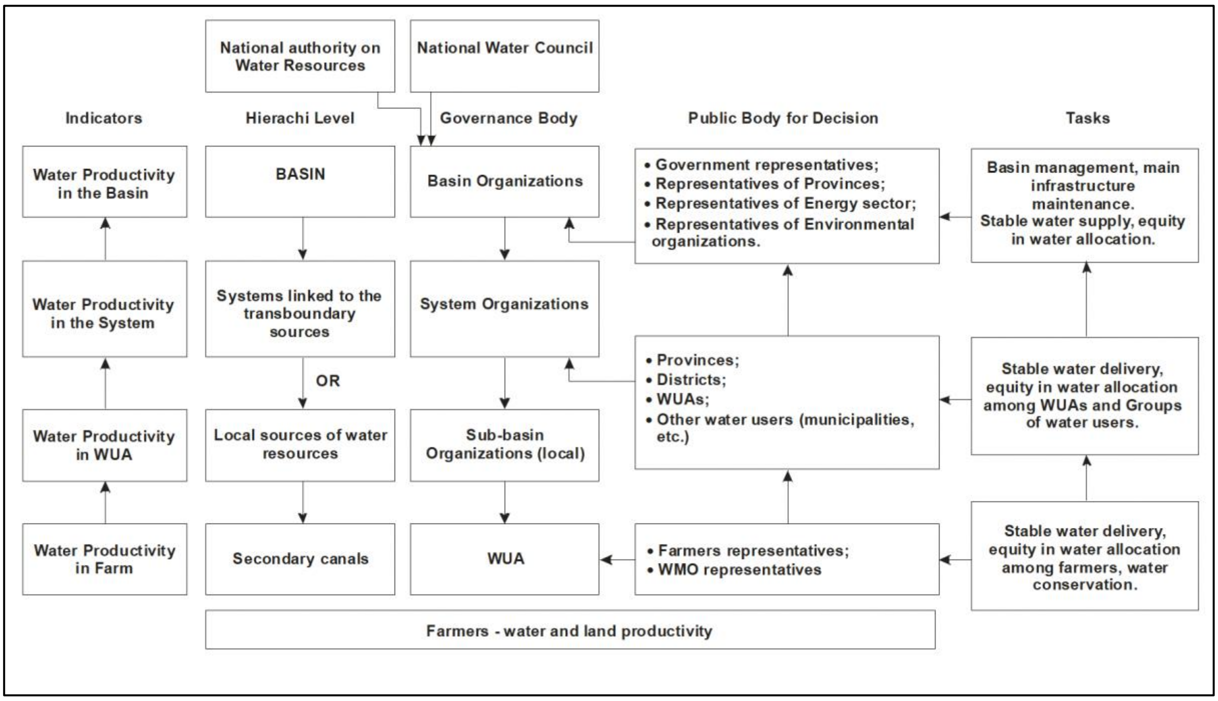

Figure 34. IWRM levels in Central Asia. Source: Dukvovny 2007a.

Besides the struggle to minimize water losses, discussed in (2.3.1. Geophysical, hydrological, ecological features and requirements of the Amudarya and the Syrdarya river basins), much more tensions in the region cause **large water infrastructure and its operation**. There have been several acute episodes of clashes between "national interests" and basin obligations. Among those are the Rogun Hydroelectric Power Station (the SRB, Tajikistan and Uzbekistan, 2016, 2018, tbc), Construction of Kambarata HPP-1 (Kyrgyzstan and Kazakhstan, 2015), the release of water from the Karakkum reservoir (SRB, Uzbekistan, Tajikistan, Turkmenistan, 2021), etc. Each time an operational decision was followed by steady diplomatic work, consultations, and sometimes armed conflicts at the borders (KGZ-KAZ 2014, 2022; KGZ-UZB 2016; KGZ-TAJ-UZB in Ferghana Valley, occasional tensions) (Sehring, ter Horst, and Said 2023).

To move towards a reality where **hydrosolidarity is mutually acknowledged and accepted**, SIC ICWC has been working on ideas for how to reform the current basin management system by improving the Institutional outlay (Dukhovny and Schutter 2011a) with hopeful that some of those provisions will dissolve a number of the problems with IWM establishment in the ARB and SRB (Figure 32). The experimental vision moderately criticizes the basin management structure of the Institutes and stresses the necessity for **increased representation of the scientific community, sectors, and lower levels of the IWRM** management hierarchy (Figure 29). According to Dukhovny, it is important to develop an environment where the experts would be somewhat deprived of representing their countries but rather **stand for a Basin Institution** (2011b). The updated architecture has to suggest a platform for consultations guided by arbitrary commissions (e.g., Water-Energy Consortium) aimed at soothing the competition over water resources between sectors: hydropower, irrigation, water supply, and nature conservation (Dukhovny and Schutter 2011b).

As one can see from Figure 31 (SDG 6.5.1), all water management administrations are divided nationally, and many of the IWRM components, which help the IWM, are unique, nationally regulated processes. It is important that, on a national level, the riparian countries address basin governance issues as a priority. One of the simplest ways to test it is by examining the National Water Codes, namely, how well the IWRM principles are articulated in it. So far, the contents of IWRM are being gradually implemented on the national level, whereas IWM still has a lot to do with the skepticism of regional integration in general. In tis regard, the first half of the criteria for IWRM establishment in an *"Enabling environment"* is curious to explore (Figure 31).

As SIC ICWC researchers state, the development of the priorities of CA countries varies Figure 25, including the vision of water issues. This predefines the lack of attention to hydrographic principles for management organizations. While Kyrgyzstan may see its top environmental water-related problem as the melting of the glaciers, Uzbekistan pushes the agenda of the Aral Sea revival. The regional IWM rhetoric is not homogeneous, which testifies to and supports the reason why there are hardly any holistic basin management plans and potent basin institutions to guard it, which might generally alarm on the mere non-understanding of the watershed and its integrated management (Sokolov, Ziganshina, and Dukhovny 2014).

To sum up the subchapter, the main challenge IWM in the ARB and SRB is equitable water allocation between countries and the factors that stand behind it. The current system, managed by the Interstate Commission for Water Coordination (ICWC) and Basin Water Organizations (BWOs), struggles with this due to:

- Lack of clear water rights for each country, only quantitative quotas based on sectoral demands; Absence of comprehensive indicators for water quantity and quality; Water allocation principles not clearly defined in basin agreements.
- Countries prioritize their own interests over basin needs, deadlocking the performance of basin organizations. IWRM is present in the national development strategies, but the national legislation does not consistently support it.

The outlined factors represent the region-specific problems within the IWRM Enabling environment pillar, which hinder both IWM System elements and Management activities (Figure 32).

5.2. Sectoral issues and lack of guarantees for IWM-driven regional integration

Looking into the deeper causes of water allocation issues, it goes without saying that each country determines its benefits from the use of water resources based on its own development strategies, yet due to the Transboundary nature of the river basins and the shared responsibilities, - to a reasonable extent (Angstadt and Möller 2020). In that regard, upstream-downstream discrimination is concerned.

The states located in the upper reaches of the river basins rely on profiting from the production and sale of electricity, considering the income from irrigated agriculture and other industries as secondary ones (for Central Asia, Kyrgyzstan, and the SRB mostly). Countries located in the middle and lower reaches of rivers determine their economic strategy based on income from irrigated agriculture and related industries (O. Saidmamatov et al. 2023).

