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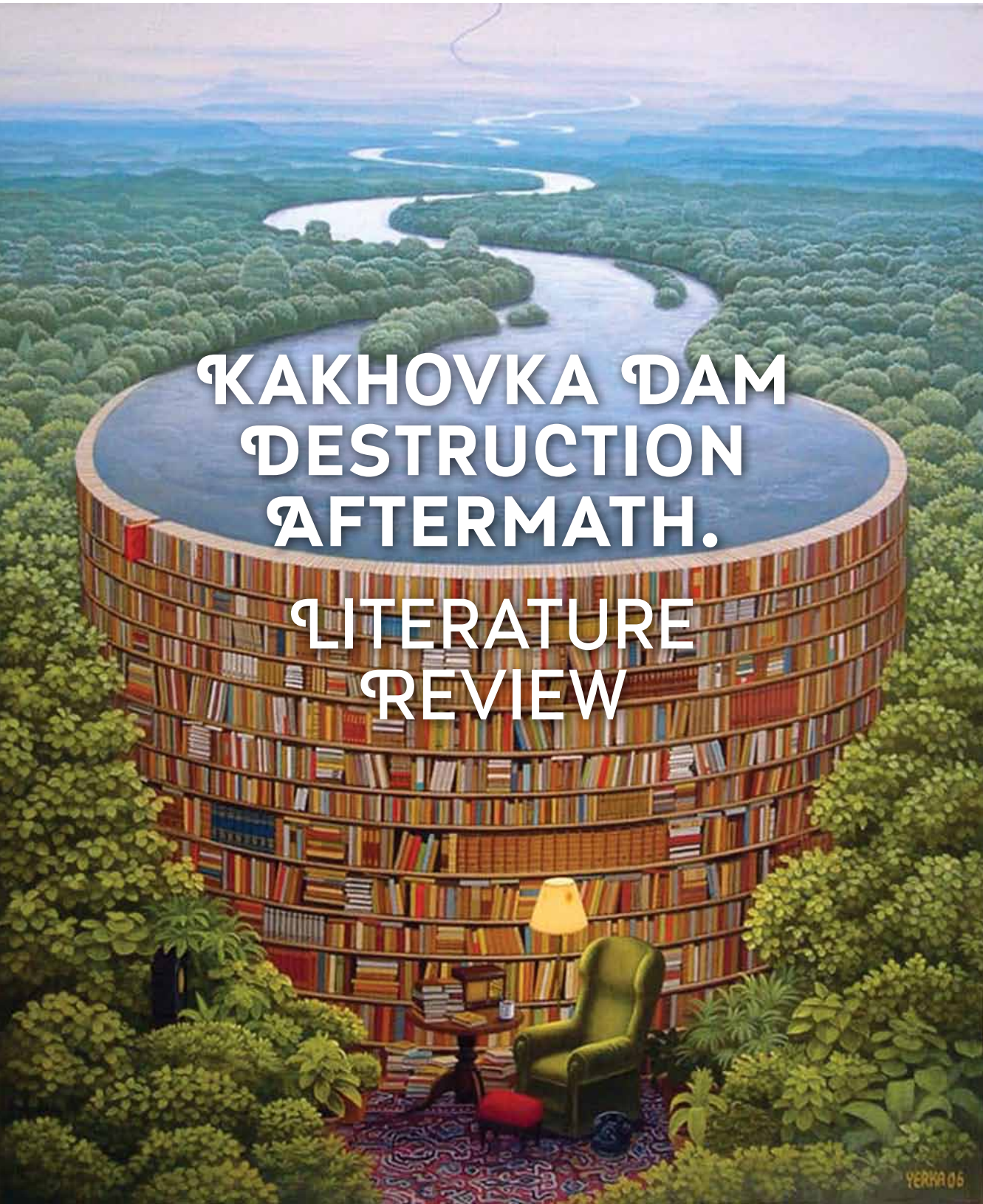

KAKHOVKA DAM DESTRUCTION AFTERMATH.

LITERATURE REVIEW

Kakhovka Dam Destruction Aftermath. Literature Review / compiled by Eugene Simonov and Oleksii Vasyliuk. UWEC/UNCG, 2026. – 86 p. – (Series: *Metamorphoses of Velykyi Luh*, No. 6).

This comprehensive review compiles more than 120 academic and grey publications analyzing the June 2023 Kakhovka Dam destruction and subsequent environmental and economic recovery paths. Divided into 12 thematic sections, from ecology and natural resource management to legal and cultural issues, it complements UNCG's 2025 reports on environmental consequences of Kakhovka catastrophe and prospects of riparian ecosystem restoration. The review summarizes diverse findings from all availableliterature, highlighting a strong scientific consensus on the value of ecosystem restoration of the Velykyi Luh riverine landscape and the lack of rationale for the Kakhovka HPP reservoir reconstruction.

Cover image: "Bobliotama" by Jacek Yerka (2006).

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¶NTRODUCTION

The consequences of Kakhovka Dam Destruction by Russian military on 6 June, 2023, became the focus of multidisciplinary research and applied investigations. This event radically altered landscapes of Lower Dnipro Valley on at least 2500 square kilometres and became the largest single environmental disaster caused by this war.

To supplement the UNCG's analysis produced in two volumes in the early 2025, we compiled a comprehensive list of academic and grey literature on the subjects directly related to the Kakhovka Dam Destruction and possible recovery paths for the affected area to provide easy access to the full spectrum of available data and views on key topics related to Kakhovka dam destruction and recovery of the Velykyi Luh riverine ecosystem..

This collection complements the works published by our UNCG team in 2025 and listed in the section (0), which have been recently translated into English. The conclusions from other expert publications do not necessarily coincide with those in the works of UNCG and UWEC.

This annotated list of literature includes more than a hundred (122) publications very diverse in volume and scope. Although not exhaustive it covers at least 90% of relevant original research, technical analyses and planning documents that has been published from June 2023 to June 2026. For the lack of capacity to analyse every abstract, we treated each conference proceedings as a single publication.

This document divides available literature in 12 thematic annotated lists and includes full bibliographic list for all entries at the end. For each thematic group of publications summaries were developed in which we analysed spectrum of approaches, findings and recommendations. We compared all collected literature with UNCG works presented in section (0). It is noteworthy, that absolute majority of researchers either support or do not exclude the possibility of ecosystem restoration in place of former Kakhovka Reservoir.

UNCG and UWEC editors hope that this Literature Review will harmoniously complement our own works and allow interested readers to access the full spectrum of available research on the aftermath of Kakhovka Dam blasting.

(0) UNCG REPORTS

This List of literature complements two analytical reports developed by the Ukraine Nature Conservation Group (UNCG), which thematically relate to the **section 1 "Comprehensive Assessments"**. These two volumes examine the consequences of the construction and destruction of the Kakhovka Reservoir, focusing on ecological, historical, cultural, and economic aspects. The Great Meadow (Velykyi Luh), which was flooded during the creation of the reservoir, was a unique natural and cultural hub of Ukraine, playing a key role in biodiversity conservation and the formation of national identity. The first volume, *"Destruction of the Kakhovka Reservoir: Consequences for the Environment"* presents comprehensive analysis of the dam blasting consequences as an act of ecocide. The second volume, *"The Great Meadow or the Kakhovka Reservoir: A Modern Vision"* explores the consequences of Kakhovka reservoir construction (and proposed rebilding) as a similr act of ecocide. It also documents restoration of natural ecosystems of the Velykyi Luh, which began right after the dam's destruction in 2023, opening the opportunities to create a modern model of sustainable regional development.

> **Kolodezhna, V. and Vasyliuk, O.** (eds.) (2025). *Destruction of the Kakhovka Reservoir: Consequences for the Environment*. Chernivtsi: Druk Art. 112 p. ISBN 978-617-8501-02-0. [In Ukrainian] Колодежна В., Василюк О. (ред.) (2025). *Знищення Каховського водосховища: наслідки для довкілля*. Чернівці: Друк Арт. 112 с. Available at: https://uncg.org.ua/wp-content/uploads/2025/02/znyshhennya-kahovskogo-vodoshovyshha-naslidky-dlya-dovkillya-2025.pdf.
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> **Kolodezhna, V. and Vasyliuk, O.** (eds.) (2025). *The Great Meadow or the Kakhovka Reservoir: A Modern Vision*. Chernivtsi: Druk Art. 128 p. ISBN 978-617-8501-03-7. [In Ukrainian] Колодежна В., Василюк О. (ред.) (2025). *Великий Луг чи Каховське водосховище: сучасне бачення* (2025). Чернівці: Друк Арт. 128 с. Available at: https://uncg.org.ua/wp-content/uploads/2025/02/velyky-luh-suchasne-bachennia2024s.pdf.
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> **Kolodezhna, V.V. and Vasyliuk, O.V.** (eds.) (2026). *Destruction of the Kakhovka Reservoir: Environmental Consequences* (adapted translation from Ukrainian). Chernivtsi: Druk Art. 112 p. Available at: https://doi.org/10.67531/kakhovka-dam.
>
> **Kolodezhna, V. and Vasyliuk, O.** (eds.) (2026). *Velykyi Luh or the Kakhovka Reservoir: A Modern Vision* (adapted translation from Ukrainian). Chernivtsi: Druk Art, 2026. 128 p. Available at: https://doi.org/10.67531/velykyi-luh.

As these reports have been translated and published in English by September 2026, we complement them with a thorough review of all related research and planning literature to provide easy access to the full spectrum of available data and views on key topics related to Kakhovka dam destruction and recovery of the Velykyi Luh riverine ecosystem. Hence summaries before each thematic section of the review explore how key questions raised in the UNCG volumes are treated by other researchers and planners from diverse backgrounds.

(1) "COMPREHENSIVE ASSESSMENTS"

This collection represents articles and reports attempting to address the aftermath of the Kakhovka dam destruction from multiple thematic perspectives. Materials converge on severe immediate/human/ecological costs and rapid partial natural recovery, with quantitative estimates (e.g., water loss, flooded areas) reinforcing Ukrainian field data. The reviewed materials align closely on immediate flooding/draining effects and biodiversity threats but vary in emphasis on restoration options, quantitative modelling, and post-war resilience strategies. Still, most works favour or explore alternatives to full reservoir rebuilding (such as natural revival, renewables, hybrid uses) for resilience in post-war conditions, prioritizing biodiversity, sustainable economy, and community adaptation over pre-2023 status quo.

KEY PUBLICATIONS:

Chen, B., An, J., Huang, Y., Chen, X., Wu, S., Lin, C. and Gong, P. (2024). Multifaceted impacts of Ukraine's Kakhovka Dam destruction. *Science Bulletin*. 69(11). Pp. 1642-1646. Available at: https://doi.org/10.1016/j.scib.2024.03.038.

Scope/methods and data: This short communication uses a rapid remote sensing framework with multi-source high-resolution satellite imagery (3-m PlanetScope for flooding, Sentinel-1 SAR for upstream changes) and geospatial datasets (land cover/use, WorldPop for population). It quantifies immediate downstream flooding and upstream water storage loss shortly after the June 6, 2023, destruction.

Main findings: Downstream inundation expanded by 742.58 km^2, affecting ~62,303 people in 23.45 km^2 built-up areas and submerging 2,361 buildings (with buffers increasing exposure significantly). Flooded areas were mostly herbaceous wetlands (539.84 km^2), with minimal direct cropland impact (4.97 km^2). Upstream, water area shrank dramatically (e.g., 1,204.32 km^2 by July 7), with ~17.53 billion m^3 storage loss by July 7 (97% of capacity) plus runoff, totaling ~22.25 billion m^3 loss. This poses threats to agriculture, Zaporizhzhia NPP cooling, and ecosystems.

Recommendations: Emphasizes urgent data-driven disaster management and humanitarian aid using remote sensing. No explicit recommendation on full reservoir rebuilding or refilling; highlights long-term hydrological/ecological risks and the need for targeted responses. *Aligns with UNCG compilations on flooding scales but adds precise early quantification missing in some qualitative Ukrainian reports.*

Malchykova, D., Pylypenko, I. and Simchenko, S. (2024). Results of the international scientific-practical conference «Catastrophe of the Kakhovka Reservoir: the year 'the day after tomorrow' and the future perspective», *Scientific Bulletin of Kherson State University*, series Geography, 20. Pp. 7-12. [In Ukrainian] Мальчикова, Д., Пилипенко, І. and Сімченко, С. (2024). Результати проведення міжнародної науково-практичної конференції «Катастрофа Каховського водосховища: рік «післязавтра» і перспектива майбутнього». *Науковий вісник ХДУ*, Серія Географічні науки, 20. С. 7-12. Available at: https://doi.org/10.32999/ksu2413-7391/2024-20-1.

Scope/methods and data: Summary of a June 6–7, 2024, interdisciplinary conference (~100 participants) with plenary sessions, expert presentations (botanists, socio-economists, administrators), and analysis of first-year post-catastrophe transformations. Draws on field observations, demographic data, water resource assessments, and stakeholder inputs from affected communities.

Main findings: Rapid natural ecosystem recovery on the former reservoir bed; transformed social-demographic situations in flooded areas (higher left-bank impacts due to terrain/occupation/evacuation failures); infrastructure losses; ongoing water supply issues for agriculture/industry and Zaporizhzhia NPP risks (controlled but unresolved). Examples include ecological shifts like Lake Solyane desalination. Confirms pessimistic prior forecasts in some areas.

Recommendations: Calls for interdisciplinary discourse on river revitalization, biodiversity, and adaptation strategies. Supports regional/local development strategies with reduced water supply and decisions on reservoir rebuilding/refilling for water security. *Strongly echoes UNCG compilations on natural recovery and community impacts, emphasizing post-war planning*.

Pylypenko, I., Malchykova, D. (eds.) (2025). *Catastrophe of the Kakhovka Reservoir: future perspective. Collection of abstracts of the International Scientific-Practical Conference, 5-6 June 2025*, Kherson: Kherson State University. 43 p. ISBN 978-617-8670-22-1. [In Ukrainian] Пилипенко, І., Мальчикова, Д. (eds.) (2025). *Катастрофа Каховського водосховища: перспектива майбутнього. Збірник тез доповідей за матеріалами Міжнародної науково-практичної конференції, 05-06 червня 2025 р.* Херсон: Херсонський державний уныверситет. 43 с. Download: https://drive.google.com/file/d/1D_FPAvZFrUo6nTrBwfTo5opYvoHUELKM/view.

Scope/methods and data: Collection of abstracts from the June 5–6, 2025, international conference, covering two years of natural recovery, public opinion on dam rebuilding or refilling vs. non-rebuilding, water supply for communities, protected areas, transport/agriculture transformation, and river revitalization under "no water" conditions. Multi-institutional, interdisciplinary inputs.

Main findings: Details ongoing ecosystem recovery on the reservoir bed, shifts in biodiversity, water resource challenges, and socio-economic adaptations. Discusses war-related threats to conservation and alternative planning scenarios.

Recommendations: Explores alternatives to full reservoir rebuilding or refilling, including natural recovery of the "Vlykyi Luh," sustainable agriculture/transport

without the reservoir, and protected area management. Recommends balanced post-war development. *Closely aligns with and extends the group compilations' scenarios for resilient ecosystems and economies*.

Shumilova, O., Sukhodolov, A., Osadcha, N., Oreshchenko, A., Constantinescu, G., Afanasyev, S., et al. (2025). Environmental effects of the Kakhovka Dam destruction by warfare in Ukraine., *Science*, 387(6739). Pp. 1181–1187. Available at: https://doi.org/10.1126/science.adt3011.

Scope/methods and data: Integrates field surveys, remote sensing, hydrodynamic modeling, flood assessment, and dam removal analogies. Analyzes sediment pollutants, benthic/fish mortality, and freshwater plumes; addresses data access constraints in conflict zones.

Main findings: Massive pollutant release from sediments threatens freshwater/ estuarine/ marine ecosystems long-term; excessive drainage caused benthic/fish mortality; large freshwater plume impacted marine life. Quantifies spatial-temporal scales of damage, with overlooked toxic contamination risks.

Recommendations: Warns against continued use of water infrastructure as a weapon; advocates ecosystem reestablishment insights from dam removals. Does not prioritize full reservoir rebuilding or refilling; emphasizes managing exposed sediments and natural recovery trends. *Complements UNCG compilations with stronger international modeling and pollution focus*.

