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current status and future priorities

Prepared to inform the Amu Darya River Basin dialogue

Dushanbe-Ashgabat-Tashkent | November 2025

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The goal of this document is to drive joint action on preservation of ecosystems within the Amu Darya River Basin, from its source to its discharge zones, by presenting solution-oriented strategies for the sustainable management of natural resources.

The document has been prepared as part of the GIZ Regional Program "Climate-sensitive water resources management in Central Asia" of the Green Central Asia initiative to inform the Amu Darya River Basin Dialogue.

The work was done by the project team of regional and national experts:

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DESIGN AND LAYOUT: A.S. Degtyareva

To inform this consolidated study, country reviews, thematic studies, and field surveys were conducted. These inputs served as the analytical foundation for the report's findings and practical recommendations.

COUNTRY REVIEWS:

- ☐ A. Gulakhmadov; R.R. Davlyatov; F.A. Karieva. Assessment of the Current State of the Amu Darya River and Key Water-Dependent Ecosystems in Tajikistan, 2025
- ☐ G. Nurmukhamedova; J. Saparmuradov; G. Akmuradov. Assessment of the Current State of the Amu Darya River and Key Water-Dependent Ecosystems in Turkmenistan, 2025
- ☐ Kh. S. Sherimbetov; Kh.S. Makhmudov; T.Sh. Khalikov. Assessment of the Current State of the Amu Darya River and Key Water-Dependent Ecosystems in Uzbekistan, 2025

THEMATIC STUDIES:

- ☐ A.M. Nazariy. Analysis of the Current State of Water Management
- ☐ M.N. Rakhimova. Assessing the Status of Ecosystems in the Amu Darya River Basin: Legal, Institutional and Administrative Measures at National, Regional and International Levels
- ☐ I.I. Ruziev. RS-based Study of Water Surface Areas and Changes in River and Lake Ecosystems in Designated Protected areas in the Amu Darya Lower Reaches

FIELD SURVEYS:

- ☐ Report on field visit to the Beshai Palangon Nature Reserve (Tigrovaya Balka) in the Khatlon province of Tajikistan (May 29, 2025)
- ☐ Report on field surveys in Bukhara province and Republic of Karakalpakstan, covering ABMC, the Kuyimazar and Tudakul reservoirs, the Jayran/ Gazelle Nursery, the Lower Amu Darya Biosphere Reserve (LABR), and the Mezhdureche Reservoir (August 27-29, 2025)

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the Bukhara Jayran Nursery – P.Yu. Toshev, Acting Deputy Director for Research; the Lower Amu Darya Biosphere Reserve – N.B. Madaminov, Acting Director, A.M. Turaev, Acting Deputy Director

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LIST OF ABBREVIATIONS

ABMC	Amu-Bukhara Main Canal
BWO Amu Darya	Basin Water Organization Amu Darya
CA	Central Asia
CDS	Collector-Drainage Systems
CDW	Collector-Drainage Waters
GEF	Global Environmental Facility
HPP	Hydropower Plant
ICSD	Interstate Commission for Sustainable Development
ICWC	Interstate Commission for Water Coordination
IFAS	International Fund for Saving the Aral Sea
IWRM	Integrated Water Resources Management
km^2	Square kilometer
km^3	Cubic kilometer
LABR	Lower Amu Darya Biosphere Reserve
MAB	UNESCO's 'Man and the Biosphere' Programme
PA	Protected area
REP4SD CA	Regional Environmental Program for Sustainable Development in Central Asia
SCO	Shanghai Cooperation Organization
SNR	State Nature Reserve
SPECA	UN Special Programme for the Economies of Central Asia
TMH	Tuyamuyun Hydroscheme
UNFCCC	United Nations Framework Convention on Climate Change
WPI	Water Pollution Index

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INTRODUCTION

Background and Significance of the Research

The Amu Darya River Basin is a unique area encompassing a wide range of natural landscapes and ecosystems, from glaciers and snowfields in the river's source area to wetlands in the river's floodplain and delta. Pamir-Alay mountain glaciers feed the bulk flow of the Amu Darya River, which makes their conservation crucial for basin's ecosystems and for water sustainability in the region as a whole. Floodplain forests along the course of the river play a key role for preservation of biodiversity. Extensive agricultural land and deserts, including Aralkum, a newly formed desert on the dried-up bed of the Aral Sea, are also a part of the river basin.

The ecological importance of the Amu Darya's ecosystems is highlighted by a network of **protected areas** (PAs) across the basin. In the upper reaches, Tajikistan protects the Beshai Palangon State Nature Reserve (known as "Tigrovaya Balka"). Turkmenistan features the Amu Darya State Nature Reserve, which safeguards the river valley's tugay (riparian) ecosystems. Further down in Uzbekistan, key PAs include the Kyzylkum State Nature Reserve, the Lower Amu Darya State Biosphere Reserve, and the Khorezm National Nature Park. Collectively, these reserves are vital for conserving rare tugay (riparian) forests and related wetlands, offering refuge for key species like the Bukhara deer and several rare bird species, and serving as critical sites for ecological monitoring and research.

CLIMATIC AND ANTHROPOGENIC CHALLENGES. Increasing anthropogenic pressure and the impacts of climate change are making ecosystems highly vulnerable to degradation. Addressing these challenges requires an integrated approach to nature conservation and sustainable resource use. This strategy must be guided by the principles of Integrated Water Resources Management (IWRM), specifically by ensuring the water needs of ecological systems are met.

THE NEED FOR COOPERATION. These challenges are inherently transboundary, impacting all basin countries: Kyrgyzstan, Tajikistan, Turkmenistan, and Uzbekistan. This shared vulnerability has fostered a consensus that effective biodiversity conservation and water management in the Amu Darya basin demand coordinated, multilateral efforts. This commitment to cooperation was formalized as early as March 1993, when the heads of the five Central Asian states signed the Agreement on Joint Actions to Address the Problems of the Aral Sea and the Aral Sea Region in Kyzylorda city. Key common goals identified in this document include the rational use of water and land resources, maintaining proper water quality in rivers and lakes, guaranteeing inflow to the Aral Sea for its preservation, restoring degraded delta ecosystems of the Amu Darya and Syr Darya rivers, and establishing protected areas for migratory species, among other related measures. Furthermore, all basin countries are parties to key international environmental conventions. These include the Convention on Biological Diversity, the Ramsar Convention on Wetlands, the UN Convention to Combat Desertification, and the UN Framework Convention on Climate Change, all of which commit them to action for ecosystem conservation and sustainable resource use.

The global Sustainable Development Goals (SDGs) hold a special place in this commitment. The UN 2030 Agenda explicitly states: "We recognize that social and economic development depends on the sustainable management of our planet's natural resources. We are therefore determined to conserve and sustainably use the oceans and seas, freshwater resources, as well as forests, mountains and drylands, and to protect biodiversity, ecosystems and wildlife."[1] This study is aimed precisely at putting this integrated approach into practice, seeking to achieve a critical balance between the necessary economic development of the basin countries and the conservation of ecosystems across the entire Amu Darya River basin.

GREEN CENTRAL ASIA INITIATIVE. In response to growing environmental concerns, the countries of the region-supported by international partners-have launched new dialogue platforms. The first Basin Dialogue meeting for the Amu Darya and Syr Darya river basins took place in Tashkent on November 30, 2023. This meeting was held as part of the regional Green Central Asia Initiative led by the German Agency for International Cooperation (GIZ). At this meeting,

[1] Resolution adopted by the UN General Assembly on 25 September 2015

representatives of the participating countries identified joint work to preserve the river's ecosystems-across both flow generation and dispersion zones-as a priority area for co-operation in the Amu Darya basin. This report was prepared as a direct follow-up to that agreement. It synthesizes findings from studies conducted by experts from the three basin countries (Tajikistan, Turkmenistan, and Uzbekistan) and offers recommendations for strengthening interstate cooperation in environmental protection within the Amu Darya basin. Its relevance is rooted in the need to adopt both Integrated Water Resources Management (IWRM) and an ecosystem-based approach. These essential frameworks view aquatic and terrestrial ecosystems as interconnected, recognizing that their conservation is a fundamental prerequisite for long-term sustainability.

Research Objectives and Tasks

The **objective** of the research is to provide an expert assessment of the state of key flow-generating and water-dependent ecosystems in the Amu Darya River Basin, in relation to river flow variability, and to develop scientific evidence-based recommendations for strengthening joint measures for the sustainable functioning and preservation of these ecosystems. The research findings are intended to serve as a foundation for policymaking and the elaboration of long-term sustainable basin development programs.

This objective was achieved through the following **tasks:**

- **Analysis of the current state of the Amu Darya's water resources.** This included evaluating the long-term flow regime, identifying trends in water level and quality, and assessing the climatic and anthropogenic factors that influence the river's discharge.
- **Assessment of the condition of key ecosystems within the Amu Darya River basin.** This involved study of glaciers, floodplain forests, desert areas, and wetlands, and their interactions with the river's water resources. The goal was to identify the most vulnerable areas and pinpoint the major threats.
- **Study of the status of Protected areas (PAs)** in the Amu Darya River Basin and assessment of their role in preserving the region's biological diversity.
- **Review of legal, institutional, and organizational measures** related to ecosystem conservation (environmental legislation, presence of PAs, existing programs and agreements) in the basin countries and globally. Identification of current barriers to interstate cooperation and water management that hinder effective nature protection.
- **Geoinformation analysis** of changes in water surface areas within selected basin's PAs using RS-data.
- **Development of recommendations** for national and regional authorities on improving the management and conservation of natural resources in the Amu Darya River Basin, including proposals to strengthen interstate cooperation.

Methodology

National expert teams were formed in Tajikistan, Turkmenistan and Uzbekistan to carry out the research. Those included experts in hydrology, ecology, and biodiversity. Regional experts on water, legal aspects, biodiversity and GIS were also engaged.

The methodology combined **desk studies with field methods**. Key approaches included:

- **Analysis of available data:** collection and review of earlier assessments of ecosystem and water resources in the basin, reports from international projects, scientific publications, and statistical bulletins of hydrometeorological and water management authorities. The analysis utilized long-term observation data on the Amu Darya River flow, materials on biodiversity and protected areas (PAs), as well as national legislation of the basin countries and relevant international agreements.
- **Expert consultations and field visits:** engaged experts conducted field missions to several key sites (Beshai Palangon Nature Reserve, the middle reaches and the delta of the Amu Darya) to gather up-to-date information on ecosystem conditions. Interviews were also held with staff of

PAs, representatives of water management organizations, and local residents regarding observed environmental changes.

- **Geoinformation analysis** in two directions:

(a) **Remote sensing:** processing of satellite images (including Landsat 8 and NASA Worldview data) to monitor the dynamics of changes in water surface areas. Changes in water body boundaries were mapped for the period from the 1990s to the present, along with calculations of moisture indicators.

(b) **Mapping and database:** developing a verified GIS database of basin's Pas (including Tajikistan, Turkmenistan, Uzbekistan and Kyrgyzstan). Within the ArcGIS Pro environment, the boundaries of the sites were systematized through a cross-analysis of national reports and international sources (UNEP-WCMC/Protected Planet, IUCN, OSM, and CEPF materials). This helped to resolve inconsistencies and incorporate into the database the sites holding international status (Ramsar sites, UNESCO properties, IBA/KBA). The work resulted in map layouts at scales of 1:2,300,000 and 1:4,800,000, as well as the structured geospatial data for uploading on the CAWATER-info portal.

- **Data harmonization and synthesis:** the conceptual approaches for conducting the analytical research were agreed upon during the Basin Dialogue meeting in Urgench in December 2024. Subsequently, national teams prepared country reports assessing ecosystem conditions, and regional thematic reviews were produced on the current state of water management in the basin, on legal, institutional, and administrative aspects, and on the extent and changes of water surfaces and ecosystems within protected areas in the lower reaches of the Amu Darya River, based on satellite images. The research findings were reviewed during joint expert meetings of the three countries, including the second meeting of the project expert group in Dushanbe on May 28, 2025. Following the discussions, the data were consolidated into a comprehensive report.

Scope of the Research

The research focuses on freshwater ecosystem of the Amu Darya basin and covers both mountain and foothill zones where flow originates and floodplain forests, lake-wetland complexes, and delta systems in the middle and lower reaches, focusing on joint measures within the Amu Darya River Basin.

The level of analysis varies across the basin countries. **Tajikistan, Turkmenistan, and Uzbekistan** are analyzed fully because they encompass the basin's main sections, key hydraulic structures, and major ecosystems, from headwaters to the delta. **Kyrgyzstan** is included only partially; its very small territorial share (the Kyzyl-Suu/Surkhob/Vakhsh sub-basin) objectively limits the analytical scope. The research **does not cover Afghanistan** despite its increasing importance as a water user in the middle and lower reaches of the Panj and the Amu Darya. The main reasons for this exclusion are the lack of Afghanistan's formal participation in regional organizations, limited access to reliable official data, and difficulties with aligning national legal framework. Consequently, the analysis concentrates on the three main basin countries and partially on Kyrgyzstan. However, future work must account for the Afghanistan factor as a critical element for regional water security.

Structure of the Report

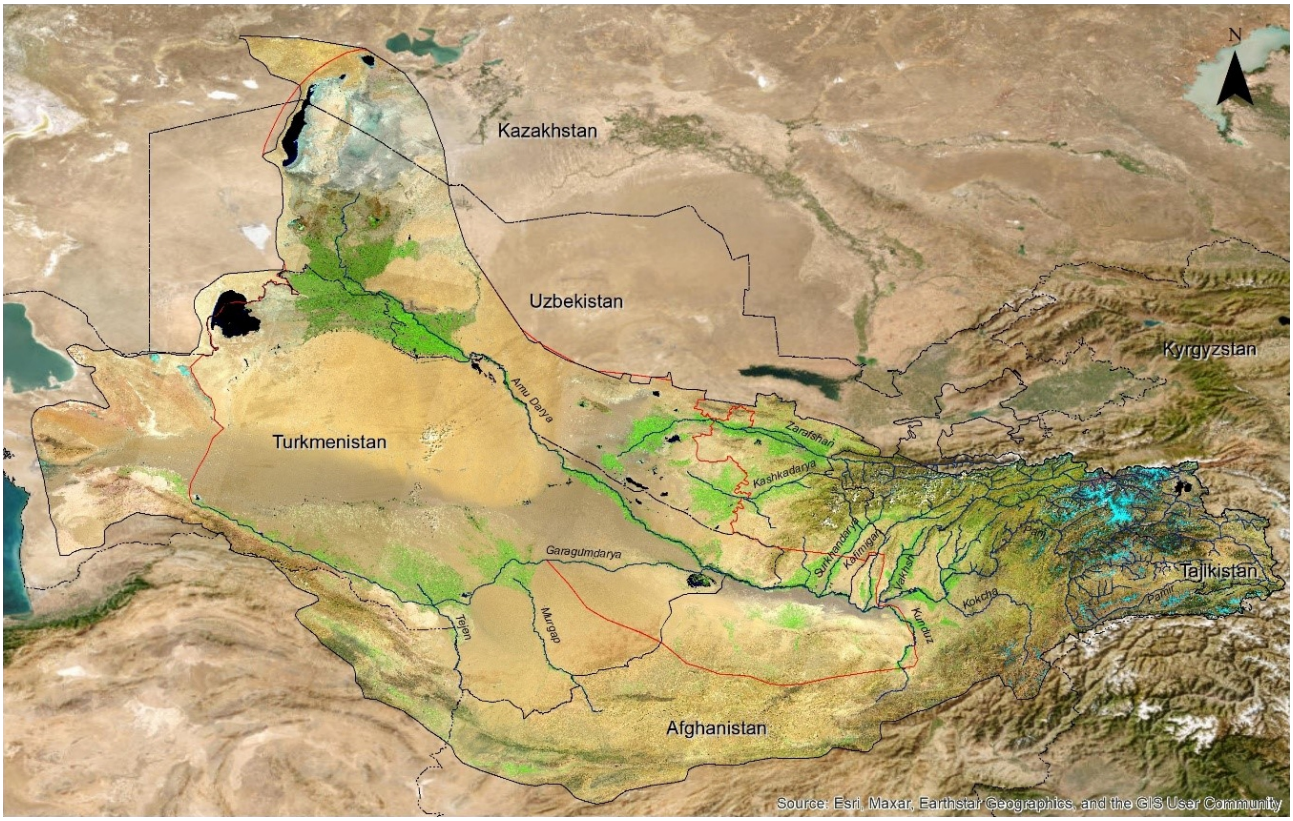
This document is organized to logically support the core thesis that the Amu Darya River Basin's ecosystems-encompassing both flow-generating (such as glaciers, snowfields, mountain meadows, and upper catchment forests) and water-dependent (including floodplain, delta, and lake-wetland complexes) – constitute a single, interconnected system that is entirely susceptible to the impacts of climate change, unsustainable water use, and other human activities. The following chapters present the basin's geographical and hydrological profile, the current status and vulnerabilities of its ecosystems, the results of field and satellite observations, a review of national and international best practices, and a set of consolidated recommendations for joint action.

CHAPTER 1
GEOGRAPHY, HYDROLOGY AND WATER USE IN THE BASIN

1.1. Geographic and Hydrographic Characteristics

The Amu Darya River Basin is the largest and most water-abundant river system in Central Asia, with a catchment area of 1,017.8 thousand km^2. Located within the inland Aral Sea region, it spans Afghanistan, the Kyrgyz Republic, Tajikistan, Turkmenistan, and Uzbekistan. The Amu Darya River originates at the confluence of the Panj and Vakhsh rivers. Its total length is 2,574 km from the sources of the Panj to the Aral Sea (1,415 km from the Panj-Vakhsh confluence).

FIGURE 1
Amu Darya River Basin



Source: SIC ICWC

The basin's hydrographic network is dense and features watercourses with varying discharge capacities, including the major rivers: Vakhsh, Panj, Kafirnigan, Surkhandarya, Zarafshan, and Kashkadarya.[2] After the Panj and Vakhsh converge to form the Amu Darya, the river is fed by three left-bank tributaries (the Kafirnigan, Surkhandarya, and Sherabad Darya) and one left-bank tributary (the Kunduz). Notably, the Amu Darya receives no further inflow from tributaries downstream of the Kunduz up to the Aral Sea (see Fig. 1).

[2] The Zarafshan and the Kashkadarya rivers, which formally belong to the Amu Darya River Basin, do not actually reach the main river and can therefore be considered independent hydrographic systems

The mountain ranges (Pamir–Tian Shan) dictate a glacial-snowmelt regime for the primary rivers (Panj, Vakhsh, Zarafshan, etc.). Other rivers, such as the Yakhsu, Kyzylsu, Kafirnigan, Surkhandarya, Kashkadarya, and Kunduz, are partially snow-fed.

The high mountains function as the main natural water storage for the arid plains, with river flow during summer sustained by snow and glacier melt. The basin contains over 11,000 glaciers. The Western Pamirs alone held 10,031 glaciers covering an area of 8,106 km^2 as of 2017. The total glaciated area in the upper reaches is estimated at 13,600 km^2 (about 2.9% of the basin), with the largest concentration found in the Pamir Mountains.[3]

Tajikistan is home to approximately 14,000 glaciers, of which over 1,000 glaciers have been already disappeared.[4] The area of the Pamir-Darvaz glacier complex (Amu Darya basin) covers almost 6% of the country's territory, where 9,139 glaciers are located, containing 559 km^3 of ice.[5] The largest glacier is the Vanjakh (Fedchenko) Glacier, which is 77 km long. The ice thickness exceeds 1,000 meters at elevations above 5,000 m a.s.l., ranges from 400-500 meters in the central part, and decreases to 40-80 meters near the glacier's terminus. It forms a complex system of more than 60 tributary glaciers, often described as a "glacial tree." Other major glaciers include those of the Academy of Sciences, Korzhenevskaya, Garmo (130 km^2), Russian Geographical Society, and Grumm-Grzhimailo (150 km^2). Some glaciers, such as Medvezhiy and Kashola, are classified as surging glaciers, which increases the risk of sudden movements and the outburst of ice-dammed lakes.

The main glaciation centers of Kyrgyzstan within the Amu Darya River Basin (the upper reaches of the Kyzylsu River, a tributary of the Vakhsh) are located in the Alai and Zaalai Ranges. This area contains a relatively compact but hydrologically significant glacial system. Among the major glaciers are the kettle-hole Lenin glacier covering 50.3 km^2, and the compound valley Abramov (21.6 km^2) and Korzhenevsky (31.3 km^2) glaciers. Such massive valley and kettle-hole glaciers, along with numerous smaller corrie and hanging glaciers, form a complex high-mountain glacial landscape, which plays a crucial role in generating flow in the Amu Darya River upper reaches.[6]

The glaciers of Uzbekistan also play a role, particularly those located in the country's southeastern mountain regions. Within Uzbekistan, glaciers are situated entirely in the Kashkadarya River Basin, partially within the Pskem River Basin (tributaries of the Oygaing River), and in the Surkhandarya River Basin (feeding the Sangardak and Tupalang rivers) (Fig. 2).

Over the past decades, up to 50% of glacier area has been lost in several sub-basins, with the rate of reduction exceeding 1% per year. This trend has led to a decline in the stability of summer river flow and an increased risk of water scarcity in the region (see details in Section "High-Mountain Ecosystems").

From a physical and geographical perspective, the "large" Amu Darya Basin includes the Amu Darya River itself along with its characteristic zones – upper, middle, and lower reaches – as well as the closed basins of the Zarafshan, Kashkadarya, Murgab, Tedzhen, Atrek, and other rivers. The "small" Amu Darya Basin comprises the Amu Darya River and its main tributaries – the Panj, Vakhsh, Kafirnigan, and Surkhandarya – which together form the focus of interstate water management and allocation in the basin.

Considering the morphological and geographical characteristics of the basin, the following sections can be distinguished:

Upper reaches – the main channels of the Vakhsh, Panj, and Kafirnigan rivers and the section of the Amu Darya up to the Kelif gauging station. This area includes the mountain-valley irrigation zones of Tajikistan, southern Uzbekistan (Surkhan-

[3] Shahgedanova, M., van den Broeke, M. R., Kutuzov, S., Marchenko, S., & Huss, M. (2023). The Status and Change of Glaciers and Glacier Systems in High-Mountain Asia. Journal of Hydrometeorology, 24(2), 123-146. https://doi.org/10.1175/JHM-D-22-0040.1

[4] UNEP (2025). Tajikistan's melting glaciers put water resources under stress, UNEP Atlas reveals. www.unep.org/ru/novosti-i-istorii/press-reliz/tayanie-lednikov-v-tadzhikistane-stavit-pod-ugrozu-vodnye-resursy

[5] Central Asianlight. (2024, 25 January). Tajikistan accumulated maximum information about glaciers. https://centralasianlight.org/news/tajikistan-accumulated-maximum-information-about-glaciers

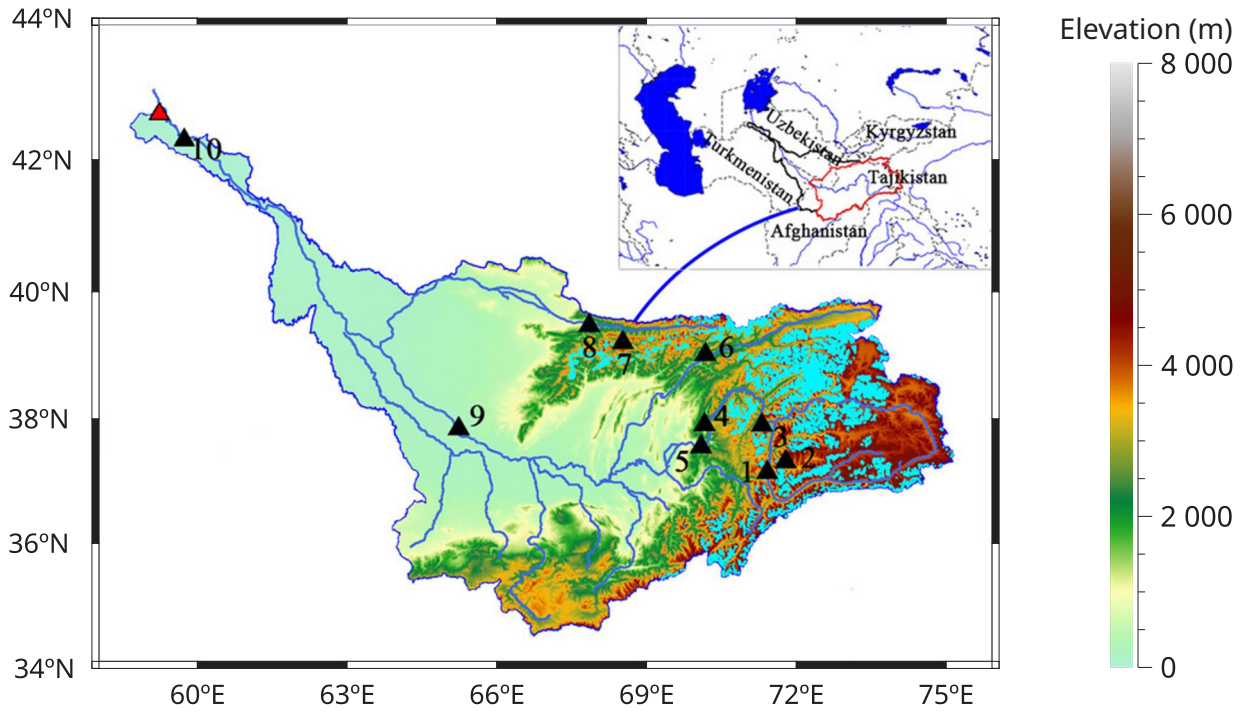
[6] Shabunin, A.G. (Author), Moldobekov, B.D. (Ed.). (2018). Catalogue of Glaciers of Kyrgyzstan (Edition 01/2024). Bishkek: Central Asian Institute for Applied Geosciences (CAIAG). www.caiag.kg/images/2_department/2022/Catalogue_of_glaciers_Kyrgyzstan_2018_Edition_01_2024_RU.pdf

darya province), and a small part of Kyrgyzstan. These irrigated areas are located in the valleys of the main tributaries of the Amu Darya – the Panj, Vakhsh, Kafirnigan, Surkhandarya, and Sherabad rivers.

Middle reaches – from the Kelif gauging station to the Tuyamuyun hydroscheme. This section features large main canals (the Karakum, Karshi, and Amu-Bukhara canals), along with off-stream reservoirs and a network of damless intake structures (Lebap velayat).

Lower reaches – downstream of Tuyamuyun, featuring an extensive network of irrigation canals on both banks (including Tashsaka, Pakhtaarna, Klychbay, Urgench-Daryalyk-Arna, Khan-Yab, Dustlik (Kyzketken), Suenli, and others) as well as delta lake systems.

FIGURE 2
Distribution of glaciers in the Amu Darya River Basin



Notes: Black triangles denote the (1) Khorog, (2) Sardem, (3) Shidzh, (4) Hirmanjo, (5) Khirmanjo, (6) Garm, (7) Kishl Pete, (8) Dupuli bridge, (9) Kerki, and (10) Chatly hydrological stations whose observations are used for model calibration and validation. Kerki and Kiziljar (red triangle) are where the deconvolution of the anthropogenic activities and climate change impacts on streamflow is performed. Glaciers are indicated by royal blue shadings, and stream channels are represented by blue lines.

Source: Qian, W., Zhong, L., Guo, L., & Liu, W. (2022). *Assessing the Impacts of Climate Change on Water Resources Using an Integrated Modeling Approach in the Tarim River Basin, Northwest China*. Journal of Hydrometeorology, 23(11), 1699-1715. https://doi.org/10.1175/JHM-D-22-0040.1

1.2. Water Resources

The annual river flow in the Amu Darya basin varies from 63.9 km^3 in low-water years to 101.0 km^3 in high-water years (SIC ICWC' Database).

According to the data of the "Revised Master Plan for comprehensive use and conservation of water resources in the Amu Darya River basin,"[7] the average long-term annual river

[7] "Revised Master Plan for comprehensive use and conservation of water resources in the Amu Darya River basin" approved by Protocol 566 of Scientific-Technincal Council under the USSR Ministry of Land Reclamation and Water Management of 10 September 1987

TABLE 1
Average long-term annual river flow of the Amu Darya River Basin over 1932/33-1980/81, km³/yr

River-section	Surface water inflow		Groundwater inflow	Total
	recorded	unrecorded		
1. Panj – Lower Panj section	33.4	–	–	33.4
2. Vakhsh – Tutkaul section	20.1	0.05	0.07	20.2
3. Kunduz – Askarkhana section	3.47	0.01	–	3.48
4. Kafirnigan – recorded surface water inflow	5.49	0.12	0.05	5.66
5. Surkhandarya – recorded surface water inflow	3.63	0.06	0.22	3.91
6. Sherabad – Sherabad section	0.23	–	–	0.23
TOTAL AMU DARYA RIVER	**66.32**	**0.24**	**0.34**	**66.88**
7. Kashkadarya – recorded surface water inflow	1.34	–	0.07	1.41
8. Zarafshan – Dupuli bridge +Magiandarya – Sudzhi section	5.27	–	0.03	5.30
9. North Afghanistan rivers	2.01	–	–	2.01
10. Turkmenistan's rivers	2.79	–	–	2.79
TOTAL BASIN	**77.7**	**0.24**	**0.44**	**78.4**

Source: Revised Master Plans, 1987

flow of the basin for the period 1932/33-1980/81 was 78.4 km³, of which 66.9 km³ was the flow of the river itself (Table 1). By the 2001 SPECA Report, the average annual flow for the Amu Darya basin for 1934-92 was 79.28 km³, of which flow of the river itself was calculated to be 67.56 km³.[8]

By SIC ICWC's assessments of 2020, over the period of 2000-2018, the average long-term flow in the Amu Darya basin was 78.77 km³, including 67.6 km³ of the Amu Darya River flow.[9] Expert assessments for the period after 2018 (2019-2023) showed that the long-term average river flow

TABLE 2
Assessment of changes in the average long-term annual flow of the Amu Darya River since 2018

Rivers of the Aral Sea Basin	2018	2019-2023	Change W1 – W2	
	W1. km³	W2. km³	km³	%
Amu Darya River Basin				
Vakhsh – inflow to Nurek HPS	21.3	20.0	-1.3	-6.1
Panj – Lower Panj section	33.5	32.6	-0.9	-2.6
Kunduz – Askarkhana section	4.4	4.4	0.0	0.0
Kafirnigan – recorded surface inflow	5.1	5.5	0.4	7.5
Surkhandarya – recorded surface inflow	3.3	3.4	0.1	1.5
TOTAL AMU DARYA RIVER	**67.6**	**65.9**	**-1.7**	**2.6**
Kashkadarya – recorded surface inflow	1.17	1.3	0.1	7.0
Zarafshan – Dupuli bridge + Magiandarya – Sudji station	5.0	5.1	0.1	2.7
Rivers of Turkmenistan	2.9	3.1	0.2	7.5
Rivers of Northern Afghanistan	2.1	2.2	0.1	8.7
TOTAL IN THE BASIN	**78.77**	**77.6**	**-1.2**	**-1.5**

Source: Data for 2019-2023. (W2) – SIC's assessment using BWO Amu Darya's data (Vakhsh, Zarafshan) and partially reconstructed based on linkage with the Vakhsh River

[8] Diagnostic Report on Water Resources in Central Asia (2001, SPECA)

[9] Overview of the use and management of water resources in Central Asia. A discussion document. SIC ICWC. 2020

amounted to 77.6 km^3, while the flow of the Amu Darya River was 65.9 km^3 (Table 2).[10] This indicates a **slight decrease in total flow** by 1.2 km^3 (-1.5%), primarily due to the Panj River (-0.9 km^3, -2.6%) and the Vakhsh River (-1.3 km^3, -6.1%).

The Kafirnigan River, by contrast, showed an increase (+0.4 km^3, +7.5%). In the middle reaches, positive trends are recorded for the Kashkadarya (+7.0%), the Zarafshan (+2.7%), and the rivers of Turkmenistan (+7.5%). Over five hydrological years (2019-2023), three years – 2019, 2022, and 2023 – had flow above the long-term average, while two years – 2020 and 2021 – showed flow below the long-term average.

Long-term observations confirm a persistent trend toward a **reduction in the total volume of available water (water availability)**[11] in the river due to climate change and increasing water use. Over the past 30 years (1993-2022), the long-term average annual water availability of the Amu Darya River has decreased by almost 15%, amounting to 59.1 km^3, including 46.2 km^3 during the growing season (Table 3). While in 1993-2002 the average annual flow of the Amu Darya at the nominal Kerki station was estimated at 63.0 km^3, it declined to 58.9 km^3 in 2003-2012 and to 55.4 km^3 in 2013-2022.

TABLE 3
Reduction of average water availability of the Amu Darya River by 10-year cycles

Inflow	1993-2002		2003-2012		2013-2022		1993-2022	
	Mm^3	%	Mm^3	%	Mm^3	%	Mm^3	%
Months of hydrological year								
October	3,192	5.1	2,521	4.3	2,645	4.8	2,786	4.7
November	2,307	3.7	1,968	3.3	1,907	3.4	2,061	3.5
December	2,316	3.7	1,845	3.1	1,660	3.0	1,941	3.3
January	1,962	3.1	1,726	2.9	1,630	2.9	1,773	3.0
February	1,787	2.8	1,698	2.9	1,537	2.8	1,674	2.8
March	2,730	4.3	2,649	4.5	3,488	4.5	2,622	4.4
April	4,202	6.7	4,506	7.7	4,244	7.6	4,317	7.3
May	7,916	12.6	7,682	13.1	7,287	13.1	7,628	12.9
June	10,071	16	9,881	16.8	9,252	16.7	9,735	16.5
July	12,018	19.1	11,015	18.7	10,640	19.2	11,224	19.0
August	9,162	14.6	8,744	14.9	7,907	14.2	8,605	14.6
September	5,293	8.4	4,624	7.9	4,292	7.7	4,736	8.0
NON-GROWING SEASON	14,293	22.7	12,407	21.1	11,867	21.4	12,856	21.8
GROWING SEASON	48,661	77.3	46,452	78.9	43,623	78.6	46,246	78.2
HYDROLOGICAL YEAR	**62,955**	**100**	**58,860**	**100**	**55,491**	**100**	**59,102**	**100**

Source: BWO Amu Darya. Processed by SIC ICWC

1.3. Flow Regulation

The river flow is regulated by cascades of hydropower plants and reservoirs in the upper and middle reaches, as well as by major water intakes on the plains. The main instream reservoirs include the Nurek hydroscheme on the Vakhsh River (a seasonal storage reservoir and HPP, Tajikistan) and the Tuyamuyun hydroscheme on the Amu Darya River (four seasonal storage reservoirs and HPP, Uzbekistan and Turkmenistan).

[10] The tributaries of the Amu Darya River (excluding the Panj River) were reconstructed based on their connections with the Vakhsh River, for which data from BWO Amu Darya are available. The discharge of the Panj River was estimated using a balance method, drawing on the BWO Amu Darya's data for the Amu Darya measured at the gauge located upstream of the Garagumdarya (Karakum Canal) intake

[11] The water availability of the Amu Darya River is determined at the nominal Kerki post (calculated at the border of Uzbekistan and Tajikistan as follows: discharge at the Kerki hydropost + (accumulation (+) or drawdown (–) of the Nurek Reservoir) + water withdrawals in the Surkhandarya province + water withdrawals upstream of the Kerki gauging station)

Intra-system reservoirs play an important role in seasonal flow accumulation. Some of them were built within cascades of pumping stations: the Talimarjan Reservoir on the Karshi Canal with a capacity of 1.5 km^3, and the Tudakul and Kuyimazar reservoirs on the Amu-Bukhara Main Canal. The Khauskhan Reservoir on the Karakum Canal, with a capacity of 0.9 km^3, provides additional regulating functions. Several reservoirs have also been built on small rivers, including the South Surkhan Reservoir on the Surkhandarya River with a total capacity of 800 million m^3; reservoirs on the Tedjen and Murgab rivers; and 15 reservoirs in the Kashkadarya River basin with a total capacity of about 2.6 km^3. Among the major tributaries of the Amu Darya – the Panj, Kafirnigan, and Kunduz have undergone comparatively limited anthropogenic modification of hydrological regimes.

Construction of the Rogun HPP on the Vakhsh River, with an installed capacity of 3,780 MW, is currently ongoing. It will create the Rogun Reservoir, with a total volume of 13.3 km^3 and an active storage volume of 10.3 km^3. Completion of the main dam is planned for 2032, with full reservoir filling expected by 2038.[12]

1.4. Water Use

Water use in the Amu Darya River basin is based on allocation of water withdrawal limits among the countries, as established by Protocol No. 566 of the meeting of the Scientific and Technical Council at the USSR Ministry of Land Reclamation and Water Management (Minvodkhoz) dated 10 September 1987[13], and reaffirmed by the Agreement "On Cooperation in the Sphere of Joint Management, Use, and Protection of Water Resources of Interstate Sources" (Almaty, 1992).

The country water withdrawal limits for the Amu Darya River[14] are established based on the river water withdrawal of 61.5 km^3 (excluding Afghanistan). The allocated limits are as follows: Kyrgyzstan – 0.6%, Tajikistan – 15.4%, Turkmenistan – 35.8%, and Uzbekistan – 48.2% (Table 4).

WATER AVAILABILITY AND DYNAMICS OF ACTUAL WATER WITHDRAWAL. An analysis of data for 2003-2022 shows a moderate improvement in water availability. In 2003-2012, the average annual water availability of the Amu Darya River was 89.0%, including 88.0% during the growing season (Table 5). The country-specific allocation was as follows: Tajikistan – 78.5% (82.7% during the growing season); Turkmenistan – 91.4% (89.7% during the growing season); Uzbekistan – 91.0% (88.7% during the growing season). For 2013-2022, a slight increase is observed: the average annual water availability rose to 90.4%, including to 89.0% during the growing season (Table 6). By country: Tajikistan – 87.8% (89.0% during the growing season); Turkmenistan – 91.1% (89.0% during the growing season); Uzbekistan – 90.8% (89.0% during the growing season).

