Looming Water Crisis in Amu Darya River Basin

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Abstract

Since the 1960s, the average annual runoff of the Amu Darya declined significantly due to human activities, including the construction of dams and increased water withdrawals for irrigation. Between 1950 and 1980, the total irrigable area within the Amu Darya river basin (ADRB) increased 150% to about 5.76 million hectares, of which around 2.3 million hectares is located in Uzbekistan. It is expected that water availability in the middle and lower reaches of the ADRB will significantly decrease during the next 20 to 30 years due to the impacts of climate change and the construction of the Rogun dam in Tajikistan and the Qosh Tepe canal in Afghanistan. Therefore, the Interstate Commission for Water Coordination of Central Asia, responsible for water allocation between countries within the ADRB, together with the concerned national governments have to develop and implement appropriate measures to adapt to the expected decrease in water availability to avoid a serious water crisis.

Key words: Amu Darya, Uzbekistan and water availability

Amu Darya River Basin

The Amu Darya is formed by the confluence of the Vakhsh and Panj rivers in Tajikistan and its length is 2,540 km measured from the source of the Panj River in the Pamir mountains. The Amu Darya forms a natural border of 1,800 km between Afghanistan and its northern neighbours, Tajikistan, Uzbekistan, and Turkmenistan, before flowing across the arid Turan plain in eastern Turkmenistan and forming part of the boundary between Turkmenistan and Uzbekistan in its lower reach where it discharged in the Aral Sea in the past. According to the Basin Water Organisation “Amu Darya”, the Amu Darya river basin (ADRB) covers a total area of 1.327 million km^2 and the Interstate Commission for Water Coordination of Central Asia (ICWC) refers to a total area of 1,017,800 km^2, whereas other documents report a total area of 465,000 to 534,700 km^2 depending on the used definition. (BWO Amu Darya 2017, UNECE 2007, Kulmatov 2026; Rakhmatullaev 2008, Mahmood 2026) The BWO Amu Darya reports that the size of the upstream catchment area is 226,800 km^2, including glacier area of 7,300 km^2, but other documents refer to a catchment area of 309,000 km^2. (BWO Amu Darya 2017; FutureWater 2023; UNEP 2011, EDB 2023, Kamil 2021, CAWater-Info)



Figure 1. Map of ADRB
Source: http://www.icwc-aral.uz/bwoamu.htm

Between 2000 and 2018, the average annual runoff in the ADRB was 78.77 km^3 with 77 to 80% of the total runoff occurring between April and September as it is mainly fed by glacier- and snowmelt water from the Tian Sian and Pamir-Alai mountains in Tajikistan. The Panj River and the Vakhsh River are the main water source of the Amu Darya with a supply of respectively 33.4 km^3 and 20.2 km^3. A total of 35 water reservoirs haven been constructed in the ADRB, including 14 dams in Tajikistan, with a total storage capacity of 29.8 km^3 for electricity production and supply of irrigation and drinking water. The main tributaries flowing directly into the Amu Darya are the Kafirnigan River, Surkhandarya River, Sherabad River and Kunduz River. (Rakhminov and Kamolidinov 2014; ADBN 2012; BWO Amu Darya 2017, EDB 2024, Olsson and Bauer 2006)

Although small-scale irrigation started to develop along the banks in the lower reach of the Amu Darya at the start of the 2nd millennium B.C., large-scale irrigation development in the

ADRB occurred during the 20th century, especially between 1950 and 1990 when the irrigable area within the ADRB expanded with 150%. (UNEP 2011, SIC ICWC 2011) The total irrigable area within the ADRB is estimated at about 5.76 million hectares, of which around 2.3 million hectares are located in Uzbekistan, 1.7 million hectares in Turkmenistan, 1.15 million hectares in Afghanistan, 0.5 million hectares in Tajikistan and 0.1 million hectares in the Kyrgyz Republic. (ADBN 2012; Kamil 2021) About 77% of the available river water in the ADRB is used for irrigation. (ADBN 2012) More than 60 canal systems withdraw water directly from the Amu Darya, of which the Karakum canal with a discharge capacity of 600 to 650 m^3/s in Turkmenistan and the Tashsaka canal (500 m^3/s), Doslyk canal (500 m^3/s) and Amu-Bukhara canal (400 m^3/s) in Uzbekistan are the largest irrigation systems. (EDB 2024)