Yermak, A., Wallström, M. et al. (2024). *An Environmental Compact for Ukraine: A Green Future – Recommendations for Accountability and Recovery*. High-Level Working Group on the Environmental Consequences of the War. 9 February. Available at: https://www.eip.org/wp-content/uploads/2025/04/Environmental-Compact-for-Ukraine-9-Feb-2024-EN.pdf.

Scope/methods and data: Policy-oriented recommendations from the High-Level Working Group on the Environmental Consequences of the War (co-chairs A.Yermak, M.Wallström) on war's environmental consequences, focusing on accountability, recovery, and green future. Synthesizes broad evidence on damages including Kakhovka.

Main findings: Highlights catastrophic economic/environmental damages from infrastructure targeting, including Kakhovka's flooding, pollution, and biodiversity loss. Stresses accountability and long-term recovery needs.

Recommendations: Strong focus on environmental accountability, justice, and sustainable recovery. Supports ecosystem restoration and resilient communities but prioritizes broader green reconstruction over specific dam rebuilding or refilling decisions. Requires proper transparent planning and public consultation for the future of Kakhovka reservoir bottom, including consideration of development alternatives. *Aligns with UNCG compilations on holistic post-war resilience*.

Epik, O., Briukhovetska, M. and Jesson, J. (2025). *Scenarios of Usage of Kakhovka Reservoir Area for Energy Production and Sustainable Recovery*. Analytical paper, Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH / Ukrainian Climate Office, March. Available in English version at the attachment. Available at: https://ukrainian-climate-office.org/wp-content/uploads/2025/03/Kakhovka-dam-EN-22.03.2025-compressed.pdf.

Scope/methods and data: Analytical paper comparing recovery alternatives for the former reservoir territory, integrating expert ecological views, natural recovery analysis, quantitative scenario modeling (e.g., energy yields, investments, CO_2), stakeholder roundtables (>35 experts), and alignment with Ukraine Recovery Plan and EU green principles. Uses multi-criteria analysis across 18 indicators for scenario comparison.

Main findings: Evaluates trade-offs: full HPP rebuilding offers water/energy benefits but high environmental costs (flooding 215,000 ha, ecosystem disruption); natural Great Meadow recovery shows rapid biodiversity return (willow growth to 4-7m in 2 years); small/floating HPPs and combined RES (SPP/WPP) provide decentralized options; energy crops on 10-20% of bed (marginal/contaminated lands) yield comparable or higher energy (up to 3.5x equivalent in multi-use) with reclamation potential (heavy metal absorption). Quantitative comparisons favor hybrids for sustainability.

Recommendations: No single option is ideal; advocates combined scenarios (e.g., natural recovery + targeted energy crops + RES/small HPPs) for maximum community benefit, minimal ecosystem harm, and pre-destruction needs fulfillment. Explicitly explores alternatives to full reservoir rebuilding or refilling, emphasizing green recovery, funding sources, and EU-aligned sustainability. *Provides practical post-war options highly consistent with and extending UNCG compilations' focus on resilient ecosystems/economies*.

SUBMERGED: *Study of the Destruction of the Kakhovka Dam and Its Impacts on Ecosystems, Agrarians, Other Civilians, and International Justice* (2025). Truth Hounds and Ecopravo Report. Available at: https://truth-hounds.org/en/cases/submerged-study-of-the-destruction-of-the-kakhovka-dam-and-its-impacts-on-ecosystems-agrarians-other-civilians-and-international-justice/

Scope/methods and data: In-depth investigative study on destruction causes, flooding/draining dynamics, impacts on ecosystems/agriculture/civilians, and justice. Uses historical, legal, and impact analysis.

Recommendations: Focuses on truth-seeking, accountability, and justice. Supports ecosystem/agricultural recovery; informs reservoir rebuilding or refilling debates with evidence on responsibility. *Supplements UNCG compilations with legal/investigative depth*.

(SUBMERGED is a very comprehensive assessment with several analytical attachments which may be reviewed in corresponding thematic sections)

Materials of the scientific-practical seminar dedicated to the 50th anniversary of the state geological reserve of national importance "Dnipro Rapids" (28 October 2024, Zaporizhzhia) (2025). Chernivtsi: Druk Art. 96 p. ISBN 978-617-8501-05-1. [In Ukrainian] Національний заповідник «Хортиця». *Матеріали науково-практичного семінару з нагоди 50-річчя загальногеологічного заказника загальнодержавного значення «Дніпровські пороги»* (2025). Чернівці: Друк Арт. 96 с. Download: https://uncg.org.ua/materialy-naukovo-praktychnogo-seminaru-dniprovski-porogy/.

The volume gathers papers on protected-area management under wartime conditions, biodiversity and landscape conservation, tourism and recreation, historical-cultural heritage and environmental education in the Dnipro Rapids / Khortytsia area. Several contributions address the ecological consequences of the Kakhovka dam breach for the local geological reserve and surrounding landscapes, documenting both damage and emerging recovery processes.

The collection supports the continued protection and possible expansion of the "Dnipro Rapids" reserve and related sites as part of post-war ecological recovery, treating the spontaneous renaturalisation of the former reservoir bed as an opportunity rather than a problem to be reversed by reconstruction.

(2) WATER MANAGEMENT AND IRRIGATION

(FOCUS ON NON-CRIMEA UKRAINE)

This section reviews research articles focused on water management in Ukraine during the aftermath of Kakhovka dam blasting. Agricultural water supply is the most prominent topic analyzed in this literature.

The destruction of the Kakhovka Reservoir in June 2023 fundamentally altered water availability for Southern Ukraine, exposing vulnerabilities in irrigation-dependent agriculture while opening pathways for ecosystem restoration. Findings in Khoriev et al. (2026) and Mhanna et al. (2026) quantify post-destruction needs for ecological flows and highlight reduced evaporative losses but increased variability in downstream supply. Pichura & Potravka (2025) and Hapich et al. (2024) align with UNCG's Volumes I/II in stressing war-induced transformations, including contamination and infrastructure damage, but add quantitative assessments of ecosystem service losses (e.g., fisheries, water purification).

Analysis of water availability for agriculture and sectoral uses reveals a consensus on reduced reliability without the reservoir but divergent solution sets. Rosa et al. are modelling regional expansion potential for climate-resilient crops using efficient systems. Sinha et al. (2025) and the Long-term Development Plan (Cabinet of Ministers, 2025) project needs through 2050, advocating Water User Organizations (WUOs) and infrastructure modernization (ICID-related report, 2025). Baliuk et al. (2024) and Shevchuk et al. (2025) focus on soil degradation and irrigation water quality post-hostilities, recommending targeted restoration subsidies. Differences emerge in scale: pragmatic technical fixes (e.g., reservoir alternatives in Slobozhan, 2025 Vision for Kherson) versus systemic shifts in UNCG works toward wetland revival, which Pichura scenarios also explore for multifunctional territory use.

Climate change adaptation is addressed across sources as amplifying variability. UNCG volumes integrate projections of drier conditions and extreme events, favoring nature-based solutions (wetland restoration for flood buffering and biodiversity) over hard infrastructure. Rosa et al. (2024) and Sinha et al. (2025) explicitly model climate-resilient irrigation expansion, showing potential yield gains through drip systems and crop shifts, aligning with UNCG vision but contrasting with its caution on salinization risks. Mhanna et al. (2026) and Khoriev et al. (2026) provide hydrological data supporting adaptive flows, while the 2050 Plan incorporates climate scenarios for infrastructure resilience. Geopolitical aspects, including potential long-term Russian control of occupied lands, add complexity:

sources like UNCG and Hapich et al. frame restoration within Ukrainian sovereignty and EU accession pathways, noting that divided control hinders basin-wide management. EU requirements (water framework directive, environmental standards) and subsidies are highlighted in Slobozhan (2025) and institutional reports as drivers for WUOs, monitoring, and sustainable practices, offering financial incentives absent under prolonged occupation scenarios.

Nature-based solutions emerge as a unifying yet variably prioritized theme. UNCG works strongly advocate meadow/wetland restoration for resilient ecosystems and communities, supported by Pichura scenarios and Hapich et al.'s ecosystem services analysis. Technical works (Khoriev, Shevchuk, World Bank/Sinha) integrate them selectively (e.g., alongside efficiency upgrades), while the 2050 Plan balances with engineered options. Overall, findings converge on diversified, adaptive strategies reducing dependence on single large infrastructure, with EU integration providing a framework for funding and standards that could accelerate post-war recovery in free Ukrainian territories. Geopolitical fragmentation risks entrenching suboptimal management, underscoring the need for diplomatic and technical pathways to holistic Dnipro basin governance

KEY PUBLICATIONS:

Pichura, V. and Potravka, L. (2025). Impact of war on natural and climatic transformation of territories in the irrigation zone of Ukraine, *Discover Applied Sciences*, 7(783). Available at: https://doi.org/10.1007/s42452-025-07404-4 .

This research employs remote sensing methods (Sentinel-2 and Sentinel-3 satellite data) alongside climatic and agro-production records to analyze changes in the irrigation zone, particularly Kherson region (excluding Crimea), following the Kakhovka drainage and cessation of farming. It quantifies shifts in hydrological conditions, soil moisture, surface heating, and fire occurrences through satellite-derived indices.

Key findings reveal that only 18% of Ukraine's 551.4 thousand hectares of irrigated land (2020) remained under control, leading to water scarcity, drainage of water bodies, soil heating increases by 1.45–1.72 times, accelerated evaporation in 80% of the territory, fires over more than 200 thousand hectares in 2024, and massive topsoil loss (>600 t/ha in storm events). This has driven desertification and negative climatic transformations, severely reducing water availability for agriculture.

Recommendations include three scenarios for the Kakhovka site in the post-war period, restoration of irrigation to 2021 levels (with ambitions toward pre-1990 scales), and climate-adaptive soil and water management. It supports potential reconstruction of the reservoir as one viable scenario within a broader set of options to reverse aridization.

(Several other similar works by V.Pichura available on his Researchgate web-page)

Pichura V., Potravka L. & Dent D. (2025). The Kakhovka Sea Before and After the Destruction of the Kakhovka Dam. *Bulletin of the National Academy of Sciences of Ukraine*. Natural Built Social Environment Health, 1(1). Pp. 104-133. Available at: https://doi.org/10.63095/NBSEH.25.290237.

Pichura V. et al. (2025). *Scenarios for the Functioning of the Kakhovka Reservoir Territory*. Journal of Landscape Ecology, 18(3). Pp. 118-154. Available at: https://doi.org/10.2478/jlecol-2025-0023.

This research report substantiates three main post-war scenarios using environmental, hydrological, and socio-economic modelling: (1) full dam/reservoir reconstruction for irrigation/energy; (2) full renaturalization to restore Great Meadow ecosystems; (3) hybrid/compromise (partial reservoir with natural zones). It evaluates impacts on agriculture (water supply for hundreds of thousands of ha), water balance, and local economies, recommending scenario selection based on comprehensive assessments balancing food security and ecology.

Khoriev, M., Karamushka, V., Huliaieva, O. and Kuns, B. (2026). Assessment of water needs in the lower Dnipro sub-basin following the destruction of the Kakhovka reservoir. *Applied Water Science*, 16(122). Available at: https://doi.org/10.1007/s13201-026-02814-0.

The analytical article was co-authored by researchers from the National University of Kyiv-Mohyla, expert/official from Ukraine HydroEnergo Company, researcher from the Swedish University of Agricultural Sciences.

This assessment compiles pre-destruction water consumption balances by sector (energy, agriculture, fishing, industry, transport, household) using historical operational data from the reservoir, combined with ecosystem requirements for the lower Dnipro. It models prospective needs without the reservoir's regulatory capacity. Findings detail the reservoir's critical role in meeting high irrigation demands (historically >12 billion m^3/year pre-1990) and maintaining flows for ecosystems and other uses, with its loss causing major imbalances in seasonal water availability, especially for southern agriculture. Recommendations focus on data-driven decisions for future infrastructure, stressing the need to balance all sectoral and ecosystem needs in planning.

The work advocates **for considering reconstruction of the dam** and reservoir but frames it as one option among alternatives for meeting assessed needs sustainably.

Baliuk, S., Kucher, A. and Romashchenko, M. (eds.) (2024). *Soil cover of Ukraine in the conditions of hostilities: state, challenges, activities for soil restoration*. Kyiv: Agrarna nauka. 340 P. [In Ukrainian] *Ґрунтовий покрив України в умовах воєнних дій: стан, виклики, заходи з відновлення* (за ред. С. Балюка, А. Кучера, М. Ромащенка). Київ: Аграрна наука, 2024. 340 с. ISBN 978-966-540-612-9 Available at: https://doi.org/10.31073/978-966-540-612-9.

This monograph examines soil degradation across Ukraine due to war, including southern irrigation zones, using soil science data, climatic records, and

assessments of irrigation's historical role. It addresses water availability indirectly through links between soil moisture, irrigation needs, and agricultural productivity. Findings highlight increased drought risks and water deficits in southern soils (e.g., climatic water balance deficits rising by 50–95 mm in dry zones), with pre-war irrigation essential for high yields on fertile southern lands. Kakhovka loss exacerbates these, limiting prospects for development without restored water supply.

Recommendations call for joint restoration of the Kakhovka Reservoir combined with long-distance transfer of Danube water resources to enable irrigation revival, soil productivity gains, and food security contributions. It explicitly recommends reservoir restoration as a core component for southern recovery.

Shevchuk S., Matiash T. and Krucheniuk A. (2025). *Assessment of Water Resources Needs for Irrigation Development in Southern Ukraine* / Conference Proceedings, 18th International Conference Monitoring of Geological Processes and Ecological Condition of the Environment, Apr 2025, Volume 2025. P.1 – 5. Available at: https://doi.org/10.3997/2214-4609.2025510141.

This assessment uses hydrological data and post-Kakhovka field observations to evaluate irrigation potential in the south. It notes severe water unavailability for large-scale systems until reconstruction. Findings emphasise the need for alternative local sourcing and efficiency upgrades.

Recommendations focus on rebuilding key infrastructure but consider decentralised options; it leans toward Kakhovka reservoir reconstruction as essential for full-scale irrigation recovery while noting interim alternatives.

Institutional Reform of Irrigation and Drainage in Ukraine (ICID or related 2025 paper on WUOs). Conference or policy report. Available at: https://icid-ciid.org/icid_data_web/WIF4-Full-Papers2025/wif4_w.3.3.01.pdf.

This policy-oriented analysis examines the implementation of Water User Organisations (WUOs) and related reforms in the context of war damage, including Kakhovka's impact on southern systems, drawing on operational data and reform progress metrics. Findings highlight institutional barriers to restoring water supply for irrigation, with significant portions of southern infrastructure still offline.

Recommendations stress completing decentralised management transitions, tariff reforms, and investments to revive functionality. The work addresses reservoir restoration as a potential enabler for large-scale systems as well as long-distance water transfer from Danube. However it also prioritises user-led local networks, modern technologies, and alternative water sources as core strategies for sustainable irrigation development independent of sole reliance on major Dnipro infrastructure.

Hapich, H., Novitskyi, R., Onopriienko, D. and Dubov, T. (2024). Water on fire: losses and the post-war future of ecosystem services from water resources of Ukraine. *Regional Environmental Change*, 24(154). Available at: https://doi.org/10.1007/s10113-024-02320-6.

The scope of this review article covers the broad consequences of damage to Ukraine's water infrastructure since 2022, with a strong focus on the Kakhovka Reservoir destruction's effects on water resource management, multiple uses (supply, irrigation, fisheries), and ecosystem services across southern Ukraine. It draws on hydrological statistics, pre- and post-war economic evaluations of irrigated agriculture, fisheries data, and ecosystem service assessments, integrating historical reservoir operation records with post-destruction observations. Main findings include an estimated total water resource loss of 18–20 km^3 (roughly one-third of Ukraine's accumulated reserves), severe disruptions to irrigation (with quantified drops in crop production efficiency on affected lands), declines in industrial and recreational fishing due to drained spawning grounds and littoral zones, and broader impacts on water supply for populations and industry. These changes threaten long-term water availability in the arid south.

Recommendations emphasize post-war strategies for ecological and economic benefits, including alternative water supply solutions (e.g., diversified sources and efficiency improvements) and sustainable development of the water sector. The article supports careful consideration of reservoir reconstruction as part of a balanced approach but does not advocate unconditional full restoration, prioritizing integrated alternatives that restore services without repeating past ecological trade-offs.