Thus, one should consider the **different times of peak use** of water resources **with each sector's operations at a timeline** (in winter for hydropower and in summer for agriculture) to resolve the root cause of the tensions (Figure 21, Figure 22). Despite the political issues, it is safe to assume that the identification of *mutually beneficial options* for compensating for economic losses due to competing water use demands will be foundational for resolving the transboundary cooperation and narrowing the gaps towards IWM in the ARB and SRB.

Disclosing one of those options, Sorokin and Averina (2002) presented an approach that could coordinate the sectoral demands under various scenarios of water, fuel, and hydropower resource management. The researchers showed that a compromise solution that minimized the total losses of all parties during water allocation was **possible**. They attempted to find a compromise by modeling different ratios of profit and damage under various options for water release regimes, from the maximum hydropower mode to the maximum irrigation mode. The optimal solution can be found by considering the total losses of all participants in the water management complex under different regimes of water releases from the water supply system storages. With this approach, the optimal mode could be determined by finding a point on a graph where the net output curves of both economic sectors intersect (2002).

The significance of the energy sector in establishing IWM in the SRB is hard to underestimate. Much of the SIC ICWC literature focused on hydropower in decoupling water from energy production, under the motto that the requirements for water releases should be considered in connection with fuel and energy issues but do not depend on them (V. Dukhovny 2021). Fully recognizing one's interests, however, makes it impossible to provide water supply to the population and irrigation downstream. That is why annual planning and implementation of water supply **cannot depend on the non-certain situations in the fuel and energy market**. Otherwise, it exposes the risk to all agricultural production, and food security, making it difficult to fight poverty and hunger and reducing the level of the general well-being of the rural population. For example, electricity produced in summer is more than the needs of Kyrgyzstan (satisfying the interests of irrigation) and should be compensated by supplies of the same volumes of electricity in winter.

The discussion under 5.2. is conceptualized as the "WEF" (Water-Food-Energy) or "WEFE" (Water-Food-Energy-Ecosystem) Nexus and used by many international organizations in their thematic reports (Boas, Biermann, and Kanie 2016). The security issues, or how the water is seen as an economic good within the system of the two transboundary basins with upstream and downstream users, are not addressed practically, as well as the water quality and quantity indicators which have been discussed in the previous subchapter. These steps may take time as far as the installation of sufficient water metering equipment and related infrastructures locally and basin-wide is concerned (Figure 32, *“Management”*). Even the informational connectivity of these metering equipment can be a dealbreaker for the scientific community in cooperation with the sectoral representatives to develop the initial strategies. For the consensus to be reached, there must be a prerequisite that the participants be clear about their annual water plans, which them can be put as a condition to the development of a comprehensive IWM plan for both basins. In a simplified, non-perfectionist way, among the measures to at least improve the WEF Nexus in CA are: saving water, increasing water use efficiency, reducing electricity consumption, development of alternative sources of energy supply (new small hydroelectric power stations, or/and “exchange” of energy resources in the region).

Concluding the subsection, the following factors should be put as variables to the present deadlocks in the IWM strategy equation:

- Upstream countries prioritize electricity production and sales;
- Downstream countries rely on irrigated agriculture and related industries;
- Peak water demands occur in winter for hydropower but in summer for irrigation;
- Lack of compromise solutions that minimize economic losses for all parties. A proposed approach models different water release regime to find an optimal balance between hydropower and irrigation benefits.

According to the SIC ICWC and many of the distinguished regional water management researchers (Rysbekov 2023; Sorokin and Sorokin 2023; Mirzaev 2022; V. Dukhovny 2021), main contradictions and tensions in relations between the countries of the region under modern **transboundary water management system** have been evolving around several main issues, which comprise: lack of agreed rules for water management, violation of water requirements, friction due to barter agreements and payments, uncertainty about future infrastructure projects.

5.3. Technical, technological, and informational aspects of river basin management

It is of particular importance to note that Central Asia has been receiving substantial financial and human resource assistance from international donors, which has helped to improve many of the infrastructural, technical, and technological shortcomings of the overall IWRM Management pillar (WECOOP 2023). However, the technological and information systems in both basins are not evenly integrated, which is crucial for the key developments necessary for designing agreed Basin action plans.

So far, the study has not found any publicly available data on basin management subnationally, as well as on a basin scale, except for some bulletin notes (ICWC 2023). There has been a confusing observation during the data gathering that, on the one hand, there is too much information and, on the other, too little information on the topic; as confirmed later on, the information on water resources is indeed evaluated by the experts as present, but not meeting the requirements (Mirzaev 2022). The lack of- or absence of agreements on free access to information on the basin scale may still be a problem for the region as well (Dukhovny and Schutter 2011a) (Figure 31. SDG 6.5.1 in CA. Source: UN-Water (2023 data), accessed June 4, 2024. Own compilation.).

Management level	IS	Com	MIS	SCADA	DM, HMZ	WM	BP, WCH	PP	Tr
Regional	x	x	x	x		x		x	x
National level	x	x	x	x		x		x	x
Subnational	x	x	x	x		x		x	x
Irrigational	x	x	x	x	x	x	x	x	x
WUA	x	x	x		x	x	x	x	x
Water user	x	x	x		x	x	x	x	x

IS – information system;
Com – communication and exchange of information;
MIS – management information system (including flow forecasting technologies and weather conditions);
SCADA – supervisory control system, data collection, processing and analysis;
DM, HMZ – demand management system, hydromodular zoning;
WM – water flow/quality monitoring;
BP, WCH – activity planning, water charges;
PP – public participation in water resources management;
Tr – training and advanced training of specialists.

Figure 35. Technical Capacity for IWRM at all levels in CA. Source: Dukhovny and Schutter 2011a, updated May, 2024.

Nowadays, the given set of tools and arrangements (Figure 35) is planned to be advanced by the establishment of a regional Earth observation platform, which would allow for scientific experience and analytical outputs from remote sensing, including hydrological modeling. This move could balance out the accessibility and standardization of geospatial data and weather forecasting and improve the assessment of subnational water supplies, creating a solid opportunity for optimizing decision-making at all levels. But so far, technical advancement are not among the strong points of CA (Figure 32. Matrix of the IWM process in Central Asia (Own compilation).

These products are now too present, but not meeting the requirements: sporadically distributed to the governments by foreign hydrometeorological organizations or produced by national research institutes for specific pilot projects or on-demand basis (Qin et al. 2022; Mirzaev 2022). However, it is a great belief that the creation of a regional, remote sensing platform with ready-to-use tools will provide stable access to near-real-time or real-time information for the basins' biophysical and hydrological factors, which are important for informed decision-making in the context of sustainable long-term basin management planning. Nowadays, there is a lack of permanent access to water infrastructure on rivers due to border restrictions, information on water intakes from rivers (water intakes) and water discharges, return waters to rivers (a significant part of water intakes is not controlled by the BWO or controlled selectively), and lack of technical capabilities and authority to limit costs - water supply or closure of water intake structures in the event of an unplanned or excessive water intake.

