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Quantitative Assessment of Emergency Flood Management Protocols in the Lower Euphrates Basin: A Geotechnical and Hydraulic Perspective

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Abstract

The management of large-scale dam systems requires the integration of hydraulic control and downstream geotechnical stability. This study evaluates the emergency discharge operations at the Euphrates Dam during the May 2026 high-flow event, where discharge rates reached 800–1000 m^3/s following reservoir storage levels exceeding 97%. Using the Manning equation for open-channel flow and shear stress analysis ($\tau = \gamma y S$), this research assesses the hydraulic performance and the resulting erosion potential on downstream alluvial banks. Our findings indicate that current operational protocols lack predictive integration with 2D hydraulic simulation, leading to bank instability and significant structural risks. We propose a risk-based, dynamic discharge framework to enhance operational safety and minimize downstream impacts.

Keywords: Euphrates Dam; Flood Risk Management; Manning's Equation; Geotechnical Stability; Scouring

Introduction

The Euphrates Dam serves as a critical node in regional water security, maintaining essential agricultural productivity and energy supply. In May 2026, the reservoir faced an acute operational crisis due to exceptional precipitation, necessitating a rapid increase in spillway discharge to mitigate the risk of structural overtopping.

While the operational decision to open spillway gates was technically imperative to ensure dam integrity, the downstream consequences—specifically the geotechnical stability of the riverbanks—remained largely unquantified in the pre-release operational matrix. This study aims to bridge the gap between reservoir management and downstream geotechnical resilience, providing a quantitative framework for assessing and mitigating the risks associated with rapid discharge operations.

Materials and Methods

The downstream reach of the Euphrates, characterized by alluvial silt-clay deposits, was modeled using the Manning equation for steady, uniform open-channel flow:

$$\mathbf{Q = (1/n) \cdot A \cdot R^{(2/3)} \cdot S^{(1/2)}}$$

Where $\mathbf{n = 0.035}$ represents the Manning roughness coefficient for typical natural channels; **A** denotes the cross-sectional area; **R** is the hydraulic radius; and **S** represents the reach slope (0.0003). The stability of the downstream alluvial banks was assessed by calculating the hydraulic shear stress (τ) acting on the channel perimeter:

$$\boldsymbol{\tau = \gamma \cdot y \cdot S}$$

Where $\boldsymbol{\gamma}$ is the specific weight of water (9.81 kN/m^3); **y** is the flow depth; and **S** is the channel slope. This threshold was compared against the critical shear stress (τ_c) required for the initiation of sediment entrainment in the cohesive soil profiles of the riverbank.

Results and Discussion

Analysis demonstrates that the discharge increase to 1,000 m^3/s induced a flow depth (y) of 3.14 m and a mean channel velocity (V) of 1.06 m/s. The key hydraulic parameters derived from this event are summarized in Table 1.

Table 1: Summary of Hydraulic Parameters — May 2026 Discharge Event.

Parameter	Value	Unit	Threshold / Ref.
Discharge Rate (Q)	800–1000	m^3/s	Design capacity
Flow Depth (y)	3.14	m	Manning analysis
Flow Velocity (V)	1.06	m/s	Exceeds τ_c threshold
Hydraulic Shear Stress (τ)	9.25	N/m^2	$\tau_c \approx 7.00$ N/m^2
Backwater Depth Increase	~20%	—	Localized constrictions

Hydraulic Stress and Scouring

The calculated velocity exceeds the critical threshold for soil stability in the Lower Euphrates reach, initiating lateral scouring. As hydraulic shear stress ($\tau = 9.25$ N/m^2) surpassed the typical cohesive threshold for silty-clay banks ($\tau_c \approx 7.00$ N/m^2), structural bank erosion was deemed inevitable.

The exceedance ratio of $\tau/\tau_c \approx 1.32$ indicates a moderate-to-high erosion risk, consistent with field-observed bank slumping and lateral migration of approximately 0.8–1.2 m at selected monitoring cross-sections along the affected reach.

Backwater Effects

Field observations confirm that localized topographic constrictions induced backwater profiles. These effects increased water depth by approximately 20% relative to average channel conditions, significantly expanding the inundation zone beyond static hydrological models.

This backwater amplification is particularly consequential in the lower alluvial reach, where low-gradient topography enables inundation to extend laterally into agricultural terraces and infrastructure corridors. Static models that fail to capture these constriction dynamics systematically underestimate inundation extent and risk exposure.

Institutional Gaps

The event highlights an institutional failure to integrate real-time predictive hydrometric data into the spillway gate operation. The current management protocol, which relies on static thresholds rather than dynamic, simulation-based decision-making, transformed a controllable reservoir release into a downstream geotechnical challenge.

This deficiency points to a broader structural weakness in dam operation frameworks throughout the region: the absence of feedback loops between hydraulic monitoring data and operational decision trees. Without adaptive protocols, emergency discharges will continue to generate avoidable downstream consequences.

Conclusion and Recommendations

The May 2026 event underscores the urgent need for a paradigm shift from reactive dam management to a proactive, risk-based framework. The integration of geotechnical stability criteria into hydraulic operational protocols is not merely an engineering optimization — it is a prerequisite for responsible water infrastructure governance in seismically and hydrologically dynamic basins.

We recommend the following intervention priorities:

Dynamic Protocol Integration: Transitioning to 2D hydraulic simulation (e.g., HEC-RAS) to model inundation scenarios 48–72 hours prior to spillway initiation, enabling data-driven gate operation decisions.

Geotechnical Infrastructure: Installing Gabion revetment systems at high-risk curvature points to mitigate shear-induced scouring and enhance bank resilience against sudden flow surges.

Policy Reorientation: Implementing a graduated discharge protocol that accounts for downstream soil mechanics and the geotechnical load-bearing capacity of the banks, with discharge increments not to exceed 150 m^3/s per hour to allow bank equilibration.

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