Slobozhan, O. (ed.) (2025) *Vision for Integrated Water Resources Management of Kherson Region*. Association of Ukrainian Cities et al. [In Ukrainian] *Візія інтегрованого управління водними ресурсами Херсонської області* (під. Ред. О. Слобожан). Available at: https://www.researchgate.net/publication/398860000.

A detailed strategic policy document prepared by a team of Ukrainian experts from the Association of Ukrainian Cities, universities (including Tavriia State Agrotechnological University and National University of Water and Environmental Engineering), and other specialists. It received advisory support from Dutch Water Authorities experts within a Netherlands-funded project focused on immediate and sustainable water supply reconstruction in Kherson. The document draws on Ukrainian legislation (Water Code), EU water framework principles, regional geographic and hydrological data, stakeholder consultations, and practical experiences from the Netherlands. This policy-oriented document integrates legal analysis, regional hydrological/geographic data, stakeholder input, and international best practices to address post-Kakhovka water management in Kherson, emphasizing agriculture's dominance (92–95% of use). It documents severe losses, including impacts on >300 thousand hectares of farmland and ecosystem services valued at over 6.4 billion USD, with sharp declines in water availability. The Vision quantifies key losses and calls for modern technologies like drip irrigation and sensors to reduce

water losses by 50–70%, wastewater reuse, wetland protection, and participatory governance involving local communities and farmers.

Recommendations outline short-term measures and long-term integrated basin planning, modern irrigation technologies, wastewater reuse, and participatory governance. It approaches Kakhovka reconstruction cautiously, advocating thorough assessment of alternatives like nature-based solutions and renaturalization alongside possible rebuilding to avoid repeating past ecological mistakes. The Vision shares UNCG's critical perspective on the long-term downsides of the original reservoir (e.g., soil salinization, altered microclimate, biodiversity loss from past flooding) and supports exploring renaturalization or hybrid options for the former Kakhovka bed rather than automatic full reconstruction. The tone is practical and solution-oriented, serving as a roadmap for decision-makers with clear targets up to 2030 and 2050 aligned with sustainable development goals.

Mhanna S. et al. (2026). Hydrological and ecological consequences of the Kakhovka dam destruction in Ukraine. *Environmental Research Letters*, 21 (064003) Available at: https://doi.org/10.1088/1748-9326/ae4d5f.

This modelling and field-based study examines long-term hydrological shifts and ecological recovery in the Lower Dnipro using hydrodynamic simulations, remote sensing, and post-2023 monitoring data. Findings show episodic inundation (peaking at 900 km² in early 2024), wetland re-emergence, but persistent risks from contaminated sediments and altered flows affecting agriculture and ecosystems.

Recommendations stress nature-based recovery and cautious infrastructure planning; it does not recommend full reservoir restoration, instead highlighting benefits of partial reliance on natural processes and alternatives like wetland restoration for sustainable water management.

Rosa, L., Ragettli, S., Sinha, R., Zhovtonog, O., Yu, W. and Karimi, P. (2024). Regional irrigation expansion can support climate-resilient crop production in post-invasion Ukraine. *Nature Food*, 5. Pp. 684–692. Available at: https://doi.org/10.1038/s43016-024-01017-7.

This study uses spatial analysis of cropland data, climate projections to mid-century, and assessments of local surface/groundwater potential to evaluate irrigation's role post-invasion and Kakhovka loss, focusing on resilience in southern regions. It finds that pre-invasion only 1.6% of cropland was irrigated (with 73% of that affected by declines), and by mid-century ~75% of croplands will face water shortages under rain-fed systems. Leveraging local resources could sustainably expand irrigation over 18 million hectares.

Recommendations strongly advocate targeted enhancements and expansions of irrigation systems using local sources as a key climate adaptation strategy for agriculture. It does not emphasize full reservoir restoration, instead highlighting decentralized, local-resource-based alternatives for resilience.

Sinha, R., Karimi, P., Rosa, L. and Ragettli, S. (2025) *The Future of Irrigation in Ukraine. Washington*, DC: World Bank. 40 p. Available at: https://documents1.worldbank.org/curated/en/099062524074575405/pdf/P18019816676490c1b4fc1484bbd031258.pdf.

This World Bank analytical report assesses climate and war impacts (including Kakhovka) on irrigated agriculture, using spatial and economic modelling. It notes ~280,000 ha affected by the dam destruction and low conveyance efficiencies (29–32%), advocating efficiency upgrades, local sources, and institutional reforms for resilience. Quote: *Opting for large-scale centralized irrigation systems could increase Ukraine's susceptibility to conflicts. It is advisable to embrace small-scale decentralized irrigation solutions like solar-powered drip irrigation to mitigate dependence on large-scale centralized systems prone to potential risks, as demonstrated by the damage to the Kakhovka reservoir*.

Yurchenko E. Irrigation Reform in Ukraine (2022–2025) (2025). Kyiv School of Economics. 20 p. Available at: https://kse.ua/wp-content/uploads/2025/05/Irrigation-Reform-in-Ukraine-2022---2025.pdf.

This policy analysis report examines institutional and legal reforms in irrigation management post-invasion and Kakhovka destruction, using data on Water User Organisations (WUOs), subsidies, and infrastructure status. It highlights accelerated decentralisation efforts, with ~5.2 WUOs uniting ~150 farmers by late 2024, and details southern challenges (e.g., Kherson/Zaporizhzhia systems devastated). Quantitative insights include pre-war irrigated areas and post-destruction losses, with recommendations for scaling WUOs, tariffs, and investments to restore ~300,000+ ha affected. It supports modern, efficient systems over sole reliance on large reservoirs. Quote: *Moreover, the catastrophic loss of the Kakhovka reservoir has sparked considerations for modern water storage and distribution methods – for example, building smaller reservoirs or on-farm ponds with lined storage, and using efficient pipe distribution instead of large open canals that are vulnerable in conflict. The long-term irrigation plan to 2050 emphasizes sustainability and climate resilience, which implicitly calls for state-of-the-art technologies and integrated water resource management*.

MANAGEMENT DOCUMENTS ON WATER SUPPLY

Dnipro River Basin Management Plan 2025–2030 (2025). Aapproved by Cabinet of Ministers of Ukraine, Order No. 1077, November 2024; published 2025. 1212 p. Available at: https://davr.gov.ua/fls18/1-RBMP_Dnipro_February_2025_ENG.pdf.

This official governance document, developed under EU-aligned frameworks by the State Agency of Water Resources and Ministry of Environmental Protection, integrates hydrological, ecological, and economic data across the entire Dnipro basin (including Lower Dnipro sub-basin). It assesses post-Kakhovka impacts on water availability, quantifies sectoral uses (agriculture remains dominant), and outlines

programmes of measures for restoration, pollution control, and climate adaptation. It addresses irrigation deficits in southern regions and promotes integrated basin management with stakeholder involvement.

> **Long-term Development Plan for the Irrigation Complex until 2050** (2025). Official government strategic policy document. Cabinet of Ministers of Ukraine, Resolution context. 35 p. [In Ukrainian] Довгостроковий план розвитку зрошувального комплексу до 2050 року; затверджено розпорядженням Кабінету Міністрів України від 25 березня 2025 р. № 280-р. Available at: https://www.agroberichtenbuitenland.nl/actueel/nieuws/2025/03/31/ukraine-development-plan-for-the-irrigation (English overview with links to Ukrainian originals). Full text https://www.kmu.gov.ua/storage/app/uploads/public/67e/6e8/0cd/67e6e80cd95a2819845944.pdf.

This national strategic plan integrates hydrological assessments, climate projections, and post-Kakhovka damage data to set water supply and irrigation goals through 2050, with emphasis on southern recovery. It quantifies needs for restoring and expanding reliable water access for agriculture amid ongoing deficits. Main findings underscore the reservoir's historical role and current gaps in seasonal supply. Recommendations call for comprehensive modernisation, institutional strengthening, and infrastructure investments. It views potential reconstruction of the Kakhovka reservoir as an important component for long-term water security but explicitly incorporates diversified alternatives, including local storage, efficiency improvements, and climate-adaptive technologies to reduce risks and enhance resilience across the Dnipro basin. Plan attached in table format does not include rebuilding the Kakhovka reservoir.

Quote: *By 2050, the implementation of the long-term plan will make it possible to increase the irrigated area of agricultural land to 700–750 thousand hectares (the area of agricultural land that can be irrigated by 2050 will be specified based on the results of an inventory of land reclamation systems), and provided that the Kakhovka Hydroelectric Power Plant is restored and additional water storage capacity is created, as well as the temporarily occupied territories of Ukraine—including the Autonomous Republic of Crimea—are liberated, a further increase in irrigated areas may be considered.*

(3) CRIMEA WATER SUPPLY

Given a special place and longer history of Crimea water supply (which for 50 years has been pursued from the Kakhovka Reservoir) we dedicate a special section to related research and reviews. Two distinct research angles are found in literature. One (domestic Russian and domestic Ukrainian) focuses on the alternative water management solutions for Crimea, while literature by authors from the third countries tends to focus on geopolitical significance of connection/disconnection of Crimea to Dnieper water supply and ways to use such supply as a bargaining chip in future peace-building efforts.

The articles analyzing actual water supply and management largely converge with the UNCG volumes and KrymSOS on the unsustainability of North Crimea Canal dependency, lack of its economic efficiency and high ecological costs. Articles point to viability of a broad spectrum of local supply/efficiency alternatives. They add quantitative baselines (e.g., 371 million m^3 on Crimean annual water resources) and international comparisons, reinforcing post-destruction opportunities for resilient management focused on Crimea's intrinsic resources rather than Kakhovka reservoir restoration (which most sources do not consider feasible).

However, quite different are political science articles striving to present the water supply as geopolitical asset, which should be utilized during peace-making diplomatic efforts. These articles largely disregard questions of environmental costs of water supply restoration and do not focus on relative efficiency of different water supply alternatives. On the contrary their authors frame discussion around political values attached to "connection/disconnection" to the North Crimea Canal and "environmental justice" in the form of returning to people of Crimea the water resources which were taken from them due to geopolitical rivalry and war between Russia and Ukraine. This aspect was also briefly discussed in the Simonov, E. & Vasyliuk, O. (2026) as likely political engine behind the persistent calls for restoration of the Kakhovka HPP.

KEY PUBLICATIONS:

Kositskii, A., Bogutskaya, E., Grechushnikova, M., Grigoriev, V., Sazonov, A., Kharlamov, M. & Frolova, N. (2022). Assessment of the own renewable water resources of the Crimean Peninsula. *Vodnye Resursy*, 49(4). Pp. 423–436. [In Russian] Оценка собственных возобновляемых водных ресурсов Крымского полуострова. *Водные ресурсы*. 2022. Т. 49. № 4. С. 423–436. Available at: https://doi.org/10.31857/S0321059622040113.

This study assesses Crimea's own renewable water resources based on long-term hydrological data from 15 gauging stations reflecting relatively natural runoff conditions. It applies statistical analysis of annual runoff series (full analysis for nine active stations), examines spatial-temporal variability, and derives relationships between

mean long-term discharges and river orders (per A. Scheidegger's method). Data draw from historical observations, addressing data gaps and non-homogeneity in records.

Main findings indicate low renewable resources: the minimum estimated mean annual runoff volume for Crimean rivers is **371 million m³**, with rivers showing increased annual runoff since 1991 in some cases. Crimea fits general Russian river patterns but exhibits higher discharges than the lower envelope curve for Russia. This underscores extreme water scarcity, exacerbated by seasonal mismatch (winter-spring runoff vs. summer demand) and the post-2014 cutoff of North Crimean Canal (NCC) supplies.

Recommendations emphasize reliance on local resources, with no mention of restoring the Kakhovka Reservoir or Dnipro supplies. It highlights the need for optimal water use planning given natural deficits and asynchrony, implicitly supporting efficiency improvements, storage optimization, and adaptation rather than external transfers. Quantitative importance: 371 million m³ provides a conservative baseline for drought conditions, far below pre-2014 demands met largely by NCC (often >1 km³/year).

Vasilenko, V. (2017). Hydro-economic problems of Crimea and their solutions. *Regional Research of Russia*, 7(1), 89–99. Available at: https://doi.org/10.1134/S2079970516040146.

Scope focuses on post-2014 hydro-economic challenges in Crimea following the NCC cutoff, analyzing socioeconomic/environmental impacts of water shortages and solutions via territorial redistribution, efficiency gains, and new sources. Methods involve synthesis of regional economic data, water balance assessments, and policy/program reviews.

Key findings highlight accumulated problems worsened by the political shift: shortages affect drinking water, irrigation, and industry. Local river runoff and groundwater can cover drinking/public needs via redistribution, but irrigation shortages persist due to insufficient local volumes. High losses in housing/communal services and reclamation offer major reserves; desalination of seawater is a proven major solution.

Recommendations prioritize reducing losses (e.g., in networks and irrigation), rational use (avoid using potable water for technical needs), and seawater desalination for agriculture/industry. No emphasis on restoring the Kakhovka Reservoir/Dnipro; focus is on local optimization and alternatives. This aligns with the two provided volumes' stress on post-destruction adaptation and ecosystem restoration over reservoir rebuilding, adding quantitative detail on losses and desalination feasibility.

Vasyliuk, O., Hubareva, V., Parkhomenko, V. (2024). *The Environment in Crimea: Changes and Losses During the Full-Scale War*. KrymSOS, 84 p. [In Ukrainian] Василюк О, Губарева, В, Пархоменко, В (2024) *Довкілля Криму: зміни та втрати в період повномасштабної війни*. КримСОС, 84 с. Available at: https://www.researchgate.net/publication/386508686.

The Krymsos report examines changes in Crimea's water supply after the loss of the former primary source from the Kakhovka Reservoir via the North Crimean Canal.

It lists the principal alternatives and management measures that have been applied or planned: increased use of local surface reservoirs and river transfers (including proposed diversion from the Belbek River into dry reservoirs); expanded groundwater extraction through new artesian wells and associated multi-kilometre pipeline systems serving eastern and southern settlements; reduction of distribution losses via pipe replacement and improved intake operations; limited consideration of seawater desalination; and demand-side measures such as water-use restrictions and conservation.

Zonn, I. (2022). Cross-technological comparison of solutions to water problems of the Republic of Crimea and the State of Israel. *Vestnik Moskovskogo universiteta im. S. Yu. Vitte*. Ser. 1. Ekonomika i upravlenie, (3). Pp. 70–81. [In Russian] Зонн И.С. Кросс-технологическое сравнение решений водных проблем Республики Крым и Государства Израиль. *Вестник Московского университета им. С.Ю. Витте*. Сер. 1. Экономика и управление. 2022. № 3 (42). С. 70–81. Available at: https://doi.org/10.17777/2587-554X-2022-3-70-81.

This comparative analysis examines water management in arid Crimea and Israel, similar in territory and challenges. Scope includes technological and policy solutions; methods likely involve cross-case review of resources, technologies, and integrated management.

Findings stress Israel's success in integrated management of limited resources for sustainable supply in arid zones (e.g., efficiency, reuse, desalination). Crimea faces similar deficits but lagged in adoption.

Recommendations advocate adopting Israel's model: advanced efficiency, wastewater reuse, desalination, and integrated planning. No restoration of Kakhovka/Dnipro; emphasizes local/technological alternatives. Complements the provided volumes by offering international benchmarks for resilient post-reservoir economies.

Klintsov, A. (2023). Analysis of the water balance of Crimean reservoirs as a strategic water reserve. *Ekonomika stroitelstva i prirodopolzovaniya*, 3(88). Pp. 5-15. [In Russian] Анализ водного баланса водохранилищ Крыма как стратегического запаса воды // *Экономика строительства и природопользования*, № 3 (88). С. 5-15 [Available at: https://cyberleninka.ru/article/n/analiz-vodnogo-balansa-vodohranilisch-kryma-kak-strategicheskogo-zapasa-vody/viewer.

Scope centers on reservoirs' role in strategic reserves post-cutoff. Methods analyze water balances using hydrological and operational data.

Findings detail balances, capacities, and vulnerabilities, positioning reservoirs as critical amid shortages.

Recommendations focus on optimizing existing reservoirs and local storage. Likely supports efficiency over large external restoration; aligns with volumes' adaptation themes.

Noorali, H., Zaki, Y., Campana, M. & Taheri, A. (2025). Hydropolitics of Russian-Ukrainian war: analyzing water governance conflicts in the Dnieper River basin through remote sensing techniques. *GeoJournal*. Available at: https://doi.org/10.1007/s10708-025-11338-0.