5.4. Fragmentation at national levels: policies, legislation, and water management

The next subgroup of issues exists because of the previously discussed problems in 5.1 and 5.2. Lack of coordination between the sectoral executive bodies is observed due to shortcomings in improving the linkage of irrigation and hydropower options at different levels and preparing the basin agreements and protocols for the joint integrated management. Without scientific evidence, land use assignments and on-site and off-site management activities for IWM are not planned accordingly (Figure 31 (Surveys), Figure 32 (IWM matrix)).

The Institutions now therefore seem to possess many overlapping tasks: various national and subnational water bodies are usually subordinate to different ministries (Forestry, Mountain conservation, Agriculture, Emergency situations, etc.) and collaborate with various international development agencies and donors, focusing on their national agendas within the context the water as a recourse is being put: *climate change, biodiversity, water management, rural development, natural resource management, agriculture, energy efficiency,* etc. (WECOOP 2023). So far, those measures have been providing management tools and management actions, along with on-site and off-site practices in particular countries, through the point of view of how the national authorities formulate the request, which may not necessarily lie within IWM but generally contribute to or go at odds to it. Only Institutional arrangements and land-use assignments are directly under the national authorities' will to be systematically adjusted into the IWM framework.

To overcome the fragmentations in tools, actions, and on-site and off-site watershed activities, as the points discussed support, it will be of great importance to work out the guidelines to optimize the functions of the national institutions in charge of land use assignments, off-site and on-site activities on national levels to the basins' requirements, both in terms of land and water management – without the risk of an economic downgrade due to potential of losing sore profitable opportunities.

According to the outputs of the new generation of basin-level institutions that the SIC ICWC foresees and hopes for (Dukhovny and Schutter 2011a), mutual trust will be fostered with the development and implementation of financial mechanisms to solve the problem of the lack of funds to purchase electricity and fuel resources, providing compensation for water supplies. The precautionary moods are understandable for human behavior; therefore, to start something new, the subjects will need to be guaranteed an insurance fund that will be able to cover possible damage. As we see from the surveys, there are not so many funds that would allow for an immediate try, but the proper of institutions should be secured by proper incentives (Figure 31).

Regional integration, as a sign of a welcoming background for IWM, also promises the gradual development of clearer water policies and fewer discrepancies with the legal frameworks — at the basin scale and nationally (Figure 31). This is how the regional integration for IWM can penetrate national IWRM processes and improve the enabling environments. Policies and corresponding laws then are more likely to include indicators for the system of downstream and upstream users as IWM management tools. This system is possible with **equal representation** of all riparian countries in **elected bodies** and open dialogue at all water management levels and sectors.

An agreed-upon short-term, mid-term, and long-term IWM action plans must be supported by national land reclamation laws and a clear distinction between a participant's sovereignty and regional obligations on water cooperation. Therefore, there is a need for the heads of state to confirm water rights, consider possible changes, and agree to environmental water releases and practices according to the ecological on-site and off-site tasks required for IWM (2.3.1. Geophysical, hydrological, ecological features and requirements of the Amudarya and the Syrdarya).

As the takeaways from the Institutional issues, one can summarize the following:

- Overlapping and duplicated functions between national and basin-level organizations, non-obedient to any coordinated IWM strategy.
- Lack of coordination between sectors like water supply, industry, and hydropower (Failure to link irrigation and hydropower operations);
- Ambiguity in management responsibilities and planning.

It has been discovered some recommendations by the SIC ICWC include (V. Dukhovny 2021; Dukhovny and Schutter 2011a; Mirzaev 2022; Sokolov 2021):

- Increasing representation of science, sectors, and lower management levels;
- Developing consultation platforms to mediate between competing sectors;
- Clarifying institutional architecture and responsibilities with the help of the Water-Energy consortium and Arbitrary Commission;
- Fostering mutual trust through continued dialogue between countries of the region and respect for the individual interests of each country;
- Eliminating sources of confrontation and increasing the level of understanding, ensuring transparency of information and clarity of positions.

5.4. Management issues: informed decision-making for IWM

Lastly, it is important to note that the data acquired and georeferenced at the grassroots level is what gives a chance of turning IWM and IWRM concepts from somewhat theoretical and politically dependent phenomena to a living process of gradual change. Presently, many efforts have started to evolve around the localization of data. In a case study (Benedek et al. 2021), GIS techniques showed that national statistics supported by geographical visualization provide more grounding for decision-making. In the case of IWRM and IWM, this could play a pivotal role in regards to some crucial IWM parameters, like water quality and availability monitoring, access to water, water supply for sectors, water productivity, identification of the land areas with high priority for restoration – environmental, natural resource data (Locke 2024) and the very basic parameters which are necessary to grow public participation and empower WUAs and BWCs (welfare, education, promotion of women's rights as traditional water users, tbc), - one of the examples is Risk-Inform visual outputs for CA from UNDRR (2021).

5.5. Top-down, bottom-up

The necessity of guaranteed reliable water supply in terms of volume and quality of water resources, as well as water supply regime to various users, the regional and local leaders will have to deal with the necessity to recognize and support the principles of IWRM and participate in the process of its implementation at the basins' scales. If that takes place, water users and water management organizations (BWOs and WUAs) must agree on a water distribution plan and water supply, as well as obligations to pay for water. In some places, the creation of permanent public-private bodies, like Basin Water Councils and transboundary commissions that would coordinate water management activities and claim water rights, has already taken place. However, for IWM establishment, they should be empowered with resources by enhanced financial mechanisms from the top and scientifically informed water-land management tasks for their administrative areas with further subtasks to WUAs. As part of those considerations, water users would need to pay for water management services to WUAs and the BWCs' commissions for coordinating water management activities and creating a network for constant cooperation to improve the current situation according to the socio-economic and ecological contexts (Dukhovny and Schutter 2011a).

In relation to that, the issues related to the fact that various organizations tend to manage water resources at the grassroots level poorly, the regional plan for water conservation and adaptation to climate change needs to be developed and approved as a blueprint for designing measures like fines for exceeding water use limits and incentives for saving water. From the side of public participation, commissions for coordination of water management activities and WUAs are expected to initiate social mobilization of water users on a regular basis.

To conclude the discussion, the overview of the perspectives of the establishment of IWM in the ARB and SRB has shown that Central Asia is moving forward with its National IWRM processes yet facing the outlined problems due to political, legal, and financial discrepancies, which hinder Institutions and Management — the most important IWRM pillars for IWM. These observations allow to note that, in practice, IWRM principles are not fully projected to the basin scale. The deep reasons for that are discussed in the subchapters 5.1.-5.5. and 4. Results spread its roots in the inability to address the basin as a socio-economic and environmental management unit due to:

- Non-contextualization of IWM according to all participants' development priorities with the readiness to sacrifice some of the short-term profits, development of the basis for management evidence: basin-specific indicators, management plans, and system of insurance of one's lost profit generated from agriculture, hydropower, and related industries. Agreements on all kinds of water releases through large water infrastructure, especially for the SRB.

- the lack of financial-informational-technological-technical capacity (funds – nationally and for the transboundary water cooperation, information sharing, water metering equipment, facilities, infrastructure, etc., human resources, IWRM education).

