Academic Journal of Science and Progress (AJSP)

ISSN: 3162-1732| www.ajsp.uz

UDK / UDC: 556.535 / 556.537

EVALUATION OF THE IMPACT OF CHANNEL DEFORMATIONS ON THE RELIABILITY OF OBSERVATION DATA AT THE QIPCHOQ GAUGING STATION

Jurayev Bahrom Bahriddinovich[1]

1 PhD / Senior Researcher, Scientific Research Institute of Irrigation and Water Problems. Samarkand, Uzbekistan.
ORCID: 0000-0002-1234-5678

e-mail: bahrom.jurayev4k@gmail.com

Abstract — *This paper evaluates the impact of riverbed deformations on the reliability of hydrological observation data, using the Qipchoq gauging station in the Lower Amu Darya basin as a case study. Hydrological records spanning the last decade (2015–2025) and field survey data obtained via modern GNSS F4/F7 receivers and a SonTek M9 Acoustic Doppler Current Profiler (ADCP) were analyzed. The findings reveal a critical decrease in annual runoff volume by approximately 7 billion m³, alongside a 30–35% decline in interannual discharge trends. This has triggered intensive sedimentation within the riverbed (with silt accumulation thickness ranging from 75 cm to 2.41 m) and the formation of stable sand islands. Substantial discrepancies and inaccuracies between the existing rating curves (gauge height readings) and actual cross-sectional discharge measurements are substantiated. Based on these findings, the construction of a settling basin upstream of the gauging station is scientifically proposed to ensure precise water accounting.*

Keywords — *Lower Amu Darya, Qipchoq gauging station, channel deformation, water discharge, sediment accumulation, Doppler current profiler, GNSS measurements, rating curve.*

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1. INTRODUCTION

Water resources form the vital foundation for the socioeconomic development of modern society. Regulating river runoff using large-scale water intake systems represents one of the primary pathways in integrated water resources management [1]. Depending on the annual water abundance levels, intensive channel processes are observed across river systems. Full and intensive utilization of water resources has driven severe erosion, riverbed deformation, and the continuous accumulation of heavy sediment loads [2, 3]. Consequently, unfavorable hydrological conditions have emerged within river basins, compromising the operational reliability of water supply managed via reservoirs and downstream intake structures. In this regard, long-term monitoring and research conducted in the lower reaches and deltas of rivers provide an opportunity to explore key issues related to flow hydrology and channel dynamics [4, 5]. Special attention is currently directed toward the temporal management of river runoff volumes and the development of advanced methods for damless water diversion supported by channel regulation structures. The evolution of channel processes into an independent scientific discipline occurred during the 1940s and 1950s, marked by the publication of major foundational

works by M.A. Velikanov, N.I. Makkaveev, E.V. Shantser, N.E. Kondratiev, I.V. Popov, and N.A. Rzhanitsyn [6, 7]. The formation of

this new field advanced alongside a deeper substantiation of its theoretical and physical principles [8, 9]. Modern frameworks have introduced new classifications of channel-forming processes, proposed defining criteria for specific channel regimes, and established indicators to categorize riverbed typologies. The interaction between riverbeds and stream flows has been reinterpreted, uncovering regularities in how structural configurations and morphological characteristics adjust in response to prevailing channel types [10]. The interaction of river flow with channel boundaries is evaluated by incorporating factors that dictate water discharge variation, sediment transport, and hydrological regime transformations [11, 12, 13]. In recent years, severe bank erosion and excessive sediment concentrations within incoming flows have created substantial operational challenges for hydraulic structures [14]. Investigating hydrological and channel dynamics through direct field surveys remains essential for addressing riverbed degradation, sedimentation management, and broader water resource challenges. The objective of this research is to identify the critical factors negatively affecting water accounting in the Lower Amu Darya region, evaluate their impact on the accuracy of discharge measurements at the Qipchoq gauging station, and scientifically substantiate effective remediation measures.