TABLE 4
Country water withdrawal limits for the Amu Darya River

Country	Water withdrawal	
	km^3	%
Kyrgyz Republic	0.4	0.6
Tajikistan	9.5	15.4
Turkmenistan	22.0	35.8
Uzbekistan	29.6	48.2
TOTAL:	**61.5**	**100**
including downstream of Kerky post:		
Turkmenistan	22.0	50
Uzbekistan	22.0	50

Source: Revised Master Plans, 1987

[12] Project of Rogun HPP – Updated ESIA. August 2025

[13] Protocol No. 566 of the meeting of the Scientific and Technical Council at the USSR Ministry of Land Reclamation and Water Management (Minvodkhoz) dated 10 September 1987 approved water withdrawal limits and the Revised Master Plan of Integrated Amu Darya River Water Use and Protection

[14] Afghanistan is not a party of the regional water allocation. Its supposed water use of 2.10 km^3/yr is deducted in the estimation of available resources

TABLE 5
Water availability by country over 2003-2012

Name	Non-growing season				Growing season				Hydrological year			
	Limit, km³	Actual, km³	Availability, %	Deviation, %	Limit, km³	Actual, km³	Availability, %	Deviation, %	Limit, km³	Actual, km³	Availability, %	Deviation, %
UPPER REACHES:	**3.223**	**2.274**	**70.6**	**-29.4**	**7.964**	**6.619**	**83.1**	**-16.9**	**11.187**	**8.893**	**79.5**	**-20.5**
Tajikistan	2.853	1.952	68.4	-31.6	6.764	5.594	82.7	-17.3	9.617	7.546	78.5	-21.5
Uzbekistan	0.370	0.322	87.1	-12.9	1.200	1.025	85.4	-14.6	1.570	1.347	85.8	-14.2
Water withdrawal from the Amu Darya River at nominal Kerki g/s:	12.480	12.067	96.7	-3.3	31.520	28.146	89.3	-10.7	44.000	40.213	91.4	-8.6
Turkmenistan	6.500	6.206	95.5	-4.5	15.500	13.904	89.7	-10.3	22.000	20.110	91.4	-8.6
Uzbekistan	5.980	5.861	98.0	-2.0	16.020	14.242	88.9	-11.1	22.000	20.102	91.4	-8.6
MIDDLE REACHES:	**8.195**	**7.752**	**94.6**	**-5.4**	**16.114**	**14.952**	**92.8**	**-7.2**	**24.309**	**22.704**	**93.4**	**-6.6**
Turkmenistan	5.100	4.628	9.07	-9.3	10.379	9.396	90.5	-9.5	15.479	14.024	90.6	-9.4
Uzbekistan	3.095	3.124	100.9	0.9	5.735	5.556	96.9	-3.1	8.830	8.680	98.3	-1.7
LOWER REACHES:	**4.285**	**4.315**	**100.7**	**0.7**	**15.406**	**13.194**	**85.6**	**-14.4**	**19.691**	**17.509**	**88.9**	**-11.1**
Turkmenistan	1.400	1.578	112.7	12.7	5.121	4.508	88.0	-12.0	6.521	6.086	93.3	-6.7
Республика Узбекистан	2.885	2.737	94.9	-5.1	10.285	8.685	84.4	-15.6	13.170	11.422	86.7	-13.3
TOTAL BASIN:	**15.703**	**14.341**	**91.3**	**-8.7**	**39.484**	**34.764**	**88.0**	**-12.0**	**55.187**	**49.105**	**89.0**	**-11.0**
Tajikistan	2.853	1.952	68.4	-31.6	6.764	5.594	82.7	-17.3	9.617	7.546	78.5	-21.5
Turkmenistan	6.500	6.206	95.5	-4.5	15.500	13.904	89.7	-10.3	22.000	20.110	91.4	-8.6
Uzbekistan	6.350	6.183	97.4	-2.6	17.220	15.267	88.7	-11.3	23.570	21.449	91.0	-9.0

TABLE 6
Water availability by country over 2013-2022

Name	Non-growing season				Growing season				Hydrological year			
	Limit, km³	Actual, km³	Availability, %	Deviation, %	Limit, km³	Actual, km³	Availability, %	Deviation, %	Limit, km³	Actual, km³	Availability, %	Deviation, %
UPPER REACHES:	**3.223**	**2.785**	**86.4**	**-13.6**	**7.964**	**7.013**	**88.1**	**-11.9**	**11.187**	**9.798**	**87.6**	**-12.4**
Tajikistan	2.853	2.420	84.8	-15.2	6.764	6.019	89.0	-11.0	9.617	8.439	87.8	-12.2
Uzbekistan	0.370	0.365	98.6	-1.4	1.200	0.994	82.8	-17.2	1.570	1.359	86.6	-13.4
Water withdrawal from the Amu Darya River at nominal Kerki g/s:	12.480	11.974	95.9	-4.1	31.520	28.123	89.2	-10.8	44.000	40.097	91.1	-8.9
Turkmenistan	6.500	6.247	96.1	-3.9	15.500	13.795	89.0	-11.0	22.000	20.042	91.1	-8.9
Uzbekistan	5.980	5.727	95.8	-4.2	16.020	14.327	89.4	-10.6	22.000	20.055	91.2	-8.8
MIDDLE REACHES:	**8.195**	**8.095**	**98.8**	**-1.2**	**16.114**	**15.722**	**97.6**	**-2.4**	**24.309**	**23.816**	**98.0**	**-2.0**
Turkmenistan	5.100	4.941	96.9	-3.1	10.379	9.845	94.9	-5.1	15.479	14.785	95.5	-4.5
Uzbekistan	3.095	3.154	101.9	1.9	5.735	5.877	102.5	2.5	8.830	9.031	102.3	2.3
LOWER REACHES:	**4.285**	**3.880**	**90.5**	**-9.5**	**15.406**	**12.401**	**80.5**	**-19.5**	**19.691**	**16.281**	**82.7**	**-17.3**
Turkmenistan	1.400	1.306	93.3	-6.7	5.121	3.951	77.1	-22.9	6.521	5.257	80.6	-19.4
Uzbekistan	2.885	2.574	89.2	-10.8	10.285	8.450	82.2	-17.8	13.170	11.024	83.7	-16.3
TOTAL BASIN:	**15.703**	**14.759**	**94.0**	**-6.0**	**39.484**	**35.136**	**89.0**	**-11.0**	**55.187**	**49.895**	**90.4**	**-9.6**
Tajikistan	2.853	2.420	84.8	-15.2	6.746	6.019	89.0	-11.0	9.617	8.439	87.8	-12.2
Turkmenistan	6.500	6.247	96.1	-3.9	15.500	13.795	89.0	-11.0	22.000	20.042	91.1	-8.9
Uzbekistan	6.350	6.092	95.9	-4.1	17.220	15.321	89.0	-11.0	23.570	21.414	90.0	-9.1

Source: BWO Amu Darya

INCREASED WATER USE IN AFGHANISTAN. In recent years, the northern provinces of Afghanistan have shown a trend toward increasing water use through agricultural development. By expert assessments, Afghanistan's current water withdrawal in the Amu Darya Basin is already 3-5 km^3/yr, primarily during the growing season.

Completion of the Qosh Tepa Canal (expected around 2028), which diverts water directly from the left bank of the Amu Darya in Kaldar District (Balkh Province), may further increase these quantities: the anticipated withdrawal could rise to 9-11 km^3/yr, i.e. up to 15-18% of the long-term average annual river flow upstream of the Karakum Canal (62 km^3).

IRRIGATION. The current allocation of Amu Darya River water among the riparian countries was determined by three key factors: historical and existing water use patterns, the extent of irrigated land areas, and calculated unit water consumption based on the assumption of full utilization of the river's water resources. For decades, the water use pattern in the basin has been shaped by the dominance of the irrigation sector: 85-90% of water is diverted for agriculture.

As of 1 January 2020, the total irrigated area in the basin reached 4.56 million ha, an increase of 10.3% compared to 1991. The country dynamics is as follows: growth of 12.5% in Tajikistan, 21.8% in Turkmenistan, and 3.7% in Uzbekistan (Table 7).

TABLE 7
Changes in irrigated land area across the Amu Darya River Basin from 1991 to 2019, gross, thousand ha

Country	1991	2000	2005	2010	2015	2016	2017	2018	2019
Tajikistan	452.1	453.6	494.4	502.3	502.3	506.3	507.1	507.9	508.7
Turkmenistan	1,305.4	1,472.1	1,506.6	1,537.8	1,583.6	1,584.0	1,585.8	1,587.6	1,589.4
Uzbekistan	2,377.5	2,376.3	2,433.5	2,422.8	2,456.6	2,468.0	2,466.8	2,465.6	2,464.6
TOTAL BASIN	**4,135.0**	**4,302.0**	**4,434.5**	**4,462.9**	**4,542.5**	**4,558.3**	**4,559.7**	**4,561.1**	**4,562.7**

Source: https://cawater-info.net/

TAJIKISTAN. Irrigated lands are concentrated in the upper reaches of the basin, primarily in Khatlon province and partly in Gorno-Badakhshan Province and the districts of republican subordination.

In 2019, their total area reached **508.7 thousand ha**, an increase of 12.5% compared to 1991 (Fig. 3). The share of non-saline lands remains high and shows a stable upward trend: from **90.9%** in 1991 to **96.6%** in 2019 (Fig. 4).

FIGURE 3
Dynamics of irrigated areas in Tajikistan's part of the Amu Darya Basin

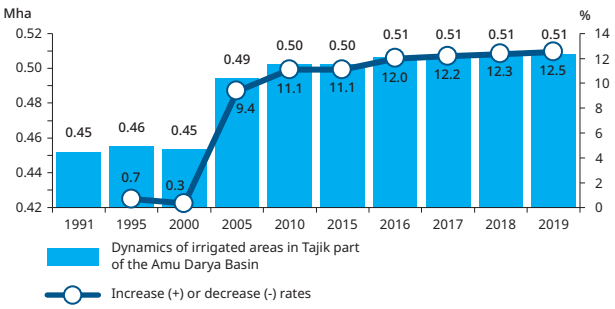
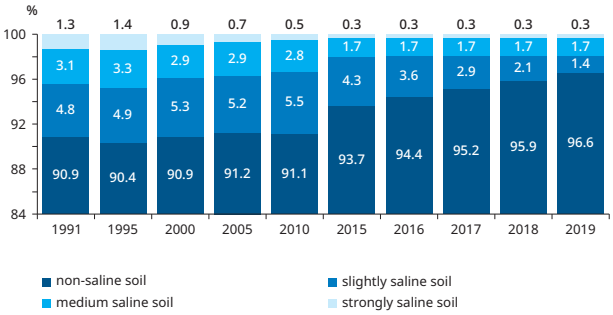


FIGURE 4
Dynamics of soil salinity in Tajikistan's part of the Amu Darya Basin



TURKMENISTAN. Irrigated lands are concentrated in the middle reaches of the basin in Lebap, Ahal, and Mary provinces (velayats) and in the lower reaches in Dashoguz province. By 2019, their area had reached **1,589.4 thousand ha** (+21.8% since 1991) (Fig. 5).

More than half of the irrigated lands fall into different categories of salinity. The ratio between non-saline areas and salt-affected areas was **48.7%** / **51.3%** in 1991 and **44.9%** / **55.1%** in 2019 (Fig. 6).

FIGURE 5
Dynamics of irrigated areas in Turkmenistan's part of the Amu Darya Basin

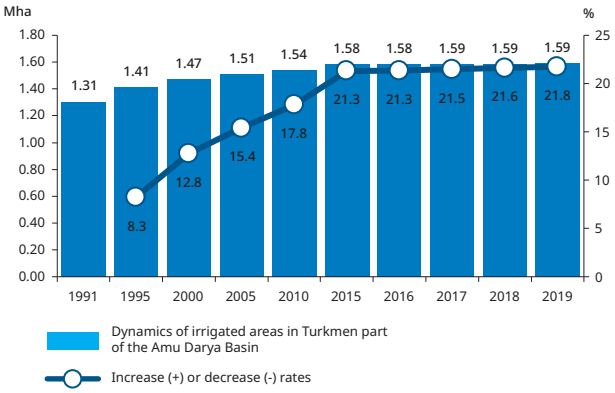
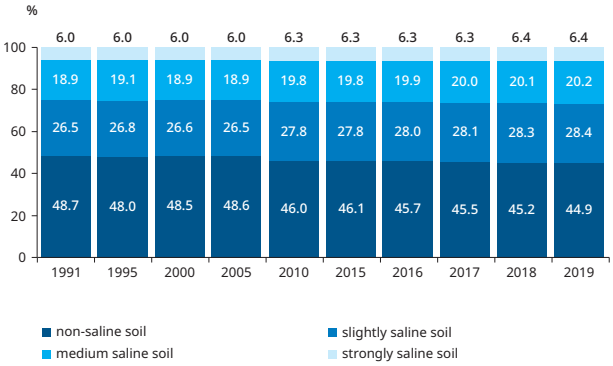


FIGURE 6
Dynamics of soil salinity in Turkmenistan's part of the Amu Darya Basin



UZBEKISTAN. Irrigated lands are located: in the upper reaches in Surkhandarya province; in the middle reaches – in Bukhara, Kashkadarya, and Navoi provinces; and in the lower reaches – in Karakalpakstan and Khorezm province. By 2019, their total area reached **2,464.6 thousand ha** (+3.7% since 1991) (Fig. 7). Positive changes have been observed due to implementation of reclamation measures. Nevertheless, more than half of the lands still fall into categories with varying degrees of salinity. The ratio of non-saline to saline areas changed from **41.2%** / **58.8%** in 1991 to **47.1%** / **52.9%** in 2019. The area of non-saline lands increased by **5.9%**, while the area of highly saline lands decreased by **3.5%** (Fig. 8). The most challenging situation persists in Khorezm province, where about **99.2%** of crop land is affected by salinization, and in Karakalpakstan, with **71.2%** of salinized crop land.

FIGURE 7
Dynamics of irrigated areas in Uzbekistan's part of the Amu Darya Basin

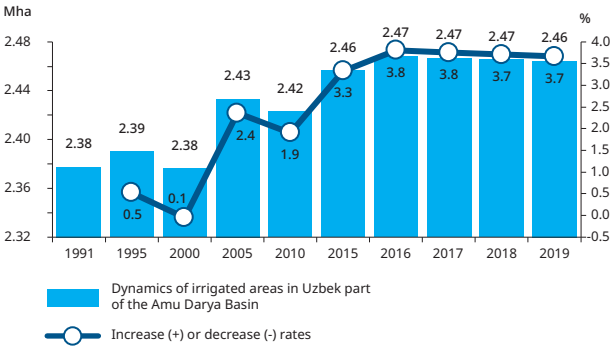
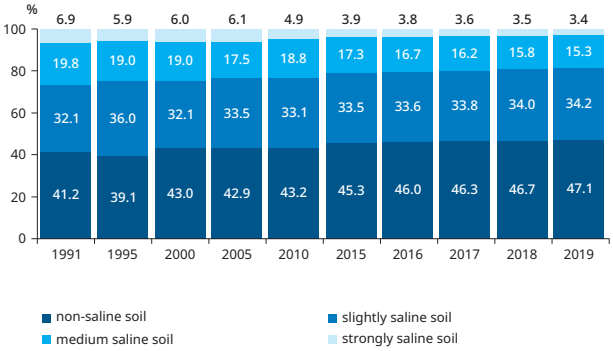


FIGURE 8
Dynamics of soil salinity in Uzbekistan's part of the Amu Darya Basin



The 10% increase in the total irrigated area in the basin during 1991-2019 confirms the continued dominance of agriculture in water use patterns. This expansion has been accompanied by mixed trends in land conditions. In this context, key priorities remain the modernization of irrigation infrastructure, adoption of water saving technologies, and improvement of land reclamation practices. This will make it possible to improve water-use efficiency under limited resource conditions.

The condition of irrigation infrastructure is a challenging issue: most of it was built during the Soviet period and is highly deteriorated now. Water losses through seepage and inefficient irrigation practices remain considerable. At the same time, in recent years a positive trend in modernization has been observed:

Tajikistan is focusing on rehabilitation of existing infrastructure; projects are implemented to restore pumping stations, clean collector-drainage networks, and reclaim land. These measures help reduce water losses and combat soil salinization.

Turkmenistan is implementing projects aimed at optimizing water management, reconstructing collector-drainage network, and saving water.

Uzbekistan is actively adopting water saving technologies. By early 2024, their total coverage exceeded 1.5 million ha, of which more than 500 thousand ha use drip irrigation. The government subsidizes farmers who use these new technologies. Extensive work is under way to concrete canals (several thousand kilometers have been lined in recent years) and to digitalize water monitoring – by 2025, more than 13,000 control points are expected to be equipped with automated "Smart Water" systems.

These measures already yield initial results, allowing saving billions of cubic meters of water annually and increasing crop yields on modernized lands.

1.5. Hydropower

The hydropower potential of the Vakhsh River is estimated at 251.15 billion kWh, while the technically feasible and economically viable hydropower resources available for HPP construction amount to 37 billion kWh[15].At present, hydropower plants with a total installed capacity of 4,775.05 MW have already been built in the main course of the Vakhsh River at 7 of 9 potential sites suitable for constructing reservoirs with hydropower facilities.

The Rogun HPP, whose first unit was commissioned on November 16, 2018, is the eighth HPP in this cascade.

Upon completion of the Rogun HPP, the total installed capacity of all hydropower plants in the Vakhsh cascade will reach 8,375.05 MW (Table 8).[16]

TABLE 8
Hydropower potential of the Vakhsh River

Vakhsh River	Volume of reservoir	Installed capacity	Generation
	km^3	MW	billion kWh/yr
Rogun HPP (under construction)[17]	13.3	3,780	17
Shurob HPP (planned)	0.027	850	2.1
Nurek HPP	10.5	3,000	11.2
Baipaza HPP	0.084	600	2.9
Sangtuda HPP 1	2.7	670	2.5
Sangtuda HPP 2	0.932	220	0.665
Golovnaya HPP	–	240	0.96
Perepadnaya HPP	–	29.95	0.21
Central HPP	–	15.1	0.114
TOTAL:	**27.543**	**9,225.05**	**33.649**

Source: MEWR RT. https://www.mewr.tj

[15] Ministry of Energy and Water Resources of the Republic of Tajikistan. (2018, 15 December). Hydropower resources of the Vakhsh River. www.mewr.tj

[16] Ministry of Energy and Water Resources of the Republic of Tajikistan. (n.d.). Hydropower resources of the Vakhsh River. (n/d) www.mewr.tj/?page_id=614

[17] Rogun Project – Updated Environmental and Social Impact Assessment

1.6. Water Quality

The chemical composition of water in the Amu Darya River is largely shaped by pollution originating from agricultural runoff from the territories of Turkmenistan and Uzbekistan. Collector-drainage waters (CDW) significantly increase salinity both in the upper reaches (Termez area: average concentration – 727 mg/L, maximum – 1186 mg/L) and in the lower reaches (Nukus area: average – 1202 mg/L, maximum – 1628 mg/L). Long-term observations show a **rise in salinity not only along the river's course from source to mouth, but also over time**: minimum, annual average, and maximum values increase. This process is closely linked to the river's flow regime: during low-water periods, water salinity reaches its highest levels, whereas during floods it decreases. The highest values are observed in winter, when discharge is low, and the lowest in summer, when discharge peaks. Nevertheless, by Water Pollution Index (PI), the quality of the Amu Darya's water at all monitoring sites falls under Class III – moderately polluted waters.[18]

In the upper section of the river (from the Uzbekistan-Tajikistan border to Kelif gauging station), about 30 collector-drainage systems (CDS) of Surkhandarya province discharge approximately 2.152 km^3 of drainage water per year into the Amu Darya, with salinity levels ranging from 1.07 to 1.43 g/L. **In the middle reaches**, the river receives discharges from 10 collectors located in Uzbekistan and Turkmenistan, with a total annual volume of about 2.9 km^3 and salinity levels of 2.8-3.1 g/L. **In the lower reaches** (from Tuyamuyun to Samanbay), collector-drainage waters are not discharged directly into the river. Drainage waters from Khorezm province are diverted outside the country through main collectors and discharged into Lake Sarykamysh in Turkmenistan; similarly, the collector-drainage waters from Turkmenistan's Dashoguz province are also routed to Lake Sarykamysh. According to SIC's data, Lake Sarykamysh receives an average of about 5.7 km^3 of drainage water annually (approximately 3.7 km^3 from Khorezm and 2.0 km^3 from Dashoguz) in high-water years, around 4.4 km^3 (2.9 km^3 and 1.5 km^3, respectively) in average years, and about 2.5 km^3 (1.6 km^3 and 0.9 km^3, respectively) in low-water years. Salinity of collector-drainage water ranges from 2.7 to 3.1 g/L.

TABLE 9
Dynamics of annual water salinity along the Amu Darya River over 2013-2022, by gauging station, g/l

Year	Gauging station									
	Termez	Kelif	Kerki	Charjou	Il'chik	Darganata	Tuyamuyun	Kipchak	Takhiatash	Samanbai
2013		0.609	0.636	0.755		0.873		1.357	1.425	1.380
2014		0.620	0.704	0.854		0.833		1.165	1.219	1.230
2015		0.645	0.662	0.747		0.885		1.105	1.137	1.212
2016		0.588	0.621	0.713		0.744		1.261	1.412	1.368
2017		0.635	0.641	0.728		0.748		1.094	1.028	0.985
2018		0.661	0.654	0.736		0.829		1.566	1.432	1.500
2019		0.645	0.652	0.729		0.784				
2020		0.678	0.691	0.746		0.931				
2021		0.616	0.618	0.709		0.890				
2022		0.618	0.648	0.692		0.759				
Avg. annual (2013-2022)	**0.590**	**0.631**	**0.657**	**0.680**	**0.710**	**0.827**	**0.890**	**1.258**	**1.275**	**1.279**
min	0.510	0.588	0.618	0.692	0.610	0.744	0.680	1.094	1.028	0.985
max	0.650	0.678	0.704	0.854	0.910	0.931	1.070	1.566	1.425	1.500
Avg. annual (1991-2022)	**0.590**	**0.530**	**0.570**	**0.680**	**0.710**	**0.790**	**0.890**	**1.150**	**1.230**	**1.150**

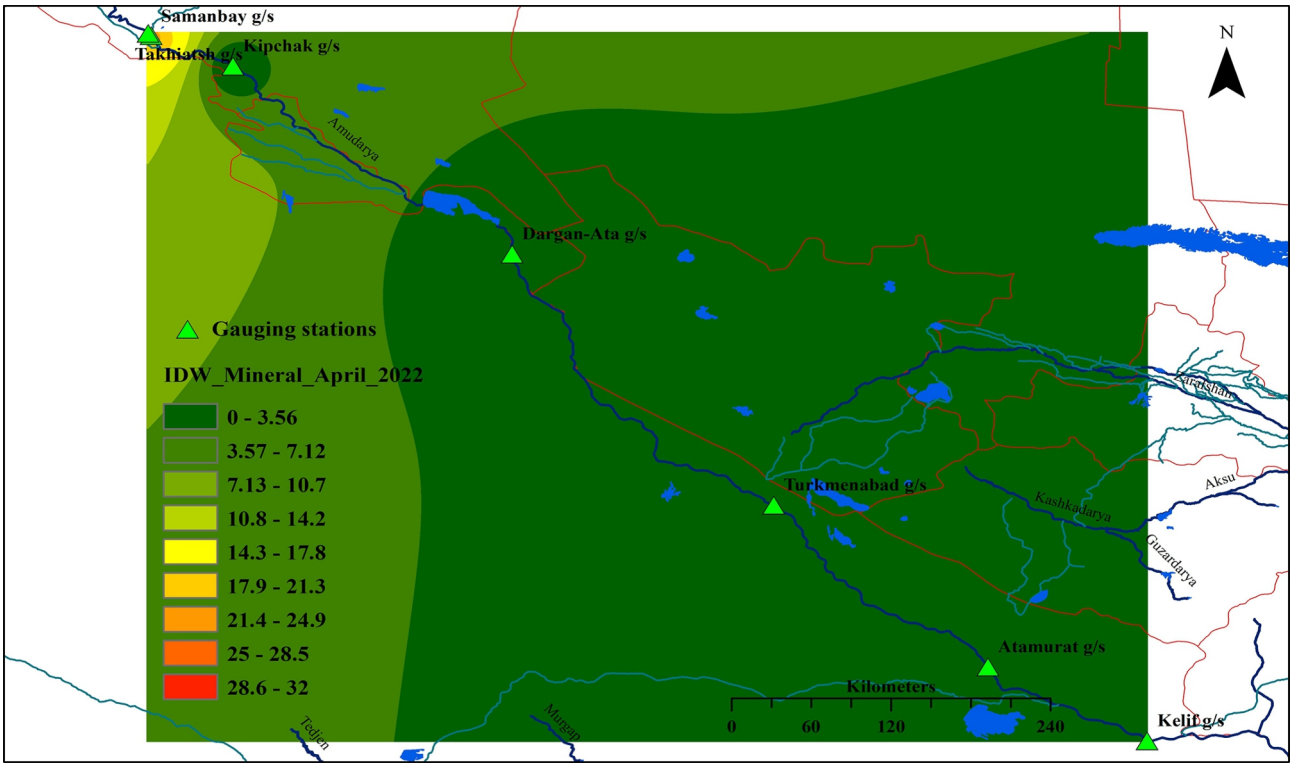
Note: Il'chik gauging station has been closed. Empty cells mean no observations or data are available
Source: SIC ICWC, 2019, www.cawater-info.net

[18] The Center of Hydrometeorological Service of the Republic of Uzbekistan. Authority for Environmental Pollution Monitoring. 2021 Yearbook of surface water quality in the UzHydromet's authority area

According to BWO Amu Darya's data, the salinity of the Amu Darya River water increases from the upper to the lower reaches. In the upper reaches, salinity ranges from about 0.51 to 0.65 g/L; by the middle reaches, near the Tuyamuyun hydroscheme, it rises to 0.68-1.07 g/L, and at the Takhiatash hydroscheme it reaches 1.03-1.43 g/L. The dynamics of annual salinity at river's main gauging stations over 2013-2022 is presented in Table 9.

For visualization of water quality indicators, SIC ICWC experts made comparative analysis of GIS maps generated by the IDW interpolation method and data from hydrochemical observations. The results showed good agreement between the simulated and observed data. In particular, the lowest salinity is recorded in the upper reaches (Kelif and Atamurat stations), whereas the highest concentrations of dissolved salts are observed in the lower reaches (Samanbay station). Thus, both information sources confirm the general pattern: low salinity is characteristic of the upper course, followed by a sharp increase downstream and consistently high values in the Samanbay area (Fig. 9).

FIGURE 9
Dynamics of salinity along the Amu Darya River from Kelif g/s to Samanbay g/s



Changes in water salinity have a significant impact on biota of freshwater and brackish-water ecosystems (see Chapter 2. Biodiversity). An increase or decrease in salinity beyond the tolerance range can alter species composition, reduce the population of certain organism groups, or even lead to degradation of ecosystem functions.

The key consequences of salinity changes for various groups of organisms include:

- **Aquatic vegetation:** Excessively high salinity can cause dehydration and death of aquatic plants (particularly freshwater species), as elevated salt concentrations disrupt osmotic balance and hinder the uptake of water and nutrients.[19]

- **Invertebrates:** A sharp increase in salinity may result in the die-off of stenohaline species, such as freshwater mollusks and crustaceans. Abrupt shifts in salinity

[19] Cañedo-Argüelles, M., Kefford, B. J., Piscart, C., Prat, N., Schäfer, R. B., & Schulz, C. J. (2013). Salinisation of rivers: An urgent ecological issue. Environmental Pollution, 173, 157-167. https://doi.org/10.1016/j.envpol.2012.10.011

regimes that exceed species' tolerance limits often lead to the collapse of invertebrate communities.[20]

- **Ichthyofauna:** Elevated salinity negatively affects fish, especially juveniles, which are more sensitive to changes in osmolarity: slowed growth, deteriorated physiological condition, and increased juvenile mortality are commonly observed. Under extreme salinity levels, some fish species may disappear entirely from freshwater bodies.[21]

- **Microorganisms:** Changes in water salinity also impact microbial communities, influencing the self-purification processes, decomposition of organic matter and nutrient cycling in the river. In highly salinized water bodies, for example, both methanogenesis and sulfate reduction may be actively occurring at the same time, reflecting a restructuring of microbial communities and reduced competition between the respective groups of bacteria.[22]

A vivid illustration of the cumulative impact of disrupted water-salt balance is the situation in the Aral Sea. The primary drivers of ecosystem degradation have been desiccation and progressive salinization. Irreversible changes occurred when the surface area shrank from 55,700 to 39,734 km^2 and average salinity exceeded the critical thresholds of 14-30 g/L, leading to a sharp decline in invertebrates, fish, and plant communities.[23] As a result, the waterbody has virtually lost its commercial fisheries value, particularly in its southern part. For comparison, 30-40 years ago the annual fish catch reached 35 thousand tons, and the regional economy was built on a well-developed fishing industry, complemented by muskrat farming and grazing livestock husbandry that supported irrigated agriculture.[24]

1.7. Environmental Flow

Flow is regulated not only to meet the needs of water users but also to ensure the stability of natural ecosystems. Environmental flow is understood as "the quantity, timing, and quality of water flows required to sustain aquatic ecosystems and the human livelihoods and wellbeing that depend on these ecosystems."[25] In this definition, aquatic ecosystems include rivers, streams, springs, riparian zones, floodplains and other wetlands, lakes, coastal waters including lagoons and estuaries, as well as ecosystems dependent on groundwater.

At present, the national legislations of the basin countries provide for various legal mechanisms to account for environmental water needs – ranging from explicitly mandated sanitary and environmental flow in national codes to the use of indirect instruments such as reservoir operation regimes and basin-wide planning. Despite the existence of regulatory frameworks, the countries' approaches differ significantly in terminology, level of detail, and the availability of approved assessment methodologies, which calls for the harmonization of approaches for effective transboundary water management (see Section 3.1 for more details).

In particular, basin-level documents establish obligations to maintain sanitary flow and to supply water to river deltas and the Aral Sea. According to Protocol No. 566, sanitary flow of at least 100 m^3/s has been established along the entire length of the Amu Darya River, amounting to 3.15 km^3 per

[20] Kefford, B. J., Buchwalter, D., Cañedo-Argüelles, M., Davis, J., Duncan, R. P., Hoffmann, A., Thompson, R., & Piscart, C. (2016). Salinized rivers: Degraded systems or new habitats for salt-tolerant faunas? Biology Letters, 12(3), 20151072. https://doi.org/10.1098/rsbl.2015.1072

[21] Nielsen, D. L., Brock, M. A., Rees, G. N., & Baldwin, D. S. (2003). Effects of increasing salinity on freshwater ecosystems in Australia. Australian Journal of Botany

[22] Selak, L., et al. (2025). Salinization alters microbial methane cycling in freshwater coastal lake sediments. Environmental Microbiology Reports, ahead-of-print, e01050, https://doi.org/10.1111/1758-2229.01050

[23] IUCN Red List of Ecosystems. (n.d.). Aral Sea. https://assessments.iucnrle.org/assessments/11

[24] Zoï Environment Network. (2018). Amu Darya. https://zoinet.org/wp-content/uploads/2018/02/AmuDarya-RU-Web-.pdf

[25] Arthington, A. H., et al. (2018). "The Brisbane Declaration and Global Action Agenda on Environmental Flows (2018)." Frontiers in Environmental Science, 6, 45. doi:10.3389/fenvs.2018.00045. See also Environmental Flow: Compendium / prepared by D.R. Ziganshina – Tashkent: SIC ICWC, 2003. – 76 p. – (Publications of ICWC Training Center; Issue 1). https://www.cawater-info.net/library/rus/01_eco.pdf

year. This requirement is reaffirmed in the 1992 Almaty Agreement, which introduced the principle of annual adjustment of volumes depending on water availability. The 1993 Kyzylorda Agreement set the objective of "maintaining a stable water area of the Aral Sea at an environmentally acceptable level." In addition, the 1988 Resolution of the USSR Council of Ministers[26] set requirements for minimum flow to the deltas and the sea, forming the legal basis for environmental flow.

The NATO project and subsequent research by SIC ICWC recommended water releases of 8 km^3 in high-water years, 4.6 km^3 in average years, and at least 3.1 km^3 in low-water years to maintain the delta and lake systems (about 180,000 ha).[27] The National Report of Uzbekistan (2013) estimates the delta's demand at 8 km^3/ year, and it was proposed to increase inflow to at least 11 km^3/year by 2025.[28] In 2020, the IFAS Agency, with support from the UNDP office in Tashkent,[29] summarized the estimates of water demand to keep lakes in the South Aral region stable (Table 10).

As described in Section 2.1.4 of the Report, implementation in practice remains limited: sanitary flow and ecosystem demands are often not met in full, and their actual quantities remain underestimated as compared to ecosystem needs of the delta and the Aral region (Fig. 10).

Moreover, sustainable functioning of river ecosystems cannot be ensured by measures taken only in the estuarine zone; an integrated approach is needed-one that covers flow regulation along the entire river. This principle is reflected in current practices of large-scale strategic infrastructure projects. For example, the World Bank's assessment of the Rogun project on the Vakhsh River confirms that flow will be regulated strictly in line with existing basin agreements (including Protocol No. 566 of the meeting of the Scientific and Technical Council at the USSR Ministry of Land Reclamation and Water Management, Moscow, September 10, 1987). In line with international environmental and social standards (ESS6), the project documents acknowledge the need to account for the requirements of critical downstream habitats. The project envisions monitoring of the hydrological regime to prevent ecosystem degradation, aiming to harmonize irrigation purposes with biodiversity conservation commitments.[30]

In this context, particular attention is paid to the World Heritage property "Tugay Forests of the Tigrovaya Balka Nature Reserve" located in the lower reaches of the Vakhsh River. When the property was inscribed on the World Heritage List, a key recommendation of the Convention Committee was the request to:

"Secure and maintain a natural hydrological regime for the property with sufficient provision of water to the property to maintain its Outstanding Universal Value, and assess regularly the management effectiveness of the property, including research on the hydrological regime of the Vakhsh River in relation to the property..."[31]

Experts have been proposing parameters of environmental flow for the lower Vakhsh River since the 1970s. As a current reference point, in 2020 the GIZ project formulated key conditions for preserving the tugay ecosystem: "By 2035, at least 76% of the area within 500 meters of the river inside the Tigrovaya Balka Reserve should be afforested, with no fewer than one Populus pruinosa seedling per square meter, and

[26] Central Committee of the CPSU and the USSR Council of Ministers (1988, September 19). Resolution No. 1110 "On Measures for the Fundamental Improvement of the Environmental and Sanitary Situation in the Aral Sea Region, Increasing the Efficiency of Use and Strengthening the Protection of Water and Land Resources in Its Basin," https://cawater-info.net/bk/water_law/pdf/ussr-1110-1988.pdf

[27] Dukhovniy, V.A. (ed.), de Schutter J. (ed.). (2003). South Prearalie – New Perspectives. Tashkent: Ecotec Resource, SIC ICWC. https://cawater-info.net/library/rus/nato.pdf. (2020). Aral Sea and the Aral Region: Review of work undertaken by SIC ICWC on monitoring and analysis of socio-economic and environmental situation in the period from 1994 to 2018 (second edition, containing data over past 4 years). Tashkent. UNESCO https://www.cawater-info.net/library/rus/aral-sic-icwc-2020.pdf

[28] State Committee of the Republic of Uzbekistan on Environmental Protection / Chinor ENK. (2013). National Report on Environment Conditions and Natural Resources Use in the Republic of Uzbekistan (2008-2011). https://www.cawater-info.net/pdf/natdok-uz.pdf

[29] At the feasibility study stage of the project "Conservation and sustainable management of lakes, wetlands, and riparian corridors as pillars of a resilient and land degradation neutral Aral basin landscape supporting sustainable livelihoods", funded by the GEF

[30] World Bank. (2024). Project Appraisal Document for Sustainable Financing for Rogun Hydropower Project (P181029); Environmental and Social Commitment Plan (ESCP). URL: https://documents.worldbank.org/en/publication/documents-reports

[31] World Heritage Committee (2023). Decision 45 COM 8B.30 Tugay Forests of the Tigorovaya Balka Nature Reserve (Tajikistan). In: Report of decisions of the 45th session of the World Heritage Committee (Saudi Arabia, 2023)

TABLE 10
Water demand of lakes in South Aral Region

Name	Water level (BS), m	Area of biodiversity zone, km²	Water volume Mm³	Water source for lake/territory	Water requirements, Mm³ per year
WESTERN ARAL, SARYKAMISH LAKE AND ADJACENT AREA OF USTYURT PLATEAU					
Western Aral and adjacent Ustyurt Plateau	24.6	5,110 (incl. water surface 3,175)	43600	Discharge of groundwater from the Ustyurt Plateau, outflow from Small (North) Aral Sea through Uzun-Aral passage in high-water years	2,000-3,500
Sarykamish Lake and adjacent Ustyurt Plateau	8.0	959.7	70000	Collector-drainage water from irrigation schemes of Khorezm and Dashoguz, conveyed through the Daryalyk and Ozerny collectors	2,000-2,500
AMU DARYA RIVER DELTA (ARAL REGION)					
Left-bank (western) zone of Aral region					
Sudoche Lake wetland system	52.5	464.7	884	Raushan canal system, KKC and GK drainage canals (Ustyurt)	600-800
Mashankul-Karadjar lake system	53.0	50.7	440	Karadjar (Kattagar) and Taldyk canals taking origin from Raushan canal	500-600
Central Zone (Amu Darya Delta)					
Mezdureche reservoir	57.0	320	420	Amu Darya River	1,000-1,500
Ribache Lake	51.0	64.0	136	Marinkinuzyak canal from Mezdureche reservoir	200-250
Muynak Bay	51.6	97.4	163	Muynak Canal (Glavmyaso) from Mezdureche reservoir and Taldyk canal (Kungrad-Muynak)	250-300
Makpalkol Lake	53.0	12.0	63,0	Marinkinuzyak canal from Mezdureche reservoir	100-150
Right-bank (eastern) zone of Aral region					
Djiltirbas Lake (incl. left and right channels)	52.0	297.2	477	Kazakhdarya canal, KC-1, KC -1.22, KC-3 drainage collectors	750-850
Akpetki landmark lake system	53.0	391.5	100	KC-4 drainage collector and Kokdarya channel	200-300
TOTAL IN THE ARAL REGION		**1,740.4**	**2,730.8**		**7,600-10,750**
Including Amu Darya delta					**3,600-4,750**

the forest should be subject to 25 or more days of flooding per year."[32] At the same time, it is understood that this does not imply a guaranteed annual flood (which is impossible given natural variability of water availability), but rather the allowance of one major high-water event every 10-15 years, when hydrological conditions permit.