The study finds it safe to assume that criticism of the "remaining problems" in the IWM establishment "regardless of donors' support" should be set aside. This belief has been mostly formed due to the features of IWM as a process and strategy, but not a goal that can be achieved or failed. The confidence to support this point of view is supported by two axioms: the sum of the efforts brought by the international donors should once highly likely be converted into quality and - a provider of goods cannot give more than a recipient can take. Even with the criticism of the institutions, the recognition of water as a socio-economic good is an inevitable yet time-consuming phenomenon in Central Asia. The latter characteristic is though hardly acceptable amid the population and climate change forecasts. Given the region's characteristics and factors that shape IWM, the political will to leverage the transitions could be accelerated with the promotion of such quantitative facts as Chen (2021) and Pohl et al. (2017) showcase in their studies, which highlight the prosperity which interrelation of water's economic recognition and regional integration brings, as well as local pilot project that can serve as a testament to that.

The study has revealed that the dilemma of IWM establishment in Central Asia incorporates the following probability: there is enough water for everyone if the highest political command gives a chance to try, to fail, and then again try to go on with designing and implementing capable Basin Institutions as a product of complex and, probably, effort-taking negotiation between the sectors of each basin's water user party and the environmental professionals.

Along with that vision, there are imperatives of starting with establishing any basin-scale indicators of water quantity, quality, and flexible water allocation strategies with the infrastructure that is already in place under different scenarios with guaranteed support in case of unintentional damage – that was already found possible in 2002, and it is of the author's slight discontentment that there are not much of practical evidence of implementing those economic models in practice. While water planning for short-, mid-term should be attempted to be secured, long-term water Basins' management plans which adhere to the IWM principles must be considered, with great importance given to the development of the relations between the Basin Water Councils (BWCs) and Water User Associations (WUAs), improving the finance flow from the top to the lower water management levels secured with the anti-corruption control measures and regular reporting.

The study suggests quite a bold assumption that if a system of basin management has had some systemic issues today, it not likely to perform a breakthrough tomorrow only because reorganization takes place or, assumably, stronger laws are in place. The cultural aspects give input conditions of strong, generational cognitive patterns and coalitional behavior, which may not be even evident at first glance. Therefore, the study assumes that the upper levels of water management may unnecessarily put pressure on poorly working basin institutions and the operational management of the watersheds, not speaking of the add-ins the concept of "integrated" brings. Rather, the role of IFAS, the secretariat, and its bodies within the topic of the IWM establishment is seen as those components which maintain the impulse and commitment to create a safe environment for the changes that all participants consent to, acknowledging the shared benefits which may or may not take place in the nearest future. Another function of the upper levels is seen in smoothing the potential conflicts between the parties engaged in the process, addressing the insecurities that would surely be arising at all levels according to most of the IWRM pillars' criteria as the experiments take place.

The accumulation and interpretation of data into the indicator framework, overlapping with demographic data, can be another ambitious yet helpful step for contextualizing basin management. The database will serve as the ground for the decentralization plans of the water management system and will allow for the promotion of the water rights of the users and, most importantly - their responsibility within the flexible system of fines and incentives, boosting both Institutional and Management IWRM Pillars.

Regarding the Management activities element of the IWM, there is a universal remedy of promoting wetlands restoration to create a safety cushion against the obvious effects of land cover change trends, optimize water and electricity consumption, and invest in other sources of renewable energy production (especially the upstreams) given each participants' socio-economic landscape and financial capacities.

6. Conclusion

The exploratory outlook on the modern state of implementation of Integrated water resource management (IWRM) and Integrated Watershed management (IWM) has shown that Central Asia has accomplished a lot of measures targeted at the improvement of resource management, including the water, as the most precious asset for socio-economic development for the region. These efforts manifest in extensive yet imperfect political and legislative frameworks, initiatives, and projects on the water as a resource. Despite the broadness of the topic, the research has established clear patterns that illustrate the problem as a whole – with the support of the UN data for 2023 SDG 6.5.1 indicator, which is synonymous with IWM in the context of Central Asia, as the water resource in all the region's countries is shared from the Amudarya and the Syrdarya rivers.

The study has made an original output as a development of the analytical framework for IWM diagnostics by establishing the correlation between IWRM and IWM as two similar yet different concepts. Their practical implication in Central Asia happened to be proceeding on two levels, which shape one another – national IWRM processes and the IWM process in the two basins, as its Institutionalization efforts by means of regional cooperation (Kazakhstan, Kyrgyzstan, Tajikistan, and Uzbekistan – for the Syrdarya; Tajikistan、Turkmenistan, Uzbekistan – for the Amudarya). The interrelations between the two frameworks and their implications in Central Asia have been presented as a matrix, focusing mostly on the stumbling blocks to the IWM establishment in the Amudarya and Syrdarya river basins. The compilation of those components is an open and continuing thought process, especially in a way represented in the given research, as this theme engages hundreds of researchers and decision-makers across Central Asia and international resource management experts worldwide.

The given work has attempted to analytically revisit the IWM implementation in the study area. Through the literature review and the UN reports, the research assumes that the Institutions responsible for IWM are commonly found as the most troublesome elements – this point of view is especially evident from the survey analysis, partially representing the defacto attitude of each Central Asian water resource ministries to IWM establishment. Along with that observation, however, the position developed through the complex yet reasonably undetailed research with a greater curiosity gravitates toward the significance of the Enabling environments for the IWM in the ARB and SRB. Acknowledging the complexities of watershed management, it is hard to follow the rhetoric that just the Institutions are to blame for the lack of breakthroughs.

Much greater importance study has seen in exploring the development of models that could help basin organizations bring coherence to their tasks and intersectoral relations. In other words, the research assumes that there could be very little stimuli from the top officials to be proactive in the relevant developments because the "path from A to B" by means of IWM *(IWM tools and actions)* is not clear and, moreover, seems not only unbeneficial for the "business-as-usual" but also potentially wasteful, as a lot of uncertainties exist. Therefore, the administrative top-down management is in place. In other words, the fostering of IWM needs positive yet critical paths to the "B", so that changes to the Enabling environments could proceed if not with greater enthusiasm, then with clarity of why the default methods must be amended. The study foresees and hopes for the emergence of the very options that incorporate the economic, environmental, and IWM principal requirements into the basin models regarding the changing hydrological regimes under each party's water allocation plans in a timeline, calculating the strategies for loss compensations and the precise highlight of the profits obtained by each party in a particular number of years. Without that condition, one can speak of the water in Central Asia in the paradigm of "hard skills", as set of technical on-site and off-site measures, which, roughly speaking, give no guaranteed results for IWM, as they are decided on as the result of incomprehensive negotiations on barter water allocation as a commodity, which is not sustainable for the long-term regional development. IWM, as the holistic paradigm, suggests otherwise. It is reasonable to conclude that the future of the concept's practical establishment in the region will depend on the pilot projects that could test those models as well as on the ability of the Institutions to protect any new water management conceptual shifts, adapt to changing environmental, political, and socioeconomic conditions while fostering greater cooperation and mutual trust among the participants.

Besides expressing interest and hope for the emergence of strategies developed based on basins' modeling, the study also sees potential in a deeper and more wholesome analysis of the practical situation. One of the valuable outputs of the given research's conclusions, which could not have been formulated as a set of concrete recommendations due to the lack of information that has been acknowledged when outlining the research aims, could sound like another ambitious research question: *"What resource management **actions**, **tools** for carrying out the management measures, and **institutional** arrangements are needed for IWM in the ARB and SRB at different planning and implementations stages within the **pillars** of Policy, Law, Finance, Institutions, and Management?"*. The research keeps this question open with the future potential of addressing it in more detail. So far, the study has assumed that the IWM establishment in the ARB and SRB is more aligned with the **designing stage,** with some cases of local manifestation of IWRM. The case of CA is not unique, as one of the ways of looking at our planet's land surface is a system of river basins that countries, many of which are too developing and have similar socioeconomic and political features. The present period is exceptional for the ARB and SRB. This time is challenging and promising with the new technological advancements, highlighting the topic's relevance and inviting resource management professionals to be alert to new developments in the region.