2. MATERIALS AND METHODS

The study analyzes scientific-practical literature and multi-year field observation datasets on riverbed dynamics. A comprehensive database tracking the flow volumes of the Lower Amu Darya from 2015 to 2025 was constructed using official reports from relevant state authorities and departments. Water discharge records from the Qipchoq gauging station over the past 10 years were critically reviewed. Consultation meetings were conducted with specialists from the departments of "Water Resources, Hydrometry, and Dispatch Services" and "Organization of Repair and Rehabilitation Works for Hydraulic Structures" to compile historical documentation on recent morphological shifts around the station. Field measurements were performed at the Qipchoq station cross-section to refine available hydrographic datasets. Parameters including water discharge, flow velocity, depth profiles, surface width, and morphological characteristics were measured, confirming severe riverbed deformation at the active monitoring cross-section. The field investigations adhered to standard hydraulic laws and hydrographic techniques. Benchmarks established along the riverbanks were used to determine reference elevations. To determine water surface elevations, a GNSS F4 receiver was set up over a known benchmark to serve as the reference base station operating across X, Y, and Z axes. Concurrently, a GNSS F7 receiver acted as the rover unit, calibrated to an accuracy range of 0.001–0.002 meters to pinpoint precise target elevation coordinates. Riverbed topography and depth profiles were mapped using a SONTEK M9 Acoustic Doppler Current Profiler (ADCP), capturing water depth measurements at discrete intervals of 2–3 cm across the entire channel cross-section.

3. RESULTS

Analysis of annual water discharge and volume data over the last decade at the Qipchoq gauging station reveals a highly dynamic flow variation, oscillating between 7 billion m^3 and 14.5 billion m^3 per

year. The 10-year trend highlights a critical decline in the total annual runoff volume, which has decreased by nearly 7 billion m³.

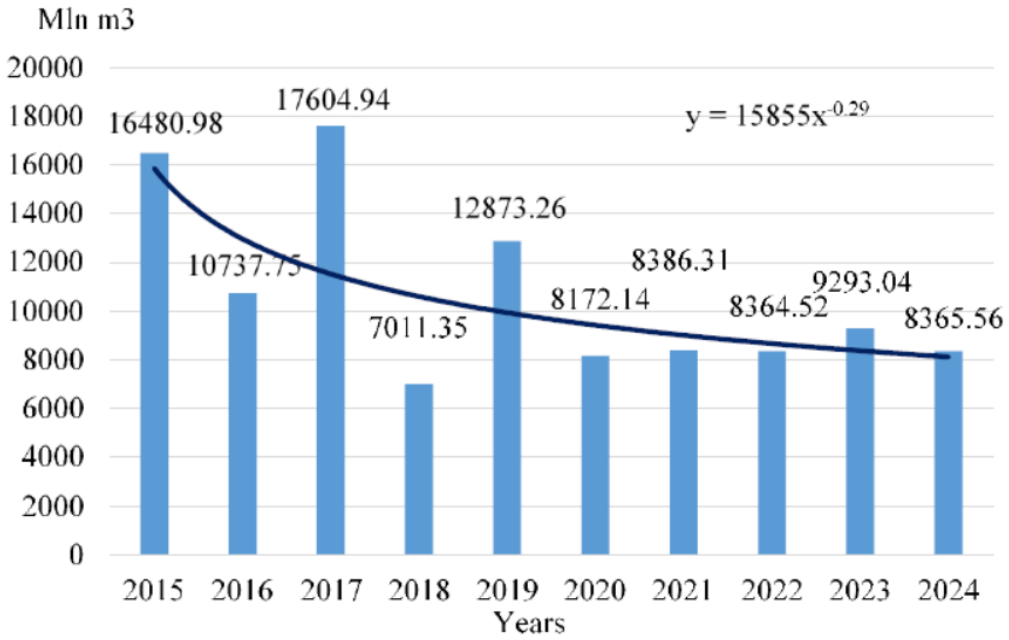


Figure 1. Flow volume at the Kipchak hydropost

Daily and monthly average water discharge rates over this 10-year period varied from 50 m³/s to 1700 m³/s. Peak discharge levels reaching 1500–1700 m³/s were observed in only two specific years (2015 and 2017). Throughout the remaining years, maximum discharge did not exceed 800 m³/s. This prolonged exposure to low-flow conditions led to accelerated deposition of suspended sediments within the channel, resulting in the formation of permanent sandbars and mid-channel islands. These changes severely obstructed the execution of reliable hydrometric measurements at the original cross-section, ultimately necessitating the physical relocation of the gauging station to a downstream reach.

The long-term discharge trend at the Qipchoq gauging station indicates a 30–35% reduction in available flow volumes. This decline progressively impairs the operational efficiency of downstream hydraulic infrastructure in the Lower Amu Darya and accelerates the development of stable island formations and wetland zones within the primary channel.