According to the 2025 assessment by the International Union for Conservation of Nature,[33] the Vakhsh Hydropower Cascade is critical for Tajikistan's energy security and economic development, significantly improving the population's quality of life. The report also notes that the long-term preservation of tugay forests depends on scientific-evidence

[32] GIZ (2020). CMP Climate-Smart Conservation Practice: Using the Conservation Standards to Address Climate Change. URL: https://conservationstandards.org/wp-content/uploads/sites/3/2021/01/210119_CSCP_Publication_Web.pdf

[33] IUCN. (2025). Conservation Outlook Assessment: Tugay forests of the Tigrovaya Balka Nature Reserve

based environmental flow (artificial floods) to be implemented as part of Cascade operational regime. Experts consider this approach a necessary compromise that effectively reconciles water development objectives with the fulfillment of international obligations (Ramsar Convention, Convention on Biological Diversity) to safeguard rare species and ecosystems amidst climate change.

1.8. Conclusion

The Amu Darya River Basin functions as a glacier-snowmelt system, where runoff is generated in the mountains with virtually no tributaries on the plains. Conversely, major water diversions are concentrated in the middle and lower reaches.

This geographic asymmetry – between mountain-generated runoff and lowland consumption-renders the floodplain and delta ecosystems critically dependent on both the seasonal distribution of flow and the specific regime of water releases from key hydroschemes.

Building upon the geographical and hydrological features and the effects of flow regulation, the subsequent chapter examines the key ecosystems and biodiversity in the upper, middle, and lower reaches. The focus will be on assessing their water dependence, current condition, and their vulnerabilities to changes in the river's flow regime.

CHAPTER 2
ECOSYSTEMS AND BIODIVERSITY OF THE BASIN

The uniqueness of the Amu Darya River basin consists in the diversity of its natural zones, which is a direct result of significant elevation gradients and varying climatic conditions. The key ecosystems of the basin are described below.

2.1. Key Ecosystems from Glaciers to the Delta

2.1.1. High-Mountain Ecosystems: Glaciers, Snowfields, Lakes, and Foothill Valleys

In the upper part of the basin, on the slopes of the Pamir and Tien Shan, there are **glaciers, snowfields, and high-mountain/subalpine ecosystems**. Harsh climate and short growing season are combined with high endemism of flora and fauna: alpine meadows, feather-grass and cereal communities, juniper shrubs; rare species include the snow leopard (irbis), argali, the Pamir Mountain goat, the Pallas's cat, and the bearded vulture. With a low density of direct impacts, the indirect factors are critical and affect ecosystems and biodiversity: accelerated degradation of glaciers and permafrost, overloading of summer pastures, the influence of industrial emissions, absence of a buffer zone or failure to comply with its special regime, poaching, local effects of mountain roads and developments, and the risks of glacial lake outburst.

The persistent trends of glacier degradation and the resulting vulnerability of water resources and ecosystems cause growing concerns.[34] According to the UNEP/UN report (2025), more than 1,000 out of approximately 14,000 glaciers in Tajikistan have already disappeared, and many small glaciers are expected to vanish within the next 30-40 years. Projections show that with an increase in average temperature of 2°C by 2050, up to 75.5% of glacier volume may be lost in the Panj basin and up to 53% in the Vakhsh basin. Taken together, this may reduce the Amu Darya River flow by approximately 30% compared to the average values of the past decade, putting at risk the water supply for ecosystems and the population of the region.[35]

Analysis of glaciation in the Kyrgyz part of the Amu Darya River basin (Kyzylsu-West) for the period 2013-2016 shows a trend of degradation and disintegration of large glaciers. Despite the overall reduction in area from 640.3 km^2 to 578 km^2 over approximately 70 years, the number of glaciers in the basin has increased from 294 to 526. This is explained by a significant increase in the number of small glaciers and a reduction in the area of larger glaciers (larger than 0.1 km^2), indicating an ongoing process of glacier mass fragmentation. The baseline rate of glacial area reduction in Kyrgyzstan is estimated by the Central Asian Institute for Applied Geosciences (CAIAG) at 0.2% per annum, which, under the current trend, may reach minus 30% by 2100. This means a peak in glaciogenic runoff in the coming decades followed by a long-term decline in summer flows of the Vakhsh, as well as an increase in the risks of mudflows in mountain valleys.[36]

The upper reaches of the basin are characterized by **high-mountain**, oligotrophic lakes of glacial origin, such as Lake Zorkul (bordering Tajikistan and Afghanistan) and Lake Karakul (Eastern Pamir). These lakes are vital for both river recharge, habitat for endemic Karakul stone loach and a critical refuge for rare bird species (e.g., the sociable plover and the black-throated loon). To safeguard this ecosystem, the Zorkul Nature Reserve was established in Tajikistan, protecting the eponymous lake at an elevation of 4,120 m. This reserve is recognized as a Ramsar Site (a wetland of international importance).

The preservation of glaciers and snowfields is anchored by a network of PAs, notably the Tajik National Park (a UNESCO World Heritage property), and the development of transboundary cooperation in high-mountain Pamir-Wakhan-

[34] Fourth National Communication of the Republic of Tajikistan to the UNFCCC (2022)

[35] Fourth National Communication of the Republic of Tajikistan to the UNFCCC (2022)

[36] Shabunin, A.G. (Author), Moldobekov, B.D. (Ed.). (2018). Catalogue of Glaciers of Kyrgyzstan (Edition 01/2024). Bishkek: Central Asian Institute for Applied Geosciences (CAIAG). www.caiag.kg/images/2_department/2022/Catalogue_of_glaciers_Kyrgyzstan_2018_Edition_01_2024_RU.pdf

Hindukush landscape, particularly as part of the Bam-e-Dunya Initiative[37] and the Central Asian Mammals Initiative.[38]

Conservation efforts prioritize glacier monitoring, maintaining connectivity (migration corridors), monitoring key wildlife populations, and combating poaching. However, data on biodiversity in the upper reaches of the Panj and Vakhsh river basins remain insufficient. In particular, the current status of snow leopard populations and their prey base in the high mountains requires further study.

2.1.2. River Ecosystems of Mountain and Foothill Areas

The biological diversity of mountain rivers such as the Pyandzh, Vakhsh, Kafirnigan, Surkhandarya, etc. and their valleys is relatively low but specialized: mountain fish species (false osman, chars), and invertebrates adapted to cold running water. The river valleys of the foothills are covered by high-altitude meadows and rocky screes, and in several valleys glacier tongues descend. Further downstream, in the larger mountain rivers, fish diversity increases; in particular, marinka and Amu Darya trout migrate there, and the endemic catfish, riffle minnow, and several species of chars are found. Rich ichthyofauna serves as food for the rare Central Asian otter. The rivers alternately flow through narrow mountain gorges and form wide floodplains with braided channels-habitats for the ibisbill and other semiaquatic birds. The river valleys are covered with meadows and shrub thickets that support a high diversity of birds and plants. The greatest biological diversity is found in the rivers of the low mountains and foothills, where the basin-endemic sturgeon – the large Amu Darya false shovelnose – occurs, along with more than twenty other native fish species. Several foothill fish species (false shovelnoses, the pike asp, etc.) are adapted specifically to life in the sediment-rich, turbid waters flowing down from mountains.

Overall, for an inland basin located in a geologically young region, the native fish fauna of the Amu Darya River basin is remarkably rich and includes around 50 species, of which at least 20 are endemic to Central Asia and nine are known only for the Amu Darya basin. Among the seven inland basins of Central Asia, the ichthyofauna of the Amu Darya is the least studied, and it is now being actively inventoried by scientists. As a result, new species are expected to be described in the near future – for example, two species of chars of the genus *Dzihunia* recently discovered by Uzbek researchers in the Sherobod and Surkhandarya river basins. The diversity and population status of aquatic invertebrates still await systematic research.

Under increasing anthropogenic pressure on the rivers, the numbers of many native fish species are declining, and spawning migrations are disrupted. Three species known to science have, in all likelihood, already gone extinct, while according to the IUCN, three species are critically endangered (CR), three are endangered (EN), and another four are vulnerable (VU). At least ten additional species have not yet undergone IUCN assessment, and their conservation status remains undetermined (see Table 12, "Fish Species Listed in Red Books").

In its 2025 assessment, the IUCN notes that within the boundaries of the UNESCO World Heritage property "Tigrovaya Balka," the Vakhsh River constitutes one of the key critical habitats for several endangered endemic fish species: the large and small Amu Darya shovelnose sturgeons, the pike asp, the Aral and Turkestan barbels, and the ostroluchka. These species are also listed in the Red Book of the Republic of Tajikistan as rare and threatened with extinction.[39]

A review of the status of Tajikistan's ichthyofauna highlights two major factors negatively affecting aquatic ecosystems.

[37] ICIMOD. (2018). Bam-e-Dunya: Network for the Roof of the World. www.icimod.org/bam-e-dunya-a-network-to-bolster-conservation-efforts-on-the-roof-of-the-world/

[38] UNEP/CMS. (2025). Work programme for the Central Asian Mammals Initiative 2026-2032. Convention on the Conservation of Migratory Species of Wild Animals. UNEP/CMS/CAMI3/Outcome1 https://cami.cms.int/sites/default/files/document/2025-10/cms_cami3_outcome1_draft-work-program_e.pdf

[39] IUCN. (2025). Conservation Outlook Assessment: Tugay forests of the Tigrovaya Balka Nature Reserve. https://worldheritageoutlook.iucn.org/explore-sites/tugay-forests-tigrovaya-balka-nature-reserve

First, since the mid-20th century, at least 14 alien fish species have become established in the Amu Darya basin, now competing with the native fauna. Second, excessive water withdrawal and river fragmentation by dams have led to the degradation of aquatic ecosystems and to the extinction or decline of many species.[40]

2.1.3. Floodplain Ecosystems in the Middle Reaches: Tugay Forests

The middle part of the basin covers the lowland areas in the south of Tajikistan and the east of Uzbekistan and Turkmenistan. This area contains river valleys, oases, and semi-deserts. The fauna of this zone includes such mammals as the goitered gazelle, the caracal, and the wildcat, as well as numerous bird species, including herons, cranes, waders, and ducks. Particularly important are the tugay forests – a rare type of floodplain vegetation that includes poplar, eleagnus, tamarisk, willow, black poplar and various shrubs. These forests provide key ecosystem services: bank stabilization, water filtration, microclimate regulation, and shelter and food resources for many animal species.

Floodplain forests and meadow ecosystems once covered the river valleys of the foothills (for example, the valleys of the Panj, Vakhsh, and Kafirnigan in Tajikistan). However, much of this area has since been converted to agriculture and settlements. Most of the population of the upper basin is concentrated in these foothill valleys, resulting in heavy pressure on the natural environment and leaving only fragments of floodplain forests intact. Even so, several areas retain high conservation value. The UNESCO World Heritage property "Tugay Forests of the Tigrovaya Balka Nature Reserve" (the Beshai Palangon Nature Reserve) in Tajikistan protects the floodplains of the Vakhsh and Panj rivers, with their relict tugay forests – a unique oasis amid the semi-desert landscape. The area is known for having been home to the Turan tiger until the mid-20th century; its extinction is linked to the destruction of tugay forests and hunting. Today, the reserve supports a large population of Bukhara deer, as well as other rare species (such as the striped hyena and, in the surrounding areas, the goitered gazelle). Over recent decades, the extent of tugay forests has shrunk dramatically due to logging, land clearing for cultivation, grazing, and changes in river flow regime (the loss of regular flooding).[41] At present, tugay tracts survive only in isolated patches along the Amu Darya and some of its tributaries. Preserving the remaining tugay forests is a top conservation priority for the entire region.

To preserve these biotopes, protected areas have been established, including the nature reserves – Beshai Palangon (Tajikistan), the Amudarya (Turkmenistan), Kyzylkum, Lower AmuDarya biosphere reserve (former Baday-Tugay), National nature parks Khorezm and Priaralie (Uzbekistan). and Reserve. They implement programs for restoring populations of the Bukhara deer – a key species of the tugay ecosystem. Nevertheless, without implementing environmental flows in the river during dry years, the tugay forests remain vulnerable.

2.1.4. Ecosystems in the Lower Reaches: the Delta and Dried Seabed

The historical delta of the Amu Darya, which consisted of a network of river arms, lakes, and wetlands with rich flora and fauna, underwent significant changes after the drying of the Aral Sea: the area of permanent water bodies sharply decreased, most of marshy and reedy banks disappeared, and a desert – the Aralkum – formed in the place of the retreating sea, becoming a source of salt and dust storms that intensify desertification processes in the region. Nevertheless, key lake systems in the delta are still preserved and maintained through drainage discharges and targeted water releases, while on the dried seabed efforts are made to develop and stabilize the landscape in order to reduce erosion and dust transfer processes.

[40] Artaev, O. N., Thoni, R., Mirzoev, N., & Levin, B. A. (2025). Ichthyofauna of Tajikistan: Diversity and changes over the past century. American Museum Novitates, 2025(4032), 1-55. https://doi.org/10.1206/4032.1

[41] Kirilenko, A., Vilnītis, V., Eriņš, G., Krutov, A., & Safarov, N. (ed.). (2023). Analytical review of biodiversity and significant ecosystems conservation priorities in Central Asia. WECOOP, https://wecoop.eu/wp-content/uploads/2020/04/Biodiversity-review-EN-130323.pdf

THE DRIED SEABED OF THE ARAL SEA (ARALKUM) consists of young desert landscapes with solonchak and saline soils, and a mosaic of dune and deflation areas. The vegetation here is xerophytic – wormwood, saxaul, tamarisk/cherkes, kandym, and other species. Many species have disappeared or are under threat, including the saiga, sturgeon, and numerous migratory birds.

In response, soil stabilization attempts are made through planting salt-tolerant species (saxaul and others) on the dried seabed. Uzbekistan has been carrying out systematic afforestation of the dried seabed of the Aral Sea at least since the early 2010s: in addition to regular work by the forestry stations of Muynak and Karauzak districts (16-20 thousand ha annually in 2013-2017), afforestation was carried out under UNDP/GEF[42] and GIZ/BMZ[43] projects. The scaling up of efforts by the Government of Uzbekistan ensured the afforestation of 1.9 million ha in 2018-2022, reaching 2.13 million ha by early 2025. In parallel, seed harversting and aerial/mechanized seeding are conducted in hard-to-access areas (in 2023, more than 540 t of seeds were harvested, including 447 t of saxaul). Large-scale afforestation reduces salt and dust transfer, stabilizes the surface, and forms green enclaves within the desert landscape.

SIC ICWC conducts continuous monitoring of the South Aral region and some parts of the Large Aral Sea using satellite imagery,[44] and also carries out field expeditions. In particular, during 2019-2023, with the support of UNDP and the participation of the International Innovation Center for the Aral Sea Region under the Ministry of Ecology of Uzbekistan, four expeditions were conducted on the dried Aral Sea bed, sequentially covering the entire Uzbek part (2.7-3.0 million ha) and providing detailed assessments of the condition of saline lands, vegetation self-establishment, and afforestation sites.[45] The results of the studies indicate, among other things, that vegetation self-establishment takes place on the dried seabed – primary succession of halophytes and shrubs, which locally stabilizes sands and reduces dust emissions, complemented by large-scale afforestation (saxaul and others) using specialized "sand-retaining" technologies. At the same time, hotspots of high dust-salt emissions and the vulnerability of delta ecosystems to fluctuations in water inflow persist, making necessary measures – maintaining environmental flow, continuing afforestation, and monitoring – critical for sustainable restoration. [46]

LAKE SYSTEMS OF THE AMU DARYA DELTA (SOUTH ARAL REGION). The key water bodies include: the Western Aral (the remaining water area), as well as delta lakes – Sudoche, Dautkul, Karadjar-Mashankul, Zhyltyrbas, Makpalkol, Akpetki; and reservoirs – Mezhdureche, Muynak, Rybache (Sarbas). Some of these sites have the status of protected areas. Sudoche (2023) and Zhyltyrbas (2024) have been included in the list of Ramsar wetlands.

The inflow to the water bodies is formed by the Amu Darya flow below Takhiatash, by water supplied through the Suenli and Kyzketken canals, and by collector-drainage discharges (KKS/Sudoche; KS-1, KS-1-22, KS-3 – Zhyltyrbass; KS-4 and the right-bank collector – Eastern Sea). Over 2011-2025, the total inflow to the South Aral region amounted to 56.21 km^3 (an average of 4.015 km^3/year). At the same time, inter-annual variability is extremely high: from 0.96-1.38 km^3/year in low-water years to 10.75-10.83 km^3/year in high-water years. Over the past seven years (2018-2025), the average inflow has decreased to 2.287 km^3/year, which is 55% of the estimated needs of 4.175 km^3/year[47] for stable lake conditions. As a result, fluctuations in water surface area and instability of biodiversity are observed[48]. The water inflow to

[42] including workshop "Basics of afforestation on the Aral Sea bed...", November 2011, and a pilot in Karakalpakstan; gefieo.org

[43] Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH. (n.d.). Ecologically oriented regional development in the Aral Sea region. www.giz.de/en/projects/ecologically-oriented-regional-development-aral-sea-region

[44] SIC ICWC. (s.d.). Monitoring of the Amu Darya [e-resource]. CAWater-Info: https://www.cawater-info.net/aral/data/monitoring_amu.htm

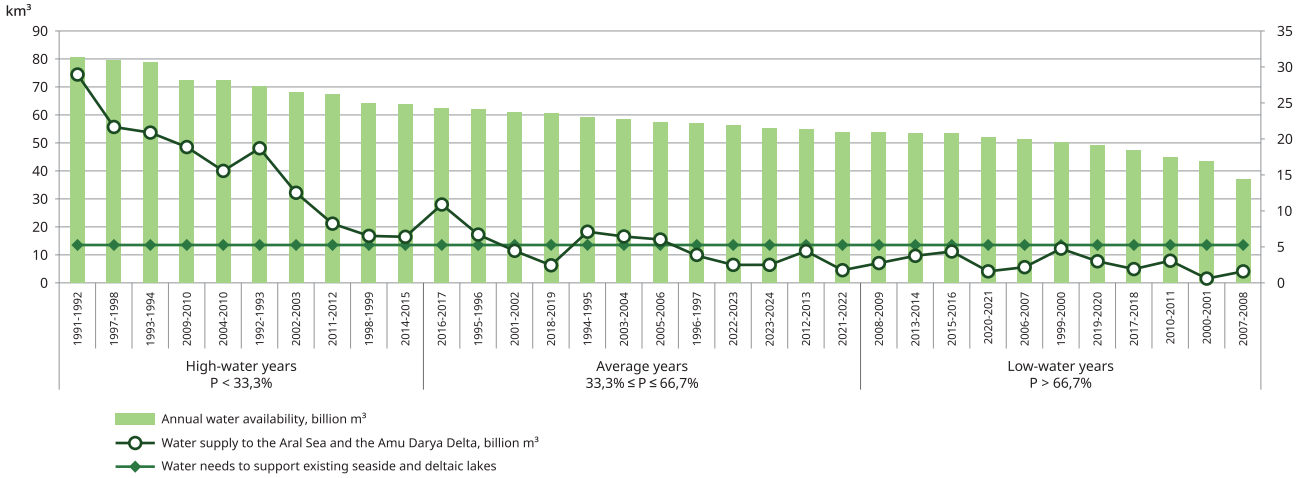
[45] UNDP. (2024, 19 January). Presented results of four expeditions on the dried seabed of the Aral Sea, www.undp.org/ru/uzbekistan/press-releases/ozvucheny-rezultaty-chetyrekh-ekspediciy-po-osushennomu-dnu-aralskogo-morya (UNDP); UNDP. (2024, April). Results of the final expedition on the dried seabed of the Aral Sea, https://www.undp.org/sites/g/files/zskgke326/files/2024-04/Expedition_English.pdf

[46] See details in Dukhovniy, V.A., Stulina, G.V., Kenjabaev Sh.M. (ed.) (2020). Monitoring of the dried Aral Sea Bed. Tashkent: UNDP. https://cawater-info.net/library/rus/un_pub_uz_report_aral_sea.pdf, SIC ICWC. (2020). The Aral Sea and the Aral Sea Region: Life Goes On. Tashkent: SIC ICWC. https://www.cawater-info.net/library/rus/aral_sea-2020.pdf

[47] South Prearalie – New Perspectives, under the editorship of Dr. Joop de Schutter and Prof. Victor A. Dukhovny. Tashkent -2003. Project "Science for Peace"

[48] Agency of IFAS. (2021). Monitoring of Wetland Biodiversity in Southern Part of the Aral Sea. Tashkent. https://aral.uz/doc/bio-2021.pdf

FIGURE 10
Water inflow to the South Aral region under different flow conditions, actual supply against estimated delta demand (calculated by the IFAS Agency)



the South Aral region in different flow conditions is presented in Fig. 10.

The system of artificially maintained lakes preserves populations of migratory birds (especially the Karadjar, Sudoche, and Mezhdureche complexes); rare species are regularly recorded in the key wetlands of the region. For example, 150 bird species have been recorded in the Akpetki lake system, 10 of which are included in the IUCN Red List.[49] Monitoring of wetlands in the South Aral region conducted by the IFAS Agency in 2020 recorded significant biodiversity even under degraded ecosystem conditions.[50] According to researchers, at least 1,000 species of vascular plants grow in the South Aral region, of which 34 species are included in the Red Book of the Republic of Uzbekistan. In terms of the fauna, 12 mammal species have disappeared, 19 mammal species, 76 bird species, 6 reptile species, and 12 fish species are on the verge of extinction. The richest ornithological composition has been recorded in the Sudoche system (64 species, of which 29 are waterbirds) and the Zhyltyrbas system (59 bird species, of which 36 are waterbirds). The presence of species typical for the region has been noted, including mammals (fox, jackal, tolai hare, wolf, muskrat), reptiles (steppe agama), and fish (carp, pike-perch, silver carp). The monitoring results indicate a gradual recovery of biodiversity, provided that environmental flow and a stable water regime are implemented, and emphasize the importance of integrated wetland management in the South Aral region as the core of the Aralkum's natural complex.

Thus, the delta and the Aralkum form an interconnected natural-anthropogenic complex: forest plantations on the dried seabed reduce dust sources, while regulated lakes maintain key habitats – provided that environmental flow is guaranteed and regular monitoring is implemented.

2.1.5. Conclusion: New Landscape in the Amu Darya River Basin

The ecosystems of the Amu Darya River basin represent **a multi-level system – from high mountains to the lower reaches** – each part of which with its own unique functions, risks, and specific conservation needs. High-mountain ecosystems are the sources of runoff and are particularly sensitive to climate change: reduction of glaciers and changes in the timing of snowmelt are directly reflected in inflow to the middle and lower reaches. The ecosystems of the middle reaches, which serve as a buffer between the headwaters and the delta, require the preservation of the remaining tugay forests against the background of intensive irrigated agriculture. The delta and the dried seabed have

[49] Red Book of the Republic of Uzbekistan. Volume II: Animal world. (2019). Ed. By Azimov Zh.A. Tashkent: Tasvir Publishing House – 392 p.

[50] Agency of IFAS. (2021). Monitoring of Wetland Biodiversity in Southern Part of the Aral Sea. Tashkent. https://aral.uz/doc/bio-2021.pdf

undergone the most radical transformations, and their resilience depends on maintaining lake systems and stabilizing the new desert ecosystem of the Aralkum through afforestation and implementation of the minimum necessary environmental flow.

In addition to natural complexes, **artificial water bodies (lakes and reservoirs)** have formed in the Amu Darya River basin and **have become ecologically significant over time**. These include large irrigation systems – for example, the Karakum Canal (Garagum Darya) in Turkmenistan, stretching for 1,300 km and being the largest canal in the world, as well as the Amu-Bukhara and Karshi main canals in Uzbekistan. Collector-drainage water bodies also play an important role, among which Lake Sarykamysh on the border of Uzbekistan and Turkmenistan stands out. This water body was formed as a result of discharge of drainage water and now represents a large body of about 3,000 km^2 with an established ecosystem inhabited by fish and numerous bird species. These sites have become new habitats for fish and birds, and green oases with shrub vegetation have formed along the canals. These anthropogenic systems partially mitigate the loss of natural water bodies by creating alternative niches for biodiversity, but they remain vulnerable due to salinization, pollution, and ecosystem instability.

Combined, the natural and anthropogenic ecosystems of the basin form **a new Amu Darya landscape**, where processes of degradation and restoration are intertwined. Maintaining resilience requires integrated management – from conserving glaciers and natural river regimes to implementing environmental water releases from reservoirs and monitoring water quality in artificial water bodies. Only through such an approach it is possible to preserve biodiversity and mitigate the consequences of environmental degradation.

2.2. Status of Biodiversity

The Amu Darya River basin, despite the harsh desert conditions in its lower reaches, is characterized by high biodiversity, especially in the mountain areas and oases. Tajikistan, which contains most of the mountain ecosystems, is home to more than 0.66% of global animal diversity and 1.8% of plant diversity, including wild relatives of domestic animals and cultivated plants.[51] Rich biodiversity includes about 23 thousand flora and fauna species, of which 1900 are endemic,[52] about 40 are autochthonous fish species.[53] Uzbekistan and Turkmenistan, with predominantly desert and lowland landscapes, have lower species richness, yet they also host at least 60 mammal species and 300 bird species adapted to deserts and tugay forests, along with dozens of reptile species. Endemic species are concentrated in isolated habitats: for example, in the Koytendag Mountains (Turkmenistan) – endemic mollusks of karst caves and rare bat species; in the Pamir – endemic plants of alpine meadows, also in the Amu Darya River itself.

The overall status of biodiversity in the basin is assessed as unfavorable: the ranges of many species are shrinking, and populations continue to decline. For example, while in the mid-20th century the Bukhara deer numbered in the thousands, by 1990 it had declined to fewer than 400, surviving only in protected areas. However, thanks to implemented conservation measures, by 2020 the population had increased to approximately 1,500.[54] The saiga (Saiga tatarica), which once migrated into the lower reaches of the Amu Darya, has completely disappeared in these areas, remaining only on the Ustyurt Plateau to the west. The Aral sturgeon and the ship sturgeon – valuable migratory fish – have virtually disappeared from the river due to blocked

[51] Third National Report on Biodiversity Conservation in Tajikistan. (2006) Convention on Biological Diversity. https://www.cbd.int/doc/world/tj/tj-nr-03-en.pdf

[52] Fifth National Report on Preservation of Biodiversity of the Republic of Tajikistan. (2014). Convention on Biological Diversity. https://www.cbd.int/doc/world/tj/tj-nr-05-en.pdf

[53] Artaev, O. N., Thoni, R., Mirzoev, N., & Levin, B. A. (2025). Ichthyofauna of Tajikistan: Diversity and Changes Over the Past Century. American Museum Novitates, 2025(4032), 1–55. https://doi.org/10.1206/4032.1

[54] Convention on the Conservation of Migratory Species of Wild Animals. (n.d.). World's Largest Bukhara Deer Population. www.cms.int/cami/fr/node/23835

migration routes (dams) and poaching. In contrast, invasive species (for example, the Chinese snakehead fish) have spread in the water bodies of the lower reaches,[55] posing a new threat to the local ichthyofauna. It should be noted that data are lacking for some groups of organisms: for example, invertebrates and aquatic microflora are poorly studied, and there is no complete picture of bird migrations through the Aral Sea region in recent years (data are collected in a fragmented manner, and research coordination is required).

These assessments are also confirmed in the national country reports on the status of biodiversity. For example, the **Fifth National Report of Tajikistan** to the Convention on Biological Diversity[56] notes an acceleration of deforestation and forest degradation; rich tugay forests have been preserved mainly in the Beshai Palangon State Nature Reserve, whereas in the valleys of the Panj, Vakhsh, and Kafirnigan only narrow strips remain. At the same time, the condition of pastures is deteriorating: their forage productivity has decreased to 10-50% due to prolonged uncontrolled grazing. This means that the "upper" source of biodiversity – the mountain–floodplain connections – no longer supports the previous ecosystem capacity.

The **Sixth National Report of Turkmenistan** to the Convention on Biological Diversity[57] identifies the reduction of biodiversity as a priority environmental problem and highlights habitat loss as the main driver: overgrazing, logging and ploughing of virgin lands, road and mining construction, fires, and fuel harvesting (including saxaul) trigger a chain of desertification, wind erosion, and the disappearance of water sources. These processes directly affect the floodplain and desert fauna of the middle and lower reaches.

The **Sixth National Report of Uzbekistan** to the Convention on Biological Diversity[58] provides detailed data on the extent of the remaining tugay forests in the delta: the largest fragmented areas of about 30,000 ha in Karakalpakstan represent about 10% of the original tugay area of the Amu Darya delta, 75% of the remaining tugay forests in the country, and 20% of all tugay forests in Central Asia. Low forest cover persists due to logging and overgrazing; loss of forests automatically deprives animals of habitats and breaks migration corridors.

The same dynamics is reflected in **national Red Books**, which list hundreds of threatened species. The Red Book of Uzbekistan[59] includes, for example, about 90 animal species associated with the aquatic and desert ecosystems of the basin (including 14 fish species, 15 reptiles, 39 birds, and 22 mammals). In Tajikistan,[60] there are 304 plant species and 242 animal species, many of which inhabit the Amu Darya basin. For Turkmenistan,[61] key species include desert endemics (the Central Asian cobra, desert monitor, karakurt, etc.), species dependent on oases (deer, goitered gazelle, kulan) and inhabitants of water bodies (large and small Amu Darya shovelnose, pike asp, etc.). Last years, large and small Amu Darya shovelnoses (or false shovelnoses) occur mainly in the Amu Darya middle reaches.

A comparison of recent and earlier Red Book editions confirms a unified trend for the Amu Darya basin: **the set of taxa in threat categories is growing and covers an increasingly broad spectrum of groups**. In Tajikistan, the transition from II (2015) to III edition was accompanied by an increase in the lists for both flora (+14%) and fauna (+10%). In Uzbekistan, between 2009 and 2019, an increase was recorded for mammals, birds, reptiles, and arthropods

[55] Key Biodiversity Areas. (n.d.). Amudarya Floodlands near Termez (site factsheet 20662). www.keybiodiversityareas.org/site/factsheet/20662

[56] Fifth National Report on Preservation of Biodiversity of the Republic of Tajikistan. (2014). Convention on Biological Diversity. https://www.cbd.int/doc/world/tj/tj-nr-05-en.pdf

[57] Sixth National Report of Turkmenistan on Biodiversity (2019). Convention on Biological Diversity. https://dev-chm.cbd.int/doc/world/tm/tm-nr-04-ru.pdf

[58] Sixth National Report of the Republic of Uzbekistan on the Conservation of Biological Diversity (2018). Prepared with the support of UNDP/GEF/State Committee for Ecology and Environmental Protection of the Republic of Uzbekistan. https://www.cbd.int/doc/nr/nr-06/uz-nr-06-en.pdf

[59] Red Book of the Republic of Uzbekistan. Volume I: Plants. (2019). Ed. By Khasanov F.U. Tashkent: Ecological Publishing Enterprise «Chinor ENK». – 356 p.; Red Book of the Republic of Uzbekistan. Volume II: Animal world. (2019). Ed. By Azimov Zh.A. Tashkent: Tasvir Publishing House – 392 p.

[60] НИАТ «Ховар». (2025, 25 июля). Презентовано третье издание Красной книги Таджикистана, куда вошли 304 вида растений и 242 вида животных. https://khovar.tj/rus/2025/07/prezentovano-trete-izdanie-krasnoj-knigi-tadzhikistana-kuda-voshli-304-vida-rastenij-i-242-vida-zhivotnyh/

[61] CentralAsia.News. (2025, 25 июля). В Туркменистане четвёртое издание Красной книги уточнило состояние флоры и фауны. https://centralasia.news/29744-v-turkmenistane-chetvertoe-izdanie-krasnoj-knigi-utochnilo-sostojanie-flory-i-fauny.html

(+12% animals overall). In Turkmenistan, between III (2011) and IV editions, the dynamics are mixed: while the number of protected plant species increased (+5%), a slight decrease was observed for animals (–2.7%), mainly due to vertebrates (–5 vertebrate species with +1 invertebrate), which may reflect both taxonomic/accounting revisions and a shift in conservation priorities. In Kyrgyzstan, after the 2009 updates, changes are minor (–3 mammals, +4 birds), while

TABLE 11
Summary Table of the Red Books of the Amu Darya River Basin Countries

Country	Kyrgyzstan		Tajikistan		Turkmenistan		Uzbekistan	
Edition (year)	II (2007)	2009	II (2015)	III (2025)	III (2011)	IV (N/A)	2009	2019
Plants (species)	89	83-89	267	304	115	121	301	314
Animals – total	114	115	222	243	149	145	182	206
Vertebrates – total	96	97	32	n/a	104	99	105	120
Invertabrates – total	18	18	90	n/a	45	46	77	83

TABLE 12
Amu Darya River basin fish species in the IUCN and country Red Books

Name in Latin	Name	IUCN	TJ (2015)	TM (2011)	UZ (2019)
Pseudoscaphirhynchus hermanni	Small Amu Darya shovelnose	CR	EN	CR	CR
Pseudoscaphirhynchus kaufmanni	Big Amu Darya shovelnose	CR	CR	EN	CR
Acipenser nudiventris	Thorn sturgeon (disappeared in Amu Darya)	CR	CR	CR	CR
Luciobarbus brachycephalus	Aral barbel	EN	VU	EN	EN
Aspiolucius esocinus	Pike asp	EN	CR		EN
Capoetobrama kuschakewitschi	Ostroluchka	EN	EN		VU
Troglocobitis starostini	Starostin's stone loach	VU			VU
Luciobarbus conocephalus	Turkestan barbel	VU			VU
Triplophysa lacusnigri	Karakul stone loach	VU	VU		
Ballerus sapa	White-eye bream	LC	VU		VU
Glyptosternon cf. akhtari Silas	Turkestan catfish (Amu Darya)	N/A	VU		VU
Sabanejewia aralensis	Aral loach	N/A	EN		NT
Salmo oxianus	Amu Darya trout	N/A	VU		VU
Salmo (trutta) aralensis	Aral salmon (extinct)	N/A	EN		EX
Pungitius platygaster	Southern nine-spined stickleback	LC			NT
Leiciscus idus	Turkestan ide	LC			DD
Abramis brama oirentalis	Eastern bream	LC	VU		
Esox Lucius	Pike	LC	EN		
Alburnoides bipunctatus	Riffle minnow	LC		EN	
Schizothorax pelzami	Transcaspian marinka	LC		EN	
Schistura sargadensis turcmenicus (Paraschistira turcmenica)	Turkmenian stone loach	N/A		VU	
Scardinius erythrophthalmus	Redeye	LC	VU		
Alburnus taeniatus	Striped bystranka	DD			
TOTAL		**9**	**15**	**7**	**14**

Note: The conservation status categories are given in accordance with IUCN standards: **EX** – Extinct, **CR** – Critically Endangered, **EN** – Endangered, **VU** – Vulnerable, **NT** – Near Threatened, **LC** – Least Concern, **DD** – Data Deficient, **N/A** – Not assessed by this organization

for plants the range of 83-89 persists due to methodological differences in accounting[62] (Table 11).

The increase in the number of protected taxa may result from improved inventory methods, but it may also indicate to degradation of the basin's ecosystems. Of 50 fish species that once inhabited the basin, 22 have already been included in at least one of the region's Red Books, reflecting the extremely high level of threat faced by freshwater ecosystems. Against the background of water scarcity, reduced flooding, fragmentation of floodplains/tugay forests, and localized deterioration in water quality, it is the groups sensitive to the water regime (floodplain plants, amphibians, fish, and wetland bird fauna) that show expanding risk lists. Taken together, this points to systemic pressure on biodiversity along the entire river: in the headwaters – due to accelerated glacier degradation and overgrazing; in the middle reaches – due to insufficient environmental flows and withdrawals for irrigation; in the lower reaches – due to the shallowing and salinization of delta water bodies.

2.3. Drivers of Ecosystem Degradation

The ecosystems of the Amu Darya River basin are subject to a wide range of anthropogenic and natural threats. Below are summarized the main drivers of degradation.

CLIMATE CHANGE. Warming and climatic variations exacerbate anthropogenic impacts on natural systems. In mountain regions, a reduction in glacier area is observed. According to scientific reviews and reports on projected changes in glaciation in the high-mountain parts of the Amu Darya River basin, by 2050 a decrease in glacier area of 38-50% is expected, depending on the climate scenario.[63] This threatens, in the long term, a reduction in the stable component of summer runoff. At the same time, extreme winter and spring floods during sharp thaws have become more frequent and may lead to flooding and riverbank destruction. In the lowlands, rising temperatures increase evaporation from canals and reservoirs. Dry years are becoming more frequent; model projections indicate an increase in the frequency of low-water periods.[64] Climatic changes also affect species distribution: ranges shift northward and upslope. Some desert species, such as the Central Asian tortoise, may lose optimal conditions due to rising summer temperatures. For cold-water fish, the only viable option for survival is to migrate to cooler areas upstream, whereas endemic aquatic organisms that inhabit springs suffer severely from their increasingly frequent drying. Overall, the climate factor amplifies other threats, creating a multiplication effect (for example, when flow decreases, ecosystem vulnerability to drought increases sharply).

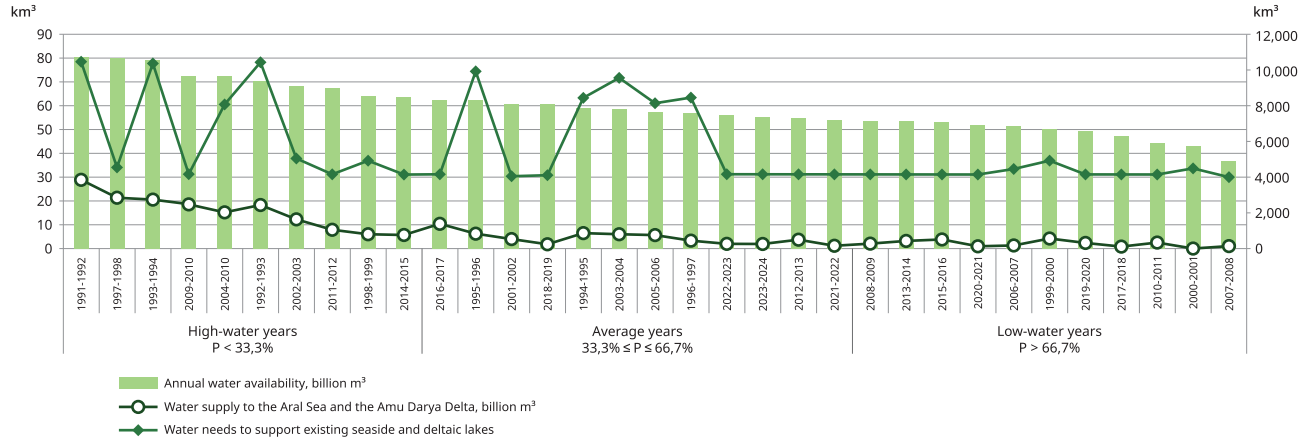
EXCESSIVE WATER WITHDRAWALS AND CHANGES IN HYDROLOGICAL REGIME are the main drivers of degradation of water-dependent ecosystems. In the Amu Darya basin, up to 90% or more of the flow is withdrawn annually for irrigation and other sectors. As a result, the river channel and delta desiccate, and tugay forests no longer receive regular floods and are drying out. In the middle reaches, the construction of hydraulic structures has led to rising water tables, causing tree mortality due to stagnant waterlogging. The construction of hydropower facilities has altered the seasonal flow distribution: spring peaks have decreased, disrupting the usual fish spawning cycle and flushing/supply of floodplains. In addition, the floodplains no longer receive sufficient sediment, which disrupts key ecosystem processes and reduces their fertility and resistance to erosion. Non-implementation of environmental flow is a serious problem. Currently, even water releases to the delta are not carried out in the required volume or regime. Overall, river regulation without consideration of ecosystem needs remains a constant threat to all water-dependent biocenoses of the basin. Figure 11 presents data on water delivery to the South Aral zone for different flow conditions.