Bibliography

Abdullaev, Iskandar, and David Molden. 2004. "Spatial and temporal variability of water productivity in the Syr Darya Basin, central Asia." *Water Resources Research - WATER RESOUR RES* 40. https://doi.org/10.1029/2003WR002364.

ADB. 2021. Kyrgyz Republic: Energy Sector Assessment. edited by Asian Development Bank.

---. 2022. Tajikistan: Economy. edited by Asian Development Bank.

Alimzhanov, Askar. 2024. Global Environment Facility to Aid Ecosystem Restoration in Central Asian Countries. The Times on Central Asia.

Angstadt, M., and I. Möller. 2020. "Agency and Norms: Who Defines What Ought to Be?". https://doi.org/10.1017/9781108688277.010.

Asarin, Alexander E., V. I. Kravtsova, and Vadim N. Mikhailov. 2010. "Amudarya and Syrdarya Rivers and Their Deltas." *The handbook of environmental chemistry*. https://doi.org/10.1007/698_2009_8.

Averina, L., and A. Sorokin. 2002. Assessment Of The Activity Of The Water-Energy Consortium Under Different Scenarios For Managing Water-Fuel-Energy Resources In The Region

Bank, World. 2019. Kazakhstan - Agriculture Sector Review.

---. 2020a. Central Asia: Regional Economic Update.

---. 2020b. Tajikistan - Power Utility Financial Recovery Program.

---. 2021a. Central Asia: Regional Demographic Trends.

---. 2021b. Turkmenistan Overview.

Bekboloto, Zh., and A. Jaloobayev. 2007. A Basin management based on resource conservation. edited by Wouters P., Duchovny V. and Allan A.: Springer, NATO Public Diplomacy Division.

Bekturganov, Z., K. Tussupova, R. Berndtsson, Nagima Sharapatova, Kapar Aryngazin, and M. Zhanasova. 2016. "Water related health problems in central Asia-A review." https://doi.org/10.3390/W8060219.

Benedek, József, Kinga Temerdek-Ivan, Ibolya Török, Arnold Temerdek, and Iulian Holobaca. 2021. "Indicator ‐ based assessment of local and regional progress toward the Sustainable Development Goals (SDGs): An integrated approach from Romania." *Sustainable Development* 29. https://doi.org/10.1002/sd.2180.

Benjamin Pohl, , Annika Kramer, William Hull, Sabine Blumstein, Iskandar Abdullaev, Jusipbek Kazbekov, Tais Reznikova, Ekaterina Strikeleva, Eduard Interwies, and Stefan G.rlitz. 2017. *RETHINKING WATER IN CENTRAL ASIA: The costs of inaction and benefits of water cooperation*. Adelphi and CAREC.

Freie Univertitat Berlin. "Introduction to Integrated Watershed Management." https://www.geo.fu-berlin.de/en/v/iwm-network/learning_content/introduction_iwm/index.html.

Bird, J., J.E. Hunink, J. Winpenny, S. Chikanayev. 2021. *CAREC: Water Pillar Scoping Report.* Asian Development Bank. https://www.futurewater.eu/projects/carec-developing-the-water-pillar-for-central-asia/.

Boas, Ingrid, Frank Biermann, and Norichika Kanie. 2016. "Cross-sectoral strategies in global sustainability governance: towards a nexus approach." *International Environmental Agreements-politics Law and Economics*. https://doi.org/10.1007/S10784-016-9321-1.

Bulkeley, H., Liliana B. Andonova, M. Betsill, D. Compagnon, T. Hale, M. Hoffmann, P. Newell, M. Paterson, Charles B. Roger, and Stacy D. Vandeveer. 2014. "Transnational Climate Change Governance." https://doi.org/10.1017/CBO9781107706033.

CA-Water. 2022. Bilateral Water Cooperation between the Countries of Central Asia.
---. accessed May 2, 2024. Syrdarya.
---. accessed May 3, 2024. Amudarya.
Chen, Chao liang, Xi Chen, Jing Qian, Zengyun Hu, Jun Liu, Xiuwei Xing, Duman Yimamaidi, Zhanar Zhakan, Jiayu Sun, and Shujie Wei. 2021. "Spatiotemporal changes, trade-offs, and synergistic relationships in ecosystem services provided by the Aral Sea Basin." *PeerJ* 9: e12623. https://doi.org/10.7717/peerj.12623. https://doi.org/10.7717/peerj.12623.
Conrad, Christopher, Björn Onno Kaiser, and John P. A. Lamers. 2016. "Quantifying water volumes of small lakes in the inner Aral Sea Basin, Central Asia, and their potential for reaching water and food security." *Environmental Earth Sciences*. https://doi.org/10.1007/S12665-016-5753-8.
De Keyser, Jan, D. S. Hayes, B. Marti, Tobias Siegfried, Carina Seliger, Hannah Schwedhelm, Oyture Anarbekov, Z. Gafurov, Raquel M. López Fernández, Ivan Ramos Diez, Bertalan Alapfy, Justine Carey, Bakhtiyor Karimov, Erkin Karimov, B. Wagner, and Helmut Habersack. 2023. "Integrating Open-Source Datasets to Analyze the Transboundary Water–Food–Energy–Climate Nexus in Central Asia." *Water*. https://doi.org/10.3390/W15193482.
Di, D., and A. Nasrulin. 2019. "ANALYSIS OF THE USE OF THE METHOD OF HYDROECOLOGICAL MONITORING IN ORDER TO IMPROVE THE ECOLOGICAL CONDITION OF THE HYDROTECHNICAL CONSTRUCTIONS OF UZBEKISTAN."
Djalalov, A. 2007. "Transfer of water resources management towards basin principles ".
Djanibekov, N., K. van Assche, and V. Valentinov. 2016. "Water Governance in Central Asia: A Luhmannian Perspective." https://doi.org/10.1080/08941920.2015.1086460.
Dukhovny, and Schutter. 2011a. *Water in Central Asia: Past, Present and Future*. CRC Press.
Dukhovny, and V. Sokolov. 2005. INTEGRATED WATER RESOURCES MANAGEMENT Experience and Lessons Learned from Central Asia – towards the Fourth World Water Forum. Tashkent.
Dukhovny, V. 2007. Prospects for Central Asia Development - Integrated Water Resources Management as Regional Issues Solution edited by Wouters P., Duchovny V. and Allan A.: Springer, NATO Public Diplomacy Division.
---. 2021. Application of IWRM principles in the Aral Sea basin. Tashkent: SIC ICWC.
Dukhovny, V., V. Sokolov Vadim, and D. Ziganshina. 2015. "The Role of Donors in Addressing Water Problems in Central Asia." *Irrigation and Drainage* 65. https://doi.org/10.1002/ird.1913.
Dukhovny V.A., Sokolov V.I. 2005. INTEGRATED WATER RESOURCES MANAGEMENT Experience and Lessons Learned from Central Asia – towards the Fourth World Water Forum. Tashkent.
Dukhovny, Viktor A., and Joop L. G. de Schutter. 2011b. *Water in Central Asia: Past, Present and Future*. CRC Press.
Ermek, N. E, and A S. Zhakupova. 2023. "TRANSFORMATION OF THE AMUDARYA RIVER BASIN IN THE CONTEXT OF CLIMATE CHANGE." *Geography and water resources*. https://doi.org/10.55764/2957-9856/2023-4-14-20.19.
ESCAP. 2022. The Aral Sea, Central Asian Countries and Climate
Change in the 21st Century. edited by M. Narbayep and V. Pavlova.
FAO. 2006. *The new generation of watershed management programmes and projects*. Rome.
---. 2020. Kyrgyzstan Country Profile.
Forch G., Schutt B. 2004. Watershed Management - An Introduction.