This uses remote sensing (NDWI/NDVI indices, satellite imagery) to examine Dnieper basin governance conflicts, including NCC and Kakhovka impacts. Scope covers war-related hydropolitics.

Findings document drastic reductions (e.g., arable land from 130,000 ha in 2013 to 14,000 ha by 2017 post-blockade), shortages, rationing, and ecosystem/agricultural shifts. Destruction of Kakhovka exacerbated issues.

Recommendations address governance conflicts; context implies sustainable local alternatives over contested transfers. Identifies war's role in reshaping availability, supporting volumes' post-destruction restoration focus.

Altingoz, M. & Ali, S. (2022). Hydropolitics in the Russian–Ukrainian Conflict. *New Security Beat*, March 1. Available at: https://www.newsecuritybeat.org/2022/03/hydropolitics-russian-ukrainian-conflict/.

This policy-oriented piece analyzes water as a conflict tool, including NCC blockade and Crimea shortages. Methods: qualitative geopolitical analysis.

Findings link annexation, blockade, and shortages (e.g., agricultural collapse, rationing).

Recommendations focus on hydropolitical peacebuilding and sustainable governance; no strong push for reservoir restoration, emphasizing alternatives amid conflict. Parallels volumes' views on long-term resilience.

Vasyliuk, O. & Simonov, E. (2024). The thirsty peninsula: How much water will Crimea need in the future? *Ukraine War Environmental Consequences Work Group*, August 1. Available at: https://uwecworkgroup.info/the-thirsty-peninsula-how-much-water-will-crimea-need-in-the-future/.

This UWEC analysis (by authors also participating in UNCG core volumes) reviews post-2014 adaptation, North Crimea Canal (NCC) dependency (up to 85% pre-2014), losses (~50%), and local resources (~371 million m^3 conservative estimate). Uses historical data, reports, and observations.

Findings: Crimea adapted via efficiency despite occupation mismanagement; irrigated agriculture (esp. rice) collapsed, proving over-reliance unsustainable. Local sources plus conservation suffice for sustainable needs; local reservoirs critical for municipal/tourism.

Recommendations: Rely on local resources for post-war sustainable development; avoid restoring wasteful NCC/Kakhovka dependency. Prioritize efficiency, reduced losses, non-rice agriculture, and climate adaptation.

(4) ENERGY SECTOR

Sources converge on possibility of avoiding full Kakhovka restoration due to ecological/economic drawbacks, favoring other RE sources, and energy efficiency. ZNPP cooling emerges as a critical concern, with groundwater and diversified strategies as key alternatives to reservoir-based surface water supply options. Quantitative data (capacity factors, losses) reinforce the shift to resilient, decentralized systems

Numerous sources on Ukraine energy system recovery that do not explore in any detail Kakhovka HPP or ZNPP have not been included in this review. However, frequent omission of this topic in literature on energy sector of Ukraine likely indicate only marginal value of Kakhovka reservoir for Ukraine's energy future.

KEY PUBLICATIONS:

Epik, O., Briukhovetska, M. & Jesson, J. (2025). *Scenarios of Usage of Kakhovka Reservoir Area for Energy Production and Sustainable Recovery* [Analytical paper]. Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH. 51 p. Available at: https://ukrainian-climate-office.org/wp-content/uploads/2025/03/Kakhovka-dam-EN-22.03.2025-compressed.pdf.

This analytical paper compares recovery scenarios for the former Kakhovka area using expert analysis, environmental data, and energy modelling. It evaluates restoration vs. alternatives like natural recovery, small/floating HPPs, energy crops, and combined RES.

Key findings: Full Kakhovka HPP restoration faces high costs, environmental risks, and limited net benefits given war damage and climate realities. Natural recovery shows positive ecosystem trends; alternatives (e.g., RES on reservoir floor, energy crops) offer sustainable energy with lower impacts. Quantitative comparisons demonstrate superior resilience and multi-use potential in non-restoration scenarios.

Recommendations strongly favor a combined scenario with RES (solar, wind), small HPPs, and energy crops over full reservoir/HPP restoration. For ZNPP cooling, it notes alternatives to reservoir dependency. This directly supports and expands the two volumes' perspectives on ecosystem-first recovery and resilient local economies.

International Energy Agency (IEA). (Year approx. 2025/2026). *Energy System Resilience: Lessons learned from Ukraine*. IEA. 39 p. Available at: https://iea.blob.core.windows.net/assets/2c6f2378-31e8-442a-815a-18e693167915/EnergySystemResilience.pdf.

This IEA report draws lessons from Ukraine's wartime energy attacks using operational data, resilience metrics (e.g., SAIDI), and case studies of infrastructure damage/recovery.

Findings underscore Ukraine's rapid adaptation via decentralization, demand management, and diverse sources despite hydropower and other losses (including Kakhovka impacts).

Recommendations focus on resilience measures like decentralization and storage applicable globally. It supports flexible systems over rigid large hydro; implicitly addresses NPP cooling via diversified water/energy strategies. Complements volumes by highlighting practical post-destruction resilience.

> **Underground Risks: Groundwater Depletion after the Destruction of the Kakhovka Dam as an Underappreciated Legacy of the Ukraine-Russia War** (2025/2026). PRIF (Peace Research Institute Frankfurt) project. Available at: https://www.prif.org/en/research/projects/underground-risks.

This project models increased groundwater extraction for Zaporizhzhia NPP cooling and southern irrigation post-Kakhovka. Preliminary findings highlight depletion risks in affected areas.

This multidisciplinary project assesses groundwater extraction increases for ZNPP cooling and irrigation post-destruction using geophysical, hydrological, and conflict data.

Findings reveal under-monitored depletion risks affecting communities, agriculture, and ecosystems, beyond surface flooding. The project emphasises sustainable groundwater management as an alternative/supplement to surface water for municipal, industrial, and agricultural supply in the post-Kakhovka context.

Project description calls for monitoring and sustainable groundwater management. It highlights ZNPP cooling challenges without advocating reservoir restoration; favors alternatives for long-term water security. Adds a new dimension (groundwater) to the UNCG volumes' analyses.

> **Stefanyshyn, D.** (2024). *Several lessons from the Kakhovka reservoir disaster: will they be learned and properly considered in the future?* Presentation at Kakhovka conference in 2024. [In Ukrainian] **Стефанишин, Д.** (2024). *Кілька уроків катастрофи на Каховському водосховищі: чи будуть вони вивчені та належно враховані у майбутньому?* Доповідь на конференції, присвяченій Каховському водосховищу, 2024. Download: https://drive.google.com/file/d/1EyJ0WeoXCwLESnAJDA-brlLISrHgriU/view?usp=sharing.

This conference paper critiques large hydropower projects using comparative international data on reservoir efficiency, environmental laws, and capacity factors.

Findings: Ukrainian hydro shows poor performance (e.g., 13% capacity factor vs. 43-45% in Nordic countries) and high ecological costs; historical lessons from Europe favour protection over expansion.

Recommendations question reservoir restoration as a «national project,» advocating better regulation and alternatives. No strong support for full restoration; emphasizes learning from global best practices. Aligns with volumes' critical view.

Burnie S. & Vande Putte J. (2024). Expert Research and Analysis of the Impacts of the Dam's Destruction on the Zaporizhzhia Nuclear Power Plant (ZNPP). Truth Hounds / Project Expedite Justice SUBMERGED study annexes. Hounds Annex B to *SUBMERGED*. 32 p. Available at: https://truth-hounds.org/wp-content/uploads/2024/06/submerged-annex-b.pdf.

This in-depth study combines legal, ecological, and technical analysis of destruction impacts, including on ZNPP cooling, using satellite data, expert input, and field evidence.

Findings detail flooding/draining effects, ecosystem damage, **and heightened ZNPP risks from altered water levels/cooling**.

Recommendations support accountability, ecosystem recovery, and alternatives to large dams. Annex stresses diversified cooling solutions for ZNPP. Consistent with UNCG Kakhovka dam restoration skepticism.

Simonov, E. & Vasyliuk, O. (2026). *Prospects of Dnipro River Ecosystem Recovery and Degradation in the Light of War-induced Destruction, Reconstruction Policies and International Financing of Hydropower during the War.* Cherkasy: NGO "Ecosociety", 2026. 41 p. Available at: https://doi.org/10.13140/RG.2.2.24101.05607.

Also available in Ukrainian: **Симонов Є., Василюк, О.** *Перспективи відновлення та деградації екосистеми річки Дніпро з огляду на руйнування, спричинені війною, політику реконструкції та міжнародне фінансування гідроенергетики під час війни.* Черкаси: ГО «Екосоціум», 2026. 41 с. https://doi.org/10.13140/RG.2.2.32489.66404.

This report synthesizes ecological, policy, and financing data on Dnipro hydropower cascade post-Kakhovka destruction and war damage. It uses field observations, historical comparisons, and policy analysis.

Findings show that after issuance of initial decree to rebuild the dam (2023) Kakhovka hydropower reconstruction shifted out of the focus of the Government of Ukraine. Main investments in water supply management are confined to construction of large water pipelines for municipal supply, which are functional alternatives to the supply from the former reservoir. Other governmental plans in agriculture and climate adaptation mention, but are not centred on dam restoration. Several large projects supported by International development banks support restoration and upgrade of other hydropower plans, despite ther continued destruction by Russian shelling. Authors show how Kakhovka loss highlighted vulnerabilities in centralized systems; international financing risks locking in outdated models.

Recommendations prioritize ecosystem recovery and decentralized renewables over reservoir restoration. It questions hydropower expansion financing. For energy supply (including NPP), it advocates diversified, nature-based resilience. Consistent with the UNCG volumes› emphasis on natural restoration and complements them by updated policy analysis.

STATE PLANS AND REPORTS

National Energy and Climate Plan of Ukraine 2025-2030 [Draft]. (2025). Ministry of Energy of Ukraine (or relevant drafting body). Available at: https://dixigroup.org/en/ukraine-updated-its-national-energy-and-climate-plan-to-2030-with-dixi-groups-contribution.

This draft NECP outlines Ukraine's integrated energy and climate strategy through 2030, using modelling (e.g., TIMES-Ukraine) and policy scenarios (WEM/WAM) to project generation, demand, efficiency, and RES integration amid war damages. It incorporates data on existing infrastructure, war impacts, and EU alignment goals.

Main findings highlight severe war-related disruptions to the energy system, including hydropower losses from Kakhovka destruction. The plan prioritizes decentralized RES, efficiency, and resilience. Hydropower (including potential Kakhovka-related assets) is part of the mix but not dominant; nuclear remains key, with attention to cooling water security.

Recommendations emphasize diversified, resilient supply with heavy RES growth and efficiency measures. It does not strongly advocate full Kakhovka Reservoir restoration; instead, it supports broader reconstruction aligned with climate goals, including alternatives like solar/wind/storage. For ZNPP, it implicitly underscores the need for reliable cooling sources, favoring diversified water strategies over sole reservoir dependency. This aligns with the two provided volumes' caution on large reservoir revival, adding quantitative policy targets for post-war energy transition.

State Nuclear Regulatory Inspectorate of Ukraine (2011). *National Report of Ukraine on the Results of "Stress Tests"*. 125 p. Available at: https://www.grs.de/sites/default/files/2022-03/National_Report_on_Stress_Test_Results_of_Ukrainian_20NPP.pdf.

This older stress test report analyzes NPP safety (incl. ZNPP) under extreme scenarios using probabilistic and deterministic methods.

Findings identify vulnerabilities in cooling and external events. Due to large volume of the semi-autonomous cooling pond, vicinity of alternative surface water sources and readily available ground-water sources the ZNPP can withstand lowering of the Kakhovka Reservoir level and use other long-term supply options.

Recommendations on safety upgrades, diversification of readily available water-supply options. Post-2023 relevance underscores reservoir dependency risks for ZNPP; supports diversification. Provides baseline for volumes' discussions.

(5) FISHERIES AND AQUATIC ECOSYSTEMS

Literature describes wide range of immediate impacts—mass fish and mussel mortality, sea salinity drops to ~4 ‰, oxygen deficits, ammonium spikes and sediment pulses into the northwestern Black Sea—are quantified consistently by Minicheva et al. (2023), Kvach et al. (2025) and Novitskyi et al. (2024). The latter place commercial losses at ~$5.5 million annually and spawning-ground losses at ~20 000 tons of fish resources. Marenkov & Borovyk (2024) add 285 million UAH in crayfish bioresource losses, while Son highlights extinction risks for rare invertebrates dependent on the former artificial regime. Mulenko & Mikhina (2026) and the IUCN assessment of *Alosa immaculata* record the opposite signal for migratory species: rapid restoration of historical upstream runs of Azov–Black Sea migratory fish once the 70-year barrier disappeared. UNCG Volume 1 and Volume 2 (Vasyliuk & Kolodezhna) embed all these losses within the longer rupture caused by the original impoundment of Velykyi Luh.

Hydro-ecological interpretations diverge sharply. The Institute of Hydrobiology (2023) and Korzhov (2024) treat the collapse of regulated water-level fluctuations as detrimental to aquatic complexes adapted to the lentic regime and therefore favour reconstruction. Mulenko & Mikhina (2026), Kvach et al. (2025) and Novitskyi et al. (2024) regard the return of free-flowing conditions as the key to renaturalising migration corridors and ichthyocomplexes. Sydorenko et al. (2025) remain neutral. UNCG Volumes 1 and 2 reject re-impoundment outright, arguing that any rebuild would recreate the original barrier and re-submerge recovering floodplain habitats.

The resulting alternatives therefore range from full reconstruction (Institute of Hydrobiology 2023; Korzhov 2024), through open-ended hybrid options (Sydorenko et al. 2025), to permanent renaturalisation, continuous monitoring and sustainable fisheries under lotic conditions (Mulenko & Mikhina 2026; Kvach et al. 2025; Novitskyi et al. 2024; Son; Marenkov & Borovyk 2024; UNCG Volumes 1 and 2).

KEY PUBLICATIONS:

Afanasyev, S et al. (2023). *Scientific Report "Development of Recommendations on the Feasibility of Rebuilding the Kakhovka Dam and Filling the Kakhovka Reservoir to Ensure Reliable Operation of Water Intakes for Municipal and Industrial Water Supply, and Restoration of the Ecological State and Biodiversity of the Lower Dnipro" Stage 1*. Kyiv: Institute of Hydrobiology NASU. 108 p. State registration No. 0123U105277. [In Ukrainian] **Афанасьєв, С та ін.** (2023).*Науковий звіт "Розробка рекомендацій щодо доцільності відбудови Каховського гідровузла та наповнення*

Каховського водосховища для забезпечення надійної експлуатації водозаборів комунального та промислового водопостачання, та відновлення екологічного стану і біорізноманіття Нижнього Дніпра" 1 Етап. Київ: Інститут гідробіології НАНУ, 108 с. Available at: https://nrat.ukrintei.ua/en/searchdoc/0123U105277/.

Scope/methods/data used: This institutional scientific report draws on historical (1970s–1980s) complex hydrobiological, hydrochemical, and hydrological surveys of Dnipro reservoirs, including detailed studies of bottom sediment composition, spatial distribution, chemical properties, and biochemical processes. It incorporates long-term forecasts of mud accumulation and geomorphological analysis of the former reservoir bed (primarily former Dnipro floodplain with partial inundation of terraces). Key focus on benthic and planktonic communities shaped by prior impoundment.

Main findings: Post-destruction drainage exposed a flattened relief with mulls and sands replacing original fertile floodplain soils. Sediment formation was driven by bank abrasion (mineral component) and hydrobiont activity (organic, especially phytoplankton, benthos, and macrophytes), with peak accumulation in early years after initial filling. By late 1970s, the sediment complex had largely stabilized.

Recommendations: The report evaluates feasibility of restoration for water supply reliability, ecological recovery, and biodiversity support in the Lower Dnipro. It recommends data-driven assessment favoring rebuilding the reservoir to restore regulated conditions. It identifies restoration of the reservoir as preferable for maintaining aquatic ecosystem services, with limited discussion of full natural riverine alternatives, though it acknowledges transformed sediments would require management. Preferred future: Re-filling and engineering interventions for stable lentic conditions.