[62] Ecostan.kg. (n.d.). Red Book of Kyrgyzstan. https://ecostan.kg/krasnaya-kniga-kyrgyzstana/63-krasnuyu-knigu-kyrgyzstana.html

[63] Fourth National Communication of the Republic of Uzbekistan under the UN Framework Convention on Climate Change (2021). https://unfccc.int/sites/default/files/resource/4NC_Uzbekistan_RU.pdf

[64] Fourth National Communication of the Republic of Uzbekistan under the UN Framework Convention on Climate Change (2021). https://unfccc.int/sites/default/files/resource/4NC_Uzbekistan_RU.pdf

FIGURE 11
Water inflow to the South Aral region under different flow conditions, plan against actual supply to the Aral region



LOSS OF HABITATS DUE TO LAND USE. Ploughing of land, drainage of wetlands, and deforestation are traditional threats to biodiversity. In the Amu Darya River basin, the conversion of natural land into agricultural land is particularly extensive: almost all floodplain areas suitable for irrigation have been developed. In the headwaters, livestock grazing leads to the degradation of subalpine meadows, which indirectly affects water runoff, since degraded land retains moisture less effectively. In the valleys, the construction of canals and roads fragments the landscape – migration routes of saiga, kulan, and goitered gazelle are disrupted. The construction of HPPs, in addition to hydrological effects, directly affects unique river sections by flooding them by reservoirs and changing water and sediment regime downstream.

DESERTIFICATION AND SOIL SALINIZATION. Intensive irrigation under arid climatic conditions has led to secondary salinization of soils over vast areas. In the lower reaches of the Amu Darya, around 50% of irrigated land is subject to some degree of salinization. Salinization reduces plant growth, including natural vegetation: tugay forests on saline soils degrade. Waterlogging caused by rising groundwater near canals also leads to salinization through evaporation. Dust storms from the exposed saline bed of the Aral Sea transport salt over hundreds of kilometers, depositing it on soils and vegetation. This is a regional environmental disaster, and its consequences are felt even in the headwaters.

DETERIORATION OF WATER QUALITY. Although the main water quality problems in the basin are related to increasing salinity, contamination with chemical substances (pesticides) is also a threat. In recent years, the volume of agrochemical use has decreased but remains significant, posing risks to aquatic fauna and public health.

INVASIVE SPECIES. Non-native species introduced into the Amu Darya basin have become a threat to local ecosystems. One example is the snakehead fish (Channa argus) introduced into irrigation systems and now spreading through water bodies in the lower reaches, competing with native species and preying on their juveniles.[65] In tugay forests, aggressive invasive plants (for example, American ash or boxelder maple and Canadian poplar) displace the native tugay poplar (Turanga). Cases of muskrat appearing in drainage canals are also recorded – it damages riverbank ecosystems. Invasive species increase pressure on fragile natural communities.

FRAGMENTATION OF FRESHWATER HABITATS: LOSS OF LONGITUDINAL AND LATERAL CONNECTIVITY OF RIVERS AND FLOODPLAINS. The construction of dams and other large hydraulic structures disrupts the transport of sediments and nutrients and blocks migration routes for aquatic fauna – an impact that is especially critical under changing climate conditions. Preserving undammed sections of major rivers with natural flow regimes ("free-flowing rivers") is essential for the health of river and floodplain ecosystems, a key factor in their ability to adapt to climate change, and one of the global priorities for biodiversity conservation. Although more slowly than other river systems in Central Asia, the Amu Darya basin is gradually losing its free-flowing

[65] Key Biodiversity Areas. (n.d.). Amudarya Floodlands near Termez (site factsheet 20662), www.keybiodiversityareas.org/site/factsheet/20662

rivers. Given the Panj remains in Central Asia the only free-flowing river longer than 1,000 km, the Amu Darya basin retains only 7 free-flowing segments longer than 100 km, with a total length of 2,432 km (7% of the assessed network), while the current network of protected areas covers about 8% of the river network and does not provide representative protection of freshwater ecosystems.[66]

POACHING AND ILLEGAL USE OF NATURAL RESOURCES. Socio-economic difficulties in the region have led to the problem of poaching: in the 1990s, saiga were almost exterminated (for their horns), and populations of deer (for meat) and kulan declined sharply. Fishing in the Amu Darya and the remaining delta lakes is often uncontrolled – the last sturgeon and other valuable species are being caught. In the mountains, cases of hunting of the snow leopard (for its fur) and mountain goats (trophy hunting) have been recorded. Although the legal frameworks of all countries provide for liability, enforcement on the ground is difficult due to large territories and limited inspection resources.

COMPARATIVE COUNTRY PERSPECTIVE. In Tajikistan, water scarcity is less pronounced than in neighboring countries, but serious risks remain, associated with overgrazing, local pollution and construction of hydraulic structures, as well as with climate change, which accelerates glacier melt. In Turkmenistan, the key issue is water stress in the delta and the middle reaches of the Amu Darya, accompanied by desertification and soil salinization. The situation is aggravated by climatic extremes: the increased frequency of droughts in recent years intensifies threats to food security. In Uzbekistan, the combination of all the challenges listed above is evident.

It is important to emphasize the **cumulative effect:** many threats act simultaneously, reinforcing one another. For example, water withdrawal causes lakes to dry up, which facilitates the penetration of poachers and invasive species (in shallow water bodies fish are easier to catch and non-native species establish more rapidly), while climatic drought further worsens the situation. This requires an integrated approach when developing measures to restore ecosystems – it is impossible to address one problem while ignoring others.

National reports also note a lack of quantitative data on some threats – for example, there is no precise statistics on the volume of illegal water abstraction or on the annual rate of tugay forest degradation. These gaps must be filled through research.

2.4. Conclusion

The ecosystems of the Amu Darya River basin are in a vulnerable state under the influence of climate change and unsustainable water use. Warming, reduction of precipitation share, and accelerated glacier melt shift the hydrograph: the peak flow occurs earlier, the summer low-water period becomes longer and more irregular, and the frequency and duration of droughts and dust storms, evaporation, and irrigation water demand increase. Extreme precipitation events increasingly cause short-term erosive floods, followed by extended periods of low water. Warming of water reduces dissolved oxygen, intensifies algal blooms and mineralization, and increases stress on aquatic ecosystems. Dust-salt storms from the exposed Aral seabed accelerate soil salinization and degradation and hinder natural vegetation recovery. Thus, water scarcity, excessive withdrawals and lack of water releases for environmental flow, loss of river connectivity, degradation and fragmentation of tugay forests (deforestation, overgrazing, ploughing), pollution (including collector-drainage flows), and climate change together form a cascade of negative consequences – from the shallowing and salinization of floodplain water bodies to declines in populations of waterbirds and fish.

[66] Egidarev, E.G., Simonov E.A. (2023). International Approaches to Assessment of Impacts on River Ecosystems and Identification of Free-Flowing Rivers. https://rivers.help/pdf/2023_Egidarev1.pdf

CHAPTER 3
INSTITUTIONAL AND LEGAL MECHANISMS OF MANAGEMENT AND PROTECTION

3.1. National Legislation

All countries within the basin acknowledge the critical importance of protecting aquatic ecosystems, a commitment consistently reflected in their respective national legislations. The legal framework governing environmental protection is generally built upon the following core legislative instruments: environmental protection (or nature protection) law), which establishes the overarching principles, objectives, and scope of the state's environmental policy; Water code specifically regulating all matters related to water use and protection; law on protected areas (PAs), which defines the legal status and regime for various categories of protected areas. PAs serve as the primary tool for in-situ (on-site) conservation of ecosystems; and, numerous other acts covering essential regulatory procedures, such as impact assessments, the management and main-tenance of environmental registers, and state-level monitoring activities. The objective of this Chapter is to make a comparative analysis of the key provisions found within these foundational legal acts across the four basin countries.

3.1.1. National Legislation of the Kyrgyz Republic

The new Water Code of the Kyrgyz Republic (2025)[67] regulates the use, protection, and development of water resources (Art. 1), is based on basin management (Art. 5) with mandatory plans (Art. 24) that take into account the risks of low-water periods, droughts, floods, and climate change, and includes a system of protection zones and measures for safeguarding against extreme hydrological events (Chapter 9, Arts. 60-67). The Code introduces the concept of environmental flow as the minimum allowable water quantity required to preserve and allow self-recovery of ecosystems (Art. 2), with the government mandated to establish such standards for individual basins. The Code also systematically regulates spatial protection around water resources, including flow generation zones and water-protection zones and measures against floods, mudflows, and landslides through planning and interagency programs (Chapter 9, Arts. 60-67). Taken together, this forms a regulatory framework for sustainable flow regulation and operation of hydraulic structures. Practically, ecosystem resilience is ensured through the combination of legal regimes governing the protection of surface waters and the prevention of environmentally harmful impacts from economic activities. Full environmental impact assessment (EIA) is mandatory for high-risk (Category I) activities and projects with significant transboundary adverse impacts (including those affecting riverine biotopes and wetlands).[68]

The Law "On Environmental Protection"[69] sets out a comprehensive framework of measures to safeguard nature, including water quality standards, environmental requirements for economic activities, and mandatory environmental impact assessments for proposed projects. The key legal instrument for conserving ecosystems *in situ* is **the Law on Protected areas**.[70] The law stipulates that protected areas are "the basis for the conservation, reproduction, and restoration of natural ecosystems," which underscores the fundamental role of nature reserves, national parks, and wildlife sanctuaries in maintaining ecological stability and preserving biodiversity.

[67] Water Code of the Kyrgyz Republic (June 27, 2025, No. 128). www.cawater-info.net/library/rus/legal_66.pdf

[68] Resolution of the Government of the Kyrgyz Republic No. 60 "On Approval of the Procedure for Environmental Impact Assessment in the Kyrgyz Republic" (of February 13, 2015)

[69] Law of the Kyrgyz Republic of June 16, 1999 No. 53 "On Environmental Protection." https://cbd.minjust.gov.kg/218/edition/6734/ru

[70] Law of the Kyrgyz Republic of May 3, 2011 No. 18 "On Conservation Areas." https://cbd.minjust.gov.kg/203262/edition/1205628/ru

The Law **"On Wildlife"**[71] and the Law **"On the Protection and Use of Flora"**,[72] mandates the establishment of state cadastres and monitoring. However, in practice, biodiversity monitoring is severely underfunded, resulting in fragmented data and a critical lack of an integrated system for continuous observation and systematic analysis.

State environmental monitoring is regulated by the Law "On Environmental Protection" (1999, Art. 29)[73] and covers air, water, soil, flora, and fauna. The main challenges are the sparse monitoring network, insufficient resources, and fragmented systems, which reduce the effectiveness of ecosystem protection.

Kyrgyzstan's national biodiversity policy is under development. The previous strategy set a specific goal – to increase the extent of protected areas to 10% of the country's total territory and to grant protected status to the most significant wetlands. At present, with the support of international partners, the development of a new long-term State Programme for Biodiversity Conservation until 2040 and an Action Plan for 2025-2030 is underway.[74]

3.1.2. National Legislation of the Republic of Tajikistan

The Water Code of the Republic of Tajikistan, adopted in 2020, establishes the principles for the rational use and protection of water resources. It defines the rights and obligations of water users, institutes the framework for basin management, and is fundamentally oriented towards preventing water pollution and depletion.[75] A key innovation of the Code is the statutory recognition of modern concepts such as 'integrated water resource management' (IWRM) and 'aquatic ecosystem.' The Code defines the latter as: "an interconnected system of living organisms and their natural environment, within which a cyclical exchange of mineral and organic substances and energy occurs in a water body." This definition is significant as it creates the legal basis for protecting not just water as a resource, but the entire natural complex it sustains.

The Code's Chapter 10 "Protection of Water Bodies" is of particular importance for ecosystem protection. It includes, among other provisions, a prohibition on the discharge of industrial and household wastes into water bodies, as well as on the pollution by petroleum products and chemical substances (Art. 77) and contains unique norms to protect glaciers and snowfields (Art. 78). The central instrument for protecting riparian ecosystems, including tugay forests, is Article 84, which introduces the concepts of "water protection zones" and "coastal protective strips." In addition, Article 85 provides for the possibility of granting water bodies or their parts that are of ecological or scientific significance the status of "specifically protected water bodies." This mechanism directly links water legislation with the **laws on protected areas**, enabling enhanced protection regimes for the most valuable ecosystems.

The **Law "On Environmental Protection"**[76] sets the legal framework for public policy on environmental protection and aims to ensure sustainable socio-economic development, guarantee human rights to a healthy and favorable environment, enhance the rule of law, prevent the negative environmental impacts of economic and other activities, promote the rational use of natural resources, and ensure environmental safety. It establishes obligations for maintaining state cadastres of natural resources, arranging environmental monitoring, and preventing water pollution and depletion. These provisions are further elaborated in the Law **"On Environmental Monitoring"** (2011)[77], which defines observation sites (water, air, soils, flora, fauna, pro-

[71] Law of the Kyrgyz Republic of 17 June 1999 No. 59 "On Wildlife." https://cbd.minjust.gov.kg/4-211/edition/1003925/ru

[72] Law of the Kyrgyz Republic of 20 June 2001 No. 53 "On the Protection and Use of Flora". https://cbd.minjust.gov.kg/435/edition/1003991/ru

[73] Law of the Kyrgyz Republic of 16 June 1999 No. 53 "On Environmental Protection". https://cbd.minjust.gov.kg/218/edition/6734/ru

[74] Ministry of Natural Resources, Ecology and Technical Supervision of the Kyrgyz Republic (23 June 2025). https://mnr.gov.kg/ru/posts/news/kyrgyzstan-obnovlyaet-nacionalnuyu-strategiyu-i-plan-deistvii-po-soxraneniyu-bioraznoobraziya-vazno-ucastie-kazdogo

[75] Water Code of the Republic of Tajikistan (No. 756 of 19 March 2020). https://www.mewr.tj/?p=1163

[76] Law of the Republic of Tajikistan No. 1160 "On Environmental Protection" (of 27 November 2014). https://tajtrade.tj/media/On%20environmental%20protection.pdf

[77] https://continent-online.com/Document/?doc_id=30983007#pos=0;141.60000610351562

tected areas, etc.), levels of monitoring and the purpose – detect changes and predict effects. This framework is complemented by the Law **"On Wildlife"**,[78] which provides for maintaining the state cadastre of wildlife (Arts. 49-50) and its use for monitoring and protection (Art. 8). Taken collectively, these legislative acts establish a systemic approach requiring the health of aquatic ecosystems to be accounted for through cadastre-based assessment and monitoring during the planning and use of water resources. However, in practice, the coverage and frequency of observations remain limited; therefore, the expansion of monitoring stations and better alignment of data collection with basin plans are urgently required.

The Law **"On Environmental Impact Assessment"**[79] links the EIA procedure with the state environmental expert review and introduces a classification of projects according to levels of impact.

The National Biodiversity Strategy and Action Plan of Tajikistan up to 2020 sets objectives for the rational use of natural resources and the achievement of sustainable development[80]. These strategic provisions are reflected in the principles and specific norms of the 2020 Water Code. By emphasizing integrated management and the protection of aquatic ecosystems, the Code creates the necessary legal framework to implement the provisions set out in the strategy.

3.1.3. National Legislation of Turkmenistan

The adoption of the new **Water Code** in 2016 – designed to "achieve and maintain an environmentally safe and economically optimal level of water use, and to ensure the protection of water resources to improve living conditions and preserve the environment" (Art. 3) – laid the groundwork for a more comprehensive approach to water management. The Code sets out requirements for maintaining water bodies in line with environmental standards, regulates the designation of water-protection zones and coastal protective strips along rivers, lakes, and other water bodies, and introduces strict rules for the discharge of wastewater (Arts. 105 and 108).[81]

The Code operates alongside the **Law "On Nature Protection"**[82] and the **Law "On Environmental Safety"**[83], which together form a multi-layered system of legal protection. The Law "On Environmental Safety" defines environmental safety as "a state of protection of the environment, life, and human health from potential adverse impacts," and assigns each citizen the responsibility to contribute to its safeguarding and to prevent environmental threats. For the protection of specific ecosystems, the **Law "On Protected areas"**[84] applies. It outlines several categories of protected areas, including state nature reserves and wildlife sanctuaries, and establishes the corresponding protection regimes for each.

The **Law "On Nature Protection"**[85] defines, among other provisions, the concept of state environmental monitoring and explicitly requires its continuous implementation, including in areas subject to intensive anthropogenic pressure. Its structure and procedures are regulated by the authorized state body (Art. 56).

The **Law "On Flora"**[86] provides for the maintenance of the state cadastre and the monitoring of flora (including under pp. 7-8, which fall within the competence of the Cabinet of Ministers). Similarly, the **Law "On the Animal World"**[87]

[78] https://faolex.fao.org/docs/pdf/taj84981.pdf

[79] https://faolex.fao.org/docs/pdf/taj183710.pdf

[80] https://www.cawater-info.net/pdf/tj-nbsap-v2-ru.pdf

[81] https://faolex.fao.org/docs/pdf/tuk184359.pdf

[82] https://unece.org/fileadmin/DAM/env/pp/compliance/MoP4decisions/Turkmenistan/Law_on_Nature_Protection.pdf

[83] https://caspianhouse.org/upload/2025/02/19/-c14a2a571739912858712694537105824 8.pdf

[84] https://online.zakon.kz/Document/?docid=31342511

[85] https://unece.org/fileadmin/DAM/env/pp/compliance/MoP4decisions/Turkmenistan/Law_on_Nature_Protection.pdf

[86] Law of Turkmenistan of 04.08.2012, https://faolex.fao.org/docs/pdf/tuk118784.pdf

[87] Law of Turkmenistan of 02.03.2013, https://turkmenistan.gov.tm/ru/post/19140/zakon-turkmenistana-o-zhivotnom-mire

establishes requirements for maintaining the state cadastre of wildlife and conducting wildlife monitoring (Art. 7, para. 6). This system is further complemented by the cadastre of protected areas (Art. 11 of the Law "On Protected areas"), which includes registration of species' habitats.

The National Biodiversity Strategy for 2018-2023[88] explicitly links nature conservation with water management. It outlines tasks for developing and implementing programs for the sustainable use of water and aquatic biological resources, with due consideration for biodiversity conservation. It also calls for strengthening environmental assessment procedures in sectors with significant ecosystem impacts, including water management and extractive industries. Special emphasis is placed on expanding the network of protected areas to 10% of the country's territory by 2030. The strategy underscores the importance of integrating conservation measures into agriculture and water management, as well as into climate change adaptation programs, thereby reinforcing the legal framework for protecting water-dependent ecosystems.

3.1.4. National Legislation of the Republic of Uzbekistan

Adoption of the new **Water Code** of the Republic of Uzbekistan[89] in 2025 marks a fundamental shift in the country's approach to water management. It explicitly establishes an ecosystem-based approach to water management as one of its core principles and, for the first time at the legislative level, declares the protection of water bodies to take precedence over their use. It also incorporates climate change considerations into the management and protection of water resources. The Water Code requires the provision of water releases for sanitary and environmental flow (Art. 122), including during the operation of hydropower plants (Art. 97) and reservoirs (Art. 84), and assigns them priority for water bodies of special national importance (Art. 119) as well as in water use generally (Art. 52). In addition, the protection objectives explicitly include preventing disruptions to the hydrological regime (Art. 115).

The Water Code operates in conjunction with the **Law on Protected areas**[90], which defines legal modalities for various categories of such areas. In the context of the Amu Darya Delta – where natural ecosystems have largely been replaced by artificial water bodies such as Zhyltyrbas – the legislation permits the establishment of protected zones to conserve biodiversity under these new conditions.

The new **Law on Environmental Expertise, Environmental Impact Assessment, and Strategic Environmental Assessment**[91] consolidates all three procedures into a single framework and extends their application to programs and plans, including those in the energy and water sectors. This is critically important for safeguarding water-dependent ecosystems at the stage of strategic planning.

The Law "On State Cadastres"[92] includes objects of the plant and animal world, and **the state environmental monitoring system**[93] covers observations of pollution sources, the quality of air, water, soils, flora, and fauna, and is maintained within a unified geoinformation database. However, there is still no explicit provision, for example, for consolidated monitoring within a single information system for environmentally vulnerable areas of the Aral Sea region or the dried seabed – current efforts are undertaken separately by individual research institutes and international projects.

The Biodiversity Conservation Strategy for 2019-2028[94] demonstrates a clear link between legislative reforms and practical action. The key objectives of the strategy are directly related to the restoration of ecosystems in the Amu

[88] National Biodiversity Conservation Strategy of Turkmenistan for 2018-2023, www.cbd.int/doc/world/tm/tm-nbsap-v2-ru.pdf

[89] Water Code of the Republic of Uzbekistan (30.07.2025, No. 25.03.1076/0672), https://lex.uz/ru/docs/7658581

[90] Law of the Republic of Uzbekistan No. 710-II of 03 December 2004, www.lex.uz/acts/415228

[91] Law of the Republic of Uzbekistan № ZRU-1036 of 24 February 2025, https://lex.uz/en/docs/7397289

[92] Law of the Republic of Uzbekistan № 171-II of 15.12.2000, https://lex.uz/docs/19480?ONDATE=07.06.2022

[93] Resolution of the Cabinet of Ministers of the Republic of Uzbekistan No. 737 of 05.09.2019, https://lex.uz/ru/docs/4502814#4504015

[94] Resolution of the Cabinet of Ministers of the Republic of Uzbekistan No. 484 of 11 June 2019, https://lex.uz/docs/4372841

Darya River basin: expanding the area of protected territories to 12% of the country's total area; afforesting the dried bed of the Aral Sea, bringing the area of forest plantations to 1.2 million hectares; and restoring and establishing tugay forests along rivers.

3.1.5. Comparative Basin-Level Perspective

A comparative analysis of the countries' legislation reveals a clear trend toward modernization and the adoption of contemporary, ecosystem-oriented approaches. The legal frameworks converge in recognizing basin-level management, the principles of integrated use and protection, and the need for spatial safeguards such as water-protection and riparian buffer zones, as well as protected areas.

BASIN MANAGEMENT AND PLANNING. The Water Codes of Kyrgyzstan, Tajikistan, and Uzbekistan establish systems of basin councils and basin plans, with the ability to account for the needs of water-dependent ecosystems and climate risks. Turkmenistan relies on basin schemes for integrated use and protection of water resources, where ecological parameters may also be taken into consideration, although the Code does not provide for the establishment of basin councils.

FLOW REGULATION AND WATER RELEASES FOR ENVIRONMENTAL FLOW. The countries differ in the level of detail with which they regulate water releases for environmental flow. Uzbekistan has incorporated sanitary and environmental water releases into its Water Code as mandatory measures for protecting river flow and ecosystems; the Ministry of Ecology is tasked with developing methodologies for calculating them, taking water availability into account. Kyrgyzstan has established a minimum environmental flow, although methodologies for determining it have not yet been developed. In Turkmenistan, the Water Code does not use the term "environmental flow," but employs functional equivalents: reservoir filling and release regimes that consider downstream needs, a system of permissions for structures that alter the natural flow, and limits on total storage volumes during low-water years. Tajikistan's legislation does not explicitly mention environmental water releases; their provision is possible through basin plans and operating regulations. For all countries, the development of unified methodologies and the implementation of single environmental flow standards remain priority tasks to ensure that existing norms become an effective tool for protecting water-dependent ecosystems.

WATER QUALITY. All countries apply a combination of pollution bans, permit-based regimes, sanitary protection zones, and state monitoring. Water quality assessment is conducted using national MACs (maximum admissible concentrations), which are defined by type of water use but largely fail to reflect basin-specific characteristics along the longitudinal river profile, interannual and seasonal flow variability, uneven water abstraction, and localized anthropogenic pressures. For integrated assessment, a unified Water Pollution Index (WPI) is used. Calculations rely on a strictly limited set of six indicators (including dissolved oxygen and BOD_5), selected based on their highest values regardless of MAC exceedance, using the formula: $WPI = (C_1/MAC_1 + C_2/MAC_2 + \ldots + C_6/MAC_6) / 6$, where C represents the actual concentration of the indicator, and 6 is the fixed number of parameters. This approach enables comparability but reduces sensitivity to spatial and hydrological specifics of each basin. In this context, for better protection of water-dependent ecosystems, it would be advisable to supplement national indices with basin-specific criteria, such as the proportion of environmental flows, seasonal flow distribution, and zonal biotic indicators.

BIODIVERSITY CADASTRES. All countries have established legal foundations for maintaining state cadastres of plant and animal species[95]. Despite a shared general approach, there are notable differences in how the objects of these cadastres are defined. For example, Kyrgyz legislation explicitly includes protected areas (PAs) among the cadastre's objects. In Uzbekistan, the cadastre covers all species (and subspecies) of wild animals inhabiting the national territory and included in the official list of wild species. A common gap

[95] The State Cadastre of Flora and Fauna includes a systematized body of data on the distribution, spatial patterns, and quantitative and qualitative characteristics of flora and fauna within the country. The cadastre is maintained for the purposes of accounting, control, and the rational use of biological resources

across all countries is the weak integration of biodiversity cadastres with water and land cadastres, which limits their practical value for assessing and protecting water-dependent ecosystems. Additional constraints include insufficient funding, irregular field surveys, and the lack of comprehensive digital platforms with open access.

ENVIRONMENTAL MONITORING is established in all countries with the aim of identifying, assessing, and forecasting changes in environmental conditions, as well as developing measures for the protection and rational use of natural resources[96]. It covers water, air, and soil quality, as well as the state of biodiversity, but the level of system development varies significantly. Uzbekistan has the most institutionalized monitoring system; however, it still requires further basin-level differentiation and an expanded network of monitoring stations. In Tajikistan and Kyrgyzstan, monitoring is conducted by sectoral agencies but is characterized by infrequent measurements, limited technical capacity, and insufficient spatial coverage. In Turkmenistan, a monitoring system exists, but the monitoring network is small and data are published selectively. Common challenges across all countries include insufficient sensitivity to seasonal and interannual variability of river flow, limited use of bioindicators, and restricted public access to monitoring results – all of which reduce the effectiveness of monitoring for protecting water-dependent ecosystems and for assessing cumulative impacts.

Limited access to monitoring results and cadastre data makes it **practically impossible to track changes in biodiversity status**. To increase the informational and regulatory value, it is recommended to: develop a set of indicators that reflect ecosystem degradation criteria; systematically incorporate the water factor into national reporting; improve the methodology and technical basis of cadastres and monitoring; ensure data openness and integration into digital platforms; develop thematic mapping of degradation processes; and establish a unified data repository accessible for interagency and transboundary use.

PREVENTIVE ASSESSMENT. Environmental impact assessment procedures exist in all basin countries. They are most comprehensively developed in Uzbekistan under the 2025 Law, which introduced a three-tier model consisting of state environmental expertise (SEE), environmental impact assessment (EIA), and strategic environmental assessment (SEA). The Law also requires the assessment of transboundary impacts (Art. 29). This creates a basis for analyzing cumulative and transboundary effects not only of individual projects but also of major development programs and plans, including those in hydropower, irrigation, and large infrastructure construction (Art. 30). In Turkmenistan (2014) and Tajikistan (2017), the regulatory framework is limited to EIA, which applies to individual project decisions but remains insufficiently developed with respect to the assessment of strategic documents (programs and plans). In particular, expert review is required for pre-project and project documentation for facilities of international significance (Turkmenistan, Art. 11), as well as for national and local projects, sectoral concepts, forecasts, programs, and schemes whose implementation involves the use of natural resources and/or may affect the environment (Tajikistan, Art. 9). Among the basin countries, only Turkmenistan and Uzbekistan are Parties to the Convention on the Protection and Use of Transboundary Watercourses and International Lakes. Article 9(j) of the Convention establishes obligations for bilateral and multilateral cooperation, including participation in environmental impact assessment related to transboundary waters.

THE EXPANSION OF SEA PRACTICE IN THE COUNTRIES is a short-term priority, as it is exactly at a strategic level the key decisions are made on flow redistribution, construction of reservoirs, hydropower facilities, and irrigation systems. Unlike project-level EIA, which evaluates the impacts of an already planned project, SEA enables the prior consideration of alternative development scenarios (for example, the balance between hydropower and irrigation); the incorporation of long-term climate trends and interannual flow variability; the analysis of cumulative impacts from a series of projects within a single basin (such as a cascade of reservoirs); the integration of requirements for environmental flows and for the conservation of tugay forests and wetlands into the planning process; and greater transparency and public participation – particularly important in the transboundary context of the Amu Darya River. For the basin, where the ecological stability of rivers directly depends on

[96] This is an environmental monitoring system that implies the collection, processing, analysis, and storage of data on the state of the atmospheric air, water, land, subsoil, flora and fauna, as well as the impact of various factors on them

coordinated strategic-level decisions, SEA becomes a key instrument for integrating environmental criteria into water management. Without its systematic application, there is a high risk that – even with project-level EIAs – cumulative effects such as reduced flow in the delta, floodplain fragmentation, and wetland degradation will remain unaddressed.

STRATEGIC BIODIVERSITY DOCUMENTS in the countries further reinforce the regulatory framework for ecosystem-oriented water management. In Turkmenistan, for example, the 2018–2023 strategy directly links the rational use of water resources and the expansion of the protected area network to the goals of preventing erosion and desertification, as well as to strengthening EIA requirements in high-impact sectors. In Uzbekistan, the 2019-2028 strategy aligns its objectives with the post-2020 Global Biodiversity Framework and includes a financial needs assessment, enabling the integration of measures for the conservation of wetlands in the delta and lower reaches of the Amu Darya River into public plans and budgets.

3.1.6. Conclusion: Common Tasks for the Future

The analysis of national legislation of the Amu Darya River basin countries demonstrates a dual, yet encouraging, outcome. On the one hand, there is **clear positive progress:** the new Water Codes of Kyrgyzstan (2025), Tajikistan (2020), Turkmenistan (2016), and Uzbekistan (2025) have established the basin approach, expanded protection regimes, and integrated ecosystem-based approaches and climate factors into water management. On the other hand, **problems in law enforcement** persist, driven by limited capacity, competition between sectoral priorities, weak interagency coordination, and the lack of reliable and comprehensive data and access to them. The absence of an integrated, reliable, and publicly accessible system for monitoring the quality and quantity of water hinders informed decision-making and complicates transboundary cooperation, which must be based on shared, unbiased data.

The primary task for the near future is not so much the development of new laws, but **ensuring that existing legislation effectively protects ecosystems**. This requires coordinated efforts by basin countries to operationalize adopted norms through methodologies, digital tools, and transparent enforcement.

To translate legal intentions into measurable environmental outcomes, the countries need to establish shared priorities. **First**, regulatory elaboration of methods for calculating and ensuring compliance with environmental (minimum) flows in sensitive river sections and in the delta – establishing threshold values, responsibilities, and implementation monitoring. **Second**, expansion of SEA to enable early consideration of cumulative and transboundary effects in water, energy, and irrigation planning. **Third**, creation and integration of digital cadastres for water-protection zones, protected areas, biodiversity, and water and land resources, with open access and interagency oversight, to allow comprehensive assessment of ecosystem conditions at the basin level. **Fourth**, modernization of water quantity and quality monitoring, including expanding the network of stations, accounting for seasonal and interannual variability, introducing bioindicators, and ensuring open publication of data.

Joint coordination and harmonization of actions – from methodologies for environmental flows to publicly accessible monitoring platforms – can transform accumulated regulatory progress into tangible conservation outcomes for ecosystems of the Amu Darya River.

3.2. Regional mechanisms

3.2.1. Regional Agreements on Water and Environmental Cooperation

The basis for water and environmental cooperation among the countries of the Amu Darya River basin was laid by two five-party agreements in the early 1990s that formalized the principles of joint water management and protection.

Agreement on cooperation in the field of joint management, use and protection of water resources in interstate sources" (Almaty, 18 February 1992)[97] set the principles of joint and rational use and protection of waters (Arts. 1-3), the annual approval of water-use limits (Art. 8), the coordination of reservoir operation regimes (Art. 8), the exchange of information and the joint research (Art. 5). The Agreement has special provisions for joint actions on environmental problems of the Aral Sea drying up and for determining the quantity of sanitary (environmental) flow for each concrete year based on water availability, with provisions for tailored decisions in exceptionally low-water years (Art. 4). To implement these tasks, the Interstate Commission for Water Coordination (ICWC) was established and mandated to define water policy and coordinate efforts for the rational use of water resources (Arts. 7-8, 10).

Agreement on joint activities in addressing the Aral Sea and the zone around the Sea crisis, improving the environment, and ensuring the social and economic development of the Aral Sea region (Kyzylorda, 26 March 1993)[98] focuses on joint actions to mitigate the consequences of the Aral catastrophe and rehabilitate the Aral region. Article 1 explicitly defines the areas of joint measures: rational use of land and water resources, maintaining adequate water quality, ensuring water supply to the Aral Sea in quantities that allow maintaining its reduced but stable water area at an environmentally acceptable level, restoring balance in degraded ecosystems, conserving biological diversity, establishing protected areas, and others. The Agreement also formalized the establishment of the International Fund for Saving the Aral Sea (IFAS) as a key institution for regional coordination and guided the Parties to develop and implement a joint action program (Art. 2), which later became the basis for the Aral Sea Basin Program (ASBP).

These agreements laid the groundwork for regional water and environmental cooperation: the Almaty Agreement established mechanisms for operational flow management, while the Kyzylorda Agreement provided the political and institutional framework for IFAS-led regional initiatives.

3.2.2. IFAS and ASBP-4

THE INTERNATIONAL FUND FOR SAVING THE ARAL SEA (IFAS), established in 1993, serves as an "umbrella" institution for regional cooperation on water and environment among the Central Asian countries, linking the political level (Council of Heads of State, Board) with technical and scientific bodies (ICWC/BWOs/SIC, ICSD/SIC).

THE ARAL SEA BASIN PROGRAM (ASBP) is the main programmatic instrument of IFAS that translates broad agreements into a coordinated portfolio of projects, including those related to the Amu Darya River. ASBP-4 for 2020-2030, approved by the IFAS Executive Committee on 29 June 2021, encompasses water, environment, socio-economic, and institutional-legal spheres to achieve measurable results: modernization of monitoring and data exchange; climate-adaptive planning and glaciological monitoring; restoration of delta ecosystems and wetlands; water saving and the "green" economy; as well as institutional strengthening of IFAS. Specific projects under ASBP-4 and their relevance for joint actions for the Amu Darya ecosystems are summarized in Table 13. If effectively implemented, they can create conditions for coordination of water releases to maintain environmental flow, transparent monitoring, and upscaling of nature-based solutions.

[97] http://icwc-aral.uz/statute1_ru.htm

[98] http://icwc-aral.uz/statute13_ru.htm

TABLE 13
ASBP-4 areas and projects relevant for joint actions

ASBP-4 area | project	Relevance
1. INTEGRATED WATER RESOURCE USE	
1.6. Implementation of automated control systems for technological processes related to distribution, accounting and monitoring of water resources; Development of national water information systems as a basis for a regional information system	A common data platform on flow, water level and quality along the Amu Darya for coordinating schedules and water releases to maintain environmental flow
1.12. Implementation of water saving technologies and water reuse in water user-sectors	Lower water abstractions guarantee more that environment flows are maintained and help sustain the Amu Darya floodplain/delta
1.13. Building the capacity and strengthening the material and technical base of regional and national water management organizations	Improved water-use discipline and more effective management of ater releases to maintain environmental flow
2. ENVIRONMENTAL	
2.7. Development of a monitoring system for the conditions of ake systems and water resources in the Aral Sea region and on the dried seabed	A basic observation system for managing and planning measures for wetlands and tugay forests
2.11. Reducing the risks of natural disasters (floods, mudflows and droughts) in the Aral Sea basin	Protection of flow generation zones and mitigation of damage to floodplains and the delta during extreme events
3. SOCIO-ECONOMIC	
3.4. Development of ecotourism and increasing tourism potential	Community support for floodplain and delta protection measures; job diversification
3.5. Development of renewable energy sources and energy efficiency	Indirectly reduces water intensity of economy and the load on river flow
4. IMPROVEMENT OF INSTITUTIONAL AND LEGAL MECHANISMS	
4.1. Improvement of institutional and legal basis of IFAS (including the development of water-energy cooperation mechanism)	Integration of water-energy-ecosystem nexus into activities of regional organizations
4.2. Improvement of water management institutions at national level	Translating regional agreements into practice: adhering to schedules and ensuring control of water releases for environment and water quality

3.2.3. ICSD and 2030 REP4SD CA

THE INTERSTATE COMMISSION ON SUSTAINABLE DEVELOPMENT (ICSD) was established by the decision of the Interstate Council for the Aral Sea Basin in 1993. It is entrusted with the mission of coordination and management of regional cooperation in the field of environmental protection and sustainable development of the CA states[99].

ICSD is one of the commissions operating under umbrella of IFAS. It consists of 15 members – three representatives per state (ministers of environment, deputy ministers of economy, representatives of academia and other sectors), assigned by their respective governments.