IFAS, INTERNATIONAL FUND FOR SAVING THE ARAL SEA, EXECUTIVE COMMITTEE. 2022. https://ecifas-tj.org/en/asbp-4/.

GRID-Arendal, UNEP, and Zoï Environment Network 2016. *Waste Management Outlook for Central Asia*. edited by Geoff Hughes.

Hamidov, A., K. Daedlow, H. Webber, Hussam Hussein, I. Abdurahmanov, Aleksandr Dolidudko, A. Y. Seerat, Umida Solieva, Tesfaye Woldeyohanes, and K. Helming. 2022. "Operationalizing water-energy-food nexus research for sustainable development in social-ecological systems: an interdisciplinary learning case in Central Asia." *Ecology and Society*. https://doi.org/10.5751/ES-12891-270112.

Han, Shumin, Ping Xin, Hui-Long Li, and Yonghui Yang. 2022. "Evolution of agricultural development and land-water-food nexus in Central Asia." https://doi.org/10.1016/J.AGWAT.2022.107874.

Hejnowicz, A., Jeff Thorn, M. E. Giraudo, J. Sallach, S. Hartley, J. Grugel, S. Pueppke, and L. Emberson. 2022. "Appraising the Water-Energy-Food Nexus From a Sustainable Development Perspective: A Maturing Paradigm?" *Earth's Future*. https://doi.org/10.1029/2021EF002622.

Hirwa and Sayidjakhon, Khasanov, Peifang Leng and Qiuying Zhang and Fadong Li and Rashid Kulmatov and Guoqin Wang and Yunfeng Qiao and Jianqi Wang and Yu Peng and Chao Tian and Nong Zhu and Hubert. 2021. "Agricultural impacts drive longitudinal variations of riverine water quality of the Aral Sea basin (Amu Darya and Syr Darya Rivers), Central Asia." *Environmental Pollution* 284: 117405. https://doi.org/https://doi.org/10.1016/j.envpol.2021.117405. https://www.sciencedirect.com/science/article/pii/S0269749121009878.

Hufschmidt, Maynard M. "A Conceptual Framework For Analysis Of Watershed Management Activities." https://www.fao.org/3/ad085e/AD085e12.htm.

Hunink, J.E., J. Bird. 2021. *Scoping Study for the CAREC Water Pillar: Climate Resilience Through Regional Cooperation.* https://www.futurewater.eu/projects/carec-developing-the-water-pillar-for-central-asia/.

ICWC. 2023. BULLETIN № 6 (99). Interstate Commissionfor Water Coordination of Central Asia (ICWC).

IEA. 2022. Kazakhstan Energy Profile. edited by International Energy Agency.

Information, analytical and resource center of the Ministry of Water Resources of Uzbekistan. 2023. SDG 6 Indicator 6.5.1:Survey. edited by Nazarov M. and Pyshev Ya.: UN-Water.

IOM. 2021. Migration and Development in Central Asia. International Organization for Migration.

Ishpulatov, Z. 2023. SDG 6.5.1 Stakeholder Consultation Report Republic of Uzbekistan. UN-Water.

Itayi, Chirenje Leonard, G. Mohan, and Osamu Saito. 2021. "Understanding the conceptual frameworks and methods of the food–energy–water nexus at the household level for development-oriented policy support: a systematic review." *Environmental Research Letters*. https://doi.org/10.1088/1748-9326/ABD660.

IWMI. , accessed May 3, 2024. "Knowledge base “IWRM: Central Asian experience”." http://www.cawater-info.net/bk/iwrm/toolbox_e.htm.

---. accessed May 3. "Knowledge base “IWRM: Central Asian experience”." http://www.cawater-info.net/bk/iwrm/toolbox_e.htm.

IWMI, Swiss Development Agency. 2008. *Hydrographization.*

Jalilov, Shokhrukh-Mirzo, Saud A. Amer, and Frank A. Ward. 2013. "Reducing conflict in development and allocation of transboundary rivers." *Eurasian Geography and Economics*. https://doi.org/10.1080/15387216.2013.788873.

---. 2018. "Managing the water-energy-food nexus: Opportunities in Central Asia." *Journal of Hydrology*. https://doi.org/10.1016/J.JHYDROL.2017.12.040.
Jaloobayev, A. 2007. IWRM financial, economic and legal aspects: the example of the 'WRM-Ferghana' project. edited by Wouters P., Duchovny V. and Allan A.: Springer, NATO Public Diplomacy Division.
Karthe, Daniel. 2018. "Environmental Changes in Central and East Asian Drylands and their Effects on Major River-Lake Systems." *Quaternary International*. https://doi.org/10.1016/J.QUAINT.2017.01.041.
Karthe, Daniel, Sergey Chalov, and Dietrich Borchardt. 2015. "Water resources and their management in central Asia in the early twenty first century: status, challenges and future prospects." *Environmental Earth Sciences*. https://doi.org/10.1007/S12665-014-3789-1.
Kazakhstan, Department of International Cooperation and Sustainable Development of the Bureau of National Statistics of the Agency for Strategic Planning and Reforms of the Republic of. 2019. IWRM action planning for SDG 6: Kazakhstan. In Summary overview.
---. 2023a. Implementation of Integrated Water Resources Management (IWRM) SDG INDICATOR 6.5.1 edited by Dosanova A.
---. 2023b. SDG indicator 6.5.1: survey. edited by Dosanova A.
---. 2024. *SDG 6.5.1 Stakeholder Consultation Report*.
Khamidov, M. 2007a. "Characteristic features of integrated water resources management in the Syrdarya River basin." https://doi.org/10.1007/978-1-4020-5732-8_2.
Kulmatov, R., S. Adilov, and S. Khasanov. 2020. "Evaluation of the spatial and temporal changes in groundwater level and mineralization in agricultural lands under climate change in the Syrdarya province, Uzbekistan." *IOP Conference Series: Earth and Environmental Science*. https://doi.org/10.1088/1755-1315/614/1/012149.
Liu, Yu, Ping Wang, Boris Gojenko, Jingjie Yu, Lezhang Wei, Dinggui Luo, and Tangfu Xiao. 2021. "A review of water pollution arising from agriculture and mining activities in Central Asia: Facts, causes and effects." https://doi.org/10.1016/J.ENVPOL.2021.118209.
Locke, Kent Anson. 2024. "Impacts of land use/land cover on water quality: A contemporary review for researchers and policymakers." *Water Quality Research Journal* 59 (2): 89-106. https://doi.org/10.2166/wqrj.2024.002. https://doi.org/10.2166/wqrj.2024.002.
M.Kh., Khamidov. 2007. "Characteristic features of integrated water resources management in the Syrdarya River basin M.Kh. Khamidov ".
Makhmudova, U., A. Djuraev, and T. Khushvaktov. 2021. "Environmental flows in integrated sustainable water resource management in Tuyamuyin water reservoir, Uzbekistan." *IOP Conference Series: Earth and Environmental Science* 937: 032024. https://doi.org/10.1088/1755-1315/937/3/032024.
Ministry of Natural Resources, Ecology and Technical Supervision of Kyrgyzstan. 2023a. Implementation of Integrated Water Resources Management (IWRM) SDG INDICATOR 6.5.1 =. UN-Water.
Ministry of Natural Resources Ecology and Technical Supervision of Kyrgyz Republic, GWP Kyrgyzstan. 2023. SDG 6.5.1 Stakeholder Consultation Report Kyrgyz Republic. edited by Dzhailoobaev A.
Ministry of Natural Resources, Ecology and Technical Supervision of Kyrgyzstan. 2023b. SDG Indicator 6.5.1: Survey. edited by Dalbaev T.: UN-Water
Mirzaev, N. 2022. Water resources management: science, practice, innovation. SIC ICWC.
Musina, Ainur, Karakoz Narbayeva, Zhanara Zhanabayeva, Ерболат Кайпбаев, and Omirzhan Taukebayev. 2023. "ASSESSMENT OF CHANGES AND USE OF