Minicheva, I et al. (2023). Reaction of the Marine Ecosystem to the Consequences of the Destruction of the Kakhovka Reservoir Dam. *Marine Ecological Journal* . №1-3. Pp. 52-68. [In Ukrainian] **Мінічева І. та ін.** (2023). Реакція морської екосистеми на наслідки руйнування греблі Каховського водосховища. *Морський екологічний журнал.* №1-3. С. 52-68. Available at: https://doi.org/10.47143/1684-1557/2023.1-2.6.

Scope/methods/data: Research addresses influx or water and sediments into marine ecosystems flllowing the dam blast. Expeditio nary research (June–August 2023, 11 stations from Koblevo to Velykyi Fontan) analyzed hydro-physical/chemical parameters, water toxicity, biotic groups (micropsammon, meiobenthos, macrozoobenthos, phytobenthos, phytoplankton, zooplankton), aquatic bioresources, and satellite chlorophyll-a data. Anomalies calculated as % deviation from regional norms; four-stage «explosive» impact assessment.

Main findings: Freshening to 3.95‰, oxygen <75% saturation, ammonium nitrogen to 13.8 MPC, acute toxicity, chlorophyll-a increase with cyanobacterial blooms, suppression of macrophytes, changes in fouling communities, mass die-off of freshwater fish and Black Sea mussels (~3.7 thousand tons biomass). «Explosive» phase ~3 months; most indicators normalized by late August. Affected species include marine mussels and various planktonic/ benthic groups.

Recommendations: Emphasizes need for continued monitoring of war-related impacts on marine ecosystems. Recommends integrated assessment and protection measures. Does not recommend restoring the reservoir; highlights temporary nature of many effects but stresses vulnerability. Natural recovery processes observed, with focus on reducing other anthropogenic pressures rather than large-scale hydro-engineering. Preferred future actions include enhanced monitoring and ecosystem-based management for resilience.

Kvach Y., Stepien, C, Minicheva,G. & Tkachenko, P. (2025). Biodiversity effects of the Russia–Ukraine War and the Kakhovka Dam destruction: ecological consequences and predictions for marine, estuarine, and freshwater communities in the northern Black Sea. *Ecological Processes*, 14:22. Available at: https://doi.org/10.1186/s13717-025-00577-1.

Scope/methods/data: Review synthesizing investigations by the Institute of Marine Biology NASU on war and dam effects. Covers aquatic biota (marine, estuarine, freshwater) with focus on toxins, habitat damage, and reduced human pressures. Discusses native species tolerances and invasive species background.

Main findings: Negative effects include pollutant release and habitat loss from flooding; positive include reduced shipping/fishing/trawling. Many impacts temporary, with reversion to historical biota. Significant persistent habitat damage due to war. Northern Black Sea species show broad environmental tolerances aiding recovery. Affected groups: various fish, invertebrates, plankton.

Recommendations: Leverage evolutionary resilience for persistence during/after conflict. Calls for ongoing environmental analyses. Does not strongly recommend full reservoir restoration; notes benefits of natural dynamics post-destruction. Preferred future: Ecosystem resilience through protection of remaining habitats and monitoring, balancing conservation with sustainable use. Natural recovery and reduced anthropogenic loads (e.g., less intensive fishing/hydraulic engineering).

Sydorenko. O., Matviienko ,M. and Bozhko, T. (2025). Kakhovka reservoir: environmental condition and feasibility of restoration.*Commodity science. Technologies. Engineering.* 56, 4 (Dec. 2025). Pp. 72–81. [In Ukrainian] **Сидоренко, О., Матвієнко, М., Божко Т.** (2025). Каховське водосховище: екологічний стан та доцільність відновлення. Journal of State University of Trade and Economics.) *Commodity Science. Technologies. Engineering*, 56(4). Pp. 72–81. Available at: https://doi.org/10.31617/2.2025(56)06.

Scope/methods/data: Analytical review of scientific debates on dam destruction consequences and restoration concepts, drawing on ecological data post-2023 event.

Main findings: Large-scale technogenic tragedy causing negative ecological and societal impacts, including aquatic ecosystem disruption. Opposing views in literature on rebuild desirability.

Recommendations: No unified recommendation; presents balanced discussion of pros/cons. Recommends further research for informed decision. Identifies restoration of reservoir as one option but highlights risks. Alternatives: Non-restoration

leading to natural river/floodplain development. Preferred future actions not singular; calls for weighing ecological, social, and economic factors in post-war planning for aquatic systems and fisheries sustainability.

Mulenko, M. & Mikhina, I. (2026). Restoration of the diadromous fish migration corridor in the Lower Dnipro following the destruction of the Kakhovka hydro-node (case study of *Alosa immaculata and Acipenseridae*). Ukrainian Nature Conservation Journal, 1 (2). Pp. 3–10.[In Ukrainian] **Муленко, М., Міхіна, І.** Відновлення міграційного коридору прохідних риб у Нижньому Дніпрі після руйнації Каховського гідровузла (на прикладі *Alosa immaculata ma Acipenseridae*). Український природоохоронний журнал, 1 (2). С. 3–10. Available at: https://doi.org/10.67531/uncg-j.2026.1.2.3-10.

Scope/methods/data: Non-invasive monitoring (2025–2026) via citizen science, amateur fishing reports, photo verification, and observations of ichthyophagous birds around Khortytsia Island. Focus on diadromous species responses post-lotic regime restoration. Species: Alosa immaculata (Azov-Black Sea shad), Acipenseridae (sturgeons).

Main findings: Rapid recovery of migration corridors; mass approaches of shad and sturgeons in June 2025 and May 2026, matching 1920s historical timings. Removal of 70-year barrier catalyzed renaturalization of ichthyocomplexes.

Recommendations: Implement continuous monitoring programs. Recommends against full restoration of the reservoir as it would re-impose the barrier. Alternatives: Maintain natural river flow with Dnipro HPP as upper limit. Sustained lotic conditions for migratory fish recovery and ecosystem renaturalization.

See on the shad: **Freyhof, J. & Kottelat, M.** (2008). Alosa immaculata. The IUCN Red List of Threatened Species 2008: e.T907A13093654. Available at: http://dx.doi.org/10.2305/IUCN.UK.2008.RLTS.T907A13093654.en.

IUCN findings: Vulnerable (B2ab(v)); reservoirs reduced spawning sites/migration routes. Overfishing threatens populations. Historic range included far upstream in Dnipro; current limited below dams. Area of spawning grounds <2,000 km². IUCN recommends measures aiding migration (relevant to post-destruction).

Novitskyi, R., Hapich, H., Maksymenko, M., Kutishchev, P. & Gasso, V. (2024). Losses in fishery ecosystem services of the Dnipro river Delta and the Kakhovske reservoir area caused by military actions in Ukraine. *Frontiers in Environmental Science*, 12:1301435. Available at: https://doi.org/10.3389/fenvs.2024.1301435.

Scope/methods/data: Analysis of commercial/recreational fishing 2020–2023, fish assemblage dynamics 1956–2021 in Kakhovske Reservoir and Dnipro lowlands. Remote sensing for water surface changes post-explosion. Species: ~40 affected fish taxa/subspecies.

Main findings: Reservoir drainage left ~19% water surface (~430 km²); new shallows drying/overgrowing. Ecological disaster for 40+ fish species. Annual commercial losses ~$5.5M; spawning grounds loss ~20,000 tons fish resources (~$40M). Cessation of water supply noted.

Recommendations: Consider biodiversity in post-war recovery for water/food security. Questions feasibility of dam reconstruction. Recommends rehabilitation of degraded areas. Alternatives: Post-war restoration prioritizing sustainable fishery and ecosystem functions over full reservoir rebuild. Integrated recovery ensuring resilient aquatic ecosystems and fisheries.

Korzhov, Y. (2024). Changes in the key hydrological factors of the Lower Reaches of the Dnieper water ecosystems functioning after the Kakhovka Hydroelectric Power Station dam was destroyed. In: *Heritage of European Science* (Chapter 9). Pp. 102–113. Available at: https://doi.org/10.30890/2709-2313.2024-27-00-028.

Scope/methods/data: Hydrological analysis post-June 6, 2023 detonation of the dam, focusing on water balance, dynamics, and hydrophysical properties downstream of the former dam: lower Dnipro reaches and floodplain lakes (~1,440–3,600 km² affected zone). Comparison of pre/post-dam fluctuation amplitudes.

Main findings: Loss of regulated inflows and daily level fluctuations (e.g., amplitudes reduced from 1.04m to 0.04m near dam site). Negative for floral/faunal complexes, threatening biodiversity. Altered external water exchange.

Recommendations: Implied need to address regime changes for ecosystem functioning. Discusses restoration of dam. Recommends rebuilding dam to restore fluctuations. Restoration of hydro-engineering for stable aquatic habitats supporting fisheries.

Son, M. (2023). Kakhovka catastrophe and risks of disappearance of aquatic invertebrates. Presentation at the conference «Zoological research during and after the war, Institute of Marine Biology NASU. [In Ukrainian] **Сон, М.** (2023). Каховська катастрофа та ризики зникнення водних безхребетних. Презентація під час круглого столу» «Зоологічні дослідження під час та після війни», Інститут морської біології НАН України. Download: https://drive.google.com/file/d/19SYOJJHNHGgs-mhOA3dUCzdgB_T4BUTT/view?usp=sharing.

Scope/methods/data: Presentation/review on catastrophe impacts on aquatic invertebrates in affected water bodies (reservoir, canal, irrigation systems). Visual and ecological data on drying zones. Focus on several rare nvertebrates wth IUCN EN-EX statuses, which were supported by artificial regime of Kakhovka dam flow releases (also mentioned in Korzhov(2024)).

Main findings: Drainage of artificial ecosystems led to habitat loss and risks of local extinctions for benthic invertebrates. Significant impacts on shallow-water and floodplain species.

Recommendations: Monitoring and conservation to mitigate extinction risks. Does not explicitly recommend full reservoir restoration. Alternatives: Protection of remaining wetlands/refugia. Preferred: Measures for invertebrate conservation in post-catastrophe landscapes supporting broader aquatic food webs and fisheries.

Marenkov O.M., Borovyk I.I. (2024). Dynamics of Crayfish Harvest in Water Bodies of Ukraine and the Volumes of Losses Caused to Aquatic Bioresources of the Kakhovka Reservoir. *Bulletin of Sumy National Agrarian University*. The Series: Agronomy and Biology, 55(1). Pp. 101-108. [In Ukrainian] **Маренков, О, Боровик І.** (2024). Динаміка вилову річкових раків у водоймах України і обсяги збитків, заподіяних водним біоресурсам Каховського водосховища. *Вісник Сумського національного аграрного університету*, 1(55). С. 101–108. Available at: https://doi.org/10.32782/agrobio.2024.1.14.

Scope/methods/data: Analysis of official statistics 2017–2023 on crayfish harvest; normative calculations of damages using Ukrainian Cabinet tax rates. Focus on Astacidae (river crayfish) in Dnipro reservoirs, especially Kakhovka.

Main findings: Pre-war growth in harvest; post-invasion/war decline 87–90%. Kakhovka/Kyiv reservoirs key (~77% national). Losses from Kakhovka: 285 million UAH to bioresources.

Recommendations: Address illegal harvest and war impacts. Recommends recovery planning. Questions full restoration viability due to losses. Alternatives: Sustainable management in remaining/renaturalized waters. Preferred: Post-war rehabilitation of fisheries with focus on resilient populations.

(6) POST-DISASTER RAPID IMPACT ASSESSMENTS

This collection includes mainly 2023-24 articles assessing immediate consequences (and causes) of the Kakhovka dam breach on 6 June 2023. It describeswide range of observed immediate and expected consequences of the dan blasting.

KEY PUBLICATIONS:

Hydrological regime and sediment dynamics. The papers examined here (Dovhanenko et al., Tuchkovenko et al., Vyshnevskyi & Shevchuk, UKCEH/HRW, UNEP) supply quantitative post-event data: 14.4 km^3 released in six days, peak discharges 40–50 × 10^3 m^3 s^{-1}, flood extents of 520+ km^2, and rapid transformation of the former reservoir into a network of branches and lakes whose thermal and hydrodynamic behaviour is now governed by the upstream Dniprovske Reservoir.

Pollution and water quality. Field studies (Trokhymenko et al., Tuchkovenko et al., UNEP, Arnika) record acute post-breach spikes in ammonium, heavy metals, oil products, pathogens and POPs that reached the north-western Black Sea. Hydrodynamic dilution reduced concentrations but did not eliminate risk.

Biodiversity and landscape recovery. Landscape and temperature studies (Dovhanenko, Vyshnevskyi & Shevchuk) confirm the shift from a large lentic system to a mosaic of lotic and shallow-lake habitats, with corresponding changes in thermal regimes that affect fish spawning cues. Rapid assessments note threats to protected areas and wetlands of international importance, while also documenting the rapid emergence of terrestrial vegetation on the exposed bed.

Range of recovery alternatives.

- **Full or partial reservoir restoration** is considered an option in Vyshnevskyi et al. (2023) and is implicitly present in some official Ukrainian planning contexts referenced by the core volumes; it would restore regulated flow, irrigation and water supply but re-create the 70-year barrier to diadromous fish and re-submerge emerging floodplain ecosystems.
- **Natural-river / Great-Meadow restoration** (favoured or left open by many ecological papers) accepts the lotic regime, prioritises sediment stabilisation, contaminant containment and biodiversity recovery, and explores alternative water-supply and irrigation solutions.
- **Hybrid or risk-based approaches** (UNEP, UKCEH/HRW, Trokhymenko) emphasise monitoring, pollution control, adaptive management and integration of

environmental recovery into broader post-war reconstruction without committing to either extreme.

Quantitative discrepancies (exact flood area, contaminant loads, economic losses) reflect differences in data sources, timing and spatial resolution, yet the overall narrative converges: the 2023 event has irreversibly altered the lower Dnipro continuum, and recovery planning must now choose between re-engineering a large reservoir or managing a new, more natural, but still heavily modified, river–floodplain system

Bilenkyi, A. & Soldatenko, D. (2024). Calculation of approximate losses resulting from the flooding of crop fields after the breach of the Kakhovka Dam. Truth Hounds / Project Expedite Justice SUBMERGED study annexes. Annex D to *SUBMERGED*. Project Expedite Justice / Truth Hounds. Available at: https://www.projectexpeditejustice.org/items/annex-d.

This short technical annex provides a conservative, bottom-up estimate of direct crop losses caused by inundation of arable fields immediately after the 6 June 2023 Kakhovka Dam breach. The authors used a local survey of flooded croplands conducted by Project Expedite Justice and Truth Hounds field teams in the Snihurivka territorial community (Mykolaiv oblast), combined with remote-sensing verification and Google Earth field mapping. The Snihurivka data (416.21 ha of productive arable land after excluding uncultivated parcels and orchards) were treated as a representative sample equalling approximately 8.3 % of the total flooded crop area. Average five-year regional yields (sunflower 2 t ha^{-1}, spring barley 3.1 t ha^{-1}) and 2021 official producer prices (sunflower USD 610.4 t^{-1}, spring barley USD 214.9 t^{-1}) were applied to convert physical losses into monetary terms. Alfalfa, vegetables and minor winter crops were aggregated into the sunflower category because of their negligible area.

Main findings: the extrapolated total area of inundated productive cropland is approximately 5 000 ha. The corresponding direct production loss is calculated at roughly USD 5.4 million (precisely USD 5 445 266 before rounding). The calculation is explicitly described as conservative and limited by the scarcity of ground data; actual losses are expected to be higher.

Dovhanenko, D., Yakovenko, V., Brygadyrenko, V. & Boyko, O. (2024). Complex characteristics of landscape components affected by the disaster at the Kahovka Hydropower Plant. *Biosystems Diversity*, 32(1)). Pp. 174–182. Available at: https://doi.org/10.15421/012418.

This study combines ground hydrometeorological data from the Ukrainian Hydrometeorological Center with Landsat-9 satellite imagery (MNDWI and NDVI indices) and a digital elevation model to map the 2023 flood pulse in Kherson and Mykolaiv oblasts. Flooding began 6 June, peaked 7–9 June (water level ~5.68 m), and largely receded by late June.

Main findings: the surge inundated azonal floodplain complexes, supra-floodplain terraces and coastal plains over areas exceeding the recorded hydrological maxima; more than 2 000 ha of downstream deposits were mobilised. The work supplies

a spatial baseline for assessing ecosystem degradation. The article also includes a map showing how the floodwaters breached the embankment on the left bank of the Dnieper, which subsequently led to a long-term change in the hydrological regime of the dry sandy steppes of the Lower Dnieper Sands, along with all their endemic species.