[99] https://sic-icsd.com.tm/ru/o-nas/mkur

REGIONAL ENVIRONMENTAL PROGRAM FOR SUSTAINABLE DEVELOPMENT IN CENTRAL ASIA (REP4SD CA)[100] is a strategic, framework document that defines priority areas of regional cooperation in the field of environmental protection until 2030. The document was developed as part of ICSD activities and agreed upon by the countries. It sets the priorities for joint work: water (SDG 6), climate adaptation, the "green" economy, ecosystem protection and partnerships. The water pillar of the Program calls for establishing a regional database on water treatment and reuse, improving water quality monitoring in the Aral Sea Basin, and analyzing techno- and natural impacts to prevent degradation of water-related ecosystems. The ecosystem pillar includes measures for restoration of delta lakes and tugay forests in river valleys, and the development of common methodology for ecosystem accounting and mapping. The climate block includes preparation of a regional adaptation strategy, monitoring of glaciers, and generation of a GIS atlas of hazardous processes – a basis for managing both flow generation and dispersion zones. Below is a summary (Table 14)

TABLE 14
2020-2030 REP4SD CA priority areas and measures relevant for joint actions on the Amu Darya River ecosystems

Priority areas and measures	Relevance
1. CAPACITY BUILDING: 1.1. Capacity building of existing institutions including training, retraining of personnel. 1.2. Knowledge sharing and scientific cooperation, joint trainings, conferences. 1.3. Development of a system of indicators for monitoring of SDGs.	▪ Common expertise on assessment and implementation environmental flow. ▪ Harmonization of water quality and biodiversity monitoring methodologies. ▪ Common indicators for assessing ecosystem status.
2. WATER AND WATER QUALITY: 2.1. Development of a regional database on wastewater treatment and reuse. 2.2. Ensuring efficiency of water quality monitoring in the Aral Sea Basin. 2.3. Analysis of anthropogenic and natural impacts to prevent water-related ecosystem degradation.	▪ Reduced water abstractions and loads on the river course, greater guarantees for environmental flow. ▪ Comparable data on water quantity and quality from headwaters to delta. ▪ Accounting for cumulative effects (dams, droughts, discharges) in flow management.
3. "GREEN" ECONOMY AND SUSTAINABLE NATURE MANAGEMENT: 3.1. Needs Assessment Study for RES, waste management and clean transport infrastructure. 3.2. Cooperation in adoption of green technology. 3.3. Regional Center for Waste Management. 3.4. Promotion of environmentally friendly modes of transport, sustainable financing. 3.5. Cooperation with international initiatives	▪ Reduced pressure on river flow through alternative technologies and water reuse. ▪ Less non-point pollution of the river network. ▪ Attraction of investment in "green infrastructure" of tugay forests and delta lakes.
4. CLIMATE CHANGE AND ADAPTATION: 4.1. Development of a Regional Strategy for Adaptation. 4.2. Implementation of regional projects jointly with donor agencies. 4.3. Consideration of climate risks in country strategies. 4.4. Monitoring of the glaciers and development of GIS-atlases of hazardous processes.	▪ Management of flow generation zones. ▪ Account of interannual and seasonal variability in water allocation. ▪ Preventive protection from floods and glacial lake outburst.
5. ECOSYSTEMS AND BIODIVERSITY: 5.1.1. Ecosystem approach in strategies and approaches. 5.1.2. Sustainable management of forests, land, and pastures. 5.1.3. Development of a unified methodology for ecosystem inventory. 5.1.4. Regional ecosystem restoration scheme (green belts, delta lakes). 5.2.1. Red Book of Central Asia. 5.2.3. Ecological corridors and transboundary protected areas. 5.2.6. Sustainable management of wetlands. 5.2.7. Restoration of tugay forests in the Amu Darya, Syr Darya and Panj river valleys.	▪ Direct restoration of flow dispersion zones. ▪ Maintaining migration routes of water fowl and spawning habitats. ▪ Strengthening the buffer role of ecosystems under water scarcity.
6. INSTITUTIONAL COOPERATION AND REGIONAL COLLABORATION: 6.1. Involvement in global environmental conventions. 6.2. Cooperation with organizations for better access to technologies and finance. 6.3. Strengthening of legal and institutional frameworks of ICSD and regional institutions. 6.4. Development of guidelines and standards for SEA. 6.5. Joint activities for the UNESCO World Heritage Sites. 6.7. Promotion of "South-South" cooperation.	▪ Embedding environmental requirements into the work of ICWC/BWO and strengthening ICSD. ▪ Expanding access to financing for restoration of delta ecosystems. ▪ Harmonized SEA methodologies – accounting for cumulative effects at the planning stage. ▪ Transparency and trust among countries regarding flow allocation

[100] https://sic-icsd.com.tm/ru/ru/strategii-i-programmy/rpoosur

of REP4SD priorities and measures that are relevant for joint conservation of the Amu Darya ecosystems (flow generation and dispersion zones).

The Program is supported by the **Roadmap (2021-2025)**[101], which ranks priorities and aligns them with national strategies and financing; it explicitly positions REP4SD and ASBP-4 as complementary frameworks for water and environmental projects across the basin.

Thus, REP4SD provides a regional agenda and roadmap that incorporate the essential elements for protecting the ecosystems of the Amu Darya River – from data and monitoring to delta restoration and mountain-area adaptation. Its effectiveness will depend on proper and timely implementation of the measures and projects it outlines.

Thus, REP4SD represents a regional agenda and a roadmap that contain necessary elements for protecting the ecosystems of the Amu Darya River – from data and monitoring to delta restoration and adaptation of mountain areas. Its effectiveness will depend on the proper and timely implementation of the measures and projects outlined.

3.2.4. ICWC and Its Role in Meeting Ecosystem Needs

THE INTERSTATE COMMISSION FOR WATER COORDINATION OF CENTRAL ASIA (ICWC)[102] was established on the basis of the Almaty Agreement in 1992 as a key mechanism for coordinated water allocation and operational management water resources in interstate sources. Within its mandate, the ICWC annually approves water withdrawal limits for the basin countries and seasonal reservoir operation schedules, with the following their implementation by its executive body – Basin Water Organization Amu Darya (BWO Amu Darya). A major strength of the ICWC is the country-recognized procedure for coordinating water limits and operation regimes of the Nurek, Tuyamuyun and other reservoirs, as well as its built-in mechanisms for responding to high- and low-water years (including intra-annual re-allocation). However, ensuring required quantities and appropriate regimes of water for ecosystems has remained a challenge.

Since the late 1990s, the need to account for sanitary-environmental flow for the lower Amu Darya and the Aral Sea region has been repeatedly emphasized at ICWC meetings and in decisions of the IFAS Board. The ICWC meeting in Kyzylorda (8-9 July 1993) made the following decision: "Water users must strictly observe water withdrawal limits and the established quantities of water to be delivered to river deltas and the Aral Sea. BWO Amu Darya and BWO Syr Darya shall treat the Aral Sea and the Aral region as an independent water user and ensure water supply in accordance with established limits".[103] This way, quantities for sanitary-environmental flow were formally established; however, their implementation in practice was highly irregular, particularly during low-water years. Figure 11 above clearly illustrates the inflow to the South Aral region under different flow conditions.

The issue of who should represent – and, when necessary, defend – the interests of the Aral Sea and the Aral region in water allocation has also been raised in connection with designating the Aral and the Aral region as a water user. The first candidate, who was even invited to ICWC meetings from 1992 to 1997, was Karakalpakstan – the region most affected by the Aral Sea disaster. However, since 1998, the practice of participation of Karakalpakstan in ICWC meetings has ceased. The second candidate was the Executive Committee of IFAS, which already has a regional status. On 22 April 1997, a special appeal was sent by ICWC members to the IFAS Board members, noting the advisability of involving the IFAS Executive Committee "as the sixth member of the ICWC to represent the interests of the Aral Sea and the Aral region".[104] However, this issue also remained unresolved.

[101] ICSD and UNEP (2021). Sustainable development roadmap. https://sic-icsd.com.tm/uploads/2021-07-12_REP4SD_Roadmap_ICSD&UNEP.pdf

[102] ICWC website: http://www.icwc-aral.uz/

[103] Protocol of ICWC meeting of 8-9 July 1993, Kyzylorda, http://www.icwc-aral.uz/meetings5_ru.htm

[104] Protocol of the 17th ICWC meeting of 26 September 1997, Tashkent, http://www.icwc-aral.uz/minutes/17-ru.pdf

Nevertheless, the ICWC and its executive bodies continue working in this direction. In particular, SIC ICWC played a key role in preparation of scientific rationale for the environmental flow required to sustain the delta and lake systems in the South Aral region and in developing practical recommendations for their implementation.[105] Continuing this work, the Center has prepared several purpose-specific publications, including on "Environmental flow"[106], "Problems of Integrated Management, Rational Use and Protection of Water Resources in Central Asia"[107], and "Environmental Flow in Laws and Practices of the Republic of Uzbekistan and Measures for Improvement".[108]

Overall, ICWC has confirmed its central role as a platform for coordination of water-withdrawal limits/quotas and seasonal reservoir operation regimes, thereby ensuring predictability of water allocation during both high- and low-water years. At the same time, as noted above, the ecosystem needs of the lower Amu Darya – the delta and the Aral region – continue to be met irregularly.

A practical avenue for improvement is to operationalize ecosystem objectives within the existing ICWC mandate by: (i) establishing dedicated monitoring of compliance with environmental flow and water quality; (ii) forming a working group specifically for ecosystems at ICWC, with the involvement of BWO, environmental agencies, and expert organizations; (iii) ensuring regular participation of a representative of the downstream area (with consultative status); and (iv) deploying a shared digital database on key sections of the Amu Darya. Together, these steps would link quota-based water allocation with ecosystem needs, reduce irregularity of water releases to maintain sanitary-environmental flow, and enhance transparency in decision-making.

3.2.5. Regional Climate Change Adaptation Strategy for Central Asia

The Regional Climate Change Adaptation Strategy for Central Asia is a framework document agreed upon by all five countries of the region that defines common priorities until 2030.[109] The Strategy aims at strengthening regional coordination, developing jointly adaptation projects, exchanging knowledge, and advancing climate monitoring systems.

The document identifies six priority and most vulnerable areas for joint action: water resources, energy, agriculture, public health, natural ecosystems, and climate-related natural disasters. In the context of ecosystems of the Amu Darya River, the Strategy provides for concrete measures directly concerning both the zones of flow generation (mountains and glaciers) and the zones of flow dispersion (floodplains and deltas). These include regional glacier monitoring, development of unified methodologies for assessing ecosystem vulnerability, and implementation of joint ecosystem restoration projects.

The Table below presents the key Strategy areas and measures that are directly relevant to ecosystems of the Amu Darya Basin.

[105] Dukhovnoy, V. A. (Ed.), & De Schutter, J. (Ed.). (2003). South Prearalie – New Perspectives. Tashkent: Ecotec Resource, SIC ICWC. https://www.cawater-info.net/library/eng/nato_eng.pdf

[106] SIC ICWC. (2018). Environmental Flow. Tashkent: SIC ICWC. https://cawater-info.net/library/rus/01_eco.pdf

[107] SIC ICWC. (2004). Problems of Integrated Management, Rational Use and Protection of Water Resources in Central Asia. Collection of Papers. https://www.cawater-info.net/library/rus/sb_tr_08.pdf

[108] Yarullina, Z. R. "Environmental Flow in Laws and Practices of the Republic of Uzbekistan and Measures for Improvement", Scientific Notes of SIC ICWC No. 24, 2024. Tashkent. http://cawater-info.net/library/rus/sic-icwc_proceedings_24_2024.pdf

[109] Green Central Asia. (2024). Regional Climate Change Adaptation Strategy for Central Asia (2023-2030). https://greencentralasia.org/wp-content/uploads/2024/05/strategy-eng.pdf

TABLE 15
Priorities of the Regional Climate Change Adaptation Strategy relevant to the Amu Darya Ecosystems

Strategic objectives	Relevance for Amu Darya ecosystems
OBJECTIVE 1: STRENGTHEN REGIONAL COORDINATION: Supporting participation and forming common positions. Building capacity of national and regional authorities.	Coordinated position on environmental flows and water management. Common approaches to ecosystem assessments.
OBJECTIVE 2. ADAPTATION PROJECTS AND FINANCING: Joint development of adaptation projects. Mobilization of resources from climate funds.	Attracting investments for projects on restoration of tugay forests and delta lakes. Financing the modernization of monitoring systems.
OBJECTIVE 3. SHARING OF KNOWLEDGE AND SCIENTIFIC COOPERATION: Development of common methodologies for vulnerability assessment. Joint development of training materials.	Common methodology for mapping and inventory of ecosystems from headwaters to delta. Capacity building in ecosystem-based adaptation.
OBJECTIVE 4. MONITORING, INFORMATION AND FORECASTING: Expanding and modernizing observation networks. Joint glaciological monitoring. Development of regional climate models.	Management of flow generation zones through glacier monitoring. Improved forecasting of river flow and extreme events (floods, droughts). Comparable data for the whole basin.

3.2.6. Conclusion: Institutional Capacity and Next Steps

The existing regional agreements have laid a ground for cooperation: they ensured the establishment of IFAS, ICWC, and ICSD, established the principles of water allocation, helped prevent conflicts, and formalized environmental objectives.

These arrangements remain the cornerstone of joint water management. However, emerging challenges – climate change, ecosystem degradation, the need for regular environmental flow, and water quality – call for an update of the institutional and legal framework.

At present, ICWC and its executive body, BWO Amu Darya effectively implement operational allocation of water limits, but their mandates are limited and do not fully encompass ecological functions. IFAS coordinates regional programs, yet lacks sufficient authority to enforce the implementation of decisions at the national level. ICSD shapes the broader sustainable development agenda through REP4SD CA, but its interaction with ICWC on water and environmental issues remains limited.

For nature-based and climate-resilient water management, it is essential to strengthen the mandates of IFAS organizations, enhance coordination, and take measures to adopt modern ecosystem-based priorities. An important step in this direction is the Regional Climate Change Adaptation Strategy for Central Asia (2023) adopted by all five countries. This strategy provides a common framework for harmonizing actions in the most vulnerable sectors – including water resources and natural ecosystems – and aims to strengthen joint monitoring and mobilize financing for adaptation measures.

Another sign of growing political attention to environmental issues is the signing of the Agreement on Cooperation in the Field of Environmental Protection within the Shanghai Cooperation Organization (SCO) in July 2024.[110] Covering areas such as biodiversity conservation, combating desertification, and cooperation on protected areas, the agreement establishes a new intergovernmental platform for deeper collaboration, including for the countries of the Amu Darya River basin.

[110] Agreement on Cooperation in the Field of Environmental Protection (July 4, 2024, Astana, Kazakhstan). Uzbekistan has ratified the Agreement among the Central Asian countries (PP-292 of September 26, 2025).
https://mid.ru/ru/foreign_policy/international_contracts/international_contracts/multilateral_contract/62629

It is also necessary to consider the possibility of strengthening the mandate of ICWC or BWO Amu Darya regarding the enforcement of approved water use limits and environmental flows. This may include the development of legal and institutional mechanisms for responding to cases of exceeding limits or non-compliance with obligations.

Additional attention should be paif to advancing scientific cooperation through joint expeditions, data sharing, and analytical work. The countries are already moving in this direction by a decision of the heads of state, and recent strategic documents further reinforce this commitment.

3.3. Multilateral Environmental Agreements

Multilateral environmental agreements play a key role in shaping the legal and institutional framework for conservation of ecosystems and sustainable use of natural resources. This section reviews the most significant international conventions and treaties to which the Amu Darya basin countries are parties, as well as their relevance for ecosystem protection and integration of environmental objectives into water planning and governance.

3.3.1. UN Convention on the Protection and Use of Transboundary Watercourses and International Lakes

The 1992 UN Water Convention (Helsinki)[111] obliges the riparian States to prevent, control, and reduce transboundary impact (Art. 2), ensure the reasonable and equitable use of waters (Art. 2, para. 2(c)), and conduct joint monitoring and assessment of water resources, joint research, and information exchange (Arts. 11-13). The Convention separately emphasizes the need to protect aquatic ecosystems and maintain their stability (Art. 2, para. 2(d)), as well as to promote the sustainable management of water resources, including the application of the ecosystem approach (Art. 3, para. 1(i)). In the Amu Darya basin, the Parties to the Convention are Uzbekistan and Turkmenistan.

A number of documents have been developed under the Convention and provide a basis for ecosystem-based management, including:

- Recommendations to Governments on Ecosystems-Based Water Management (1992) and the Guidelines on the Ecosystem Approach (1993) – specify the provisions of Arts. 2 and 3 of the Convention regarding the prevention of ecosystem degradation and integration of ecosystem needs into planning.
- Recommendations on Payments for Ecosystem Services in IWRM (2007) – an instrument for implementing Art. 2, para. 6 (economic measures and incentives).
- WEFE Nexus tools (methodology, solutions and investments, assessments on the Syr Darya) – developing Arts. 2 and 9 on the reasonable use of water by linking water, energy, agriculture, and ecosystems.
- Water and Climate Change Adaptation in Transboundary Basins (2015) – advancing the provisions of Arts. 2 and 13 on risk management and information exchange.

The Water Convention and its guidelines provide the Amu Darya basin countries with a ready-made framework for translating ecosystem objectives into operational decisions through coordinated environmental flows and water quality indicators, information exchange, development of joint monitoring and assessments, and the application of other cooperation instruments (Table 16).

[111] Convention on the Protection and Use of Transboundary Watercourses and International Lakes (17 March 1992, Helsinki). www.un.org/ru/documents/decl_conv/conventions/watercourses_lakes.shtml

TABLE 16
Applicability of the 1992 Convention to joint actions on the Amu Darya River

Convention's Article (key provisions)	Applicability
ART. 2. GENERAL PROVISIONS: States shall prevent, control and reduce transboundary impact; ensure the reasonable and equitable use of waters; take measures to conserve and, where necessary, restore ecosystems	Basis for incorporating environmental flow into interstate allocation schedules and for restoring deltaic wetlands
ART. 3. PREVENTION, CONTROL AND REDUCTION OF TRANSBOUNDARY IMPACT: use of best available technologies; development of water quality criteria; application of more stringent measures when required for ecosystem protection; implementation of EIA	Opportunity to harmonize water quality objectives and ensure their compliance; application of EIA to hydraulic structure operation regimes and irrigation
ART. 4. MONITORING: establishment and maintenance of programs of monitoring the condition of transboundary waters	Joint network of gauging stations for discharge, water level and water quality, and assessment of ecosystem status
ART. 5. RESEARCH AND DEVELOPMENT: cooperation on scientific research and exchange of results, including environmentally sound water management	Development of methods for calculating minimum environmental flows and bioindicators of tugay/delta ecosystem condition
ART. 6. EXCHANGE OF INFORMATION: regular exchange of data on the condition of transboundary waters	Establishment of a common data system on the Amu Darya (discharge-level-quality) accessible to all basin countries
ART. 9. BILATERAL AND MULTILATERAL AGREEMENTS AND JOINT BODIES: States shall conclude agreements and establish joint bodies to implement the Convention	Strengthening mandates of existing regional organizations, including on environmental flow and water quality
ART. 11. JOINT MONITORING AND ASSESSMENT: coordination of monitoring programmes; joint assessments of conditions of waters; publication of results	Joint assessments; regular reports on the conditions of waters and ecosystems
ART. 12-13. COMMON RESEARCH AND EXCHANGE: joint research; exchange of information on conditions of water, pollution sources and measures	Harmonization of national methods for accounting flow and pollution; development of a shared database for planning water releases
ART. 14. WARNING AND ALARM SYSTEMS: establishment of early-warning systems for emergency situations	Early warning of floods, droughts and emergency discharges to minimize ecosystem damage

3.3.2. UN Convention on the Law of the Non-Navigational Uses of International Watercourses

THE 1997 UN WATERCOURSES CONVENTION[112] establishes general rules for the use and protection of international watercourses: equitable and reasonable utilization and participation (Arts. 5-6), the obligation not to cause significant harm (Art. 7), cooperation (Art. 8), data and information exchange (Art. 9), and notification of planned measures (Arts. 11-19), as well as specific articles on the protection of ecosystems, prevention of pollution, and flow regulation (Arts. 20-26) (see Table 17).

In the Amu Darya Basin, Uzbekistan is the only Party to the Convention but many of its provisions constitute customary international law, and therefore apply to all states, even those that are not Parties to it.

TABLE 17
Applicability of the 1997 Convention to joint actions on the Amu Darya River

Convention's Article	Applicability
ARTICLE 1-2: Scope of application; Use of terms ("watercourse", "international watercourse")	Establishes that the norms cover both surface and connected groundwater
ARTICLE 3-4: Watercourse agreements; Parties to watercourse agreements	Allows adapting regional agreements to the principles of the Convention and involving concerned states when concluding agreements on individual reaches of the watercourse
ARTICLE 5-6: Equitable and reasonable utilization and participation; factors relevant to equitable and reasonable utilization	Legal framework for balancing the interests of all countries: taking into account hydrology, ecology, demography, alternatives and water saving when planning water allocation and environmental flows
ARTICLE 7: Obligation not to cause significant harm	May provide for the adjustment of discharge/abstraction regimes when there is a risk of harm to ecosystems
ARTICLE 8-9: General obligation to cooperate; Regular exchange of data and information	Defines procedures and mechanisms for regular interaction
ARTICLE 10: Relationship between different kinds of uses	Helps resolve water-use conflicts based on Articles 5–7 and vital human needs
ARTICLE 11-19: Planned measures (notification, information, assessment of possible effects, consultations, etc.)	Procedure for notification and consultations on new hydraulic structures/regimes to account for cumulative effects on the river and ecosystems
ARTICLE 20: Protection and preservation of the ecosystems of international watercourses	Direct mandate for an ecosystem approach and maintaining ecosystem needs in flow regulation
ARTICLE 21-23: Prevention, reduction and control of pollution; Introduction of new/alien species	Goals/measures on water quality and biosafety
ARTICLE 24-26: Management; Regulation; Installations related to international watercourses	Legal framework for flow regulation and joint management of hydraulic structures with ecological objectives
ARTICLE 28: Emergency situations	Joint preparedness plans and early warning of floods/droughts/accidents
ARTICLE 33: Settlement of disputes (including fact-finding, arbitration/ICJ upon request)	Mechanisms in case of dispute; encourages preventive agreements

[112] Convention on the Law of the Non-Navigational Uses of International Watercourses. Adopted by UN General Assembly Resolution 51/229 of 21 May 1997. www.un.org/ru/documents/decl_conv/conventions/watercrs.shtml

3.3.3. Convention on Biological Diversity

CONVENTION ON BIOLOGICAL DIVERSITY (Rio de Janeiro, 1992), to which all basin countries are Parties, establishes three equally important objectives: (i) conservation of biological diversity, (ii) sustainable use of its components, and (iii) fair and equitable sharing of benefits arising from the utilization of genetic resources. It obliges its Parties to integrate biodiversity into national policies, develop monitoring and accounting systems, expand protected areas, conduct impact assessments, exchange data and technologies (Table 18). The Convention also provides the framework for access and benefit-sharing through the Cartagena (2000) and Nagoya (2010) Protocols. For the countries of the Amu Darya basin, it serves as a legal and programmatic basis enabling the integration of ecosystem conservation into water management and the financing of nature-based solutions.

TABLE 18
Applicability of the Convention on Biological Diversity to ecosystems of the Amu Darya River

Convention's provisions	Applicability
ART. 6: General measures for conservation and sustainable use – development of national strategies/plans and integration into sectors	Integrate the goals on tugay forests, wetlands, and delta lakes into national legislations and basin plans
ART. 7: Identification and monitoring of components of biodiversity	Establish harmonized indicators and monitoring networks for floodplain and delta ecosystems and link them with environmental flow and water quality
ART. 8: In situ conservation – system of protected areas, restoration of degraded ecosystems; **ART. 8(J)** – traditional knowledge	Expand and connect protected areas along the river and in the delta; implement restoration projects for tugay forests as "green infrastructure"; incorporate traditional knowledge of local communities
ART. 9: Ex situ measures	Support nurseries and seed banks of tugay species for floodplain and delta restoration
ART. 12: Research and training	Conduct joint field expeditions and capacity building for competent authorities and basin councils on bioindicators and environmental flow management
ART. 13: Public education and awareness	Publish public reports and ensure community participation
ART. 14: EIA – assessment and minimization of negative impacts	Include riverine and delta indicators in EIA/SEA for hydropower and irrigation projects
ART. 15: Access to genetic resources and ABS; Nagoya Protocol	Establish access and benefit-sharing rules for projects involving wild populations (fish, tugay species); use as a financing mechanism for habitat conservation
Cartagena Protocol (biosafety)	Risk assessment regime for wetlands/delta regarding transboundary movement of GMO crops
GBF 2022 (goals and targets to 2030)	Preservation of 30% of three types of ecosystems and restoration of 30% of three types of ecosystems – "30×30", restoration, business dependency/risk assessments – grounding for donors/budgets and KPIs on the Amu Darya

After the 2011-2020 Strategic Plan (Aichi Targets), the Kunming-Montreal Global Biodiversity Framework was adopted in December 2022. This document contains 4 goals and 23 targets to 2030 (including clear benchmarks such as "30×30" – protection of at least 30% of terrestrial, inland water, and marine and coastal ecosystems by 2030; restoration of degraded ecosystems; phased reduction of ecologically harmful subsidies; transparency of business-related nature risks). The new framework makes targets measurable and links them to financing and data disclosure. This facilitates the integration of ecosystem objectives (environmental flows, water quality, restoration of tugay forests and the delta) into basin plans for the Amu Darya River, as well as increases the chances for support from donors and business partners.

An important innovation was the inclusion of "inland water ecosystems" in the global framework as a distinct category requiring protection on par with terrestrial and marine ecosystems. The data reflects that the loss of freshwater biodiversity is progressing at more than double the rate found in the two other major ecosystem types. In response, nations have committed to safeguarding at least one-third of their rivers, lakes, wetlands, and deltas in their natural state–a goal that will require enormous effort from the global community. Additionally, plans are in place to restore another 30% of degraded freshwater ecosystems. This restoration will be achieved through actions like implementation of environmental flow, removal of outdated hydraulic structures, and rehabilitation of wetlands on less productive farmlands.

Overall, the Convention on Biological Diversity and its protocols provide concrete legal mechanisms – strategies, monitoring, protected areas, EIA and biosafety – that can be used in ecosystem-based approaches when making water management decisions in the Amu Darya basin.

3.3.4. Ramsar Convention on Wetlands

THE RAMSAR CONVENTION is a global agreement on the conservation of wetlands and the wise use of their resources. All four states of the Amu Darya River Basin (Kyrgyzstan, Tajikistan, Turkmenistan, Uzbekistan) are Contracting Parties. The Ramsar Convention requires participating countries to: (i) designate wetlands of international importance and include them in the List of Ramsar Sites, (ii) take measures to maintain and restore their "ecological character" through planning and monitoring, (iii) develop a network of protected areas and management systems for them, and (iv) establish cooperation in a transboundary format.

This directly corresponds to the tasks of conserving the ecosystems of the Amu Darya Basin (Table 19).

TABLE 19
Applicability of the Ramsar Convention to joint actions on the Amu Darya River

Convention's Article	Applicability
ART. 2: List of Wetlands of International Importance (designation of Ramsar sites, Criteria 1-9)	Designate and/or expand sites in the Amu Darya delta and floodplains and in the upper reaches; link the status to environmental flow regimes and conservation management
ART. 3(1): "Wise use" of wetlands; maintenance of "ecological character"	Establish targets on "ecological character" (water levels/seasonality, biota) in basin plans and link them to flow schedules and water quality
ART. 3(2): Monitoring and notification of changes in ecological character	Common database on discharge, water quality and bioindicators at key sections
ART. 4: Establishment/management of reserves; restoration of wetlands; training	Management plans for delta lakes/tugay forests; nature-based solutions as part of restoration measures; training for infrastructure operators and inspectorates
ART. 5: International cooperation	Joint projects in the zones of flow generation and dispersion in line with ASBP-4/REP4SD CA

The Ramsar Convention translates the protection of wetlands from general intentions into concrete management procedures: designation of key areas (Ramsar List of sites), targets on ecological character, monitoring, notification, and joint actions.

For the Amu Darya River basin, this means managing the flow in a way that maintains water availability and quality in priority areas, using the status of Ramsar Sites to mobilize resources and expertise, and integrating "wise use" into regional and national plans and decisions.

3.3.5. UN Convention to Combat Desertification

The UN Convention to Combat Desertification in those countries that suffer from serious drought and/or desertification, especially in Africa, (UNCCD, 1994) is a key international agreement aimed at combating land degradation and drought in arid regions. All countries of the Amu Darya River Basin are Parties to the Convention. It obliges countries to develop and implement National Action Programs (NAPs), integrate land-degradation control measures into sectoral policies, adopt sustainable land-use practices, restore degraded lands, and strengthen international cooperation to mitigate the impacts of drought.

For the Amu Darya River Basin, this Convention is particularly importan, as it brings together the tasks of sustainable management of land and water resources, restoration of degraded territories in the Aral region, and prevention of secondary salinization of irrigated land (see Table 20).

It provides a framework for integrating nature-based solutions (afforestation, phytostabilization, adaptive land use) into water and land management planning.

TABLE 20
Applicability of the UN Convention to Combat Desertification to the Amu Darya Basin

Provisions of the Convention	Applicability
ART. 4-5: General obligations, as well as obligations of affected countries – to take comprehensive measures to combat desertification; integrate strategies	Basis for integration of measures on afforestation of the dried Aral seabed, restoration of degraded pastures, and improving irrigation efficiency into national and regional plans
ART. 9-10: National Action Programmes (NAPs) – development and implementation of national plans with participation of all stakeholders	A tool for linking water planning with land restoration goals
ART. 16-18: Scientific and technical cooperation; collection, analysis and exchange of information	Basis for joint monitoring of salinization processes and dust storms originating from the Aralkum. Development of common approaches to phytoreclamation and production of salt- and drought-resistant crops
Concept of "Land Degradation Neutrality" (LDN) – SDG 15.3	Provides a measurable target for the basin: to halt land degradation and restore ecosystem productivity
ART. 8: Relationship with other conventions – coordination of activities with other relevant agreements	Establishes the need for synergy. Measures for tugay restoration (CBD) and ensuring environmental flow (Water Conventions) simultaneously constitute measures to combat desertification (UNCCD) and adapt to climate change (UNFCCC)

3.3.6. UN Framework Convention on Climate Change and the Paris Agreement

The UN Framework Convention on Climate Change (UNFCCC, 1992)[113] established the general obligations of all Parties to prevent dangerous interference with the climate system, develop monitoring and reporting, cooperate on adaptation, and ensure the sustainable management of sinks and reservoirs of greenhouse gases (including ecosystems). The Paris Agreement (2015)[114] strengthened the focus on adaptation (Art. 3.3), transparency, and regular updates of national contributions, and also called for conservation and enhancement of sinks (Art. 4.1), while creating opportunities for countries to cooperate voluntarily in achieving their national contributions (Art. 3.5).

All four Amu Darya basin states – Kyrgyzstan, Tajikistan, Turkmenistan, and Uzbekistan – are Parties to the UNFCCC and the Paris Agreement. This creates a common legal framework for integrating measures on the protection of flow generation zones, runoff, water quality, and ecosystem restoration into climate policy and climate finance.

In this context, of particular relevance are nature-based solutions for climate adaptation and mitigation, including floodplain restoration projects that enhance flood protection and help replenish groundwater reserves

3.3.7. Conclusion

Taken together, the international environmental conventions reviewed above form a complementary legal framework for ecosystem-based management in the Amu Darya Basin. The Water Convention (1992) and the 1997 Watercourses Convention establish the procedural basis for transboundary cooperation: joint objectives on water quality, monitoring and data exchange, notification of planned measures, equitable and reasonable water allocation, and the integration of ecosystem protection requirements into flow regulation regimes. The Convention on Biological Diversity, together with the Cartagena and Nagoya Protocols, translates these requirements into the conservation and economic dimensions (protected areas, habitat restoration), while the Ramsar Convention specifies the management of wetlands through maintenance of their "ecological character" and promotion of transboundary cooperation. The UN Convention to Combat Desertification (1994) links water and land, ensuring the integration of land degradation and desertification management into a common strategy. The UNFCCC and the Paris Agreement, in turn, add a climate dimension, enabling water-ecosystem measures to be framed as adaptation and/or carbon projects (including nature-based solutions) and to attract financing.

With regard to glaciers and snowfields in the flow generation zone, environmental obligations are anchored in the Convention on Biological Diversity (ecosystem monitoring and conservation, research) and in the climate block (adaptation, early warning, sustainable management of "sinks"), whereas water conventions provide a regime for joint monitoring, accounting for climate-hydrological risks, and harmonizing the infrastructure operation rules, with due consideration of projected meltwater and seasonal variability.

Thus, the application of these conventions can serve as a practical basis for interstate cooperation, enhanced environmental security, and preservation of the unique natural heritage of the Amu Darya for future generations.

We now move to the analysis of national protected areas within the Amu Darya Basin and sites protected by international mechanisms – UNESCO World Heritage List, UNESCO Biosphere Reserve Network, and the Ramsar List – to demonstrate how this legal framework is translated into concrete territories and management regimes.

[113] https://www.un.org/ru/documents/decl_conv/conventions/climate_framework_conv.shtml

[114] https://lex.uz/docs/5075088

CHAPTER 4
PRACTICAL MEASURES FOR THE PROTECTION OF THE AMU DARYA RIVER ECOSYSTEMS: NATIONAL PROTECTED AREAS AND INTERNATIONAL MECHANISMS

Conservation of ecosystems in the Amu Darya basin is based, first and foremost, on the national network of protected areas,[115] which is further enhanced by international mechanisms of recognition and support. This section reviews the protected areas (PAs) existing within the countries of the Amu Darya basin, as well as the sites safeguarded under international mechanisms such as UNESCO World Heritage, the UNESCO Biosphere Reserve Network, and Ramsar List.

4.1. Protected Areas in the Amu Darya River Basin

4.1.1. PAs: Coverage, Typology and Management Priorities

TAJIKISTAN. The Law on Protected areas[116] establishes the following their categories: state nature reserves; state national parks; state nature sanctuaries; natural monuments; as well as special forms (ecological and ethnographic zones, recreation and health zones, dendrological parks/botanical gardens, ecological corridors and protective (buffer) zones).

TURKMENISTAN. The Law[117] includes the following categories of protected areas: state nature reserves; state biosphere reserves; national nature parks; state nature sanctuaries; state natural monuments; natural recreational areas; state botanical gardens; and state zoological parks (with protected areas classified as those of international, national, or local significance).

UZBEKISTAN. The Law[118] defines the following categories of protected areas: state reserves; nature (landscape) reserves; nature parks; natural monuments; areas designated for the conservation/reproduction/restoration of individual natural features and complexes; protected landscapes; and, areas for management of some types of natural resources. Establishment of national parks, biosphere reserves, and interstate protected areas is also permitted.

Thus, the conceptual framework and core categories are compatible across the three countries: they include reserves, parks, and sanctuaries, which makes it possible to assess protection and sustainable-use areas in a harmonized manner. There are differences in the details of special regimes: for example, ecological corridors and ecological-ethnographic zones in Tajikistan; biosphere reserves and national parks as directly established categories in Turkmenistan; protected landscapes and resource-management areas in Uzbekistan – which may influence the choice of instruments for floodplain connectivity and ecological-hydrological regimes.

For analytical comparison and transboundary ecosystem planning, a common matrix is proposed:

- *reserves, core zones of national parks and biosphere reserves* – strict protection, research, exclusion of economic activity;
- *national nature parks and biosphere reserves (except their core zones), ecological-ethnographic zones, recreational and health zones* – multi-purpose areas with limited activities, allowing ecotourism and research;

[115] Some countries use the term 'specifically protected areas' (SPA), while others 'protected areas' (PA). Here we use PA as a common term

[116] Law of the Republic of Tajikistan No. 1159 of 27.11.2014, No. 1975 of 22.06.2023, www.portali-huquqi.tj/publicadliya/viewqonunhoview.php?showdetail=&asosiid=13446

[117] Law of Turkmenistan No. 286-IV of 31.03.2012 (with amendments and additions as of 03.06.2023)

[118] Law of the Republic of Uzbekistan No. 710-II of 03.12.2004, https://lex.uz/ru/docs/415228

- *sanctuaries, protected landscapes, resource areas, and protected natural monuments* – targeted conservation depending on their actual regime;
- *ecological corridors and buffer protection zones* – special regimes.

Such harmonization ensures correct comparability across the basin and directly links legal categories with the objectives of environmental flow, tugay forest connectivity, and wetland protection. Information on protected areas in the Amu Darya River basin is provided in national reports and is briefly summarized in Table 21.