Water Allocation and Withdrawals

Following the collapse of the Soviet Union at the end of 1991, the Kyrgyz Republic, Tajikistan, Turkmenistan and Uzbekistan as new independent countries agreed in the Alma Ata Agreement of 1992 and the Nukus Declaration of 1995 to allocate available water resources within the ADRB according to limits established in Protocol No. 566 of the U.S.S.R. Ministry of Land Reclamation and Water Management approved in 1987. (Rakhminov and Kamolidinov 2014) The agreed maximum annual water allocation for the Amu Darya is shown in Table 1:

Table 1. Maximum water allocations per country for Amu Darya

Country	**Maximum Annual Water Allocation (km^3/year)**	**% of Total Maximum Annual Water Allocation**
Kyrgyz Republic	0.40	0.6%
Tajikistan	9.50	15.4%
Turkmenistan	22.00	35.8%
Uzbekistan	29.60	48.2%
Total	61.50	100%

Source: Rakhminov and Kamolidinov 2014

In addition, it was assumed that Afghanistan has the right to 2.1 km^3 per year and that 6.4 km^3 per year would be sufficient to maintain the water level in the Aral Sea. (Hydrosolutions 2023)

The allocation of the maximum annual water withdrawal limits per country is the responsibility of the Interstate Commission for Water Coordination of Central Asia (ICWC), whereas the Basin Water Organisation "Amu Darya" as executive organ of the ICWC has the task to manage the water allocation and distribution between the countries.

Between 2018 and 2025, an average annual volume of 55.14 km^3 was allocated or 89.7% of the total maximum annual water allocation of 61.50 km^3. During the same period, the average annual water withdrawal was 47.45 km^3 or 86.1% of the average annual allocated volume of 55.14 km^3, of which 69.7% was withdrawn during the irrigation season (March/April-October/November) and the remaining 30.3% during the winter months, mainly for leaching of salinity-affected farmlands. Whereas Tajikistan and Turkmenistan withdrew on average 90.3% of the annual water allocation, it was only 80.3% for Uzbekistan. (SIC ICWC 2019-2026)

As about 9 to 11 km^3 of highly saline drainage water (2.3 tot 8.7 mg/m^3) flows back annually into the Amu Darya, it is one of the main reasons for the high salt level of the river water in the lower reach of the Amu Darya. The river water salinity has increased notably since the 1960s due to intensification of irrigated agriculture and exceeds safe drinking and irrigation standards (1000 mg/l) in the middle and lower reaches of the river (SIC ICWC 2011, Lingang Hao 2023) Furthermore, the Amu Darya is one of the most turbid river in the world with an estimated average annual reservoir volume loss of 0.5% in Uzbekistan. (ADRN 2012)

Declining Annual Runoff

The long-term average annual runoff in the ADRB (1934-2011) was 74.22 km^3. (FutureWater, 2023) The annual runoff in the ADRB between 1989/90 and 2025 measured at the Kerki gauging station located upstream of the Karakum Canal is shown in Figure 2:

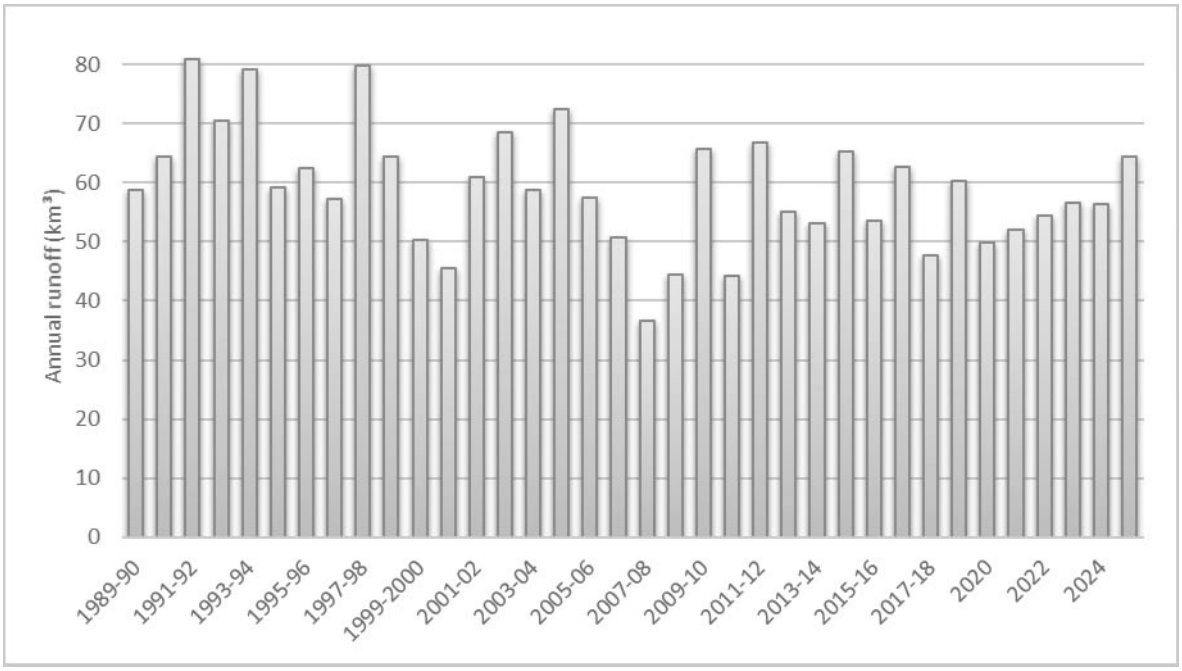

Figure 2. Annual unoff with ADRB at Kerki gauging station between 1989/90 and 2025
Source: FutureWater 2023, SIC ICWC 2019-2026

Between 1989/90 and 2025, the average annual runoff of the ADRB at the Kerki gauging station was 59.19 km^3: a decline of 20.3% compared with the long-term average annual runoff of 74.22 km^3. Between 1989/90 and 1998/99, the average annual runoff in the ADRB was 67,67 km^3 or 8.8% less than the long-term average annual runoff, but it dropped to 54.58 km^3 between 1999/2000 and 2008/09 (-26.5%), 57.44 km^3 between 2009/10 and 2019 (-22.6%) and 55.62 km^3 (-25.1%) between 2020 and 2025. (FutureWater 2023, SIC ICWC 2019-2026)

According to a recent study, the rapid decline of the annual runoff in the ADRB measured at the Kerki gauging station during the last 25 years is caused by human activities. Although climate change resulted in increased runoff in the Vakhsh and Panj rivers due to more precipitation and higher temperatures causing more rapid melting of glaciers (surface of glaciers in the Pamir mountains decreased with 7.8% between 1978 and 1990 and 11.6% between 1990 and 2001), the construction of dams and increased water withdrawal for irrigation in Tajikistan contributed to the rapid decline in the runoff in the Amu Darya measured at the Kerki gauging station. (Mahmood 2026) Climate change have altered the hydrological processes in the catchment area of the ADRB as increased temperatures caused a shift from snow to rain and earlier melt of snowpack resulting in a change in the seasonal pattern of the runoff. (Hou 2025)

The demand for irrigation water increased in Uzbekistan due to climate change as: a) temperature in Uzbekistan increased on average with 0.13 ºC per decade between 1901 and 2013 and even 0.51 ºC per decade between 1983 and 2013; b) number of days with maximum temperatures of at least 40 ºC increased from 10 days during the 1950s to more than 20 days in 2016, especially in the lower reach of the ADRB; c) precipitation became less predictable

and reliable; d) increased frequency of droughts; and e) combination of higher temperatures, more droughts and lower air humidity caused higher wind speeds resulting in more dust storms. (UNEP 2011, USAID 2018)