Recovery recommendations: continuous monitoring of contaminant accumulation zones, agrochemical surveys of flooded soils, and design of liquidation/adaptation plans under rising technogenic risk. The paper does not advocate full reservoir restoration; it treats the event as a new baseline for landscape recovery and risk reduction.

> **Hryshchenko, O., Palamarchuk, R., Melnyk, M., Zhuchenko, S. & Vozniuk, N.** (2023). Eco-toxicological assessment of agricultural lands of Kherson oblast that suffered flooding as a result of the destruction of the Kakhovka HPP, *Visnyk NUWGP,* 4(104). Pp. 17-37. [In Ukrainian] **Грищенко, О., Паламарчук, Р., Мельник, М., Жученко, С., & Вознюк, Н.** Еколого-токсикологічна оцінка земель сільськогосподарського призначення Херсонської області, які зазнали підтоплення внаслідок руйнування Каховської ГЕС. *Вісник Національного університету водного господарства та природокористування*. Серія «Сільськогосподарські науки», 4(104). С. 17–37. Available at: https://doi.org/10.31713/vs420232.

Soil, silt and mud samples (10 soil + silt/mud) from Kherson and Beryslav districts analysed for mobile heavy-metal compounds.

Main findings: lead exceeded MPC in 4 soil samples (1.04–2.9×), silt (1.04×) and mud (4.2×); cadmium, nickel and zinc also exceeded limits in selected samples; mud and silt carried higher contaminant loads than soil, indicating downstream transfer risk.

Recovery recommendations: continuous monitoring of flooded agricultural soils; recognition that mobilised sediments can re-contaminate land. Implicit caution against uncontrolled re-flooding without remediation.

> **Hrytsei, A., Koval, R. & Burnett, M.** (2024) *Flood and Fire: Russia's Disruption of Emergency Response in Ukraine after the Destruction of the Kakhovka Dam* (Truth Hounds / Project Expedite Justice). 35 p. Available at: https://truth-hounds.org/wp-content/uploads/2026/06/flood-and-fire_russias-disruption-of-emergency-response-in-ukraine-after-the-destruction-of-the-kakhovka-dam.pdf

Assessment of the causes of the Kakhovka HPP dam collapse based on a comprehensive analysis of structural monitoring, seismic, and infrasound studies. *Progress in Disaster Science*, 100549. doi: 10.1016/j.pdisas.2026.100549.

Integration of long-term geodetic monitoring (1995–2021), DInSAR (104 Sentinel-1 images), seismic and infrasound data.

Main findings: pre-2021 deformations were within seasonal norms; seismic/infrasound signals on 5–6 June 2023 are consistent with a high-energy explosive event (estimated 767–914 ± 170 kg TNT); progressive deformation and hydrostatic loading alone cannot explain the failure.

Recovery recommendations: multi-sensor forensic assessment for critical infrastructure under conflict; the paper does not address reservoir restoration scenarios.

Kadam, P., Thakur, P., Dwivedi, S., Garg, V. & Dhote, P. (2024). Dam Breach Analysis and Damage Assessment of Nova Kakhovka Dam using Satellite data and 1D and 2D Hydrodynamic Modeling. *The International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences*, XLVIII-3-2024. Pp. 251–256. Available at: https://doi.org/10.5194/isprs-archives-XLVIII-3-2024-251-2024.

HEC-RAS 1D/2D hydrodynamic modelling combined with ALOS DEM, Landsat-9 and ESRI LULC data was used to simulate two breach scenarios. Main findings: a 300 m breach produced a peak discharge of 35 962 $m^3 s^{-1}$ and a modelled flood extent of 823 km^2 that matched observed remote-sensing inundation. The model quantified water-level rise, wave travel time and velocity downstream.

Recovery recommendations: the results support emergency planning and risk management for structural failures; no position is taken on reservoir restoration versus alternative river management.

Khoshnood, K., Raymond, N., Howarth, C. et all. (2023). *Rapid Assessment: Impact of the Kakhovka Hydroelectric Station Destruction*, 9 June. New Haven: Yale School of Public Health Humanitarian Research Lab. Available at: https://web.archive.org/web/20260112023448/https://files-profile.medicine.yale.edu/documents/bd04d2e8-eda9-40f2-a7e2-8e8ac0ca1695.

Satellite (Maxar, ICEYE) and open-source mapping quantified immediate inundation of ≈520 km^2 affecting 51 settlements, 5 schools, 3 hospitals, 7 energy sites and 21 crop-storage facilities. Main findings: rapid documentation of civilian infrastructure exposure and legal framing under Additional Protocols I & II of the Geneva Conventions.

Recovery recommendations: prioritise humanitarian access, water-supply restoration and damage assessment. The report is silent on long-term reservoir restoration versus natural-river alternatives.

Oreshchenko, A. (2024). *Analitychni materialy Ukrainskoho hidrometeorolohichnoho instytutu DSNS Ukrainy ta NAN Ukrainy shchodo pidryvu rf Kakhovskoi HES ta znevodnennia Kakhovskoho vodoskhovyshcha.* Kyiv: UkrHMI. 31 p. [In Ukrainian] **Орещенко, А.** (2024). *Аналітичні матеріали Українського гідрометеорологічного інституту ДСНС України та НАН України щодо підриву рф Каховської ГЕС та зневоднення Каховського водосховища.* Київ, 31 с. Київ, Український гідрометцентр. Available at: https://uhmi.org.ua/pub/books/Kakhovka-reservoir-annual.pdf.

Presentation by autor: https://www.youtube.com/watch?v=wQyBSPCdMXQ.

Comprehensive hydrometeorological analysis of the breach and subsequent dewatering. Main findings: detailed quantification of water-level, discharge and morphological changes.

PAX (2023). *A Preliminary Environmental Risk Assessment of the Kakhovka Dam Flooding*. Environment and Conflict Alert Ukraine. Available at: https://paxvoorvrede.nl/wp-content/uploads/2023/06/PAX_REPORT_Kakhovka_FIN.pdf.

This short Environment & Conflict Alert, issued in June 2023, provides an early open-source mapping of the principal environmental risks arising from the 6 June 2023 collapse of the Kakhovka Dam. It draws on UNOSAT flood-extent data, Ukrainian government datasets, OpenStreetMap industrial and waste-site inventories, information on Russian military positions, and existing knowledge of protected areas within the Emerald Network. The analysis distinguishes downstream flooding impacts from upstream desiccation effects and identifies five priority areas of concern.

Main findings: hundreds of square kilometres and more than 80 settlements were submerged within days. Key risk categories mapped are (1) potentially hazardous industrial facilities (oil depots, shipyards, factories, petrol stations) capable of releasing fuels, solvents, pesticides and other toxins; (2) military positions and mined riverbanks whose munitions and energetic materials were redistributed by floodwaters; (3) formal and informal landfills whose solid waste, plastics and heavy metals were dispersed; (4) nature reserves (including the Lower Dnipro National Nature Park) affected by both flooding and progressive reservoir drainage over an estimated area of at least 5 000 km^2; and (5) water-security threats arising from damaged intakes, clogged pipelines and the interruption of irrigation canals serving southern Kherson and Crimea. The report characterises the event as generational in scale and notes calls for its recognition as ecocide.

The document **recommendations** focus on immediate risk reduction, systematic post-conflict environmental assessment, clean-up and remediation of conflict-related pollution, and improved protection of both ecosystems and the populations that depend on them.

Petrlík, J., Černochová, M., Jelínek, N., Skalský, M. et all. (2023) *First research of the contamination of the sediments from Kakhovka reservoir*. Arnika. 69 p. Available at: https://doi.org/10.13140/RG.2.2.21591.65449.

Field sampling and laboratory analysis of exposed reservoir-bed sediments for heavy metals, persistent organic pollutants and other contaminants. Main findings: elevated concentrations of toxic substances that pose long-term risks once the bed is exposed or re-flooded.

Recovery recommendations: careful management of contaminated sediments; avoidance of uncontrolled re-mobilisation. Implicit caution against simple re-filling without sediment remediation.

REACH (2023). REACH Ukraine Situational Overview: Kakhovka Dam breach, 16 June. 8 p. Available at: https://repository.impact-initiatives.org/document/impact/4671cd41/REACH_UKR_Situational-Overview_Kakhovka-Dam-Breach__16-June-2023_EN.pdf.

Spears, B. et all. (2024). A rapid environmental risk assessment of the Kakhovka Dam breach during the Ukraine conflict. *Nature Ecology & Evolution*, 8, pp. 834–836. doi: 10.1038/s41559-024-02373-0. Available at: https://www.nature.com/articles/s41559-024-02373-0 (accessed 4 August 2026).

Risk-assessment combining hydraulic modelling with 23 geospatial datasets and the UNDRR hazard framework. Main findings: maximum flood extent ≈83 000 ha (temporary flood ≈53 000 ha, 62 % herbaceous wetland); 1 087 potential pollution sources (≈4 300 ha hazardous land); >500 000 ha of conservation-importance habitat affected (Ramsar/Emerald); 21 habitats at risk from multiple hazards; ≈43 fish species (20 commercial) impacted.

Recovery recommendations: independent scientific evidence must inform biodiversity recovery plans during reconstruction; early assessments should shape post-conflict environmental priorities. No explicit call for full reservoir re-filling.

Trokhymenko, G., Magas, N., Shumilova, O. & Klochko, V. (2023). Analysis of surface water quality indicators in the Dnipro-Bug estuary region in the first months after the destruction of the Kakhovka hydroelectric power station dam. *Environmental Problems*, 8(4). Pp. 231–240. Available at: https://doi.org/10.23939/ep2023.04.231.

Sanitary-chemical and microbiological sampling at seven points in Mykolaiv oblast documented post-flood deterioration, especially in the Inhulets River (sewage, cattle-burial sites, debris). Main findings: elevated ammonium, oil products, heavy metals, pathogens (*Salmonella*, rotaviruses, *E. coli*, *Vibrio*) and parasite eggs; risk of infection and groundwater contamination.

Recovery recommendations: intensified crisis monitoring of hydrological and pollution parameters, restoration of water-supply systems, and long-term ecological-balance recovery (decades). No preference for dam rebuild versus alternative water-management schemes is stated.

Tuchkovenko, Yu., Kushnir, D., Ovcharuk, V., Sokolov, A. & Komorin, V. (2023). Characteristics of the spread in the Black Sea of freshened and polluted transitional waters from the Dnipro-Bug estuary after the destruction of the Kakhovka Reservoir dam], *Ukrainian Hydrometeorological Journal*, 32. Pp. 95–114. [In Ukrainian] **Тучковенко Ю., Кушнір Д., Овчарук В., Соколов А., Коморін В.** Особливості розповсюдження в Чорному морі розпріснених і забруднених перехідних вод з Дніпровсько-Бузького лиману після руйнування греблі Каховського водосховища' *Український гідрометеорологічний журнал*, No 32. С.95-114. Available at: https://doi.org/10.31481/uhmj.32.2023.07.

Satellite colour and chlorophyll-a imagery plus Delft3D-Flow Flexible Mesh hydrodynamic modelling were used to track the 14.4 km³ of water (≈27 % of mean annual Dnipro runoff) released 6–12 June 2023. Peak discharges reached 40–50 × 10^3 m^3 s^{-1}.

Main findings: the freshwater–pollutant plume reached the Odesa coast by 9–10 June and the Tuzly Lagoons by 14 June; hydrodynamic dilution reduced contaminant concentrations to ~60 % of Kherson levels near Odesa and ~30 % farther west. Circulation was driven first by sea-level gradients then by density fronts, modulated by wind.

Recovery recommendations: continued satellite–model monitoring of plume dynamics and pollutant fate. No explicit call for reservoir reconstruction; emphasis is on understanding the new hydrodynamic regime of the north-western Black Sea shelf.

> **Spears, B., Harpham, Q., Brown, E., Thackeray, S., Elliott, A., Hofman, B., Taylor, P., Barnett, C., Barwell, L., Collel, M. R., Davison, M., Garbutt, A., Hazlewood, C., Lanyon, J., Lofts, S., MacKechnie, C., Noble, J., Medinets, S., Ramsbottom, D., ... Wilson, D.** (2023). *A rapid assessment of the immediate environmental impacts of the destruction of the Nova Kakhovka Dam, Ukraine*. Report for UK FCDO, 29 June. 112 p. Available at: https://doi.org/10.59117/20.500.11822/43696.

Hydraulic modelling validated by satellite data, sediment-transport assessment, land-cover and biodiversity impact mapping, and a risk-based hazard classification. Main findings: quantified flood extent, sediment mobilisation, irrigation-system failure, and elevated risks to high-conservation-status ecosystems and species.

Recovery recommendations: risk-based prioritisation of hazards (biological, chemical, physical), continued monitoring, and evidence-based planning for environmental recovery. No explicit preference for dam reconstruction.

> **United Nations Environment Programme** (2023). *Rapid Environmental Assessment of Kakhovka Dam Breach, Ukraine*, 2023. Nairobi: UNEP. 130 p. Available at: https://doi.org/10.59117/20.500.11822/43696.

Multi-agency rapid assessment (UNEP, FAO, USGS, national partners, UKCEH/HRW) covering hydrology, sediment, ecosystems, biodiversity, pollution and socio-economic impacts. Main findings: large-scale flooding, drainage of the reservoir bed, contaminant mobilisation, habitat loss, threats to protected areas and wetlands of international importance.

Recovery recommendations: urgent monitoring, pollution control, ecosystem restoration planning, and integration of environmental recovery into post-war reconstruction. The report remains neutral on full reservoir re-filling versus alternative landscape futures.

> **Vyshnevskyi, V. & Shevchuk, S.** (2024). The impact of the Kakhovka dam destruction on the water temperature in the lower reaches of the Dnipro River and the former Kakhovske reservoir. *Journal of Landscape Ecology*, 17(2). Pp. 1-17. Available at: https://doi.org/10.2478/jlecol-2024-0008.

In-situ and remote-sensing temperature data tracked the post-breach thermal regime. Main findings: initial surface-temperature drop at the river mouth from

mixing; subsequent return toward pre-breach values; former reservoir transformed into a network of branches and lakes whose temperature is now strongly influenced by the upstream Dniprovske Reservoir.

Recovery recommendations: recognition that the new lotic–lentic mosaic cannot be compared with the former reservoir; continued thermal monitoring to support ecological recovery.

Vyshnevskyi, V., Shevchuk, S., Komorin, V., Oleynik, Yu. & Gleick, P. (2023). The destruction of the Kakhovka dam and its consequences. *Water International*, 48(5). Pp. 631–647. Available at: https://doi.org/10.1080/02508060.2023.2247679.

Multi-source synthesis (hydrometric stations, Landsat/Sentinel/Maxar imagery, water-quality sampling by UkrSCES and volunteers) of hydraulic, downstream and reservoir consequences. Main findings: uncontrolled release flooded four cities and dozens of villages; bacteriological and chemical pollution reached the north-western Black Sea; water supply cut to agriculture, cities and the Zaporizhzhia NPP; reservoir emptied.

Recovery recommendations: outline near-term conditions and "consider options for restoration." The paper explicitly frames reconstruction of the hydraulic structure as one possible pathway while documenting irreversible changes to the former reservoir bed.

Yang, Q., Shen, X., He, K., Zhang, Q., Helfrich, S., Straka III, W., Kellndorfer,. & Anagnostou, E. (2024). Pre-failure operational anomalies of the Kakhovka Dam revealed by satellite data. *Communications Earth & Environment*, 5, 230. Available at: https://doi.org/10.1038/s43247-024-01397-5.

This study reconstructs the pre-breach operational history of the Kakhovka Dam using multi-source optical satellite imagery (PlanetScope and Maxar), meteorological reanalysis products and published dam-design criteria. The analysis covers 2017–2023 and focuses on spillway-gate activation patterns, reservoir water-level trajectories and visible structural changes downstream of the spillway.

Main findings: anomalous operation began on 11 November 2022 after damage to a right-bank bridge segment. From that date until the breach the spillway remained fixed at approximately 15 % of total capacity, in contrast to the normal seasonal pattern of 30–80 % activation lasting less than two months. Consequently the reservoir reached its lowest late-January and highest April levels of the preceding three decades. Persistent overtopping commenced around 23 April 2023; estimated outflow exceeded design capacity by 22 April. Ultra-high-resolution imagery shows progressive erosion damage to piers and supporting structures by late May, with further bridge compromise visible on 2–4 June. The authors identify a sequence of six safety checkpoints (November 2022–May 2023) at which corrective action could have reduced risk.