TABLE 21
Protected areas in the Amu Darya River Basin

No.	Name of PA	Year of establish.	Location	Area, ha	Purpose of establishment
			REPUBLIC OF TAJIKISTAN		
1	State Nature Reserve "Beshai Palangon"	1938	Dusti, Jayhun and Kubodiyon districts, Khatlon province	49 786	Conservation of the natural complex typical for the southern deserts and floodplains of Central Asian rivers; protection of rare animals and conducting research. Preservation of floodplain tugay forests
2	State Nature Reserve "Rammit"	1959	Regions of Republican Subordination and Vahdat district	16 162	Protection of golden eagle, brown bear, snow leopard, Siberian ibex and others
3	State Nature Reserve "Dashti Jum"	1983	Khatlon province, Shamsiddin Shohin district	19 700	Biocoenological research – preserving one of the last full and viable populations of the screw-horned goat (markhor) and urial in Central Asia; protection of the brown bear and the snow leopard
4	State Nature Reserve "Zorkul»	2000	Gorno-Badakhshan Autonomous province (GBAO), Murghab and Ishkashim districts	87 770	The lake is of great value as the largest freshwater reservoir in the Pamirs. The river Gunt, a tributary of the Panj, originates from the lake. Created to protect species such as bar-headed goose, argali, Siberian ibex, snow leopard
5	Tajik National Park (Pamir Mountains)	1992	GBAO	2 611 674	Protection of high-mountain meadow-steppe, desert ecosystems and mountain tugay, as well as argali, Siberian ibex, snow leopard
6	Shirkent National Historical-Nature Park	1991	Regions of Republican Subordination and Tursunzade district	3 000	Protection of walnut and juniper forests, Ungernia victoris, snow leopard, urial
7	Sari-Khosor Nature Park	2003	Regions of Republican Subordination, Baljuvon district	3 085	Protection of unique natural complexes, mountain mesophilic broadleaf forests; development of various forms of tourism
8	Muzkul Sanctuary	1972 г.	GBAO, Murghab district	66 916	Protection of typical ecosystems of Eastern Pamirs and species such as bar-headed goose, argali, Siberian ibex, snow leopard
9	Komarov Sanctuary	1970	Regions of Republican Subordination, Rasht district	9 000	Conservation of shiblyak communities (almond and pistachio sparse forests) and rare species of wild animals listed in the Red Book of Tajikistan – striped hyena, Persian leopard, goitered gazelle, urial, brown bear, Siberian ibex, trout; control of grazing load and prevention of hunting

TABLE 21 (Continued)

No.	Name of PA	Year of establish.	Location	Area, ha	Purpose of establishment
			REPUBLIC OF TAJIKISTAN		
10	Childuhtar Sanctuary	1970	Khatlon province, Muminabad district	14 500	Protection of juniper, brown bear, urial, partridge, wild boar
11	Dashtijum Sanctuary	1972	Khatlon province, Shurabad district	50 100	Main goal: preventing the extinction of one of the last viable populations of the markhor in the CIS; protection of juniper stands, brown bear, urial, partridge, wild boar
12	Siyokukh (Karatau) Sanctuary	1972	Khatlon province, Parkhar district	14 500	Protection of shiblyak communities (almond and pistachio sparse forests) and rare wildlife species listed in the Red Book of Tajikistan – striped hyena, Persian leopard, goitered gazelle, urial; also chukar, Bukhara deer
13	Sangvor Sanctuary	1972	Regions of Republican Subordination, Tavildara district	38 000	The purpose is to preserve at least one untouched fragment of Tajikistan's mountain-forest ecosystems
14	Nurek Sanctuary	2013	Regions of Republican Subordination, Nurek district	30 763	Protection of mountain ecosystems in the area of the artificial reservoir; study of their evolution. Potential future basis for a national park on the shores of the Nurek and Rogun reservoirs. Protection of urial, brown bear, partridge, snow leopard
15	Almasin Sanctuary	1983	Regions of Republican Subordination, Shahrinav district	6 000	Ensuring preservation of Ungernia victoris populations and habitats
TOTAL – 15, incl.: **nature reserves – 4,** **national parks – 3,** **sanctuaries – 8**				**3 020 956** **173 418** **2 617 759** **229 779**	
			TURKMENISTAN		
1	Repetek Biosphere Reserve	1927	Lebap Velayat, Charjou and Sayat etraps	34 600	Study of the unique black saxaul forests of Repetek and surrounding areas; study, protection, and restoration of the distinctive flora and fauna of the Eastern Karakum Desert
2	Yeradjinsky State Nature Sanctuary	1977	Lebap Velayat, Charjou etrap	30 000	Conservation of black saxaul around Lake Yarajy; protection of migratory and nesting bird species, goitered gazelles, wild boars, and other species; preservation, restoration, and study of their natural habitats
3	Khazar State Nature Reserve	1932	Balkan Velayat, Turkmenbashy and Esenguly etraps, city of Hazar	260 961	Conservation, protection, and restoration of unique flora and fauna, including goitered gazelles, kulans, and large natural pistachio grove
4	Ogurdjali State Nature Sanctuary	1982	Balkan Velayat, city of Hazar	7 000	Semi-wild keeping and breeding of one of the rare species – the goitered gazelle – with subsequent resettlement across the country

TABLE 21 (Continued)

No.	Name of PA	Year of establish.	Location	Area, ha	Purpose of establishment
			TURKMENISTAN		
5	Badkhyz State Nature Reserve	1941	Mary Velayat, Tagtabazar etrap	140 430	Protection and restoration of unique flora and fauna, including goitered gazelles, kulans, and large natural pistachio grove
6	Chemenebit State Nature Sanctuary	1956	Mary Velayat, Tagtabazar etrap	26 000	Preservation of pistachio groves, protection of rare animals at watering sites (kulans, Turkmen mountain sheep, goitered gazelles)
7	Gyzyljar State Nature Sanctuary	1956	Mary Velayat, Tagtabazar etrap	30 000	Creating necessary conditions for habitation and reproduction of rare ungulates (foaling and lambing areas for kulans, Turkmen wild sheep, goitered gazelles)
8	Pulhatyn State Nature Sanctuary	1956	Ahal Velayat, Sarahs etrap	15 000	Preservation of major concentration sites of kulans and mountain sheep, and their protection
9	Kopetdag State Nature Reserve	1976	Ahal Velayat, Geokdepe and Akbugday etraps	50 980	Complex study and conservation of ecosystems of Central and Eastern Kopetdag, its foothills, unique juniper and wild fruit forests, and rare wildlife such as argali, bezoar goat, leopard, Caspian snowcock, etc.
10	Gurykhovdan State Nature Sanctuary	1976	Ahal Velayat, Akbugday etrap	15 000	Strengthening protection of flora, fauna, and mountain ecosystems of Central Kopetdag
11	Mäne-Chachin State Nature Sanctuary	1976	Ahal Velayat, Sarahs etrap	60 000	Strengthening protection of flora, fauna, and mountain ecosystems of Eastern Kopetdag; protection of migratory birds
12	Nature Monuments Garayalchy and Charlak	1987 1988	Ahal Velayat, Baharden and Kaakhka etraps	2 020	Study, conservation, and restoration of unique populations of walnut and pistachio trees and associated natural complexes
13	Sunt-Hasardag State Nature Reserve	1978	Balkan Velayat, Magtymguly etrap; Ahal Velayat, Baharden etrap	26 461	Comprehensive study, conservation, and restoration of natural complexes of Southwest Kopetdag
14	Sunt-Hasardag State Nature Sanctuary	1990	Balkan Velayat, Magtymguly etrap	3 800	Supporting improvements in socio-economic conditions of the local population while preserving natural ecosystems
15	Gaplangyr State Nature Reserve	1979	Dashoguz Velayat, S. Turkmenbashy etrap	275 735	Conservation and population recovery of Ustyurt argali, kulan, goitered gazelle, honey badger, and other rare vertebrates and plant species
16	Sarykamysh State Nature Sanctuary	1980	Dashoguz Velayat, S. Turkmenbashy etrap	541 466	Conservation and population recovery of birds, goitered gazelles, mountain sheep, kulans inhabiting the Sarykamysh Lake area, and migratory saiga antelope
17	Shasenem State Nature Sanctuary	1983	Dashoguz Velayat, S. Turkmenbashy etrap	109 002	Strengthening protection of ungulates, including kulans, and of saiga antelopes wintering in the area
18	Amu Darya State Nature Reserve	1982	Lebap Velayat, Darganata and Dehkan etraps	48 351	Restoration of tugay ecosystems in the middle Amu Darya; protection and recovery of the Bukhara deer population

TABLE 21 (Continued)

No.	Name of PA	Year of establish.	Location	Area, ha	Purpose of establishment
			TURKMENISTAN		
19	Kelif State Nature Sanctuary	1970	Lebap Velayat, Keryki and Halach etraps	103 000	Protection of one of the southernmost wintering areas for wetland birds in Turkmenistan and conservation of the Kelif Lakes natural complex
20	Koytendag State Nature Reserve	1986	Lebap Velayat, Koytendag etrap	27 139	Conservation and restoration of ecosystems of the Koytendag range and Govurdag mountains and surrounding areas; safeguarding genetic diversity of flora and fauna; development of scientific principles for nature conservation
21	Garlyk State Nature Sanctuary	1986	Lebap Velayat, Koytendag etrap	40 000	Protection of mountain landscapes of the southern slopes of Koytendag, its flora and fauna, and the thermal spring "Gaynarbaba"
22	Khodzheypil State Nature Sanctuary	1986	Lebap Velayat, Koytendag etrap	31 635	Protection of the Dinosaur Plateau; Kyrkgyz and Umbardere gorges; karst lakes Kette-köl, Aigyrköl, Khorjun-köl
23	Khodzhaburdjy-Belent State Nature Sanctuary	1986	Lebap Velayat, Koytendag etrap	17 592	Conservation of natural balance of ecosystems of Sakyrtma, Takhtadag, Khodzhaburdjy-Belent slopes and surrounding areas; protection of flora and fauna
24	Khodzhagaravul State Nature Sanctuary	1990	Lebap Velayat, Koytendag etrap	16 011	Conservation of natural balance and protection of flora and fauna of Daraidere and Khodzhagaravul gorges; study and protection of the Karluk caves as natural monuments
25	Bereketli Garagum State Nature Reserve	2013	Ahal Velayat, Akbugday and Tenjen etraps	62 500	Study, restoration, and protection of complexes of dune-ridge, barchan, basin, and erosional landforms, and the flora and fauna of stony, saline, and sandy deserts in the heart of the Karakum
26	Chomuchly State Nature Sanctuary	2013	Ahal Velayat, Tenjen etrap	25 000	Ensuring integrity and connectivity of the reserve's areas
TOTAL – 26, incl.: **nature reserves – 9,** **wildlife sanctuaries – 16,** **natural monuments – 1**				**1 999 683** **927 157** **1 070 506** **2 020**	
			REPUBLIC OF UZBEKISTAN		
1	Surkhan State Nature Reserve	1986	Surkhandarya province, Sherabad District	23 802	Conservation of mountain-juniper ecosystems in the eastern part of the Kugitang Ridge
2	Kyzylkum State Nature Reserve	1971	Bukhara province, Ramitan District; Khorezm province, Tuprakkala District	10 311	Conservation of tugay ecosystems in the middle reaches of the Amu Darya River
3	South Ustyurt National Nature Park (including park and strictly protected area)	2020	Republic of Karakalpakstan, Kungrad District	1 447 143 (512559/ 934584)	Conservation of habitats for rare species such as goitered gazelle, Indian honey badger, Ustyurt mouflon, Central Asian tortoise, and other species, as well as the ecosystems of Lake Sarykamysh

TABLE 21 (Continued)

No.	Name of PA	Year of establish.	Location	Area, ha	Purpose of establishment
			REPUBLIC OF UZBEKISTAN		
4	Aralkum National Nature Park (including park and strictly protected area)	2022	Republic of Karakalpakstan, Muynak District	1 000 000 (300 000/ 700 000)	Protection of natural complexes of the dried bed of the Aral Sea
5	Aral Region National Nature Park (including park and strictly protected area)	2020	Republic of Karakalpakstan, Buzatau District	3 166 (2 166/ 1 000)	Conservation of tugay natural complexes of the Aral region
6	Upper Tupalang National Nature Park (including park and strictly protected area)	2022	Surkhandarya province, Sariasia District	27 851 (9 851/ 18 000)	Conservation of mountain-juniper ecosystems of the Gissar Ridge and the upper reaches of the Tupalang River
7	Babatag National Nature Park (including park and strictly protected area)	2022	Surkhandarya province, Uzun District	12 064 (4 064/ 8 000)	Conservation of mountain-juniper and pistachio forest ecosystems of the Babatag Ridge
8	Khorezm National Nature Park (including park and strictly protected area)	2019	Khorezm province, Yangibazar, Khiva, Khonqa and Tuprakkala Districts	21 668 (16 130/ 5 538)	Conservation of tugay and desert ecosystems and waterfowl habitats in the Khorezm valley
9	Sudoche-Akpetki State Nature Reserve	2021	Republic of Karakalpakstan, Takhtakupyr and Muynak Districts	280 507	Conservation and restoration of coastal landscapes, canals, collectors, watercourses, populations of waterfowl, and rare and endangered species of fish, birds, and mammals
10	Lower Amu Darya State Biosphere Reserve (including strictly protected area)	2011 1971	Republic of Karakalpakstan, Beruniy and Amu Darya Districts	68 717 (57 149/ 11 568)	Conservation of tugay ecosystems and Bukhara deer in the lower reaches of the Amu Darya River
11	Dengizkul State Ornithological Reserve	1973	Bukhara province, Alat District	50 000	Protection of wetland ecosystems of Lake Dengizkul and waterfowl
TOTAL – 11, incl.: **2 nature reserves with 7 strictly protected areas,** **6 nature parks, excluding strictly protected areas,** **1 wildlife reserve excluding strictly protected areas,** **2 wildlife sanctuaries**				**2 945 229** **1 712 803** **844 770** **57 149** **330 507**	
TOTAL BASIN – 52 PAs, incl.: **nature reserves – 15,** **nature parks – 9,** **wildlife reserves and sanctuaries – 28**				**7 965 868** **2 813 378** **3 462 529** **1 689 961**	

Source: country reports

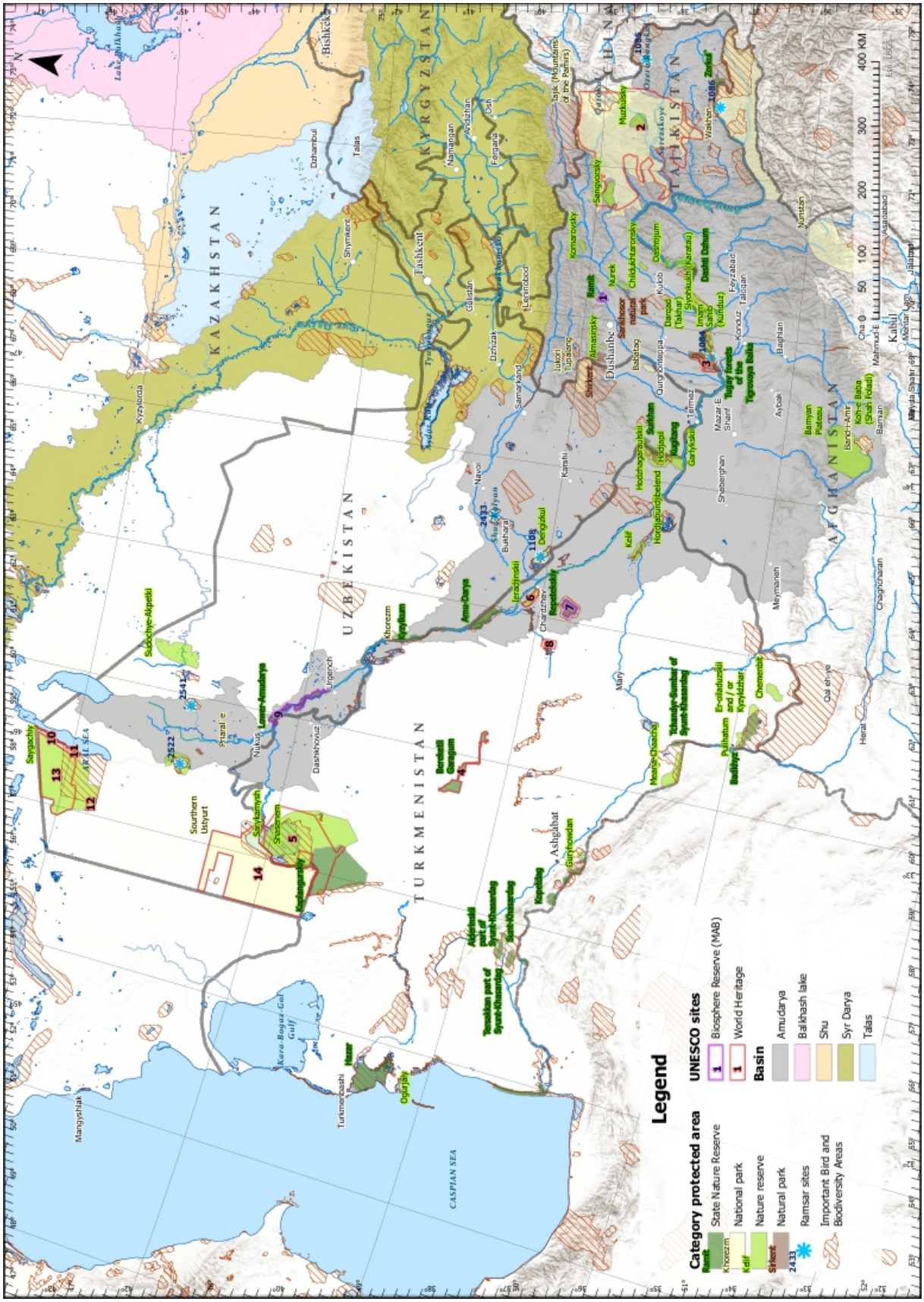


FIGURE 12
Map of protected areas of the Amu Darya River Basin

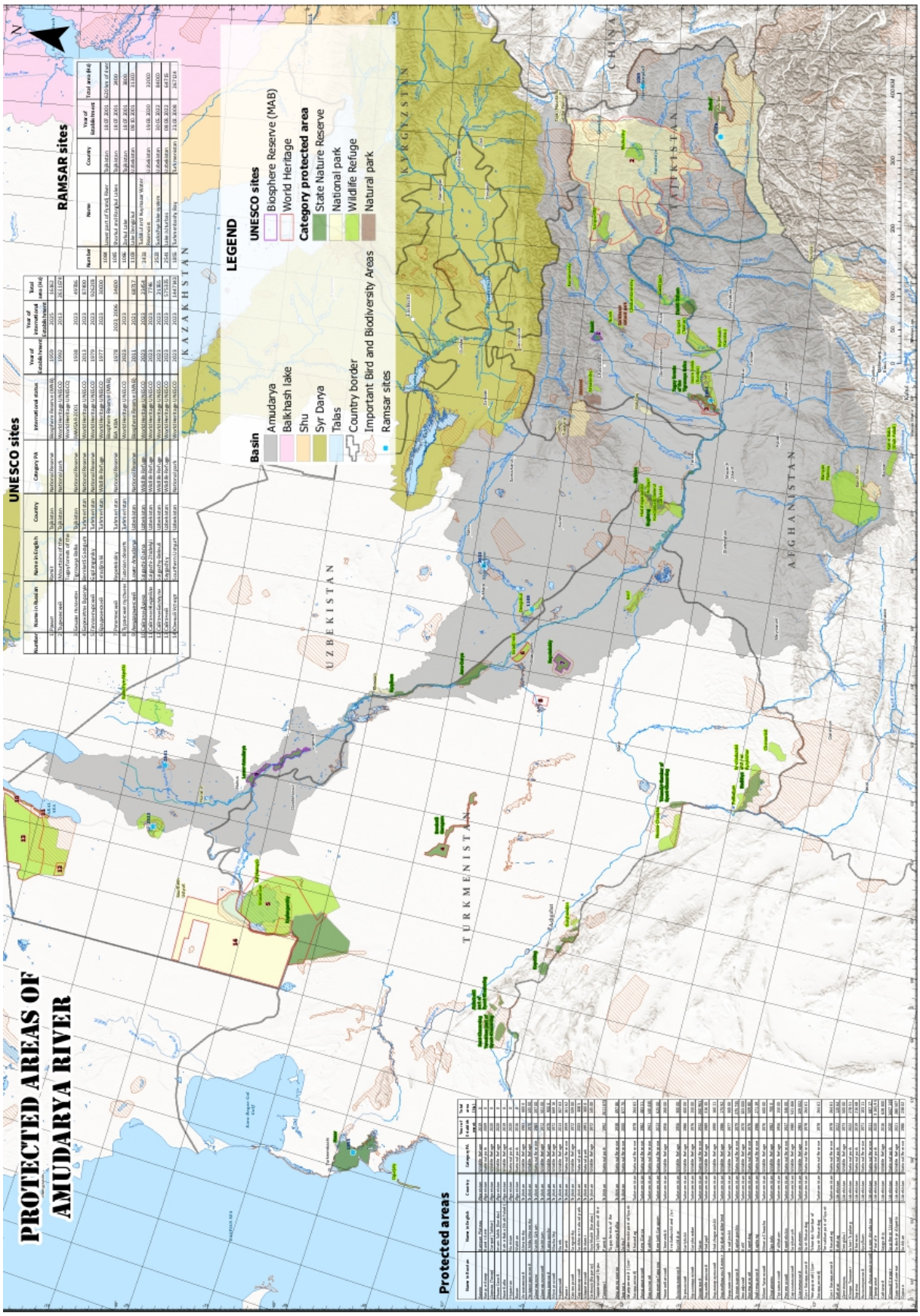


FIGURE 13
Map of protected areas of the Amu Darya River Basin with the full list of sites

In addition to the tabular data, a special GIS database and schematic maps of the basin's protected areas were generated as part of the project for spatial visualization and information verification. Figure 12 shows the location of the sites on a cartographic base, and Figure 13 presents a map of protected areas in the Amu Darya River basin with a complete list of the sites.

An analysis of available data on the protected area network within the Amu Darya Basin allows for the following conclusions.

Development of the protected area network in the Amu Darya Basin has a long history and reflects the sustained commitment of the region's countries to conserving natural complexes, landscapes, and biodiversity. As early as the first half of the 20th century, the first nature reserves were established: in Turkmenistan – the Repetek State Biosphere Reserve (1927), and in Tajikistan – the Tigrovaya Balka Nature Reserve (now Beshai-Palangon, 1938). At present, the basin includes 15 protected areas in Tajikistan and 26 ones in Turkmenistan. In Uzbekistan, the protected area system began later: the first reserve (Kyzylkum) and the then Badai-Tugay wildlife sanctuary were established in 1971, and today 11 protected areas function within the Uzbek territory of the basin. Moreover, between 2019 and 2025, the total area of protected areas in the Uzbek part of the basin increased by almost 2.8 million ha. Seven new PAs were established – South Ustyurt, Aralkum, Aral Region, Upper Tupalang, Babatag, Khorezm, and Sudoche-Akpetki – demonstrating positive progress and strengthening nature conservation policy in the region.

COVERAGE OF PROTECTED AREAS BY COUNTRY AND WITHIN THE BASIN. The area of the Amu Darya River basin (excluding Afghanistan, Kyrgyzstan, and the Zarafshan River basin) is 98.40 million ha. According to the results of the consolidated inventory, a network of 52 protected areas associated with the Amu Darya basin covers 7.96 million ha, which is 7.36% of the combined territory of the three countries (108.32 million ha) and approximately 8.1% of the basin itself (98.40 million ha). The highest relative coverage is observed in Tajikistan (3.03 million ha, 21.2%), reflecting the country's mountainous character and the high concentration of natural areas in the upper reaches. Protected areas occupy 2.95 million ha (6.6%) within the basin in Uzbekistan and 1.99 million ha (4%) in Turkmenistan. Table 22 presents a comparison of protected area coverage by country.

TABLE 22
Country coverage of protected areas in the Amu Darya River Basin

Country	Country area	Area of «basin» regions	PA in basin	Share of the country	Share of «basin» regions
	ha	ha	ha	%	%
Tajikistan	14 309 900	11 733 000	3020956	21.1	25.7
Turkmenistan	49 121 000	49 121 000	1 999683	4.0	4.0
Uzbekistan	44 890 000	36 749 000	2 945 229	6.56	8.0
Total	**108 320 900**	**98 403 000**	**7 965 868**	**7.35**	**8.1**

STRUCTURE AND CATEGORIES OF PAs. Within the basin, the protected areas are primarily structured around 28 wildlife reserves, sanctuaries, and natural monuments, followed by 15 nature reserves and 9 natural and national parks. In terms of area, parks dominate, covering 3.46 million ha (43.5%). Nature reserves cover 2.81 million ha (35.3%), while wildlife reserves, sanctuaries, and natural monuments together make up 1.7 million ha (21.1%).

The structure of protected areas across the countries is as follows: Tajikistan has 4 nature reserves (0.17 million ha), 3 national parks (2.62 million ha), and 8 sanctuaries (0.23 million ha); Turkmenistan includes 9 nature reserves (0.93 million ha) and 16 sanctuaries (1.07 million ha); Uzbekistan has a more complex structure:

- The total area under strict protection, comprising 2 standalone nature reserves (0.034 million ha) as well as conservation zones within national parks and the biosphere reserve, amounts to 1.71 million ha.
- Six national parks with recreational and regulated economic use zones (excluding their protected areas) cover 0.84 million ha.

- One biosphere reserve and two wildlife sanctuaries, whose combined area (also excluding protected areas) totals 0.38 million ha.

Table 23 presents the distribution of 52 protected areas across countries and categories, indicating quantity of sites, their total area, and their share in the total protected area of the basin.

TABLE 23
PAs by category and by Amu Darya basin countries
(quantity of sites, their total area and share in basin's PA network and in the basin area of a country)

PA category	Tajikistan	Turkmenistan	Uzbekistan	Total by category
NATURE RESERVES				
Quantity	4	9	2	15
Area, ha	173 418	927 157	1 712 803	2 813 378
Share in basin's PA within a country, %	5.7	46.4	58.1	–
Share in total protected area of the basin, %	2.2	11.6	21.5	35.3
NATURAL (NATIONAL) PARKS				
Quantity	3	–	6	9
Area, ha	2 617 759	–	844 770	3 462 548
Share in basin's PA within a country, %	86.3	–	28.7	–
Share in total conservation of the basin, %	32.8	–	10.6	43.4
WILDLIFE RESERVES/SANCTUARIES/MONUMENTS				
Quantity	8	17	3	28
Area, ha	229 779	1 070 506	387 656	1 689 961
Share in basin's PA within a country, %	8.0	53.1	12.2	–
Share in total conservation of the basin, %	3.1	13.4	4.8	21.3
TOTAL IN THE COUNTRY				
Quantity	**15**	**26**	**11**	**52**
CA, ha	**3 020 956**	**1 999 683**	**2 945 229**	**7 965 868**
Share in total protected area of the basin, %	**38.0**	**25.1**	**36.9**	**100**

Tajikistan leads in terms of the area of conservation territories within the Amu Darya River basin, with a total of 3.02 million ha – about 26% of the country's territory within the basin and 38% of the total protected area of the basin. The largest sites – the Tajik National Park (assuming it is counted entirely within the basin), as well as the Zorkul and Beshai-Palangon nature reserves – together cover approximately 2.75 million ha (around 90% of all protected areas in the country). These sites encompass key flow generation zones in the upper reaches. However, the share of strictly protected areas (state nature reserves) remains relatively small – about 5.7% of the country's protected area within the basin and 2.2% of the basin's total network.

Uzbekistan's larger protected areas dominate in the middle and lower reaches of the basin. The total area of the country's national protected areas within the basin amounts to 2.95 million ha, equivalent to about 8% of its basin regions and 37% of the total protected area in the basin. The largest sites include the South Ustyurt National Park (1.4 million ha), the Aralkum National Park (1.0 million ha), the Sudoche-Akpetki wildlife sanctuary (0.28 million ha), and the Lower Amu Darya Biosphere Reserve (0.07 million ha). The share of strictly protection areas (nature reserves and strictly protected areas) is about 21.5% of the total network area in the basin and 58% of national protected area, being the highest in the region. This reflects the state's priority of preserving delta ecosystems and mitigating the consequences of the Aral Sea's drying up.

In the lower reaches of the basin, the protected areas network of Turkmenistan plays a significant role, covering 1.99 million ha, which accounts for about 4% of the country's territory and 25% of the total conservation network within the Amu Darya River basin. The network includes key sites such as the Amu Darya Nature Reserve (48,000 ha), the Sarykamysh Sanctuary (541,000 ha), the Gaplangyr Nature Reserve (276,000 ha), and the Koytendag Nature Reserve (27,000 ha). The share of strictly protected territories in Turkmenistan constitutes 11.6% of the basin's total protected areas network and about 47% of the national protected area within the basin, indicating a high proportion of strictly protected zones in the structure of the national network. At the same time, in terms of the overall coverage of natural areas, the country lags behind Tajikistan and Uzbekistan.

When analyzing the structure of protected areas, a shift becomes evident – from protecting natural floodplains to focusing on artificially maintained or modified ecosystems, especially in the lower reaches. Only 6.7% of the basin's conserved areas (approximately 0.533 million ha) are floodplain-delta territories directly dependent on river flow. These include the Amu Darya and Kyzylkum Nature Reserves, the Keliff Sanctuary, the Lower Amu Darya Biosphere Reserve, the "Sudoche-Akpetki" system, and the Khorezm National Park. At the same time, more than 38% of the conserved area is formed by "substitute" systems. Of this, 30.8% consists of terminal deserts in place of the dried-up sea – the Aralkum (1.0 million ha) and South Ustyurt (1.45 million ha) National Parks – and another 7.4% consists of large drainage water bodies such as Sarykamysh (0.541 million ha) and Dengizkul (0.050 million ha). This shift is particularly visible at the country level:

- In Uzbekistan, two desert national parks account for 83% of the country's entire protected area within the basin (2.45 million ha out of 2.95 million ha), while floodplain-delta systems represent only 15%, and the upper-basin areas (Surkhandarya province) – 2%.

- In Turkmenistan, Sarykamysh Sanctuary fed by collector-drainage waters covers 27% of all national protected areas in the basin, whereas the natural floodplain sites – Amu Darya and Keliff – together account for only 7.6%.

This demonstrates a structural shift: conservation efforts are moving away from natural floodplain habitats toward areas supported by artificial hydrology. Consequently, water quality (salinity, pollution) and water discharge management regimes become critically important for biodiversity conservation in such systems, while the deficit of river flow in the natural floodplain remains a key problem. The strategic priority is restoring and maintaining an environmental flow regime - otherwise, even expanding protected areas will not deliver the desired ecosystem outcomes.

THE TUGAY "GREEN CORRIDOR" OF THE AMU DARYA IS HIGHLY FRAGMENTED. The main reasons are the flattening of flood peaks due to flow regulation, which in turn leads to landscape alteration and a reduction in the food base for wildlife inhabiting these territories. Even with local

TABLE 24
Comparison of tugay areas by year and season, ha

Site	2015	2024	2015	2024
	May		September	
Beshai Palangon state nature reserve (Tajikistan)	6 313	5 653	6 235	6 091
LABR (Uzbekistan)	21 750	16 200	19 277	15 604

Source: SIC ICWC research results

successes (such as 1,600 Bukhara deers in the LABR), the risk of population isolation remains. Therefore, without restoring seasonal water releases and feeding arms/dead stream branches, isolated measures will not restore the continuity of the ecological corridor. Table 24 presents RS data from May and September/October for 2015 and 2024, which clearly show a reduction in areas of tugay vegetation.

For more detailed research and future monitoring, it is proposed to introduce the following indicators and track them regularly:

Water dependency index: classify protected areas into high, medium, and low water dependency and compare them with the guarantees of environmental flow;

Water quality in the delta and drainage lakes: combine GIS metrics (water area dynamics, NDWI) with field measurements of salinity and nutrients to assess habitat suitability for fish and birds, and to prioritize water treatment and dilution measures;

Tugay corridor connectivity: integrate the strip of floodplain protected areas into a single ecological corridor along the river (Tugay Connectivity Index) and identify critical zones where environmental flow or river branch restoration are urgently needed;

Water release scenarios: identify hydro-ecological relationships of flow quantity – flooded tugay and lake area – biodiversity indicators to justify water releases from reservoirs for minimum environmental flow.

4.1.2. Condition of Some of Protected Areas: Field Visits and Satellite Monitoring

This Section describes the results of studying some of protected areas through field visits and satellite data.

FIELD STUDIES

As part of the projects, field visits/expeditions were conducted to key conservations sites in the Amu Darya River Basin, including: SNR "Beshai Palangon" (Tajikistan), LABR (Uzbekistan), Jayran Ecocenter and related lakes, as well as the Kuyimazar and Tudakul reservoirs in Bukhara province, Uzbekistan. The expedition results provided a comprehensive understanding of how these ecosystems depend on water regimes and confirmed the need for closer coordination with water management agencies.

SNR "Beshai Palangon" (former Tigrovaya Balka, Tajikistan). Established in 1938, the reserve is located in the interfluve of the Vakhsh and Panj rivers (Khatlon province; the districts of Dusti/Jayhun/Kubodiyon). The area encompasses extensive tracts of tugay forests, the Kashka-Kum sands, and the mountainous areas of Khoja-Koziyon. Thanks to long-term protection, a representative fauna and flora of the floodplain desert have been preserved here: around 200 bird species and 36 mammals. For the indicator species – Bukhara deer – a positive trend has been recorded: according to a census conducted in October 2024 jointly with the National Academy of Sciences of Tajikistan and announced in March 2025, the population is estimated at approximately 320 heads, up from earlier benchmarks of about 150.[119]

The expedition conducted on 30 May 2025[120] confirmed both the site's high conservation value and its escalating vulnerability – a common fate of floodplain ecosystems along regulated rivers. These include the reduction in the extent and duration of natural flood inundation due to flow regulation (leading to degradation of seasonally flooded meadow-floodplains, a key component of the tugay cycle), livestock incursions during drought periods, poaching along the periphery, and localized salinization of soils and lake waters. The latter is causing dieback in areas dominated by oleaster (Elaeagnus) and a contraction of habitats associated with willow-poplar and oleaster communities. Institutional challenges include the need to renovate the State Nature Reserve's museum and inadequate equipping of

[119] Narodnaya. (2025, 13 March). Experts has counted the population of Bukhara deer in Tigrovaya Balka, https://narodnaya.tj/2025/03/13/specialisty-poschitali-chislennost-buharskih-olenej-v-tigrovoj-balke

[120] SIC ICWC (2025, May 30). Report on the results of field visit to State Nature Reserve "Tigrovaya Balka" (currently, "Beshai Palangon") (30 July 2025), http://sic.icwc-aral.uz/pdf/report_tj_27_29_july_2025_ru.pdf

ranger services (transport, communications, and equipage), as well as the absence of a targeted program to investigate the causes of salinization and to implement mitigation measures.

The priority solutions are clear and feasible under the existing protection framework: (i) coordination and maintenance of environmental flow for floodplain (including local hydrotechnical measures using existing inundation channels); (ii) regulation of grazing through buffer zones and agreements with local communities; (iii) strengthening anti-poaching patrols and improving the material and technical base of the ranger service; (iv) monitoring and reducing salinization, along with targeted restoration of tugay forest belts (willow, poplar, oleaster). This combination of conservation and management actions will help safeguard the properties of the SNR Beshai Palangon, stabilize the Bukhara deer population, and enhance the resilience of tugay ecosystem to climatic and anthropogenic pressures.

Lower Amu Darya State Biosphere Reserve (LABR, Uzbekistan) was established in accordance with Cabinet of Ministers' Resolution No. 243 of August 26, 2011. The total area of the reserve is 68,717.8 ha, of which 11,568.3 ha refer to a protected area (its core – former nature reserve "Baday-Tugai", 50% of the area covered by tugay forest). The main tree species include Asiatic poplar, tamarisk, willow, and oleaster; flora - 167 species. The fauna includes the Bukhara deer, wild boar, jackal, and jungle cat. The ornithofauna is represented by more than 91 bird species. Rivers are home to 15 fish species. The reserve was included in the World Network of Biosphere Reserves under UNESCO's 'Man and the Biosphere' (MAB) Programme on September 16, 2021.

The key problems include: the reduction of natural flooding following the regulation of the Amu Darya River by the Tuyamuyun Hydroscheme; not complete commissioning of the new water supply system (a ~3 km canal and two electric pumps, with only one operating at 500 l/s); the lack of regular budget financing for electricity; overpopulation of Bukhara deer (about 1600 heads in Baday-Tugai - three times the permissible capacity) and deterioration of food supply.

Recommendations: include the reserve's in the water quotas; speed up the transfer of the newly constructed canal to ownership of reserve's administration, which would allow for budgetary funding; consider the possibility of drilling wells and arranging local ponds on the edges of the territory; partially relocate deer to alternative sites (including the left bank), with the construction of a 30-km fence.[121]

Amu-Bukhara Main Canal (ABMC) is not only the key waterway for irrigated agriculture and drinking water supply but also a vital source for natural sites in Bukhara province, Uzbekistan. Field observations confirmed that the resilience of ecosystems in the surveyed sites largely depends on water supply through this canal.

Bukhara Jayran Nursery: This area, which is of international importance for the conservation and recovery of rare animal species and is designated as a key ornithological site, is directly dependent on ABMC. Water supply to the nursery's lake system, consisting of four water bodies, is provided exclusively from ABMC via the Shokhrukh feeder canal. The lack of water has led to drying up of one of the nursery lakes, transforming it into solonchak. At present, water abstraction for the needs of the eco-center is carried out without approved limits, making the ecosystem vulnerable. To preserve this unique ecosystem, it is necessary to calculate the water demand and formally include the corresponding water quantities in the annual water limits/quotas, in line with the priorities set out in the Water Code of the Republic of Uzbekistan.

Kuyimazar and Tudakul reservoirs included in the Ramsar List of Wetlands of International Importance in 2020 (see Section 3.3.4 Ramsar Convention on Wetlands) are also closely linked with ABMC. The canal is one of their main sources. The Kuyimazar reservoir as the main source of drinking water for the city of Bukhara is under strict protection. The Tudakul reservoir is under increasing pressure since the opening of a recreation zone on its shores. Under conditions of climate change and water scarcity, sustainable management of the reservoirs requires enhanced intersectoral cooperation – between water, environmental, and tourism agencies – for balancing all water needs without damaging the ecosystems.

[121] SIC ICWC. Report on the results of field visit to some of ecosystems in the Republic of Uzbekistan (Bukhara province, Karakalpakstan, 27-29 July 2025). http://sic.icwc-aral.uz/pdf/report_uz_27_29_july_2025_ru.pdf

South Aral Region and the Mezhdureche Reservoir (a system-forming water body in the Amu Darya delta). Reservoir's design capacity is 450 million m^3, with the useful capacity of 400 million m^3. On the day of the visit, the actual water volume of the reservoir was 145 million m^3. In high-water years, the reservoir receives the bulk of river flow and shapes water regime of other lakes; in low-water years, the situation is critical: for example, only 2.69 km^3, or 34% of the recommended quantity, were delivered to South Aral region in 2020. In the context of water scarcity, it is impossible to sustain all the lakes; priority water bodies, regardless of annual water availability, should be the Mezhdureche Reservoir, Muynak Bay and Lake Rybachye, with the focus on drinking water supply and maintenance of basic ecosystem resilience.

A SATELLITE-BASED PERSPECTIVE: CHANGES IN WATER SURFACE AREA IN KEY PROTECTED AREAS

The study analyzed changes in water surface area in four protected areas in the Amu Darya lower reaches of Uzbekistan over 2015-2024, with May selected as a representative month. The analysis was based on satellite data (Landsat 8 and NASA Worldview), statistical processing of quantitative indicators, and their visualization in the form of histograms. The assessment covered the Kyzylkum State Nature Reserve, the Sudoche Lake system, Khorezm National Nature Park, and the Lower Amu Darya State Biosphere Reserve (LABR), for which precise coordinates and observations were available (Figs. 14-15).

The results show that two of the four sites, located downstream of the Tuyamuyun Hydroscheme (TMH) are vulnerable to fluctuations in the Amu Darya flow. For comparability, the key parameters of each site are summarized in Table 25, allowing a clear assessment of their hydro-ecological dependence on the operating regime of TMH.

Kyzylkum State Reserve: The water surface area here varies widely, ranging from 804 to 1,376 ha. Peak values recorded in 2015 and 2024 directly reflect dependence on periods of high-water flow or major flood releases from the reservoir. The water bodies form the core of the 3,177-ha tugay zone, which is critically important for the conservation of the Bukhara deer population.

Khorezm National Nature Park: The park's landscapes include the river valley, tugay forests, and desert ecosystems. This area is characterized by very small and fragmented water bodies, ranging from 12 to 81 ha. Despite their limited size, these water bodies serve as habitats for waterfowl and stopover points for migratory birds. Their small size makes them especially sensitive to even minor fluctuations in water levels in the Amu Darya River, putting them at risk of complete desiccation during low-water periods.