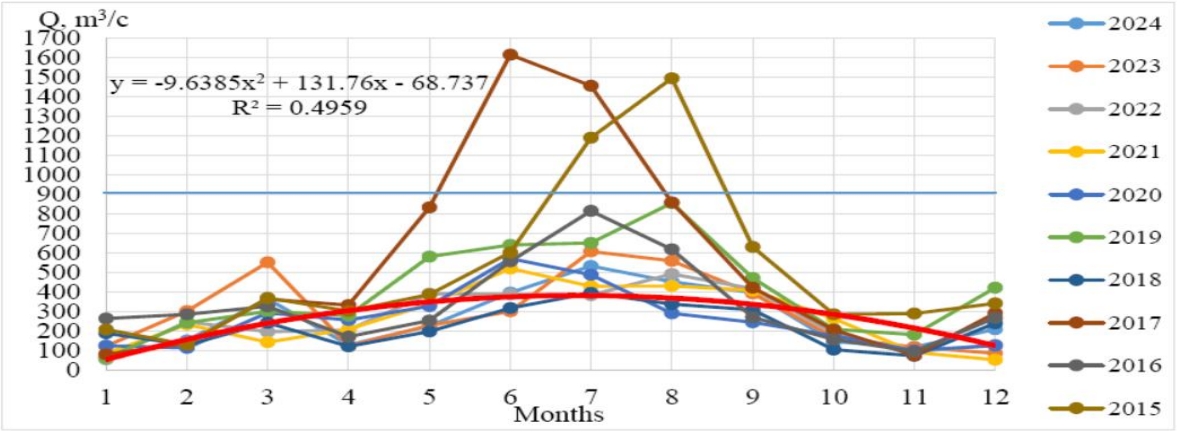


Figure 2. Monthly water discharge from the Kipchak hydropost

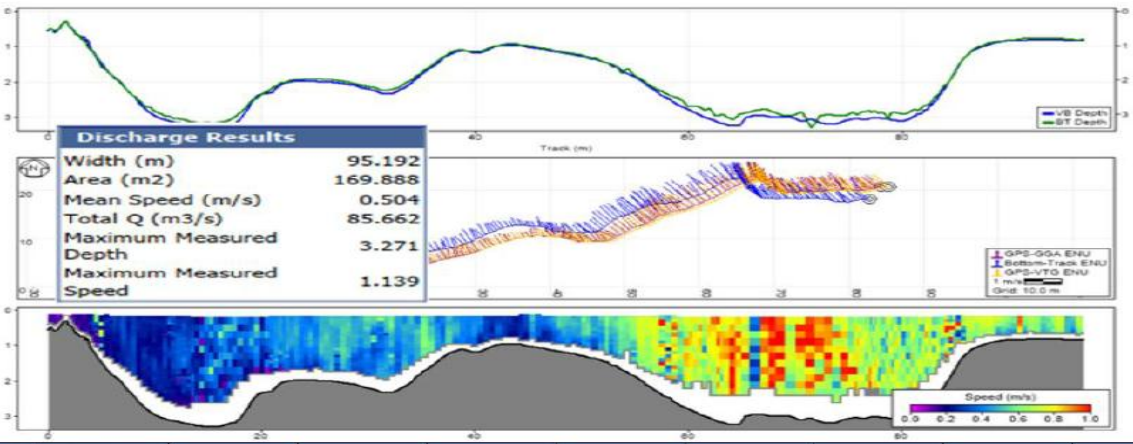
To evaluate the accurate water surface elevations at the station, existing benchmark references were audited against our field survey results. The comparative baseline data is structured in Table 1.

Table 1. Measured water surface elevations and benchmark references at the Qipchoq gauging station

Observation Points	Latitude (X)	Longitude (Y)	Elevation (Z), m
Base Benchmark Elevation	-	-	84.45
Water Surface Elevation (General)	-	-	80.12
Installed Base Benchmark Coordinate	4680718.4532	261474.3338	84.4540
Identified Water Level Elevation (Point 1)	4680709.2414	261517.0343	80.1180
Identified Water Level Elevation (Point 2)	4680933.1920	261547.8439	80.0957
Identified Water Level Elevation (Point 3)	4680960.7047	261758.0477	80.1073

The high-precision field survey identified an actual water surface elevation of 80.11 m. The absolute variance against the reference base benchmark was restricted to 0.01 m, yielding a negligible error margin of 0.01%, which confirms the high precision of the field data.

Direct field cross-sectional surveys executed on December 2, 2025, recorded the following morphological and hydraulic parameters: channel width of 95.19 m, cross-sectional area of 169.89 m², mean flow velocity of 0.50 m/s, maximum recorded flow velocity of 1.14 m/s, and a maximum channel depth of 3.27 m. The actual verified water discharge was established at 85.66 m³/s, confirming a corresponding water surface elevation of 80.120 m.