WATER RESOURCES IN THE SYRDARYA RIVER." *Ìzdenìster, nǽtiželer*. https://doi.org/10.37884/4-2023/21.
Nasrulin, A. 2019. "ANALYSIS OF THE USE OF THE METHOD OF HYDROECOLOGICAL MONITORING IN ORDER TO IMPROVE THE ECOLOGICAL CONDITION OF THE HYDROTECHNICAL CONSTRUCTIONS OF UZBEKISTAN."
Nazirov, A. 2007. "Interstate, Intersectoral Scientific and Practical Integration ".
Norkobil, Rakhmatov. 2019. "WATER RESOURCES MANAGEMENT OF SIRDARYA RIVER." *Austrian Journal of Technical and Natural Sciences*.
Saidmamatov, O., Rudenko I., Pfister S., and Koziel, J. 2020. Water–Energy–Food Nexus Framework for Promoting Regional Integration in Central Asia. In *Water*.
Pohl, B., Annika Kramer, William Hull, Sabine Blumstein, Iskandar Abdullaev, Jusipbek Kazbekov, Tais Reznikova, Ekaterina Strikeleva, Eduard Interwies, and Stefan G.rlitz. 2017. "RETHINKING WATER IN CENTRAL ASIA: The costs of inaction and benefits of water cooperation". *Adelphi and CAREC*.
Qin, Jingxiu, Weili Duan, Yaning Chen, Viktor A. Dukhovny, Denis Sorokin, Yupeng Li, and Xuanxuan Wang. 2022. "Comprehensive evaluation and sustainable development of water–energy–food–ecology systems in Central Asia." *Renewable and Sustainable Energy Reviews* 157: 112061. https://doi.org/https://doi.org/10.1016/j.rser.2021.112061. https://www.sciencedirect.com/science/article/pii/S136403212101323X.
Rafikov, V., and Rahmatullaev. 2016. "Compendium problems of trans-boundary water quota allocation in Central Asia."
Rahaman, Mohammad. 2012. Principles of Transboundary Water Resources Management and Water-related Agreements in Central Asia: An Analysis. In *International Journal of Water Resources Development*: Routledge.
Rakhmatov, N., L. Maksudova, F. Jamolov, B. Ashirov, and D. Tajieva. 2020. "The concept of creating a new water management system in the region." *IOP conference series*. https://doi.org/10.1088/1757-899X/883/1/012007.
Rau, Alexey, Kai Zhu, Balgabayev Nurlan, Mirdadayev Mirobit, Kalybekova Yessenkul, Meymank Hozhaev Bek, M. Nabiollina, Zhanymhan Kurmanbek, Yerlan Issakov, Sándor Antal, Apolka Ujj, and Lóránt Dénes Dávid. 2023. "Agronomic and reclamation strategies to enhance soil fertility, productivity and water accessibility." *Frontiers in Sustainable Food Systems*. https://doi.org/10.3389/FSUFS.2023.1288481.
Ruziev, M., and V. Prikhodko. 2007. Implementation of the Aral Sea Basin Socio-Economic Model: An Assessment of the Opportunities to be Gained through Regional Economic Integration edited by Wouters P., Duchovny V. and Allan A.: Springer, NATO Public Diplomacy Division.
Ryabtsev, A. 2007. "On Public Participation in Water Resources Management ".
Rysbekov, A. 2023. Amudarya is a Tricky Business. Tashkent: SIC ICWC.
Saidmamatov, O., Nicolas Tetreault, D. Bekjanov, Elbek Khodjaniyazov, Ergash Ibadullaev, Yuldoshboy Sobirov, and Lugas Raka Adrianto. 2023. "The Nexus between Agriculture, Water, Energy and Environmental Degradation in Central Asia—Empirical Evidence Using Panel Data Models." *Energies*. https://doi.org/10.3390/EN16073206.
Saidmamatov, Olimjon, Orifjon Saidmamatov, Yuldoshboy Sobirov, Peter Marty, Davron Ruzmetov, T. Berdiyorov, J. Karimov, Ergash Ibadullaev, Umidjon Matyakubov, and Jonathon Day. 2024. "Nexus between Life Expectancy, CO2 Emissions, Economic Development, Water, and Agriculture in Aral Sea Basin: Empirical Assessment." *Sustainability*. https://doi.org/10.3390/SU16072647.

Saidmamatov, Olimjon, Yuldoshboy Sobirov, Peter Marty, Davron Ruzmetov, T. Berdiyorov, J. Karimov, Ergash Ibadullaev, Umidjon Matyakubov, and Jonathon Day. 2024. Nexus between Life Expectancy, CO2 Emissions, Economic Development, Water, and Agriculture in Aral Sea Basin: Empirical Assessment. In *Sustainability*.

Sehring, J. 2009a. "Path dependencies and institutional bricolage in post-Soviet water governance." *Water alternatives*.

---. 2015. "Bridging gaps and connecting experts: the linkages of water, scientific collaboration and regional security."

Sehring, Jenniver, R. ter Horst, and A. Said. 2023. "Water diplomacy: A man's world? Insights from the Nile, Rhine and Chu-Talas basins." *Journal of Hydrology X*. https://doi.org/10.1016/J.HYDROA.2023.100152.

Sehring, Jenniver, R. ter Horst, and M. Zwarteveen. 2022. *Gender Dynamics in Transboundary Water Governance*.

Sehring, Jenniver, and S. Ibatullin. 2020. "Prolonging or resolving water conflicts in Central Asia?". https://doi.org/10.4324/9780429266270-12.

Sehring, Jenniver, Dinara R. Ziganshina, Márton Krasznai, and T. Stoffelen. 2019. "International actors and initiatives for sustainable water management." *The Aral Sea Basin*. https://doi.org/10.4324/9780429436475-11.