LABR: The biosphere reserve is located in the Amu Darya lower reaches and was established to conserve the floodplain tugay forest ecosystems. It exhibits the greatest amplitude of water surface variations, ranging from 1,179 to 3,920 ha. Significant increases in area observed in 2020 and 2024 are likely a direct result of managed releases from TMH, designed to mimic natural floods and support the health of tuga forests, which cover up to 50% of the reserve's protected zone.

Sudoche Lake System: As the largest and most remote water system (up to 28,000 ha), the lake system is subject to multiple pressures. Since 2018, there has been an overall trend of shrinking water surface. This indicates that the system is affected both by reduced freshwater inflow from the Amu Darya and, likely, by changes in quantity and quality of collector-drainage waters. The temporary recovery observed in 2023-2024 also highlights the critical role of large, albeit irregular, water releases.

TABLE 25
Hydro-ecological characteristics of PAs in the lower reaches (2015-2024)

PA	Total area, ha	Water surface area (max-min), ha	Key protected sites	Dependence on TMH regime
Kyzylkum State Reserve	10 311	804 / 1 376	Preservation of tugay ecosystems in Amu Darya middle reaches	High
Khorezm National Nature Park	21 687	12 / 81	Preservation of tugay and desert ecosystems and waterfowls in Khorezm valley	Critical
Lower Amu Darya State Biosphere Reserve	68 717	1 179 / 3 920	Preservation of tugay ecosystems and Bukhara deer in Amu Darya lower reaches	High
Sudoche Lake System	52 938	to 28 000	Waterfowls, fishes	High

FIGURE 14
Dynamics of water surface area

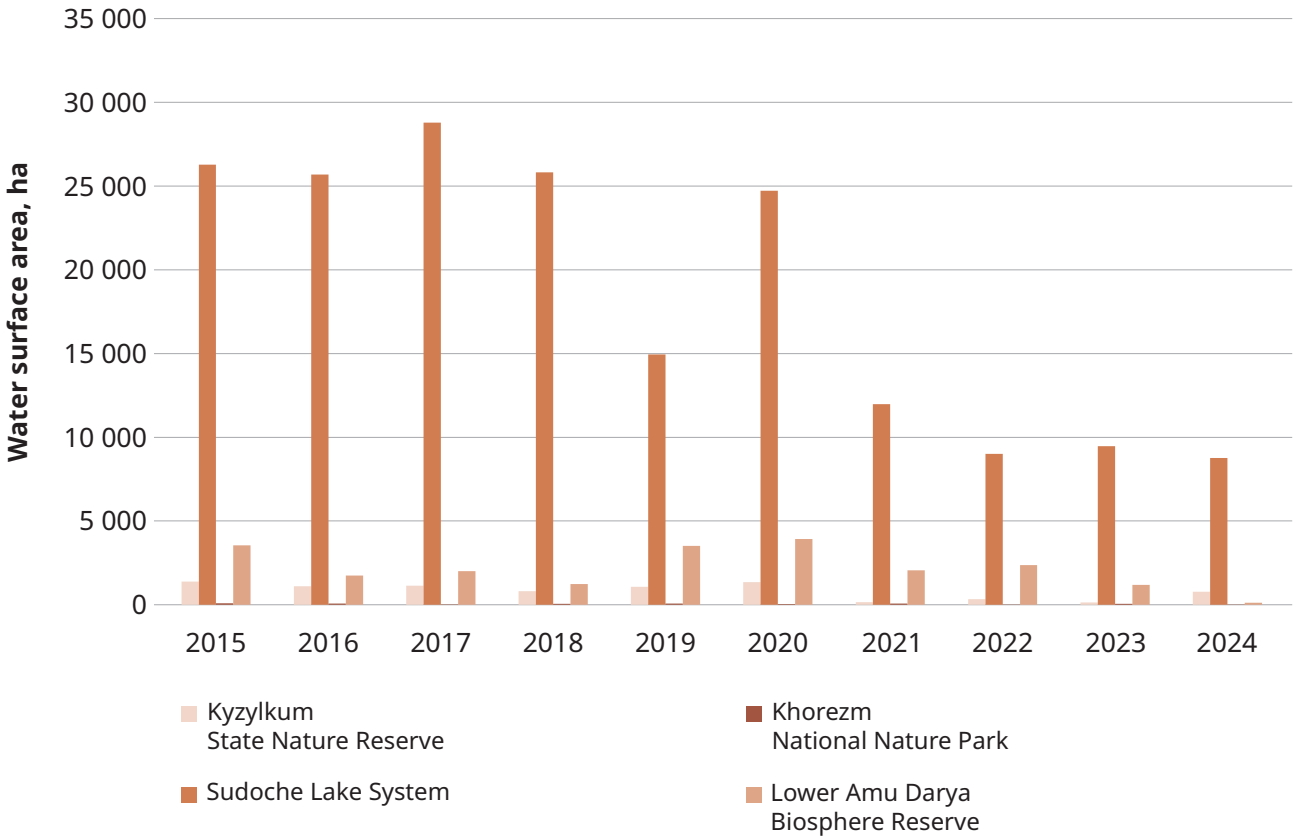
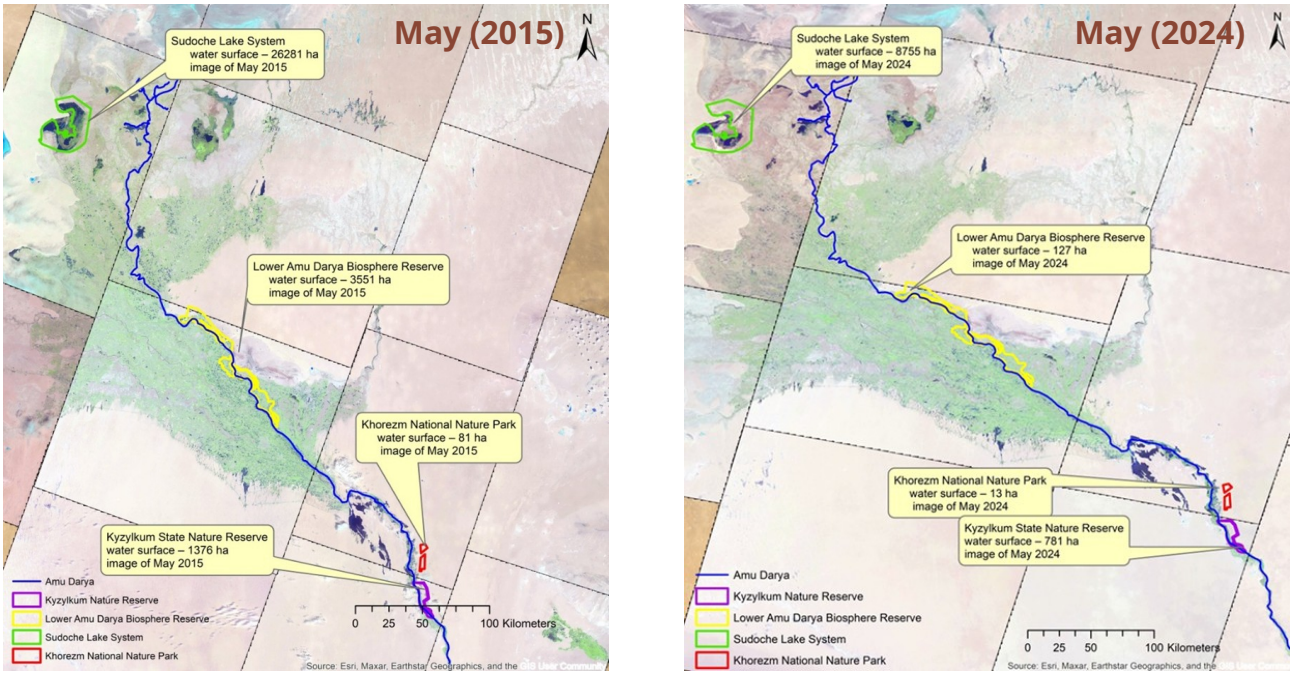


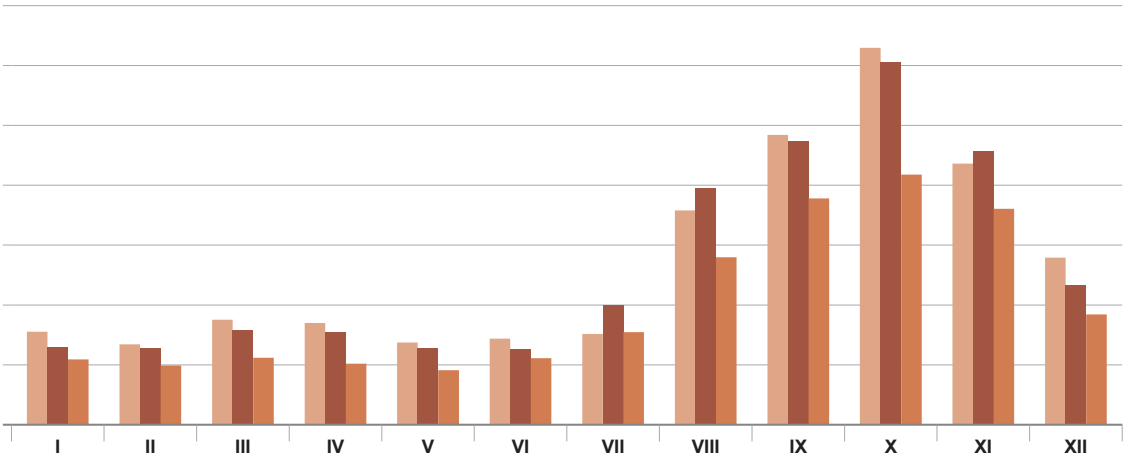
FIGURE 15
Comparison of water surface areas by satellite images



Tuyamuyun Hydroscheme's role and external factors. All of the surveyed protected areas are under the direct hydrological influence of the Tuyamuyun Reservoir, which serves as the main regulator of flow in the lower Amu Darya. Years with peak water surface areas (2015, 2020, 2024) correspond to periods of high-water and/or increased water releases from the reservoir, confirming the role of the reservoir's operating regime. Water surface areas in the lower Amu Darya PAs vary widely and align with Tuyamuyun Reservoir's operation (inflow/drawdown) (Fig. 16). A decline in average May inflows to TMH by 1.148 km^3 during 2013-2022 compared to 2003-2012 has led to less stable spring floodplain inundation and, consequently, to the reduction and fragmentation of water bodies in highly sensitive habitats. Therefore, regular monitoring, adaptive measures, and the limitation of anthropogenic pressure on the most vulnerable sites are essential.

FIGURE 16
Intra-annual monthly inflow to Tuyamuyun Reservoir (average by decade cycle)

W, Mm^3



	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII
1993-2002	1,554	1,343	1,754	1,698	1,373	1,438	1,517	3,578	4,842	6,296	4,361	2,791
2003-2012	1,295	1,274	1,573	1,541	1,270	1,264	1,998	3,944	4,738	6,058	4,568	2,332
2013-2022	1,092	988	1,118	1,020	910	1,112	1,546	2,796	3,780	4,177	3,605	1,842

Source: BWO Amu Darya

The observed instability of aquatic ecosystems is driven not only by the operation of the Hydroscheme but also by broader basin-wide processes. The region is experiencing a steady rise in temperatures and a decline in precipitation. Studies show that from 1928 to 2019 the average temperature increased by 1.9-2.9°C[122] in the Amu Darya basin. Forecasting models predict a further rise of 1.5°C by 2050. This is expected to significantly reduce river flow, particularly during summer months. Consequently, reduced inflow to the Tuyamuyun Reservoir may become the new normal.

Moreover, the operation of the Tuyamuyun Reservoir is constrained by interstate agreements. According to the 1996 Agreement between Uzbekistan and Turkmenistan, the flow of the Amu Darya is divided equally (50/50) at the nominal Kerki station (located upstream of TMH). This means that when the river's total flow decreases due to climatic or other factors, the reservoir receives only half of an already reduced volume. This situation places TMH operators in a very difficult position, forcing them to balance irrigation demands with the minimum environmental requirements of the lower reaches.

The instability of the water regime, exacerbated by the factors described above, triggers a cascade of ecological threats to protected areas.

- **Disturbance of wetland ecosystems:** Drying of water bodies leads to the direct loss of habitats for aquatic organisms, as well as nesting sites and feeding grounds for birds.
- **Biodiversity reduction:** Species reliant strongly on the natural water regime (including endemics and those listed in the Red Book) may experience sharp population declines, up to local extinction.
- **Growing anthropogenic impact:** The exposure of previously seasonally flooded lands encourages unauthorized use (grazing and illegal logging), which hinders natural regeneration of tugay forests and accelerates their degradation.
- **Microclimate changes:** The reduction in evaporative surface area increases aridity, negatively affecting the resilience of adjacent terrestrial ecosystems.

Collectively, these factors create a risk of irreversible transformation of ecosystems – for example, replacement of tugay forests with xerophytic shrubland, which would result in the complete loss of unique biodiversity and ecological functions.

4.1.3. Conclusion: Water Dependence and Vulnerability of Ecosystems

Field studies and satellite monitoring clearly demonstrate that the condition of protected areas in the Amu Darya basin is determined not only by their conservation activities but, above all, by water availability. The expeditions have shown that key sites – such as the Beshai Palangon State Nature Reserve in Tajikistan, the Lower Amu Darya State Biosphere Reserve, the Bukhara Jayran Nursery, as well as the Kuyimazar and Tudakul reservoirs in Uzbekistan – are critically dependent on water supply through major hydraulic systems: the Vakhsh, the Tuyamuyun Hydroscheme, and the Amu-Bukhara Main Canal. Similarly, the satellite analysis confirmed the vulnerability of other delta's PAs (Kyzylkum State Nature Reserve, Khorezm National Nature Park, and the Sudoche Lake system) to variations of inflow, showing a direct dependence of water surface dynamics on operation regimes of reservoirs and canals.

The historically established system of protected areas in the basin has been primarily focused on conservation of terrestrial landscapes. According to the conducted analysis, less than 8% of the river network currently falls under protected status, highlighting significant potential for strengthening measures to conserve aquatic ecosystems. At present, the region is continuing efforts to integrate tailored approaches to conservation of riverine biodiversity and rivers themselves. In the context of implementation of the global Kunming-Montreal framework goals (GBF 2022), further development of the protected area network is considered appropriate. In particular, it is relevant to identify representative river sections for formal protection and improve legal mechanisms in support of maintenance of natural hydrological regime and sediment balance in key catchments.

[122] Fourth National Communication Report of Uzbekistan under the UNFCCC, https://unfccc.int/sites/default/files/resource/4NC_Uzbekistan_RU.pdf

Thus, ensuring the long-term resilience of ecosystems in the Amu Darya basin is closely linked to the continued harmonization of conservation and water management objectives. A key factor for success lies in the implementation of adaptive approaches, in which environmental flow is treated as a tool to mimic critical elements of the natural flow regime, flexibly adjusted according to seasonal and annual water availability. Implementing this approach requires enhanced interagency coordination in scheduling water deliveries, systematic monitoring, and maintenance of relevant water infrastructure. It is precisely the balanced alignment of water management interests with the needs of nature that will enable protected areas to effectively fulfill their functions amid increasing climate pressures.

4.2. International Mechanisms of Protection

International mechanisms and designations enhance the quality of protection and the management standards (monitoring, zoning, and community engagement) of protected areas, while also facilitating access to funding. For water-dependent ecosystems of the Amu Darya basin, these international frameworks are particularly important because they provide a comprehensive system of protection from the headwaters to the middle reaches and the delta, where the flow regime remains the key determining factor.

The upper reaches, floodplain, and delta of the Amu Darya are already partially covered by internationally recognized forms of protection: the upper basin – the Tajik National Park "Mountains of the Pamir" (UNESCO, 2013) and the Tugay Forests of the Beshai Palangon Nature Reserve (UNESCO, 2023); in the lower basin – the Lower Amu Darya State Biosphere Reserve (MAB, 2021) and Ramsar sites – Sudoche (2023) and Zhyltyrbas (2024). In Turkmenistan, significant desert areas (Repetek, Gaplangyr) are included in the serial UNESCO site "Cold Winter Deserts of Turan" (2023). At the same time, there are currently no Ramsar-designated sites in the Amu Darya portion of the country. These differences call for harmonization of the "international protection portfolio": prioritizing Ramsar candidate sites in the Turkmen section of the basin and consolidating transboundary initiatives (Koytendag-Surkhan), with a focus on environmental flow and water quality.

4.2.1. UNESCO: Natural World Heritage

UNESCO Natural World Heritage sites in the Amu Darya basin represent key links in the ecosystem chain from the headwaters to the middle reaches and the delta (Table 26).

In the upper reaches, the **Tajik National Park "Mountains of the Pamir"** is of fundamental importance (2013; criteria vii, viii),[123] encompassing the largest glaciers of the Pamir (including Fedchenko Glacier), which generate flow of the Panj-Amu Darya system. The Tajik National Park "Mountains of the Pamir" takes 3rd place by glacierized area (5,117 km^2) and 2nd place by number of glaciers (3,934) among World Heritage properties globally.[124] The Fedchenko Glacier extending over 70 km and covering an area of over 700 km^2, with a maximum thickness of 1 km, is the largest valley glacier in Central Asia.

The floodplain territory in the middle reaches hosts the **"Beshai Palangon" tugay forests** (2023; criterion ix-"ecological and biological processes")[125] as the largest preserved tract of tugays between the Vakhsh and Panj rivers in southwestern Tajikistan. The area of the Reserve is 49,786 hectares and its buffer zone is 17,672 hectares. It is composed of a series of floodplain terraces covered by alluvial soils, comprising tugay forests, freshwater bodies and marshes, and semi-desert areas (takir, solonchak). The dominating species are turanga (Asiatic poplar), tamarix, oleaster (Elaeagnus),

[123] UNESCO World Heritage Centre. (n.d.). *Tajik National Park (Mountains of the Pamirs)*, https://whc.unesco.org/en/list/1252/

[124] UNESCO–IUCN World Heritage Glaciers: Sentinels of Climate Change (2022), https://portals.iucn.org/library/sites/library/files/documents/2022-040-En.pdf

[125] UNESCO World Heritage Centre. (n.d.). *Tugay forests of the Tigrovaya Balka Natural Reserve*, https://whc.unesco.org/en/list/1685/

reflecting natural hydrological processes in the floodplain of arid climate. These are "alive" river water and groundwater that support tugays, leading to recognition of this property (criterion ix) as an example of modern biological and ecosystem processes in floodplain forests of Central Asia.[126] Wildlife includes key indicator species like rare Bukhara deer (population exceeds 300), goitered gazelle, striped hyena, gray monitor, and many waterfowl and steep birds.[127] In 2025, IUCN conducted a comprehensive analysis of the conservation prospects of this World Heritage site and recommended developing and implementing an environmental flow program to prevent the gradual degradation of floodplain ecosystems.[128]

The components of the serial transnational property **Cold Winter Deserts of Turan** (Kazakhstan-Uzbekistan-Turkmenistan) are located in the lower reaches and the Aral Sea region (2023; criteria ix "ecological and biological processes" and x "biodiversity").[129] This property sets global-level protection of desert ecosystems associated with the lower reaches of the Amu Darya and the Aral Sea region. It consists of 14 component parts on a total area of 3,366,441

TABLE 26
UNESCO World Heritage Sites in the Amu Darya Basin: Composition, Area and Basin Section

Country	UNESCO site	Year	Component (for serial sites)	Area, ha	Buffer zone, ha	Basin section
TAJIKISTAN	Tajik National Park "Mountains of the Pamir"[130]	2013	—	2 611 674	427 401.9	Headwater (flow generation zone)
	"Beshai Palangon" tugay forests	2023	—	49 786	17 672	Upper basin (Vakhsh/Panj floodplain)
TURKMENISTAN	Cold Winter Deserts of Turan[131]	2023	Repetek biosphere reserve	34 600	47 324	Middle reaches (Eastern Karakum, Amu Darya Valley)
			Yeradji nature sanctuary	30 000		Middle reaches (Eastern Karakum, Amu Darya Valley)
			Bereketli Garagum nature reserve	87 400	30 745	(Central Karakum)
			Gaplangyr state nature reserve	926 203	22 950	Lower reaches (Aral region/ Ustyurt, left bank)
UZBEKISTAN			Southern Ustyurt national nature park	1 447 143		Lower reaches (Aral region/ Ustyurt, right bank)
			Saigachy complex (landscape) reserve	575 335	219800	Lower reaches (Northern Ustyurt/Aral region)
			Saigachy-Beleuli	21 765		
			Saigachy-Duana	23 454		
			Saigachy-Zhidely	7 746		

[126] UNESCO World Heritage Convention

[127] UNESCO World Heritage Convention, iucn.org

[128] https://worldheritageoutlook.iucn.org/explore-sites/tugay-forests-tigrovaya-balka-nature-reserve

[129] Decision 45 COM 8B.29, including list of components, https://whc.unesco.org/en/decisions/8410

[130] UNESCO World Heritage Centre. (n.d.). *Tajik National Park (Mountains of the Pamirs)*, https://whc.unesco.org/en/list/1252/

[131] UNESCO World Heritage Centre. (n.d.). *Cold Winter Deserts of Turan*, https://whc.unesco.org/en/list/1693/

ha, with buffer zones of 622,812 ha, and encompasses a range of cold winter deserts from Ustyurt to Altyn Emel (Kazakhstan, Ili River basin). The approximate distribution of property areas by country is as follows: Kazakhstan – 6%; Turkmenistan – 32% (Bereketli Garagum, Gaplangyr, Repetek, Yeraji); Uzbekistan – 62% (Southern Ustyurt National Nature Park and the Saigachy complex (landscape) nature reserve).[132] Each component complements the others in terms of biodiversity, desert types, and ongoing environmental processes. The property demonstrates adaptation to an extreme continental climate and supports globally threatened species: saiga (Saiga tatarica, CR), kulan (Equus hemionus kulan, EN), urial (Ovis vignei, VU), as well as rare desert birds (including great bustard, Egyptian vulture, and others). The property forms external protective contours for desert–delta systems that support migrations of ungulates and birds. Key risks include migration barriers, linear infrastructure, and poaching, which necessitate sustainable transboundary migration monitoring, harmonization of land-use regimes in buffer zones, and funding of a joint coordination mechanism. [133]

Thus, UNESCO World Natural Heritage properties in the Amu Darya River basin protect three key components of its ecosystem: flow generation zones (the Pamir glaciers), floodplain systems (tugay forests), and desert landscapes (the Turan deserts in the Aral Sea region). Their total area is 5.82 million hectares, with an additional 0.77 million hectares of adjoining buffer zones. In terms of country distribution, the largest share of these territories belongs to Tajikistan – 2.66 million hectares (45.7%). Significant areas are also located in Uzbekistan (2.08 million hectares, or 35.7%) and Turkmenistan (1.08 million hectares, or 18.6%). As to geographical distribution along the river course, the lower reaches properties (the Aral Sea deserts and the Ustyurt Plateau) prevail, accounting for 51.7% of the total area. The upper reaches (Pamir glaciers and the floodplains of the Vakhsh and Panj rivers) occupy a nearly comparable share at 45.7%, while only about 1.1% of the protected areas fall within the middle reaches (or 2.6% if the deserts of the Central Karakum are included).

In addition to the already inscribed nominations, the basin countries of the are working on the inclusion of new properties from the Tentative List. Tajikistan proposes for nomination the Dashti-Djum State Reserve (on the Tentative List since 2006) located directly along the Pyanj River and protecting unique populations of Markhor (screw-horned goat) as well as pistache woodland,[134] and the Kusavlisay Reserve (since 2006), which is important for conservation of juniper forests of the Turkistan Range.[135] The nominations submitted by Turkmenistan (Koytendag Nature Reserve)[136] and Uzbekistan (Surkhan Nature Reserve, Kughitang Range)[137] open prospects for establishment of a transboundary property in the Surkhandarya River basin (a tributary of the Amu Darya). Finally, the Amu Darya State Nature Reserve (Turkmenistan, on the Tentative List since 2009), which protects tugay forests and riverine waters in the middle reaches of the river, is also a candidate.[138] Advancing these nominations will require substantial preparatory work to meet the criteria of Outstanding Universal Value and to develop management plans fitting international standards.

The inscription of UNESCO statuses under criteria (vii), (viii), (ix), and (x) highlights the global significance and vulnerability of key components of the basin: glacial complexes, geomorphological formations, and unique ecosystem processes and biodiversity in floodplains and deserts. This, in turn, gives as a strong argument in favor of maintaining environmental flows to support tugay and delta ecosystems, developing adaptation measures in the context of glacier melt, and conserving desert eco-corridors in the Aral Sea region.

[132] Property profile (WHC, ID 1693), description, maps, documents, https://whc.unesco.org/en/list/1693/

[133] IUCN Technical Evaluation (2023): criteria (ix)/(x), threats, recommendations. https://whc.unesco.org/document/205774

[134] UNESCO World Heritage Centre. (2006, April 4). State reserve Dashti Djum. Tentative Lists. UNESCO Ref: 2110, https://whc.unesco.org/en/tentativelists/2110/

[135] UNESCO World Heritage Centre. (2006, April 4). Zakaznik (reserve) Kusavlisay. Tentative Lists. UNESCO Ref: 2109, https://whc.unesco.org/en/tentativelists/2109/

[136] UNESCO World Heritage Centre. (2024, January 26). Dinosaurs and Caves of Koytendag. Tentative Lists. UNESCO Ref: 887, https://whc.unesco.org/en/tentativelists/6887/

[137] UNESCO World Heritage Centre. (2024, January 30). Surkhan State Nature Reserve. Tentative Lists. UNESCO Ref: 6898, https://whc.unesco.org/en/tentativelists/6898/

[138] UNESCO World Heritage Centre. (2009, March 16). Amudarya State Nature Reserve. Tentative Lists. UNESCO Ref: 5436, https://whc.unesco.org/en/tentativelists/5436/

An international protection framework has already been established for the river system's most distant components: the headwaters in the Pamir Mountains and the estuarine zone in the Aral Sea region. The logical next step is therefore to ensure ecological connectivity between these areas by implementing integrated water resource management and water quality monitoring along the entire river course. Inclusion of key sections of the basin on the UNESCO World Heritage List obliges countries to develop management and monitoring plans, while simultaneously providing access to international expertise and targeted funding. This establishes a solid basis for maintaining ecosystem integrity and restoring connectivity between valuable habitats. In practical terms, the high international status of these properties should be aligned with programs on restoration of ecological corridors and control of anthropogenic pressures. This will ensure integrated protection of the entire ecosystems – from glacial headwaters to delta zones.

4.2.2. UNESCO: World Network of Biosphere Reserves (MAB)

Within the Amu Darya Basin, the internationally recognized sites of the UNESCO's Man and the Biosphere (MAB) Programme are concentrated in the lower reaches: the **Lower Amu Darya State Biosphere Reserve** (2021)[139] ensures protection of the last largest tugay tracts and key wetlands in the delta. Its zoning (reserve zone – 11.568 thousand hectares, buffer zone – 6.7 thousand hectares, transition zone – 50.4 thousand hectares) allows combining strict protection with sustainable nature management in adjacent areas. The biosphere reserve is home to about 419 plant species, registered 348 invertebrates, including 41 fishes, 2 amphibians, 24 reptiles, 243 birds (including migratory species) and 38 mammals. Of these, 10 fish species, 2 reptiles, 14 birds, and 4 mammals are listed in the Red Book of the Republic of Uzbekistan, and 18 species are included in the IUCN Red List.[140]

On the Turkmen side, the **Repetek Biosphere Reserve** (MAB site since 1979, area – 34,600 ha) covers a desert territory. This complements the floodplain area and forms the connectivity of the desert-floodplain complex in the lower reaches. In the upper reaches (Tajikistan), there are currently no MAB sites. This is a possible direction for strengthening the country's international portfolio, given the role of flow-generation zones and the already existing nature sites of international conservation status of a different type (e.g., World Heritage sites). Table 27 provides a summary of UNESCO World Network of Biosphere Reserves (MAB) sites in the Amu Darya River basin.

At the 37th session of the International Coordinating Council of the Man and the Biosphere (MAB) Programme (27 September 2025, Hangzhou), the **Romit Biosphere Reserve** was officially included in the UNESCO World Network of Biosphere Reserves.[141] The reserve is located in the upper reaches of the Kafirnigan River, the lower part of the Sardai-Miena-Sorbo interfluve, on the southern slope of the Gissar Range. Its territory forms part of the Pamir-Alay mountain ecosystem and encompasses the mid-mountain zone, with a small portion extending into high-mountain area. Elevations range from 1,176 to 3,195 m above sea level. Situated in a unique ecological setting, the reserve is characterized by rich biodiversity and rare and protected species. It provides habitat for the golden eagle (Aquila chrysaetos laphanea), brown bear (Ursus arctos), snow leopard (Uncia uncia), Siberian ibex (Capra sibirica), and other wildlife species, and is also notable for the occurrence of endemic species. A distinctive feature of the Romit Biosphere Reserve is the integration of nature conservation objectives with sustainable traditional land-use practices, making it a model of balance between ecosystems and human activity.[142]

[139] UNESCO news (16 September 2021), www.unesco.org/en/articles/two-new-biosphere-reserves-were-approved-central-asia

[140] https://gov.uz/ru/eco/news/view/22753

[141] UNESCO. (2025, September 27). 37th session of the International Coordinating Council of the Man and the Biosphere (MAB) Programme: Inclusion of the Romit Biosphere Reserve (Tajikistan) into the World Network of Biosphere Reserves. Hangzhou, China

[142] NIAT "Khovar". (2025, September 27). Romit Biosphere Reserve Became Part of the UNESCO's World Network of Biosphere Reserves, https://eng.khovar.tj/2025/09/romit-biosphere-reserve-became-part-of-the-unesco-s-world-network-of-biosphere-reserves/

TABLE 27
Sites of the UNESCO World Network of Biosphere Reserves (MAB) in the Amu Darya River Basin

Country	Name	Year of inscription	Total area, ha	Zoning (core/buffer/ transition), ha	Location / biome	Relevance
UZBEKISTAN	Lower Amu Darya State Biosphere Reserve	2021	68 717.8	11 568 / 6 731 / 50 418	Amu Darya delta (South Aral region); tugay forest, floodplain and lake ecosystems	Core of floodplain and bird migration corridor protection in estuary area
TURKMENISTAN	Repetek Biosphere Reserve	1979	34 600	No data (no zoning made in MAB profile)	East Karakum (Lebap velayat); sand-desert ecosystems, haloxylon desert	Adjacent desert core area of lower reaches; climate and landscape connectivity with Amu Darya floodplain
TAJIKISTAN	Romit Biosphere Reserve	2025	65 760	16 100 / 2 889 / 46 772	Southern slope of Hissar range, Romit river gorge	Kafirnigan River headwater

Source: unesco.org

4.2.3. Ramsar Convention: Wetlands of International Importance

In the Amu Darya River basin, seven sites have been designated under the Ramsar List of Wetlands of International Importance: two in Tajikistan and five in Uzbekistan (Table 28). Their total area is 215,815 ha (excluding Lower Part of Panj River in Tajikistan, for which the RSIS database shows 0 ha[143]). Spatially, the headwaters site – Zorkul Lake (Tajikistan[144]) – covers 3.8 thousand ha; the midstream anthropogenic water systems – the Tudakul and Kuyimazar reservoirs[145] and Lake Dengizkul[146] (Uzbekistan) – cover 63.3 thousand ha; and the deltaic sites – the Sudoche Lake System[147] and Lake Zhyltyrbas[148] (Uzbekistan) – cover 148.7 thousand ha. No Ramsar sites have yet been designated in the Amu Darya part of Turkmenistan; the country's existing national Ramsar site – Turkmenbashi Bay on the Caspian Sea – lies outside the basin.[149]

[143] https://rsis.ramsar.org/ris/1084

[144] https://rsis.ramsar.org/ris/1086

[145] https://rsis.ramsar.org/ris/2433

[146] https://rsis.ramsar.org/RISapp/files/RISrep/UZ1108RIS.pdf

[147] https://rsis.ramsar.org/RISapp/files/RISrep/UZ2522RIS2310en.pdf

[148] https://rsis.ramsar.org/RISapp/files/RISrep/UZ2541RIS2305en.pdf

[149] https://rsis.ramsar.org/sites/default/files/rsiswpsearch/exports/Ramsar-Sites-annotated-summary-Turkmenistan.pdf

TABLE 28
Ramsar sites in the Amu Darya River Basin

Country	Ramsar site	Date of inscription	Area, ha	Location in the basin	Type/Origin of waters
TAJIKISTAN	Lower Part of Panj River	18.07.2001	no data	Headwaters (Panj River floodplain)	Natural floodplain
	Lake Zorkul	18.07.2001	3 800	Headwatesr (source/Pamir-Panj)	Mountain lake
UZBEKISTAN	Lake Dengizkul	08.10.2001	31 300	Middle reaches (Bukhara oases)	Lake fed by collector-drainage water
	Tudakul and Kuyimazar reservoirs	19.08.2020	32 000	Middle reaches (Navoiy/Bukhara)	Reservoirs connected with the Amu Darya through the Amu-Bukhara Canal; key water supply sources
	Sudoche Lake System	30.05.2022	84 000	Lower reaches/delta	Deltaic lakes/wetlands fed by Amu Darya and canal water
	Lake Zhyltyrbas	08.08.2022	64 715	Lower reaches/delta	Deltaic lakes/wetland complex. Depend on water releases and quality of water
Turkmenistan	Not available in the Amu Darya basin				

Source: https://rsis.ramsar.org/

4.2.4. Conclusion

The key ecosystems in the headwaters and the delta of the Amu Darya have the international protection status: Tajik National Park (UNESCO, 2013), Beshai Palangon Tugay Forests (UNESCO, 2023), and Lake Zorkul and Lower Part of Panj River (Ramsar, 2001) in headwaters; Tudakul and Kuyimazar Ramsar sites hydraulically connected with the Amu Darya and Dengizkul in the middle reaches; and, Lower Amu Darya State Biosphere Reserve (MAB, 2021), Sudoche and Zhyltyrbas Ramsar sites (2022) and components of serial property Cold Winter Deserts of Turan in Uzbekistan and Turkmenistan (UNESCO, 2023) in the lower reaches.

The total area of the Amu Darya River basin covered by internationally designated protection sites (UNESCO World Heritage, MAB, and Ramsar), after eliminating double counting, is 6.09 million ha, which is equivalent to 6.2% of the basin area. The largest share refers to UNESCO World Heritage properties (6.6 million ha, including buffer zones), notably the Tajik National Park, Beshai Palangon Tugay Forests, and components of Cold Winter Deserts of Turan in Turkmenistan and Uzbekistan. This is added by MAB sites (LABR, 68.7 thousand ha) and Ramsar sites (approximately 215.8 thousand ha: Sudoche, Zhyltyrbas, Dengizkul, Tudakul-Kuymazar, and Zorkul). The tentative distribution among countries is as follows: Tajikistan – 2.66 million ha, Uzbekistan – 2.3 million ha, and Turkmenistan – 1.1 million ha. The total figure may vary due to local boundary overlaps and incomplete reporting for certain sites (Table 29).

To ensure the integrity of ecosystem protection in the Amu Darya River basin as a single, interconnected natural system from glaciers to the delta, it is **necessary to strengthen conservation measures in the middle reaches** of the river. One possible step would be the submission of a joint

TABLE 29
Summary list of sites assigned international protection status in the Amu Darya River Basin

Country	UNESCO World Heritage (nature)	UNESCO Biosphere Reserves (MAB)	Ramsar wetlands
ТАДЖИКИСТАН	Tajik National Park Pamir Mountains (2013), Beshai Palangon Tugay Forests (2023)	Romit Biosphere Reserve	Lower Part of Panj River (floodplain), Lake Zorkul (2001)
ТУРКМЕНИСТАН	Components of Cold Winter Deserts of Turan (e.g., Repetek, Gaplangyr)	Repetek (active MAB)	— (no Ramsar sites in the Amu Darya Basin)
УЗБЕКИСТАН	Components of Cold Winter Deserts of Turan (Southern Ustyurt, etc.)	LABR (MAB, 2021)	Dengizkul Lake (2001), Tudakul-Kuyimazar (2020) connected with Amu Darya through canals/collectors; Sudoche Lake System (2022), Zhyltyrbas Lake (2022) – delta

Source: UNESCO WHC (properties 1685 and 1693), UNESCO MAB (WNBR), Ramsar list RSIS and formal announcements (UNESCO, UNESCO). List of Wetlands of International Importance. Published 15 July 2025, www.ramsar.org/sites/default/files/2023-08/sitelist.pdf

transboundary nomination by Turkmenistan and Uzbekistan to the UNESCO World Heritage List for Koytendag and Surkhan,[150] and to reach agreements on more evenly distributed seasonal water releases and the maintenance of natural wildlife migration corridors. Turkmenistan could also consider the possibility of designation for international Ramsar status of key floodplain and lacustrine sites along the Amu Darya, such as Kelif lakes. This would help link existing protected desert areas (UNESCO/MAB) with the network of wetlands, which are important for biodiversity conservation and as stopover places for migratory birds.

International status – financing and coordination levers. The designated international status facilitates access to resources from the GEF, Green Climate Fund, and other financing mechanisms to support environmentally focused projects, including on environmental flows, restoration of tugay forests, monitoring of dust and salt storms, and improvement of water quality. International mechanisms can also help establish an integrated monitoring and observation system - covering satellite-based monitoring (NDWI/water surface area; tugay dynamics) and hydrochemical monitoring (EC/TDS, nutrients) – and harmonize outcome indicators (area of tugay forests conserved, populations of indicator species, salinity/eutrophication indices) at the basin level, with regular basin-wide update summary and open data exchange among countries.

[150] https://mineco.gov.tm/?/HABARLAR/&page=habar&habar=746; https://www.uzdaily.uz/en/uzbekistan-and-turkmenistan-prepare-joint-nomination-for-unesco-world-heritage-status; Lethier, H. (2020). World Heritage thematic study for Central Asia. Priority sites for World Heritage nomination under criteria (ix) and (x). Gland, Switzerland and Belgrade, Serbia: IUCN and IUCN ECARO, https://doi.org/10.2305/IUCN.CH.2020.02.en

CONCLUSION ON NATIONAL AND INTERNATIONAL MEASURES

The national network of protected areas in the basin covers 7.95 million ha (8.1% of the basin area), while international mechanisms (UNESCO World Natural Heritage, MAB, and Ramsar, without double counting) account for 6.09 million ha (6.2%). Some of these areas are designated under both national protection frameworks and international conservation mechanisms. The highest concentration of such areas is found in the following locations:

- Upper floodplain (Tajikistan): Tajik National Park Pamir Mountains and Beshai Palangon (PAs and UNESCO World Natural Heritage).
- Left bank of the Aral Sea region (Turkmenistan): Gaplangyr (PA and UNESCO World Natural Heritage) and Repetek (PA, UNESCO World Heritage, and MAB).
- Ustyurt/Aral Sea region (Uzbekistan): Southern Ustyurt National Nature Park and the Saigachy Landscape Reserve clusters (PAs and UNESCO World Heritage).
- Delta (Uzbekistan): LABR (PA and MAB) and Sudoche, Dengizkul, and Zhyltirbas lakes (PAs and Ramsar sites).