Gauge indicator	402	501	527	567	576	588	590	613
Measured	85.00	267.00	305.00	496.00	477.00	535.00	562.00	614.00
Graph	68.40	256.60	327.00	448.80	480.00	530.80	540.00	663.70
Variation	16.60	10.40	-22.00	47.20	-3.00	4.20	22.00	-49.70

Figure 3. Measurement results at the Kipchak hydropost

Comparing the station's historical rating curves (staff gauge height records) against the newly captured field survey datasets exposed distinct systematic discrepancies and non-conformities:

• At low-flow stages with discharges up to 250 m³/s, historical rating curves systematically overestimate the actual measured discharge rates.

• Within the mid-range interval of 250–350 m³/s, the rating curve values align tightly with field measurements.

• In the 350–550 m³/s discharge range, actual measured flows fall below the values predicted by historical rating curves.

• Conversely, when water discharge exceeds 550 m³/s, direct field measurements yield values higher than the historical rating curves.

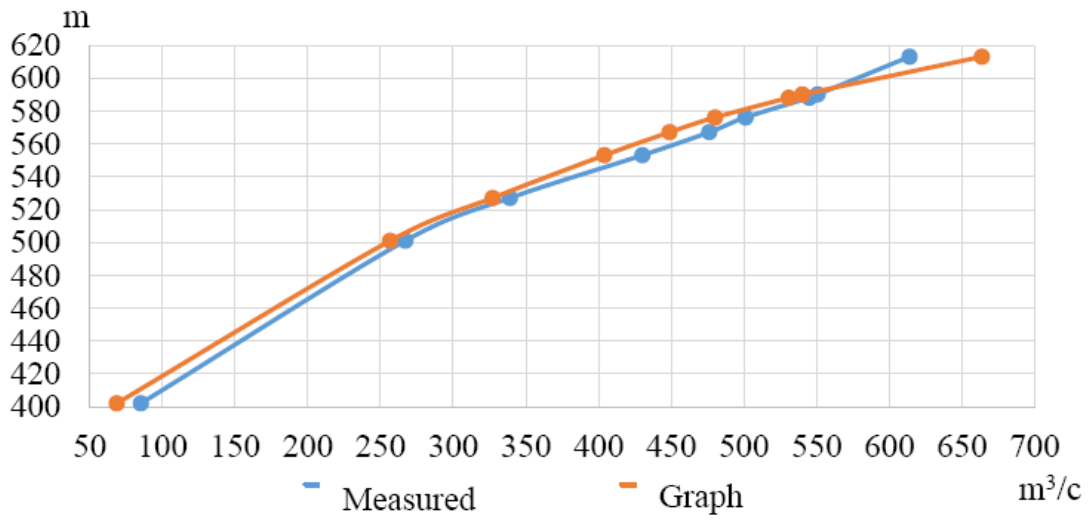


Figure 4. Measurement and graphical difference in water discharge at the hydropost

These shifts are driven by continuous channel bed deformations and structural modifications of the riverbed topography caused by localized sediment redistribution.

4. DISCUSSION AND CONCLUSION

Analysis of the bed topography reveals that for depth calculation, setting the deepest point of the channel (elevation 76.100 m) to a conditional "0" relative to the water surface elevation (80.120 m) corresponds to a staff gauge reading of 402 cm, representing an officially recorded discharge of 94.5 m³/s. However, direct ADCP measurements demonstrated an actual maximum depth of 3.27 m and an average depth of 1.60 m.

Subtracting the verified maximum depth (3.27 m) from the water surface elevation (80.120 m) isolates the true bed elevation at 76.85 m. This indicates that the riverbed at the Qipchoq gauging station cross-section has accumulated a heavy silt layer up to 75 cm thick. Incorporating average depth profiles shows that subtracting 1.61 m from the 80.120 m elevation reference isolates a bed level at 78.51 m, revealing that localized sediment deposition thickness reaches up to 2.41 m across certain sections.

Based on the channel width and geometry of the sediment profile, the total volume of accumulated sediment within a 1 km monitoring reach surrounding the gauging station is calculated at approximately 250,000 m^3.

To secure the long-term accuracy of hydrometric accounting and mitigate the impacts of channel deformation, it is recommended to construct a specialized sediment settling basin upstream of the Qipchoq gauging station cross-section and introduce a protocol for regular recalibration of the station's hydraulic rating curves.

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