In the lower reach of the Amu Darya, the annual runoff dropped dramatically as the average annual discharge at the Kipchak gauging station situated 53 km upstream of Nukus city decreased from 953 m^3/s between 1989 and 1995 to 334 m^3/s between 2017 and 2021: a decline of 65%. In addition to increased irrigation water demand due to climate change, the rapid decline of the annual runoff in the lower reach of the Amu Darya is also the result of the policy of the Uzbek government to guarantee sufficient supply of irrigation water to the cotton farmers in the middle reach, especially in years with a lower than normal runoff in the Amu Darya, at the expense of farmers growing other crops. (Wegerich 2001) An analysis of the annual water withdrawals between 2010 and 2024 clearly shows that the annual water withdrawal in the middle reach of the Amu Darya with an average volume of 15.03 km^3 was more or less constant with a minimum of 12.94 km^3 (-14%) in 2011 and a maximum of 15,80 km^3 (+5%) in 2014 and 2015. The annual water withdrawal in the lower reach of the Amu Darya with an average volume of 12.01 km^3 fluctuated significantly with a minimum of 8.02 km^3 (-33%) in 2011 and a maximum of 15.18 km^3 (+26%) in 2012.

The reduced and more fluctuating runoff in the lower reach of the Amu Darya has seriously affected irrigated agriculture in the autonomous Republic of Karakalpakstan located in Western Uzbekistan: average irrigated area dropped from 410,000 hectares between 1990 and 1999 to about 250,000 hectares during the first two decades of the 21st century. Furthermore, the proportion of irrigable farmland with salinity problems increased from 50 to 73% and the average yields for almost all crops are significantly lower than the overall average yields for Uzbekistan. (Statistics Department of the Republic of Karakalpakstan)

Expected Impacts of Future Climate Change

The expected impacts of future climate change in Central Asia will increase the pressure on water availability in the ADRB in general and Uzbekistan in particular. The glaciers in the Tien Shan mountains in Central Asia may lose 50% of their 2020 ice mass in 2050 and 69 to 93% by 2100 depending on the climate change scenario. (GFZ 2015; Van Tricht 2026) The envisaged impacts of climate change in Uzbekistan include an increase of average temperature of 1.8 to 3.3 ºC in 2050 and 2.0 to 5.4 ºC in 2085; an increase in duration of heatwaves of 4 to 17 days in 2050 and 6 to 43 days in 2085; an increase of intensity of heavy rains with 7 to 36% and increase of frequency of 12 to 74% in 2085; and an increase in length of droughts with 4 days in 2085. (USAID 2018)

According to the World Bank, the annual runoff of the Amu Darya may decrease by 10 to 15% and the yields for nearly all crops may decrease by 20 to 50% in 2050 due to climate change. As it is expected that irrigation water demand in Uzbekistan will increase by 5% by 2030, by 7 to 10% by 2050 and by 12 to 16% by 2080, the envisaged decrease in the annual runoff of the Amu Darya will worsen water scarcity, especially during years with low water flow. (World Bank 2013) The Asian Development Bank expects that the water volumes in the

ADRB could decrease by 40% by the end of this century and the water deficit in Uzbekistan will increase to 7 billion m^3 in 2030 and 15 billion m^3 in 2050. (ADB 2022)

Construction of Rogun Dam in Tajikistan

The construction of the Rogun dam in the Vakhsh River in Tajikistan will also impact the runoff of the Amu Darya as it will require 16 years to fill the reservoir with a capacity of 13.3 km^3. It is expected that construction of the dam will be completed in 2033 and the reservoir will be filled in 2038. (AIIB 2024) It is estimated that the runoff in the Amu Darya will drop with 25% during the impounding of the reservoir. (Eurasianet 2025) The operation of the completed Rogun dam for electricity production may also have a significant impact on water availability, especially during the summer season when the demand for irrigation water is the highest.