These are the priority sites for rapid investment and joint monitoring.

Thus, a strong system of national protected areas and internationally designated sites has already been established within the basin; however, their ecological effectiveness will be fully realized only if the required water regime is ensured in a synchronized manner – both in terms of timing and water quality – and if institutional gaps in the management of middle reaches of the Amu Darya are addressed.

CHAPTER 5
EXAMPLES OF INTERNATIONAL BEST PRACTICES IN COOPERATIVE ECOSYSTEM CONSERVATION INITIATIVES WITHIN TRANSBOUNDARY RIVER BASINS

As follows from international practices, protection of aquatic ecosystems is effective only when environmental objectives and measures are fully integrated into basin management plans - from flow generation zones to deltas. Key elements of such integration include: the legal establishment of environmental flows; restoration of river-floodplain connectivity (including fish passes and the removal or mitigation of barriers); nature-based solutions (floodplains, wetlands, forests) in combination with "grey" engineering infrastructure; establishment of an integrated observation system (covering discharge, sediment transport, water quality, and bioindicators); and transparent data sharing through unified monitoring networks for water quantity and quality, and biota. The INBO/GWP Handbook (2015) systematizes these approaches, which have been tested across hundreds of practical case studies, and place particular emphasis on the need for standardized monitoring protocols, economic instruments, and data exchange through basin information systems.[151] Below are several examples of implementation of joint ecosystem conservation solutions in transboundary river basins worldwide.

5.1. High-Altitude Ecosystems: The Alps, Himalayas, Central America

In mountainous "water towers", resilience of ecosystems and reliability of flow are ensured not only through local protected areas, but also through interstate mechanisms for planning, adaptation, and coordinated monitoring.

IN THE ALPS, the "Water Management in the Alps" Platform of the Alpine Convention prepared Guidelines on local adaptation to Climate Change for Water Management and Natural Hazards in the Alps.

These documents formalize practices such as floodplain restoration, flood management, and consideration of sediment transport at the scale of the entire river basin.

These approaches are integrated into the target framework "Climate Neutral and Climate Resilient Alps 2050" and the Climate Action Plan 2.0 (adopted in 2020). Within these strategic documents, a dedicated section is devoted to climate-resilient water management, including measures to address droughts. In parallel, the ALPARC network of protected areas promotes the concept of ecological connectivity by establishing natural corridors between mountain and lowland areas. This approach reduces the vulnerability of biodiversity to extreme events and sustains the critical role of mountain landscapes as sources of flow generation.[152]

The International Centre for Integrated Mountain Development (ICIMOD) advances a transboundary landscape approach for **THE HIMALAYAS**. Under this approach, participating countries harmonize cartographic baselines (such as vegetation type and land cover maps) and adopt unified

[151] Brachet, C. et al. (2015). The handbook for management and restoration of aquatic ecosystems in river and lake basins. INBO & GWP, https://ianas.org/wp-content/uploads/2020/07/wbp02.pdf

[152] Alpine Convention Water Platform. (2017). Guidelines on local adaptation to climate change for water management and natural hazards in the Alps. European Climate Adaptation Platform, https://climate-adapt.eea.europa.eu/en/metadata/guidances/guidelines-on-local-adaptation-to-climate-change-for-water-management-and-natural-hazards-in-the-alps;
Alpine Convention. (2017). Report on the 7th Water Conference: Water management in the Alps – An integrated approach, www.alpconv.org/fileadmin/user_upload/Fotos/Banner/Topics/watermanagement/Report_water_conference_Annecy_EN.pdf

monitoring protocols. A key focus is the management of hydrological source areas ("springshed management")[153] – a methodology for revival and maintenance of springs that sustain baseflow during low-flow periods and play a crucial role for water security of local communities.

The Kailash Sacred Landscape initiative (China-India-Nepal) serves as a clear illustration. As part of this project, vegetation type and land cover maps were harmonized to enable coordinated management at the landscape scale, and the springshed management is applied as a practical tool for adaptation and the resilience of water supply systems. The initiative demonstrates a systemic approach to transboundary ecosystem management, linking high-altitude alpine meadows in headwater areas with tropical and subtropical forests in the foothills.[154]

IN CENTRAL AMERICA, the Trifinio Plan (Guatemala–El Salvador-Honduras) represents a successful example of managing the Upper Lempa. The Plan combines the conservation of unique mountain and cloud forests (including the transboundary Montecristo Biosphere Reserve) with elements of integrated water resource management.[155] Its primary focus is on protecting headwaters, recharging groundwater, and reducing erosion, thereby contributing to the stabilization of river flows and improvements in downstream water quality. The institutionalization of the Trifinio Plan provides a common policy framework and management plans for protected areas, as well as the coordination of water and land management projects to achieve common environmental and water objectives.[156]

Across all the regions considered, the key to sustainable management is the same: establishing joint frameworks that integrate ecosystem-based measures into basin planning. These include restoration of floodplains, adaptation to droughts, and maintenance of base flow in mountains, underpinned by a shared information base and regular monitoring. Such an approach fully aligns with the UNECE's recommendations on source-to-sea resource management. The core principle is in linking actions upstream with their effects downstream in lowlands, deltas, and coastal marine areas.[157]

5.2. Danube: Restoration of Floodplains and Migration Corridors and Sediment Management

The International Commission for the Protection of the Danube River (ICPDR) is a key cooperation body for 14 countries of the Danube River Basin and the European Union. It has been established to implement the Danube River Protection Convention (signed in 1994, came into force in 1998) to ensure the sustainable and equitable use of waters. The Commission serves as the platform for the implementation of all transboundary aspects of the EU Water Framework Directive (WFD) and the Floods Directive, while coordinating basin planning and monitoring.[158]

[153] Springshed management is a method for protection and revival of mountain sources, in which the unit of planning is not an administrative boundary but the recharge area of a spring - the zones where precipitation infiltrates the ground and feeds the spring through subsurface flow. The objective is to stabilize spring discharge, particularly during the dry season, by implementing conservation measures precisely within the recharge area. See details in Rathod, R., Kumar, M., Mukherji, A., Sikka, A., Satapathy, K. K., Mishra, A., Goel, S., & Khan, M. (2021) Resource book on springshed management in the Indian Himalayan Region: Guidelines for policy makers and development practitioners. New Delhi: International Water Management Institute (IWMI), NITI Aayog, & Swiss Agency for Development and Cooperation (SDC), https://doi.org/10.5337/2021.230

[154] ICIMOD. (2021, 26 октября). Anchoring transboundary cooperation: A harmonised vegetation and land-use type map of the Kailash sacred landscape, https://www.icimod.org/anchoring-transboundary-cooperation-vegetation-and-land-use-type-map-of-kailash-sacred-landscape/

[155] Artiga, R. (2014). Case study on the Upper Lempa River Basin. UNECE, https://unece.org/fileadmin/DAM/env/documents/2014/WAT/05May_22-23_Geneva/case_studies/7.3.R.Artiga_Upper_Lempa_Basin_case_study.pdf

[156] UNESCO. (2003). Trifinio Fraternidad Biosphere Reserve (El Salvador/Guatemala/Honduras). UNESCO - MAB Biosphere Reserves Directory, https://unesdoc.unesco.org/ark:/48223/pf0000133304

[157] UNECE. (2024). Applying the source-to-sea approach: A guide for practitioners. Key messages&, https://unece.org/sites/default/files/2025-06/Key%20messages_S2S%20Guidance%20Note_Water%20Convention.pdf

[158] ICPDR. (n.d.). About Us. International Commission for the Protection of the Danube River, www.icpdr.org/

The updated Danube River Basin Management Plan for 2022 to 2027 identifies the joint priorities and is coordinated with the Danube Flood Risk Management Plan. The Basin Management Plan focuses on five key issues that require joint actions. These are: pollution by organic substances and by nutrients, pollution by hazardous substances, hydromorphological alterations (channel and flow disturbances), effects of climate change (droughts, water scarcity). The Plan also includes annexes dedicated to restoration of river continuity for fish migration and measures for preservation of sturgeons.

The Commission uses practical tools and international target projects for implementation of the plans. For example:

"DanubeSediment" Project developed a handbook on sediment management, while its successor "Danube Sediment_Q2" (since 2024) aims at integrated management of sediment quantity and quality on the basin scale.[159]

"Danube Floodplain" Project (2018-2021) proposed a strategy for restoration of floodplains and reconnection of side channels to simultaneously reduce flood risk and improve ecosystem condition.

"MEASURES" Project (2018-2021) systematized approaches to restoring the Danube's "ecological corridor" for migratory fish, including sturgeons, and developed guidance on the restoration of their habitats.[160]

The public-private partnership between WWF and the Coca-Cola Foundation (Living Danube Partnership) financed large-scale restoration of floodplains and wetlands in six basin countries, complementing intergovernmental plans.[161]

Thus, the Danube model demonstrates how ecosystem conservation measures become an integral component of a common program of action – from restoring river-floodplain connectivity and ensuring fish migration to sediment management. This confirms feasibility of the basin approach, in which environmental objectives are embedded in planning instruments and their implementation is ensured through joint projects, harmonized methodologies, and an open monitoring system.

5.3. Spain-Portugal: from Annual Limits to Intra-Annual Ecological Regimes of Flow

The bilateral Convention on Cooperation for the Protection and Sustainable Use of Waters of the Portuguese-Spanish River Basins (Albufeira Convention) was signed on 30 November 1998 and came into force in 2000. The Convention covers five transboundary rivers: Minho, Lima, Douro, Tagus and Guadiana. It established the Conference of Parties and the Commission for the Application and Development of the Convention (CADC), which is supported by Permanent Technical Secretariat (through national Spain and Portugal secretariats) and thematic working groups.[162]

Initially, the Convention's core requirement was compliance with minimum annual flows. However, the 2008 Review Protocol specified the regime in greater detail by establishing mandatory quarterly quantities and introducing control of weekly discharges at key gauging stations (such as Cedillo on the Tagus/Tajo and Miranda on the Douro/Duero).

[159] Interreg Danube. (n.d.). DanubeSediment - Danube Sediment Management – Restoration of the Sediment Balance in the Danube River. Danube Region Programme, https://environmentalrisks.danube-region.eu/projects/danube-sediment/; Interreg Danube. (n.d.). DanubeSediment_Q2. Interreg Danube Region Programme. https://interreg-danube.eu/projects/danubesediment-q2

[160] Interreg Danube. (n.d.-c). MEASURES - Managing and restoring aquatic ecological corridors for migratory fish species in the Danube River Basin. Interreg Danube Transnational Programme. Retrieved October 10, 2025, from https://dtp.interreg-danube.eu/approved-projects/measures

[161] WWF. (2020). Living Danube Partnership: A 6-year partnership for wetland and floodplain restoration along the Danube River and its tributaries. Summary report. WWF & The Coca-Cola Foundation, https://wwfeu.awsassets.panda.org/downloads/ldp_summary_fy20_26jun2020_1_.pdf

[162] CADC. (n.d.). The Albufeira Convention. Convention on Cooperation for the Protection and Sustainable Use of the Waters of the Luso-Spanish River Basins. Retrieved October 10, 2025, from https://www.cadc-albufeira.eu/en/

In 2024, in response to changing hydrological conditions, Spain and Portugal took a further step by agreeing on a regime of monthly releases on the Guadiana River to ensure favorable ecological status of its estuary. The CADC regularly publishes reports analyzing weekly, monthly, and quarterly flows, which serve as the basis for assessing compliance with the agreed regimes.[163]

5.4. Orange-Senqu: from Joint Monitoring to Coordinated Ecosystem Measures

The Orange-Senqu River Commission (ORASECOM) is an intergovernmental platform established in 2000 by Botswana, Lesotho, Namibia, and South Africa. It aims at the equitable and sustainable management of the shared basin in line with the Revised Protocol on Shared Watercourses of the Southern African Development Community (SADC). ORASECOM coordinates basin planning (including the Transboundary Diagnostic Analysis and the Strategic Action Programme), develops a shared Water Information System (WIS), and applies harmonized monitoring tools.

A key element of ORASECOM's work is the Aquatic Ecosystem Health Monitoring Programme (OSAEH). It provides the basis for regular assessments of the condition of rivers and associated ecosystems, as well as for the formulation of recommendations on protection and restoration measures.[164]

The programme's main instrument is the Joint Basin Survey (JBS) conducted every five years and delivering comparable "snapshots" of data across the entire basin. JBS-1 (2010) established a baseline for comparison; JBS-2 (2015) covered 51 monitoring sites, including hydrochemical parameters and biological indices; and JBS-3 (2021/2022) updated the assessment and identified trends, helping to define areas requiring priority interventions.

The data and reports from these surveys are published in ORASECOM's basin information system (https://wis.orasecom.org/) and serve as a direct basis for management decisions. This demonstrates an effective linkage between harmonized monitoring and practical ecosystem protection measures at the basin scale.

5.5. Mekong: Coordinated Rules, Eco-Regimes and Joint Monitoring

The countries of the Lower Mekong Basin (Cambodia, Lao PDR, Thailand, and Viet Nam) cooperate under the 1995 Agreement, with practical coordination carried out by the Mekong River Commission (MRC). To support joint management, the MRC has adopted five key procedural documents:

- Procedures for data and information exchange and sharing;
- Procedures for water use monitoring;
- Procedures for notification, prior consultation, and agreement;
- Procedures for the maintenance of flows on the mainstream;
- Procedures for water quality.[165]

[163] CADC. (2025). Relatório de controlo do regime de caudais. Ano hidrológico 2024-2025. 1º trimestre [Report on the control of the flow regime. Hydrological year 2024-2025. 1st trimester]. Comissão para a Aplicação e o Desenvolvimento da Convenção de Albufeira, https://apambiente.pt/sites/default/files/_SNIAMB_Agua/DRH/AssuntosInternacionais/CADC/RegimeCaudais/Relatorio_CADC_2024-2025_1Trimestre.pdf

[164] ORASECOM. (2017). Manual for the Orange–Senqu Aquatic Ecosystem Health Monitoring Programme (OSAEHMP). Orange-Senqu River Commission, https://orasecom.org/wp-content/uploads/2020/05/661Manual-for-the-Aquatic-Ecosystem-Health-Programme.pdf

[165] MRC. (2001). Procedures for Data and Information Exchange and Sharing, www.mrcmekong.org/wp-content/uploads/2024/08/PDIES-3.pdf;
MRC. (2003). Procedures for Water Use Monitoring, www.mrcmekong.org/wp-content/uploads/2024/08/Procedures-for-Water-Use-Monitoring-PWUM.pdf;
MRC. (2003). Procedures for Notification, Prior Consultation and Agreement, https://portal.mrcmekong.org/procedure/pnpca-overview;
MRC. (2006). Procedures for the Maintenance of Flows on the Mainstream, www.mrcmekong.org/wp-content/uploads/2024/08/Procedures-for-the-Maintenance-of-Flows-on-the-Mainstream-PMFM.pdf;
MRC. (2011). Procedures for Water Quality. Mekong River Commission, www.mrcmekong.org/publications/proceduers-for-water-quality/

In addition, the Commission develops and implements strategic policy documents. The Basin Development Strategy 2021-2030 and the MRC Strategic Plan 2021-2025 set shared objectives on issues such as water quality, fish migration, sediment management, and drought and flood management.[166] Their preparation is preceded by the regular State of the Basin Report, which assesses trends and emerging challenges.[167] To oversee the impacts of major hydropower projects, a Joint Environmental Monitoring Programme is implemented at the Xayaburi and Don Sahong hydropower projects,[168] while drought management is coordinated through a dedicated Strategy 2020-2025.[169]

This package of procedural and strategic instruments enables environmental and water management requirements (such as minimum flows, water quality standards, and fish migration needs) to be translated into operational regimes and supported by joint monitoring at the basin scale.

5.6. Restoration of the Colorado River Delta (US-Mexico)

Management of the transboundary Colorado River basin is carried out bilaterally by the United States and Mexico through the International Boundary and Water Commission (IBWC). The core agreement governing water allocation is the 1944 Treaty. To address operational and emerging issues, such as management of environmental flows in the delta, the two countries adopt supplementary agreements in the form of "Minutes" to the Treaty.

Environmental flows, first provided for under Minute 319 to the 1944 Treaty (2012-2017), served as an experimental basis for delta restoration. In 2014, a spring "pulse flow" was released, complemented by base flows to sustain mainstream conditions.[170] Monitoring demonstrated an immediate positive response: floodplain vegetation "greenness," as measured by NDVI, increased on average by 16-17%, reaching 43% in areas subjected to direct inundation. At the same time, increases in bird diversity and populations were recorded.

The success of the experiment allowed to institutionalize this approach on a long-term basis under Minute 323 (2017-2026). This document provides for the allocation of 259 million m^3 of water for ecosystem needs, with contributions shared equally between the United States, Mexico, and the Raise the River coalition of NGOs (including Audubon, the Sonoran Institute, Pronatura, and others), supported by private foundations (including the Walton Family Foundation). The Minute also includes funding for habitat restoration activities and joint monitoring.[171]

This example illustrates how legally formalized environmental flows, targeted bioengineering measures (e.g., planting of willow and cottonwood), the acquisition of water rights for nature, and transparent monitoring together deliver measurable positive outcomes for degraded delta ecosystems.

[166] MRC. (2021). Basin Development Strategy 2021-2030 and MRC Strategic Plan 2021-2025. Mekong River Commission, www.mrcmekong.org/publications/basin-development-strategy-2021-2030-and-mrc-strategic-plan-2021-2025

[167] MRC. (2023). State of the Basin Report 2023. Mekong River Commission, www.mrcmekong.org/publications/state-of-the-basin-report-2023-2

[168] MRC. (2021). Joint Environmental Monitoring Programme at Two Mekong Mainstream Dams: The Don Sahong and Xayaburi Hydropower Projects. Mekong River Commission, www.mrcmekong.org/publications/joint-environmental-monitoring-programme-at-two-mekong-mainstream-dams-the-don-sahong-and-xayaburi-hydropower-projects

[169] MRC. (2020). Drought Management Strategy for the Lower Mekong Basin 2020-2025. Mekong River Commission, www.mrcmekong.org/publications/drought-management-strategy-for-the-lower-mekong-basin-2020-2025-2

[170] IBWC (2012). Minute No. 319: Interim International Cooperative Measures in the Colorado River Delta, www.ibwc.gov/wp-content/uploads/2012/11/Minute_319.pdf

[171] IBWC (2017). Minute No. 323: Extension of Cooperative Measures and Adoption of a Binational Water Scarcity Contingency Plan in the Colorado River Basin, www.ibwc.gov/wp-content/uploads/2023/03/Min323.pdf

5.7. Tools for the Protection of Free-Flowing Rivers: International Experience and Legal Innovations

In 2021, a special issue of the *Sustainability* scientific journal launched a comprehensive review of legal instruments and methodologies for the systematic protection of natural river ecosystems.[172] The issue synthesized global experience in protective free-flowing rivers through legislative regulation, implementation of scientific evidence-based restoration strategies, and adaptive management. Particular attention is paid to mechanisms that strike a balance between biodiversity conservation and the sustainable use of ecosystem services.

The global analysis focuses on three main policy mechanisms used for such protection: (1) specialized national river conservation systems; (2) executive decrees and laws; (3) rights of rivers.[173]

NATIONAL SYSTEMS AND EXECUTIVE DECREES. A pioneer in this field is the **United States**, where the National Wild and Scenic Rivers System was established as early as 1968. By 2020, similar national systems have been established in, at least, eight countries, including New Zeland, Canada, Scandinavian countries, and China. Besides, the analysis revealed 27 river basins in seven countries, where protection is ensured through targeted executive decrees, demonstrating the effectiveness of focused legal instruments.

RIGHTS OF RIVERS. The concept of granting legal rights to natural entities ("rights of rivers") has been spreading most rapidly worldwide. This approach marks a paradigm shift: from viewing nature solely as an object of ownership to recognizing it as an independent legal subject. In 2017, by a judicial decision in **New Zealand**, the Whanganui River, revered by the Māori people, was recognized as a legal person. This created a precedent in which the river "owns itself" and is represented by legally appointed guardians. In **Canada**, the Council of the Innu Indigenous Nation and a municipal legislative body recognized the Magpie River as a legal person, endowing it with nine fundamental rights, including the right to exist and to flow; respect for natural cycles; the preservation of natural biodiversity and integrity; the ecosystem functions; protection from pollution; regeneration; and the capacity to bring legal action. A 2024 review confirms the relevance of this trend: of the 88 documented cases in which legal personhood has been granted to water bodies across 20 countries, 56 occurred between 2016 and 2023.[174]

In Europe, where river systems are characterized by high fragmentation, the focus shifts to restoration of connectivity.[175] Case studies of Slovenia, France, Spain, and the Nordic countries demonstrate the effectiveness of integrating conservation measures into broader policies. A new impetus to this process was provided by the 2030 EU Biodiversity Strategy, which set an ambitious target to restore free-flowing river conditions along 25,000 km. The methodology for identifying Key freshwater Biodiversity Areas (KBAs) within catchment boundaries is considered as a priority management tool. This facilitates their integration into River Basin Management Plans under the EU Water Framework Directive.

SCIENTIFIC PLANNING: CHINA'S EXPERIENCE. A case study of the Qingzhu River basin (Southwest China) - one of the world's biodiversity hotspots – serves as the illustrative example of science and planning integration.[176] To identify priority protected areas, an ecosystem-based approach was applied, assessing landscape integrity and authenticity. The model incorporated three factors: hydrology, vegetation

[172] Perry, D., Harrison, I., Fernandes, S., Burnham, S., & Nichols, A. (2021). Global Analysis of Durable Policies for Free-Flowing River Protections. Sustainability, 13(4), 2347, https://doi.org/10.3390/su13042347

[173] Perry, D., Harrison, I., Fernandes, S., Burnham, S., & Nichols, A. (2021). Global Analysis of Durable Policies for Free-Flowing River Protections. Sustainability, 13(4), 2347, https://doi.org/10.3390/su13042347

[174] Yanquiling, R., et al. (2024). Exploring the rights of nature in freshwater and marine ecosystems. Earth System Governance, 22, https://doi.org/10.1016/j.esg.2024.100247

[175] Schäfer, T. (2021). Legal Protection Schemes for Free-Flowing Rivers in Europe: An Overview. Sustainability, 13(11), 6423, https://doi.org/10.3390/su13116423

[176] Li, P., Zhang, Y., Lu, W., Zhao, M., & Zhu, M. (2021). Identification of Priority Conservation Areas for Protected Rivers Based on Ecosystem Integrity and Authenticity: A Case Study of the Qingzhu River, Southwest China. Sustainability, 13(1), 323, https://doi.org/10.3390/su13010323

cover, and anthropogenic pressure. Overlaying spatial datasets revealed that sections accounting for 49.33% of the total length of the mainstream need priority protection. The study confirmed the practical value of modeling for spatial zoning and the sound management of river basins.

Overall, the protection of natural river systems at the global scale has evolved from a largely theoretical concept into a phase of practical implementation, underpinned by a robust legal framework and advanced scientific methods.

5.8. Conclusion: Effective Ecosystem Protection Tools in Transboundary Basins

The analysis of international practices makes allows identifying five key elements, which in combination lead to sustainable outcomes in protection of transboundary aquatic ecosystems:

- **LEGAL REGULATION:** Formal designation of river reaches with free flow and legislative specification of environmental flow requirements for regulated watercourses.
- **UNIFIED MONITORING:** Joint observations based on an agreed system of indicators.
- **NATURE-BASED SOLUTIONS:** Integration of "green" approaches with conventional engineering infrastructure.
- **FOCUS ON FLOW-GENERATION ZONES:** Priority attention to mountain ecosystems.
- **INCLUSIVENESS:** Active involvement of civil society and private financing mechanisms.

Practices confirm that measurable ecosystem benefits are achieved where these components are combined into a single, coherent management approach.

FOCUS ON FLOW GENERATION ZONES. Experiencеы from the Alps, the Himalayas, and Central America show that when headwaters become the focus of coordinated actionы, the entire water cycle, including the delta, benefits. In the Alps, conservation networks link climate adaptation with the restoration of river corridors; in the Himalayas, unified mapping and management of springs stabilizes baseflow; and in Central America, protection of montane forests is integrated into basin water management.

PRESERVATION OF UNALTERED FRESHWATER ECOSYSTEMS. Experiences from the United States, China, Mexico, Brazil, the European Union, New Zealand, and other countries demonstrate the critical importance of identifying and protecting, within each basin, still unaltered reference river ecosystems that sustain natural ecological processes and native biodiversity. This is also a priority under the KBA Programme of Action.

LEGAL FRAMEWORK AND FLOW REGIMES. A key factor for success is the legally enshrined environmental flows and intra-annual flow regimes in transboundary agreements, as is the case in the Colorado and Mekong basins and the rivers of the Iberian Peninsula. In the Danube Basin, environmental objectives are embedded directly in integrated river basin management and flood risk management plans.

DATA, MONITORING AND JOINT RESEARCH. Durable outcomes require unified data infrastructure: coordinated monitoring, shared methodologies, and transparent reporting against agreed thresholds. The Orange-Senqu Basin uses regular joint studies that produce comparable data on water quality and biota to drive management decisions, while the Mekong and Danube basins rely on agreed procedures and harmonized observation networks to inform basin planning. Joint monitoring and research – from RS-based analysis of water surfaces and sediments to field-based bio-indices and environmental flow – establish calibrated thresholds (such as salinity and water levels) and early warning system. These tools allow adjusting water release schedules and the broader portfolio of measures.

COMBINATION OF NATURE-BASED AND ENGINEERING SOLUTIONS. Synergizing 'green' and 'grey' infrastructure yields the greatest benefits. In the Danube Basin, floodplain and fish passage restoration are integral to flood management plans. In the Colorado River Delta, combining pulse flows with riparian restoration has triggered a swift and quantifiable ecosystem response.

NGOs AND PRIVATE FINANCING. In the Colorado River Delta, a coalition of NGOs supported by private foundations plays a key role in acquiring water rights for nature and implementing restoration projects. On the Danube, partnerships between businesses and environmental organizations (for example, WWF–Coca-Cola) co-finance the restoration of wetlands. NGOs provide flexibility and expertise, while private foundations supply additional funding for ecosystem services.

LESSONS FOR THE AMU DARYA BASIN:

(1) Legally formalize **environmental flows** by establishing seasonal and dekadal (ten-day) discharge schedules for different flow conditions.

(2) Identify and keep under protection status the remaining intact freshwater ecosystems, including sections of large free-flowing.

(3) Establish a **unified monitoring network** comprising harmonized gauging stations, standardized indicators (discharge, sediment, water quality, and biota) and regular joint surveys.

(4) Integrate **nature-based solutions** (floodplain restoration, oxbow reconnection, and sediment management) directly into the operating rules of hydroschemes.

(5) Implement a dedicated **high-mountain adaptation** component, including monitoring of glaciers and snowfields, ensuring that upstream measures are linked to downstream needs.

(6) Develop robust mechanisms to **mobilize NGOs and private capital** for financing and implementation of environmental measures.

CHAPTER 6
FINDINGS AND RECOMMENDATIONS ON JOINT MEASURES

The ecosystems of the Amu Darya River basin – extending from high-altitude flow-generation zones to downstream floodplains and deltaic lakes – rely directly on a predictable and ecologically sustainable flow regime. This equilibrium is currently jeopardized by the dual pressures of anthropogenic intervention (such as flow regulation, abstraction, and pollution) and climate change.

The latter shifts seasonal inflow patterns, undermining the reliability of summer runoff, and increases the frequency of natural disasters, including glacial lake outburst floods.

Despite habitat degradation, significant potential for ecosystem restoration still remains. Realizing this potential requires transition to integrated management using an ecosystem-based approach, embedding environmental flow requirements into the operational protocols of hydroschemes, combining infrastructure modernization with nature-based solutions, and supported by a shared data and monitoring system.

The objective of joint actions is to ensure an ecologically sustainable flow regime and to restore ecosystem connectivity from the headwaters to the delta. This can be achieved through harmonized legal frameworks, joint data analysis, and coordinated investments in both "grey" and "green" infrastructure. This requires a clear allocation of roles among countries, IFAS institutions, and international partners and shall be accompanied by strengthened regional governance, community engagement, and transparent financing involving NGOs and the private sector.

Below is a package of 14 practical recommendations designed to achieve this objective. Each recommendation is cross-referenced with relevant actions from the ASBP-4 and REP4SD CA programs.

Recommendations (Package of Joint Measures)

Block 1: Governance and Planning

1. **Protection of flow generation zones:** Establish a unified system for monitoring glaciers, snow cover and associated hazards (mudflow, lake outburst). Implement springshed management programs in mountain communities to stabilize baseflow and ensure early warning.

   Related actions: the ASBP-4 climate adaptation block (glaciological monitoring and planning) includes similar actions and will contribute to reduction of flow uncertainty. REP4SD CA 4.1 and 4.4 (regional adaptation strategy; monitoring of glaciers) are directly targeted at this.

2. **Integration of ecosystem approach:** Incorporate ecosystem services assessment, the identification and protection of intact freshwater ecosystems, and requirements for environmental flow regimes into national and regional river basin plans. Make Strategic Environmental Assessment (SEA) mandatory for all sectoral programmes (agriculture, energy, water) to ensure that environmental considerations are addressed at the earliest stage of planning.

   Related actions: ASBP-4 4.1-4.2 (institutional/legal improvement of IFAS and national organizations) contain a similar message and will help to anchor institutionally the environmental objectives. REP4SD CA 5.1.1 and 6.3 will support their practical implementation.

3. **Formalizing environmental flow regimes:** Formally adopt legal and operational frameworks for quantities and intra-annual schedules (seasonal and dekadal) of water releases for environmental flow at key control sections, tailored to varying hydrological conditions. Establish a mandatory benchmark of 4.2 km^3 for the delta. Furthermore, adopt drought and flood management plans that are synchronized with these environmental flow regimes.

   Related actions: ASBP-4 1.6 ПБАМ-4 (automated control systems for water distribution, accounting and monitoring) contains a similar message on transition to evidence-based management and will contribute to more robust planning and implementation of environmental

flow. REP4SD CA 5.1.1/5.1.4 (ecosystem approach; regional ecosystem restoration scheme) prioritize nature needs that will help to embed environmental flows in planning.

4. Institutional coordination: Establish an interagency working group (water, environment, hydropower, SIC) under the ICWC to coordinate environmental flow schedules and assess cumulative impacts.

Related actions: ASBP-4 4.1-4.2 aim at better coordination at the level of IFAS/national institutions that will facilitate operation of this group. REP4SD CA 6.1-6.7 (strengthening institutions and partnerships) lay the joint framework.

Block 2: Data, Monitoring and Research

5. Common data infrastructure: Strengthen the coordinated observation network (discharge, water quality, sediments), adopt common bioindicators, and establish an open basin dashboard. Conduct joint surveys using a standardized methodology every five years. It is important to include an air quality/salt-dust (Aralkum) module, build on long-term observation series, and publish data in open access.

Related actions: ASBP-4 1.6 (national information system as a basis for a regional system) and 2.7 (monitoring of lake systems and Aral region) have similar provisions and will contribute to establishment of a common database. REP4SD CA 1.3 and 2.2 (system of indicators; water quality monitoring) have the same tasks. In addition, the forthcoming GEF/FAO project (ID 11380) including a TDA/SAP for the Amu Darya-Zarafshan-Panj system may provide methodological and financial basis for basin-wide diagnostics and the development of agreed indicators.[177]

6. Joint research: Implement a joint research and pilot program focused on key thematic areas: environmental flow assessment, fluvial and sediment dynamics, the ecological status of tugay forests and deltaic lakes, and the economic valuation of Nature-based Solutions (NbS). This will require: (i) a consolidated research roadmap with priorities for 3-5 years, (ii) regular joint field missions utilizing harmonized methodologies and open data protocols, (iii) models of environmental flow and water-salt regimes of the delta to calibrate water release schedules, (iv) pilots of nature-based solutions with before/after monitoring, (v) volunteer monitoring involving local residents (bird counts, camera traps, simple sensors) to expand spatial coverage.

Related actions: ASBP-4: 1.6 (information systems and monitoring), 1.13 (training and capacity building), 2.7 (monitoring of lake systems and Aral region), 2.11 (assessment and reduction of flood/mudflow risks), and climate adaptation block (glaciological monitoring) have similar focus and will contribute to launch of a joint research and pilot program. REP4SD CA: 1.1-1.2 (capacity building, knowledge sharing), 1.3 (system of indicators), 2.2-2.3 (water quality monitoring, analysis of anthropogenic and natural impacts), 4.1/4.4 (regional adaptation strategy, monitoring of glaciers and GIS-atlases of hazards), 5.1.1/5.1.3/5.1.4 (ecosystem approach, common inventory methodology, scheme of ecosystem restoration) also support joint research and data comparability.

7. Transparent reporting and indicators: Establish a unified suite of core indicators to evaluate ecosystem health: percentage of environmental flows met, area of floodplain flooding, salinity at key sections, biodiversity indices, invasiveness indices, frequencies of salt-dust episodes, etc.

Related actions: ASBP-4 1.6 and 2.7 (data and monitoring of Aral region) contain a similar message and will contribute to regular reporting. REP4SD CA 1.3 and 2.2 (system of indicators; monitoring of water quality) help to enshrine KPI and their publication.

[177] GEF (n.d.). Project 11380: Strengthening integrated water management in the Amu Darya, Zarafshon, and Panj River Basins (Water–Land Nexus mainstreaming), www.thegef.org/projects-operations/projects/11380

Block 3: Implementation and Technologies

8. Operation of hydroschemes and canals: Embed the approved environmental flow regimes into the operating rules and dispatch schedules of hydroschemes and main canals, ensuring compliance monitoring.

> **Related actions:** ASBP-4 1.6 and 1.13 (management and improvement of the material and technical base of water management organizations) have similar approach and will contribute to translation of environmental requirements into routine operations. REP4SD CA 6.4 (guidelines and standards on SEA) will support integration of ecological factors into regulatory frameworks.

9. Modernization and water saving: Accelerate the deployment of water-saving technologies (canal lining, drip irrigation, and automated control systems) and economic incentives by establishing a rule under which a share of the water saved is allocated to environmental needs. Provide for shifts in cropping patterns to less water-intensive and more salt-tolerant crops, and pay due attention to drainage and salinity management.

> **Related actions:** ASBP-4 1.12 and 1.13 (water saving; capacity building) contain closer solutions and will help to free resource for the nature. REP4SD CA 3.1-3.4 (green technologies/sustainable financing) will support implementation.

10. Nature-based solutions: Upscale projects to reconnect oxbows, restore tugay forests, establish fish passes, and implement phytoreclamation, giving priority to projects that combine "grey" and "green" infrastructure. Require before/after monitoring of biological and hydrological indicators in pilot projects to enable subsequent replication.

> **Related actions:** ASBP-4 2.11 (reduction of flood/mudflow risks) and 2.7 support implementation of NbS and monitoring of their effects. REP4SD CA 5.1.4, 5.2.6, 5.2.7 (restoration of ecosystems, sustainable functioning of wetlands, tugay forests) contain similar targets and will contribute to upscaling.

11. Enhanced enforcement: Shift the focus from law design to operational enforcement: strengthen inspection services, modernize laboratories, and adopt digital water accounting. Increase stable budgetary funding for environmental and water management agencies, and roll out targeted training programs for staff.

> **Related actions:** ASBP-4: 1.13 (staff and material-technical base), 1.6 (automated control and monitoring systems and national IS), 1.12 (water saving technologies), 2.7 (enhanced monitoring in Aral region), 4.1-4.2 (legal and institutional improvement). REP4SD CA: 1.1-1.2 (capacity building and knowledge sharing), 1.3 (system of indicators/KPI), 2.2 (efficient monitoring of water quality), 6.2 (access to technologies and finances), 6.3-6.4 (strengthening institutions; guidelines and standards for SEA).

Block 4: Partnerships and Participation

8. Development of a network of protected areas and ecological corridors. To strengthen the region's ecological framework, it is advisable to continue efforts to expand and ensure the spatial connectivity of key protected areas, including through the establishment of transboundary ecological corridors. A strategically important step would be the development of a comprehensive basin action plan for biodiversity conservation. As part of the basin approach, identification and legal designation of intact freshwater ecosystems should be prioritized. The focus should be placed also on planning of ecological rehabilitation measures for water bodies of critical importance for the conservation of endemic freshwater fauna.

> **Related actions:** ASBP-4 3.4 (ecotourism) addresses social support to protection and will contribute to sustainable management of protected areas. REP4SD CA 5.2.3 (ecological corridors/transboundary PAs) sets appropriate framework. This will also constitute an important contribution to implementation of the Kunming-Montreal Global Biodiversity Framework under the Convention on Biological Diversity.

9. Financing and partnerships: Develop public-private partnership mechanisms and payments for ecosystem services to mobilize additional financing from businesses, NGOs, and private foundations. Further advance payments

for ecosystem services and introduce mandatory assessment of ecosystem benefits when selecting projects for financing.

> **Related actions:** ASBP-4 3.4 and 4.1 contain similar priorities (diversification, institutional mechanisms) and will facilitate fund mobilization. REP4SD CA 3.5 and 6.2 imply cooperation with international initiatives and access to finances/technologies.

10. Public engagement: Implement programs on environmental education and the involvement of local communities in monitoring and on-the-ground conservation actions. Ensure participation of stakeholders in basin and project planning from the earliest stages. Scale up youth program and support for NGOs (field activities, awareness-raising campaigns).

> **Related actions:** ASBP-4 1.13 and 3.4 (staff and socio-economic measures) are close in substance and will contribute to public engagement. REP4SD CA 1.1-1.2 and 5.2.6 (capacity building; sustainable functioning of wetlands) support the same approaches.

As evidenced, many of these core elements are already anchored in ASBP-4 and REP4SD CA. The current imperative is to transform these provisions to tangible implementation by integrating legal instruments, operational schedules, shared data, and financing into a single, coherent system of actions.