Tretyak, K., Zayats, O., Kuplovskyi, B., Liashchuk, A., Korliatovych, T., Nesterenko, S. & Bisovetskyi, Y. (2026). Assessment of the causes of the Kakhovka HPP dam collapse based on a comprehensive analysis of structural monitoring, seismic, and infrasound studies', *Progress in Disaster Science*, 30, 100549. Pp. 1-12. Available at: https://doi.org/10.1016/j.pdisas.2026.100549.

This multi-sensor forensic study integrates long-term ground-based geodetic monitoring (geometric levelling 1995–2021), differential interferometric synthetic-aperture radar (DInSAR) processing of 104 Sentinel-1 images (2020–2023), and seismic plus infrasound records from the collapse itself. The aim is to determine whether progressive structural deformation, hydrostatic loading or an external high-energy event best explains the failure of the Kakhovka HPP concrete structures on 5–6 June 2023.

Main findings: pre-2021 geodetic data show only small seasonal displacements (vertical $\leqslant -2$ mm yr^{-1}; horizontal ±1.2 mm) that remained within design tolerances and were insufficient to threaten stability. DInSAR confirms comparable rates (up to −13 mm yr^{-1}) with no critical pre-failure acceleration. Seismic P-wave arrivals indicate a shallow local impulsive event at 23:34:50 UTC on 5 June 2023 (46.783°N, 33.364°E); independent infrasound arrays locate the source within <1.9 km and yield an explosive energy estimate of 767–914 ± 170 kg TNT. The high signal-to-noise ratio and clear onset are inconsistent with gradual structural collapse. Water levels prior to failure never exceeded the design surcharge elevation (18.04 m), further ruling out hydrostatic overload as the primary cause.

The paper concludes that progressive deformation and hydrostatic loading alone cannot account for the observed failure; the integrated evidence is consistent with a high-energy explosive event. It does not discuss reservoir restoration, alternative river-management scenarios or long-term recovery pathways.

(7) LOSSES AND RECOVERY COSTS

Only most authoritative sources on losses/restoration costs are used in this sample. It should be noted that in this literature the restoration of Kakhovka Dam is treated as opportunity for requesting reparations from the aggressor or soliciting assistance from multilateral development banks and bilateral partners and for this reason is treated more favourably. UWEC/UNCG critique of this approach is presented in Simonov, E. & Vasyliuk, O. (2026) placed in Energy literature section. This literature differs by sector and largely relies on figures approved by governmental agencies. The UWEC's critique of this approach can be found in the article **"Building Back Business as usual"** (March, 2026).

Aggregate damage and loss figures. Early KSE estimates (US$2.1 billion direct damage) were rapidly superseded by the more comprehensive PDNA (US$2.79 billion damage + >US$11 billion losses). RDNA4/5 embed Kakhovka within national war totals and attribute roughly US$14 billion of environmental losses and several hundred million dollars of irrigation damage specifically to the breach. The gap between physical-damage figures (≈US$2–3 billion) and total economic + ecosystem losses (US$11–14 billion) is consistently driven by the environment and long-term irrigation/energy revenue losses.

Energy sector. All sources agree the HPP itself is irreparably destroyed (damage US$1.2–1.26 billion). Replacement cost is cited at ≈US$1 billion (KSE) to US$1.76 billion total energy recovery needs (PDNA). Annual revenue losses for Ukrhydroenergo and potential ZNPP impacts add several hundred million to multi-billion-dollar figures. Only the PDNA and KSE explicitly cost a possible new HPP; RDNA documents leave full reconstruction outside core tabulated needs, implying alternative generation or delayed rebuild.

Housing and municipal services. PDNA provides the most granular figures (US$1.1 billion damage, US$1.5 billion recovery needs for ≈37 000 units). KSE's earlier US$960 million is consistent in order of magnitude. Recovery emphasises resilient reconstruction (flood-resistant foundations, winterisation) rather than simple replacement.

Agriculture and irrigation. Direct flood damage is modest (KSE US$25 million; PDNA US$24 million damage component), but irrigation disruption dominates losses (PDNA US$377 million crop losses; KSE annual indirect US$182 million). Recovery needs are relatively modest (PDNA US$180 million) because they focus on alternative water sources, drought-resistant crops and liquidity support rather than full canal/reservoir restoration. RDNA4 explicitly includes major Kakhovka Dam/pumping-station repairs within Kherson's US$1.85 billion irrigation need, showing divergence between PDNA's adaptive approach and RDNA's residual restorative line item.

Environment. PDNA values ecosystem-service losses at US$6.4 billion yet budgets only US$59.5 million for recovery (cleanup, surveys, demining, limited reforestation). UNEP reinforces that much upstream damage is irreversible and recommends soil stabilisation and nature-based solutions rather than full ecological restoration to the pre-1950s reservoir state. RDNA4/5 treat the environmental loss as a major, lasting national cost.

Range of alternatives and restoration stance.

- Full HPP/reservoir reconstruction appears as a long-term option in KSE (≈US$1 billion) and PDNA energy needs, but is not costed as an immediate priority and is excluded from some RDNA recovery tables.
- Adaptive/alternative pathways dominate: alternative water pipelines and artesian wells (already funded at tens of millions), drought-resistant agriculture, nature-based soil stabilisation, possible smaller or more riverine reservoir configurations (UNEP), and green/Build-Back-Better standards across housing, energy and water sectors.
- No document presents a fully costed "do-not-rebuild" Great Meadow renaturalisation scenario with quantified benefits; the low environmental recovery budgets and emphasis on monitoring/adaptation effectively treat the new riverine landscape as the medium-term baseline.

Overall, the assessments converge on the scale of immediate physical damage (US$2–3 billion) and the far larger, longer-term economic and ecological costs (US$11–14 billion). They diverge most clearly on whether and when to restore the reservoir itself versus investing in distributed, climate-resilient alternatives. The PDNA and UNEP lean toward adaptive management and limited restorative spending; RDNA irrigation chapters retain a larger residual commitment to dam-related infrastructure

KEY PUBLICATIONS:

Kyiv School of Economics et al. (2023). *The explosion at the Kakhovka Hydroelectric Power Plant/Dam has caused Ukraine at least $2 billion in direct damages, according to the initial calculations of KSE Institute*. 30 June 2023. Kyiv School of Economics ("Russia Will Pay" project), in cooperation with the Office of the President, Ministry of Economy and Ministry for Communities, Territories and Infrastructure Development of Ukraine. Available at: https://kse.ua/about-the-school/news/the-explosion-at-the-kakhovka-hydroelectric-power-plantdam-has-caused-ukraine-at-least-2-billion-in-direct-damages-according-to-the-initial-calculations-of-kse-institute/ and https://kse.ua/wp-content/uploads/2023/06/Presentation-eng_compressed.pdf.

This early rapid assessment (three weeks after the breach) used population-based proxies, satellite modelling and sectoral expert estimates to quantify direct physical damage. It covers housing, energy, transport, industry, agricul-

ture and environment, with explicit separation of direct damage from annual indirect losses linked to irrigation failure.

Main findings: total direct damage ≈ US$2.079 billion. Breakdown: Housing & utilities US$960 million (20 000–30 000 houses affected, majority on the left bank); Energy US$624 million (of which HPP destruction alone ≈ US$586–1 000 million replacement cost); Transport US$311 million (>290 km roads); Industry US$105 million; Social sphere US$55 million; Agriculture US$25 million (direct crop/livestock/fish). Indirect annual losses: crop production +US$182 million, other sectors +US$49 million. Environmental losses estimated separately at ≈ US$1.5 billion by the Ministry of Environmental Protection. Water-pipeline construction already allocated US$41 million.

Recovery recommendations focus on immediate water-supply alternatives and note that a new HPP of equivalent capacity would cost nearly US$1 billion. No detailed alternative landscape scenarios are developed; restoration of the HPP is treated as a possible future option once security permits.

> **Balakrishnan B.** (2023). *Post-Disaster Needs Assessment: 2023 Kakhovka Dam Disaster, Ukraine*. Government of Ukraine & United Nations 16 October 2023. 104 p. Available at: https://ukraine.un.org/en/248860-post-disaster-needs-assessment-report-kakhovka-dam-disaster (English & Ukrainian).

This is the most comprehensive multi-sectoral assessment dedicated solely to the dam breach, following the standard UN-EU-World Bank PDNA methodology. It combines government data, satellite imagery, sectoral expert teams and Build-Back-Better costing across social, productive, infrastructure and cross-cutting sectors for the four affected oblasts (Kherson, Mykolaiv, Dnipropetrovsk, Zaporizhzhia).

Main findings: direct damage US$2.79 billion; losses >US$11 billion (total impact ≈ US$13.8 billion). Environment dominates losses (US$6.4 billion ecosystem-service losses, 58 % of total losses). Energy damage US$1.26 billion (HPP alone US$1.2 billion) + losses US$3.8 billion (including ZNPP cooling risks). Housing damage US$1.1 billion (≈37 000 units). Agriculture damage+loss US$406.6 million (mostly irrigation disruption). Water & sanitation damage+loss ≈ US$149 million. Recovery and reconstruction needs (Build Back Better): total US$5.04 billion, of which immediate/short-term (2023–24) US$1.82 billion. Sectoral recovery needs: Energy US$1.756 billion; Housing US$1.502 billion; Water & Sanitation US$701 million; Culture US$364 million; Municipal services US$293 million; Agriculture US$180 million; Environment only US$59.5 million (cleanup, surveys, demining, reforestation).

The recovery framework is phased (immediate 2023–24, medium 2025–30, long-term to 2033). It prioritises restoration of essential services, housing return, irrigation alternatives and environmental remediation. Reconstruction of the HPP is listed as one possible long-term energy option; nature-based and green solutions are encouraged. No detailed costed alternative to full reservoir restoration is presented, but the low environmental recovery budget implies acceptance of a transformed landscape in the short-to-medium term.

United Nations Environment Programme (2023). *Rapid Environmental Assessment of Kakhovka Dam Breach, Ukraine*, 2023. Nairobi: UNEP. Available at: https://wedocs.unep.org/20.500.11822/43696.

Remote multi-expert assessment (22 experts, 13 institutions) focused exclusively on environmental dimensions: hydrology/geomorphology, chemical contamination, disaster waste and ecology/protected areas. Conducted under severe access constraints (front-line conditions).

Main findings: hundreds of km^2 flooded and thousands of km^2 of reservoir/wetlands desiccated; irreversible transformation of a 70-year-old aquatic ecosystem into an early-stage riverine system; 54 chemical pollution hotspots identified; ≈150 t machine oil released; at least 2 million m^3 disaster waste; major impacts on protected areas (including Velykyi Luh). No comprehensive monetary valuation of losses is provided (defers to PDNA figures).

Recovery recommendations emphasise immediate coordination, baseline data collection, hotspot investigation, soil stabilisation with non-invasive vegetation, disaster-waste management strategy, and demining. Reconstruction of the dam is acknowledged as a government priority, but the report explicitly recommends assessing nature-based solutions and a possibly smaller reservoir that more closely simulates a natural riverine environment. Update of the Dnipro River Basin Management Plan is proposed as a recovery instrument. External financial and technical support is described as urgent.

World Bank (2025). *Ukraine Fourth Rapid Damage and Needs Assessment (RDNA4)*, February 2022 – December 2024. Washington, D.C. : World Bank Group. Available at: https://documents.worldbank.org/en/publication/documents-reports/documentdetail/099022025114040022.

This is the fourth nationwide war-damage assessment. Kakhovka impacts are embedded within broader sectoral figures rather than isolated. Methodology follows the standard RDNA approach with progressive data refinement.

Main findings relevant to Kakhovka: the dam breach accounts for a substantial share of environmental losses (cited as US$14.1 billion or 51 % of environment-sector losses in one formulation) and contributes significantly to irrigation/water-resources damage (US$359 million attributed specifically to the dam). Khersonska oblast shows the highest irrigation investment need (US$1.85 billion), explicitly including major repairs to the Kakhovka Dam and pumping station to restore irrigation for 780 000 ha. Environment-sector losses overall rose sharply because of the breach. Note: "Kakhovka Dam recovery estimates are not included" in certain tabulated recovery-need totals, indicating that full HPP reconstruction remains outside the core RDNA4 costing envelope.

Recovery recommendations prioritise water-quality monitoring, irrigation rehabilitation in deficit areas, and climate-resilient water management. Full reservoir restoration is not costed as a stand-alone item; alternative water-supply and irrigation solutions are implied by the focus on local deficits and climate adaptation.

World Bank (2026). *Ukraine Fifth Rapid Damage and Needs Assessment (RDNA5)*, February 2022 – December 2025. Washington, D.C. : World Bank Group. Available at: https://documents.worldbank.org/en/publication/documents-reports/documentdetail/099022026094036395.

Updated nationwide assessment incorporating an additional year of war impacts. Kakhovka-related figures are further integrated and updated. Main findings: continued recognition of the dam breach as a major driver of environmental, agricultural and water-resources damage and loss. Specific incremental quantification relative to RDNA4 is limited in the available excerpts, but the overall trajectory confirms persistent irrigation and ecosystem losses. Recovery needs remain dominated by housing, transport, energy and agriculture at national scale; Kakhovka-specific line items continue to appear under irrigation/water resources and environment.

Recovery framing continues the RDNA series' emphasis on Build Back Better, climate resilience and phased reconstruction. No new costed alternative to reservoir restoration is introduced; the documents treat the emptied reservoir and disrupted irrigation as a lasting baseline requiring adaptive rather than purely restorative solutions.

Ramsar Convention Secretariat (2025). Implementation of Resolution XIV.20: Final assessment report of environmental damage on Wetlands of International Importance in Ukraine stemming from the Russian Federation's aggression (COP15 Inf.2). 15th Meeting of the Conference of the Contracting Parties, Victoria Falls, Zimbabwe, 23–31 July 2025. Final Report, January 2025. 66 p. Available at: https://www.ramsar.org/sites/default/files/2025-04/COP15_inf2_implementation_ResXIV20_assessment_report_e.pdf; https://www.informea.org/en/decision/resolution-xiv20-ramsar-conventions-response-environmental-emergency-ukraine-relating.

This assessment report was prepared pursuant to Ramsar Resolution XIV.20. It consolidates and triangulates evidence from literature review, Earth Observation (EO) analysis (Sentinel, land-cover change, fire and flood mapping), site-manager questionnaires and workshop inputs (Kyiv, May 2024), and limited field visits (six accessible sites used as proxies). The report assesses direct and indirect war-related impacts on Ukraine's Wetlands of International Importance (Ramsar Sites) and provides guidance on immediate, short-, medium- and long-term rehabilitation and restoration.

EO analysis and site-specific assessments identify three Ramsar Sites as having experienced major changes in ecological character directly linked to the 6 June 2023 Kakhovka Dam breach:

- **Site 2282 – Archipelago Velyki and Mali Kuchugury** (7 740 ha, designated 2013; part of Veliky Lug National Nature Park). Located as sandbank islands and shallows in the upper Kakhovka Reservoir. Completely drained after the reservoir emptied. Pre-breach values included important waterfowl nesting/moulting habitat, endemic plants (*Centaurea konkae*), fish reproduction areas and natural water filtration. Post-breach: total loss of aquatic habitats, major shift in abiotic/biotic components, vegetation change and loss of ecosystem services. Management access lost since March 2022 occupation.

- **Site 2273 – Sim Maiakiv Floodplain** (2 140 ha, designated 2013; also within Veliky Lug NNP). A tertiary river channel and steppe-river confluence forming floodplain forests, wet meadows, reed beds and karst features at the reservoir edge. Partially drained; aquatic habitats largely destroyed; remaining small lakes; vegetation shift to ruderal species and self-seeded trees; military use (trenches, heavy vehicles, mining, pollution). Major change in hydrological regime, species composition and ecosystem processes.
- **Site 767 – Dnipro River Delta** (34 425.8 ha, designated 1997; Nizhnyodniprovsky National Nature Park). Downstream delta with swampy areas, floodplain forests, sandy ridges and lakes. Completely flooded by the breach, causing pollution, destruction of islands, significant hydrological regime change, vegetation loss and fires (7 443 ha burned from shelling). Coastal areas heavily mined and on the front line. Major ecological-character change from combined flooding, shelling and altered hydrology.