Construction of Qosh Tepe Canal in Afghanistan

The Qosh Tepe canal with a length of 285 km in Northern Afghanistan with a design capacity of 20.5 billion m^3 per year and a maximum discharge capacity of 650 m^3/s is another threat for water availability in the middle and lower reaches of the Amu Darya. The construction started in March 2022 and the first 100 km were completed in October 2023. It is expected that the entire canal system will be completed in 2030. It is estimated that about 15 billion m^3 per year will be required to supply water to the planned irrigable area of 550,000 to 600,000 hectares, which is 25 to 30% of the average annual runoff of the Amu Darya. (Hydrosolutions 2023, Berlin Economic 2023)

The Swiss-based consultancy company Hydrosolutions has assessed the impact of the future operation of the Qosh Tepe canal on the existing water allocation between the four Central Asian countries as stipulated in the Alma Ata Agreement of 1992. The current water balance of the Amu Darya is shown in Figure 3:

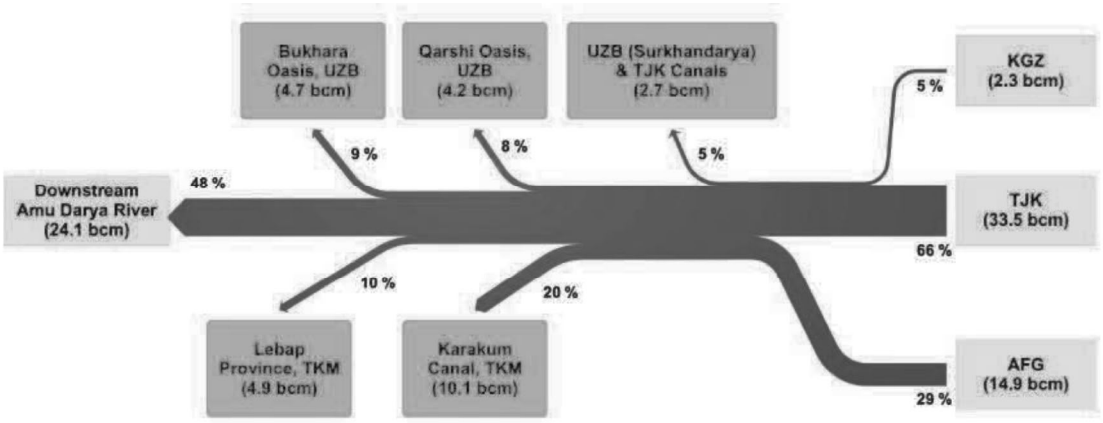

Figure 3. Current water balance of Amu Darya
Source: Hydrosolutions, 2023

At present, the available water in the Amu Darya is almost equally distributed between the head and middle reach (52%) and the downstream reach of the river (48%). As soon as the Qosh Tepe canal becomes fully operational, about 15.4 billion m^3 per year or 30% of the total average annual runoff will be diverted. As shown in Figure 4, this would have a very significant impact on the water balance as only 17% of the total annual runoff (8.7 billion m^3) would be distributed to the lower reach of the Amu Darya assuming that the canal systems in the middle reach would receive the same volume of river water as currently.