Sehring, Jenniver. 2009b. "The politics of water institutional reform in neopatrimonial states : a comparative analysis of Kyrgyzstan and Tajikistan." VS, Verlag für Sozialwissenschaften. http://site.ebrary.com/id/10276687.

Sehring, Jenniver, Aminjon Abdulloev, Nataliya Chemayeva, Botir Ismailov, Nargiza Osmonova, and Botagoz Sharipova. 2021. "Reforaming legal frameworks for water management in Central Asia." https://doi.org/10.4337/9781783477005.X.26.

Sehring, Jenniver, Rozemarijn ter Horst, and Alexandra Said. 2023. "Water diplomacy: A man's world? Insights from the Nile, Rhine and Chu-Talas basins." *Journal of Hydrology X*. https://doi.org/10.1016/J.HYDROA.2023.100152.

Sharda, V., Pradeep Dogra, and B. Dhyani. 2012. "Indicators for assessing the impacts of watershed development programmes in different regions of India." *Indian Journal of Soil Conservation* 40: 1-12.

Sokolov, V. 2021. Cooperation within the framework of the International Fund for Saving the Aral Sea to solve the problems of the Aral Sea region. Tashkent: IFAS Project Implementation Agency Republic of Uzbekistan.

Sokolov, V., D. Ziganshina, and V. Dukhovny. 2014. *Integrated water resources management in Central Asia*.

Sorokin, D., and A. Sorokin. 2023. Recommendations for water resource management in the Amudarya River Basin. Tashkent: SIC ICWC.

Statute, BWO "Amudarya". 1992a. http://www.icwc-aral.uz/statute9.htm

Statute, BWO "Syrdarya". 1992b. http://www.icwc-aral.uz/statute10.htm.

Tajikistan, Committee for Environmental Protection under the Government of the Republic of. 2023a. Implementation of Integrated Water Resources Management (IWRM) SDG INDICATOR 6.5.1. edited by Shukurov I.

---. 2023b. SDG indicator 6.5.1: survey. edited by Shukurov I.

Tarlock, A. 2007. Integrated Water Resources Management: Theory and Practice edited by Wouters P., Duchovny V. and Allan A.: Springer, NATO Public Diplomacy Division.

Times, The Astana. 2024. Kazakhstan's Renewable Energy Sector Gains Momentum with 146 Facilities in Operation.

Tuchin, A. 2007. "Ensuring stable and even water distribution for irrigation systems at national and local levels ".

Turkmenistan, State Committee for Water Resources of. 2023. Implementation of Integrated Water Resources Management (IWRM) SDG INDICATOR 6.5.1 Turkmenistan. UN-Water.
UN-Water."Indicator 6.5.1 “Degree of integrated water resources management implementation (0-100)”." https://www.unwater.org/our-work/integrated-monitoring-initiative-sdg-6/indicator-651-degree-integrated-water-resources.
UNDESA. 2022. World Population Prospects 2022.
UNDP. 2021. Turkmenistan: Energy Profile.
UNDRR. 2021. Subnational INFORM model for Caucasus and Central Asia. edited by Early Warning and Preparedness and the European Commission Inter-Agency Standing Committee Reference Group on Risk.
UNECE. 2011. Strengthening Water Management and Transboundary Water Cooperation in Central Asia: the Role of UNECE Environmental Conventions.
Uzbekistan, Ministry of Energy of the Republic of. 2020. Concept Note for Ensuring Electricity Supply in Uzbekistan in 2020-2030.
Uzbekistan, Ministry of Water Resources of the Republic of. 2023a. SDG 6 Indicator 6.5.1.: Survey [rus]. UN-Water.
Uzbekistan, The Ministry of Water resources of the Republic of. 2023b. Implementation of Integrated Water Resources Management (IWRM), SDG INDICATOR 6.5.1
Vandas, Steve, Thomas C. Winter, and William A. Battaglin. 2002. *Water and the environment*. Alexandria, Vancouverm USA: American Geological Institute.
Wang, Guangyu, Shari Mang, Haisheng Cai, Shirong Liu, Zhi-Qiang Zhang, Liguo Wang, and John Innes. 2016. "Integrated watershed management: evolution, development and emerging trends." *Journal of Forestry Research* 27. https://doi.org/10.1007/s11676-016-0293-3.
Wang, Xiaolei, Junze Zhang, Shuai Wang, Yingzi Ge, Zihao Duan, Lin Sun, Michael E. Meadows, Yi Luo, Bojie Fu, Xi Chen, Yanyan Huang, Xiaoting Ma, and Jilili Abuduwaili. 2023. "Reviving the Aral Sea: A Hydro-Eco-Social Perspective." *Earth's Future*. https://doi.org/10.1029/2023EF003657.
Wang, Xuechao, Peng Jiang, Lan Yang, Yee Van Fan, Jiří Jaromír Klemeš, and Yutao Wang. 2021. "Extended water-energy nexus contribution to environmentally-related sustainable development goals." *Renewable & Sustainable Energy Reviews*. https://doi.org/10.1016/J.RSER.2021.111485.
Wang, Yanxin, S. Yuan, Jianbo Shi, T. Ma, Xianjun Xie, Yamin Deng, Yao Du, Y. Gan, Zhilin Guo, Yiran Dong, Chunmiao Zheng, and Guibin Jiang. 2023. "Groundwater Quality and Health: Making the Invisible Visible." *Environmental Science and Technology*. https://doi.org/10.1021/ACS.EST.2C08061.
Wani, Suhas, and Kaushal Garg. 2009. "Watershed Management Concept and Principles."
WECOOP. 2023. Project DB. edited by EU.
WHO. 2023. Drinking-water.
Wouters, and V. Dukhovny. 2007a. Integrated Water Resources Management - International Best Practice.   . NATO Science Series: IV.
Wouters, P., and V. Dukhovny. 2007b. Integrated Water Resources Management - International Best Practice. NATO Science Series: IV.
Wouters, Patricia, Victor Dukhovny, and Andrew Allan. 2007. *Implementing integrated water resources management in Central Asia*.
Xenarios, Stefanos, Jenniver Sehring, Aliya Assubayeva, Dietrich Schmidt-Vogt, Iskandar Abdullaev, and Eduardo Araral. 2019. "Water Security Assessments in Central Asia: Research and Policy Implications."

Yang, Yongsheng, Yuanyue Pi, Xiang Yu, Zhijie Ta, Lingxiao Sun, Disse Markus, Fanjiang Zeng, Yaoming Li, Xi Chen, and Ruide Yu. 2019. "Climate change, water resources and sustainable development in the arid and semi-arid lands of Central Asia in the past 30 years." *Journal of Arid Land*. https://doi.org/10.1007/S40333-018-0073-3.

Yapiyev, Vadim, Andrew J. Wade, Maria Shahgedanova, Zarina Saidaliyeva, Azamat Madibekov, and Igor Severskiy. 2021. "The hydrochemistry and water quality of glacierized catchments in Central Asia: A review of the current status and anticipated change." https://doi.org/10.1016/J.EJRH.2021.100960.

Yoshida, K. 2022. *The CAREC Water Pillar a vehicle for long term cooperationCentral Asia case in view of geographical expansion.* UNECE. https://unece.org/sites/default/files/2023-01/7.%20Yoshida_ADB_Engl.pdf.