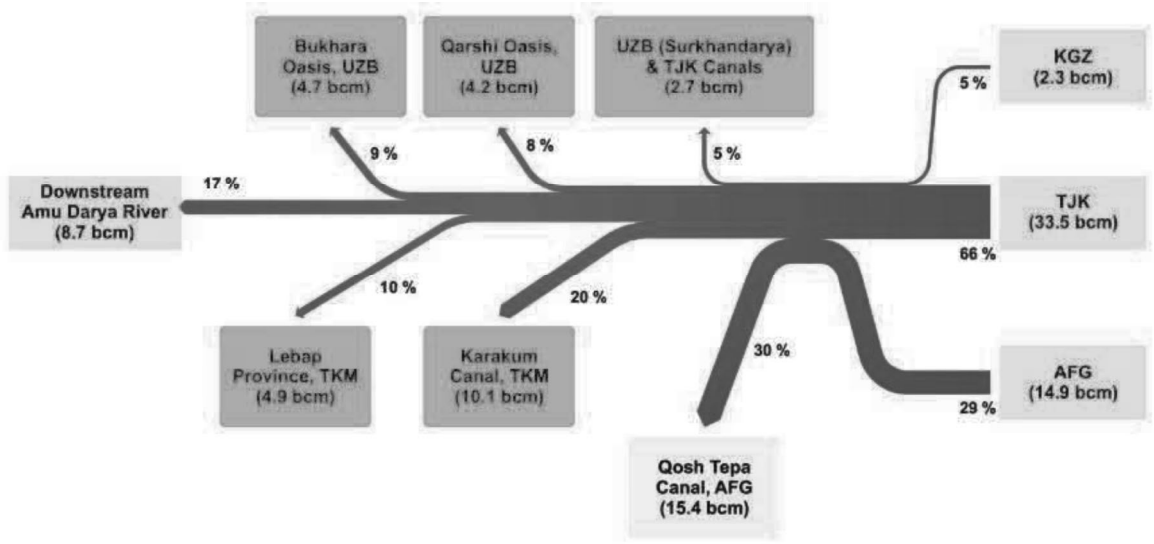

Figure 4. Hypothetical water balance of Amu Darya with Qosh Tepa Canal
Source: Hydrosolutions, 2023

If the irrigation water use per hectare in the middle and lower reaches of the ADRB would not be reduced, the expected decline in water availability due to the operation of the Qosh Tepe canal would lead to a decrease of irrigated area by 18.9%, a decline in crop production by 12.9% and a loss of about 250,000 jobs in the ADRB. (Berlin Economics 2023)

Potential Socio-Economic and Geopolitical Consequences

The reduced water availability in the middle and lower reaches of the ADRB would have serious socio-economic consequences for many farmers and their households in the middle and lower reaches of the Amu Darya in terms of lower yields, incomes and food security. Despite good regional cooperation between the riparian countries during last 10 years, the disturbance of the current water balance for the Amu Darya could have major geopolitical consequences and instability in the region leading to more diplomatic tension between countries depending on the Amu Darya for the supply of water. (Hydrosolutions 2023, EDB 2024)

Proposed Mitigation and Adaptation Measures

To avoid a water crisis in the middle and lower reaches of the ADRB that would have serious socio-economic consequences for the farming communities relying on irrigation and other water consumers, the ICWC and the concerned national governments have to develop and implement appropriate policies and interventions for the middle and lower reaches of the ADRB to mitigate and adapt to the impacts of reduced runoff in the Amu Darya. The following mitigation and adaptation measures should be considered:

- Preparation, adoption and implementation of an improved and fair water allocation agreement between the concerned countries based on a new water balance for the Amu Darya following the completion of the Qosh Tepe irrigation system and by taking into account the expected impacts of future climate change.
- Development and adoption of a long-term climate-resilient master plan for the ADRB by the ICWC in collaboration with all concerned countries, including Afghanistan.
- Enhancement of water storage capacity through the construction of dam reservoirs to be filled during the winter months.
- Reduction of conveyance losses in irrigation sector through rehabilitation and modernisation of irrigation canals and structures, including lining of earthen canals, and/or replacing open canals with pipe systems.
- Implementation of smart demand-driven water management systems at all levels of the irrigation systems based on real-time data provided by remote sensing technology and water sensors.
- Improvement of farm-level water management through introduction and promotion of appropriate water-saving technologies and practices among farmers through improved agricultural extension services.
- Focus of future irrigation development in irrigated areas with highest social and economic potential.
- Introduction and promotion of (more) drought-tolerant varieties for major food and industrial crops, such as winter wheat and cotton.
- Reduced cultivation of crops with high crop water requirements, such as rice.
- Where feasible, promotion of conjunctive use of surface and groundwater for irrigation, whereby low or moderately saline groundwater would be mixed with surface water.
- Increased re-use of drainage water and treated wastewater for irrigation.

Equitable allocation and distribution of available water within the ADRB is fundamental for maintaining (political) stability, peace and prosperity in the region. Confronted by the looming water crisis, new water diplomacy between the concerned countries relying on water resources in the ADRB would be required that is based on collaboration and negotiation rather than competition.

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