EO further shows water-regime changes and land-cover shifts (sharp drop in water content in 2023) at Sites 2273 and 2282, and flood/water-quality impacts extending to the Dnipro Delta and Black Sea coastal sites. Hydrological connectivity maps illustrate how the reservoir system linked multiple Ramsar Sites upstream and downstream.

Main findings (broader context). Military activities caused direct impacts on 31 Ramsar Sites (4 major ecological-character change, 27 moderate) and indirect impacts on a further 17 (minor change). Only two sites showed no detectable change. Principal impact categories are physical destruction (craters, trenches, fires, mines/UXO), pollution, disturbance, management disruption and budget loss. 96 % of Ukraine's Ramsar Sites registered at least some of these impacts.

Recommendations for recovery. For the three Kakhovka-affected sites the report notes two alternative pathways: (1) restoration linked to refilling of the Kakhovka Reservoir (stated Ukrainian government priority), or (2) restoration of the broader Dnipro River floodplain system instead of the reservoir, allowing natural regeneration of the exposed bed (already observed to be rapid). Immediate priorities common to these and other front-line sites include demining, removal of military infrastructure, landscape restoration, and assessment of whether international (Ramsar) status remains appropriate after the war. Broader recommendations call for coordinated monitoring, baseline data collection on habitats and red-listed species, nature-based soil stabilisation, and integration of findings into river-basin management planning. External financial and technical support is described as essential. The report does not provide monetary cost estimates; its focus is ecological character change and practical restoration options rather than economic valuation.

(8) LEGAL ISSUES

This section lists studies and calls for application of international law relevant to the Kakhovka Dam disaster. Only limited number of samples is included and highly specialized legal literature has not been the focus of our attention.

KEY PUBLICATIONS:

Didukh, Ya., Baran, S., Kravchenko, O., Kuzemko, A., Moysiienko, I., Polyanska, K. & Khodosovtsev, O. (2024). Ecocide in Ukrainian and international legislation: concept, features and criteria. *Scientific Perspectives*, 5(47). Pp. 1139–1153. [In Ukrainian] **Дідух, Я., Баран, С., Кравченко, О., Куземко, А., Мойсієнко, І., Полянська, К. і Ходосовцев, О.** (2024). Екоцид в українському та міжнародному законодавстві: поняття, ознаки та критерії. *Наукові перспективи*, 5(47). С. 1139–1153.] Available at: https://doi.org/10.52058/2708-7530-2024-5(47)-1139-1153.

This multi-author legal-ecological study (botanists, lawyers and conservationists) critically examines the definition of ecocide under Article 441 of the Ukrainian Criminal Code and international law. Using a biotope-based approach, the authors propose refined criteria that incorporate irreversible ecosystem loss, biodiversity collapse and the risk of cascading environmental emergencies, moving beyond the current Ukrainian wording toward more precise international standards.

Main findings: the existing Ukrainian definition is too vague for effective prosecution; clear, multi-level biological criteria (species, biotope, ecosystem) are required for consistent classification and investigation. Recommendations centre on legislative amendment to embed these criteria, improved expert methodologies for evidence collection, and heightened societal awareness. No alternative future development scenarios for the Kakhovka site itself are discussed; the focus is doctrinal refinement to enable future prosecutions of large-scale environmental harm, including events of the scale of the dam destruction.

IUCN (2025) Establishing mechanisms for engagement with IUCN Members involved in armed conflict. Resolution WCC-2025-Res-064, World Conservation Congress, Abu Dhabi. Available at: https://portals.iucn.org/library/node/52714.

This short policy motion recalls prior IUCN resolutions on environmental crime, notes the Independent Expert Panel definition of ecocide (2021), the EU Environmental Crime Directive (2024) and the Pacific Island States' proposal to amend the Rome Statute. It declares that unlawful or wanton acts creating a substantial likelihood of severe and either widespread or long-term environmental damage should be prosecuted as ecocide under both national and international law.

Recommendations: the World Commission on Environmental Law should study the crime's scope (especially in developing-country systems); States are invited to adopt national ecocide laws; Rome Statute parties should consider an explicit peacetime-and-wartime ecocide crime. No site-specific recovery alternatives for Kakhovka are addressed; the motion is purely normative and forward-looking.

Miniailo, A., Stasiuk, N., Novytskyi, V. & Miniailo, N. (2026). [Ecocide of the animal world: concept, issues, methodology. *Criminalistics and Forensics*, 71. Pp. 97–111. [In Ukrainian] Екоцид тваринного світу: поняття, проблематика, методологія. *Криміналістика і судова експертиза*, 71. С. 97–111. Available at: https://doi.org/10.33994/kndise.2026.71.07.

The paper develops a specialised methodology for identifying "zoocide" (ecocide of fauna) in wartime conditions. It critiques the lack of quantitative and territorial thresholds in existing law and proposes a multi-level (population–ecosystem–administrative) assessment framework.

Main findings: mass destruction of wildlife should be defined as mortality exceeding natural rates by at least three times, or the creation of a real extinction threat for at least one taxonomic category within defined administrative units. Over-globalisation of the concept hinders prosecution of local but critical losses.

Recommendations focus on refining national criminal and environmental legislation, standardising forensic-ecological expertise, and applying differentiated damage assessment. No landscape-restoration alternatives for the former reservoir are considered.

Burke, A. (2022). Attacks on Ukrainian nuclear-power plants challenge treaties. *Nature* 611. Pp. 232-235. Available at: https://doi.org/10.1038/d41586-022-03580-0.

Opinion analysis by an environmental-politics scholar listing quantifiable impacts (18 billion m^3 water released, 340 000 ha flooded, 103 species threatened, etc.) and mapping legal pathways under Ukrainian ecocide law, Rome Statute Article 8 (environmental war crime), Additional Protocol I (protection of dams) and the law of occupation.

Recommendations: UN Security Council resolution (even if vetoed) calling for ICC investigation; possible special tribunal; redrafting of the Rome Statute and Additional Protocol I to lower the "widespread, long-term and severe" threshold and remove the military-advantage clause; eventual rem oval of Security Council veto. The piece treats full ecological recovery as a long-term consequence rather than a policy choice and does not explore alternative river-management scenarios.

Also found in "Here's how to prosecute Russia for Ukraine's catastrophic flood", *The Washington Post*, 21 June. Available at: https://www.washingtonpost.com/opinions/2023/06/20/ukraine-flood-prosecute-russia/.

Tignino, M., Kebebew, T. & Pellaton, C. (2023). International law and accountability for the Nova Kakhovka Dam disaster. *Articles of War* (Lieber Institute West Point), 13 July. Available at: https://lieber.westpoint.edu/international-law-accountability-nova-kakhovka-dam-disaster/.

Legal analysis focusing on IHL protections for dams (Article 56 AP I), objects indispensable to civilian survival (Article 54 AP I), the natural environment (Articles 35(3) and 55 AP I), and occupation law (GC IV Articles 53, 55–56; PERAC Principles). The authors examine whether destruction by an Occupying Power constitutes an "attack" and whether the "absolute necessity" exception can be met.

Main findings: the dam enjoyed special protection; even internal sabotage would violate Article 54; the high environmental-damage threshold is likely satisfied; occupation-law duties to maintain water infrastructure were breached.

Recommendations emphasise accountability under existing IHL and occupation law. No alternative future development pathways for the river or reservoir are discussed.

Pantazopoulos, S. (2023). *Reflections on the Destruction of the Nova Kakhovka Dam from an International Law Perspective*. ELIAMEP Policy Paper #140/2023, June. Available at: https://www.eliamep.gr/en/skepseis-gia-tin-katastrofi-tou-fragmatos-nova-kakhovka-ypo-ti-skopia-tou-diethnous-dikaiou-stavros-evdokimos-pantazopoulos/.

Policy brief surveying attribution evidence, IHL rules (proportionality, precautions, special protection of dams), occupation duties, individual criminal responsibility (including the ICC environment-specific war crime) and domestic ecocide provisions. It notes that conflict-related environmental damage should be included in the Council of Europe International Register of Damage for Ukraine.

Recommendations centre on ensuring the Register's mandate covers environmental harm and on pursuing both state and individual responsibility. Alternative river-management scenarios are not examined.

Latsyba, A. & Hryshko, V. (2024). Study on Interpreting "Attack" on Protected Objects: Article 56 of the Additional Protocol I and Jurisprudence of the International Criminal Court in Light of Kakhovka Dam Attack. Truth Hounds / Project Expedite Justice SUBMERGED study annexes. Annex F to *SUBMERGED*. 24 p.Available at: https://truth-hounds.org/wp-content/uploads/2024/06/submerged-annex-f.pdf.

Detailed doctrinal study of the term "attack" under Article 56 AP I, contrasting the original ICRC draft (which prohibited both attack and destruction) with the final text. It analyses ICC jurisprudence and scholarly debate on whether internal sabotage of an object under a party's control constitutes an "attack".

Main findings: the deletion of "destroy" from the draft has created interpretive ambiguity that may shield certain forms of sabotage; the Kakhovka case highlights the need for clarification.

Recommendations are implicit: courts and prosecutors should adopt an expansive reading that captures internal destruction. No recovery alternatives are proposed.

Latsyba, A. & Markova, M. (2024). Statements by representatives of the Russian political and military authorities confirming awareness of the potential consequences of the Kakhovka HPP explosion. Truth Hounds / Project Expedite Justice SUBMERGED study annexes. Annex G to *SUBMERGED*. 10 p. Available at: https://truth-hounds.org/wp-content/uploads/2024/06/submerged-annex-g.pdf.

Compilation of public statements by Russian occupying officials (2022) acknowledging that destruction of the dam would be "catastrophic", could block navigation, and risk nuclear consequences at Zaporizhzhia NPP.

Main findings: the statements establish knowledge of the likely severe consequences, supporting the mental element required for both war-crime and (potential) ecocide charges. The annex is evidentiary rather than normative; no policy alternatives are discussed.

Maroonian, A. (2023). Ukraine Symposium – Destruction of the Kakhovka Dam: Disproportionate and Prohibited. *Articles of War* (Lieber Institute West Point), 29 June. Available at: https://lieber.westpoint.edu/destruction-kakhovka-dam-disproportionate-prohibited/.

Focused analysis under Article 53 GC IV (destruction of property in occupied territory). The author applies a proportionality/balance-of-interests test: military advantage versus humanitarian and environmental harm.

Main findings: any military advantage (impeding a Ukrainian crossing) is far outweighed by long-term human and ecological catastrophe; the "absolute necessity" exception is not met; the destruction is therefore prohibited. Recommendations are limited to the legal conclusion itself. No alternative landscape scenarios are considered.

(9) RECOVERY STRATEGIES OF LOCAL COMMUNITIES AFTER THE DESTRUCTION OF THE KAKHOVKA RESERVOIR

This collection focus on recovery needs and plans at sub-national level, no research is available on actual attitudes and aspirations of local communities around the former reservoir. Collected planning documents from regional and hromada levels are far from exhaustive, but give an idea of the way local governments interpret various consequences of Kakhovka dam blasting.

Water security and basic services as precondition. Across official plans (2023 Action Plan, Kherson city programme, PDNA) and academic analysis (Malchykova & Pylypenko), stable water supply emerges as the single most urgent local need for population return and well-being. Existing projects remain under-funded and sized only for minimal household use. Solutions range from emergency repairs and alternative supply systems (decentralised, innovative irrigation) to eventual large-scale infrastructure decisions. The gap between immediate household needs and long-term regional water architecture is a shared diagnosis.

Infrastructure restoration versus strategic landscape choice. Operational documents (Action Plan, Kherson programme, Zaporizhzhia Green Book, PDNA) prioritise concrete, costed or to-be-costed measures—roads, housing, education, social services, navigation locks—under "Build Back Better" or green-recovery principles. Strategic and civil-society texts (Malchykova & Pylypenko, Ro3kvit–Greenpeace, Sushko) treat the former reservoir bed itself as the core decision node. The range of alternatives is therefore wide: full rebuild of the HPP and reservoir; partial/hybrid solutions; complete restoration of Velykyi Luh; and agro-economic transformation toward dryland/small-scale low-water farming. Official plans largely defer the landscape choice; academic and NGO work force the trade-offs into the open.

Ecological regeneration versus economic restoration. Economic and agricultural analyses (implicit in PDNA losses, explicit in Malchykova & Pylypenko and some local strategies) quantify large losses in irrigation, fisheries and energy and therefore keep rebuild or alternative water-provision options on the table. The tension is between irreversible ecological opportunity costs of flooding the regenerating landscape again and the socio-economic costs of permanent water scarcity for southern agriculture and settlements.

Governance scale and sequencing. Local programmes and methodological guides emphasise hromada-level capacity, bottom-up needs assessment and phased recovery contingent on de-occupation and security. National/international documents (PDNA, Action Plan) supply the financing architecture and sectoral priorities. Vision documents (Ro3kvit–Greenpeace) attempt multi-scalar integration. The practical difference is sequencing: security and basic services first (consensus), followed by either rapid infrastructure rebuild or deliberate design of adaptive, nature-based or hybrid futures.

Range of alternatives summarised.

- Full reservoir + HPP restoration (official signals, some economic arguments).
- Renaturalisation of Velykyi Luh / Great Meadow (Sushko, many ecologists, parts of Ro3kvit–Greenpeace Scenario 2).
- Agro-economic transformation: small-scale farming, innovative irrigation, dryland systems, redesigned hydro-social networks (Malchykova & Pylypenko preferred alternative).
- Hybrid / multi-layer redesign: sustainable infrastructure + enhanced nature + decentralised solutions (Ro3kvit–Greenpeace preferred Scenario 2).
- Service-first, decision-deferred: restore critical local infrastructure and water access now; leave large landscape choice for post-security planning (Action Plan, PDNA, most local programmes).

The collection therefore reveals a clear spectrum from operational recovery plans **that treat the reservoir decision as secondary**, through quantified needs assessments that remain agnostic on the final landscape model, to explicit advocacy for either full rebuild or permanent renaturalisation/adaptive transformation of new natural systems. Local community needs are consistently framed around security, water, housing and livelihoods; the divergence lies in whether the former reservoir is viewed as infrastructure to be restored or as an opportunity for a fundamentally different socio-ecological system

KEY PUBLICATIONS:

Cabinet of Ministers of Ukraine (2023). Action Plan for the Restoration and Development of Territories affected by the emergency caused by the destruction of the dam of the Kakhovka Hydroelectric Power Plant (draft project submitted to international partners, unofficial English translation circulated 2023). Presentation (video): https://www.youtube.com/watch?v=AG94JCXEDis.

This official Ukrainian government action plan (English unofficial translation prepared for UNESCO) sets out concrete measures, deadlines, responsible bodies and indicative costs for restoring territories of Dnipropetrovsk, Zaporizhzhia, Mykolaiv and Kherson oblasts affected by the June 2023 dam breach. It prioritises demining, damage surveys, infrastructure repair and immediate life-support systems for local hromadas.

It covers demining and survey of infrastructure (2023–2025), technical inspection of damaged private/communal/state objects, prioritised lists of restoration projects for transport, medical, social, cultural, energy and residential infrastructure, repair of roads, railways, hydrotechnical structures (including modernisation of the Kakhovka shipping lock with an additional branch estimated at UAH 8 billion), social assistance payments, restoration of education and administrative service centres (TsNAPs), and recovery of access to electronic registers. Costs are mostly to be determined after hostilities end; funding is from state/local budgets and other lawful sources. Deadlines run mainly to 2025–2027.

Water-supply measures for local settlements and hromadas form the core of the communal-infrastructure section and receive the largest quantified allocations:

- Immediate transportation of drinking water for the population (2023, 845.1 million UAH from the state reserve fund) to prevent a man-made emergency.
- Alternative drinking-water supply for Mykolaiv (2023, 72.75 million UAH).
- Surface-water supply via the Dnipro–Ingulets canal to meet needs of Dnipropetrovsk and Mykolaiv regions (2023, 183 million UAH).
- Purchase of specialised machinery and equipment for Kherson city's water utility (2023–2024, ≈195.4 million UAH) to restore critical water-supply and drainage infrastructure (52 units).
- Experimental construction of three new main water pipelines (Karachuniv Reservoir–Kryvyi Rih–Southern Reservoir; Marganets–Nikopol; Khortytsia–Tomakivka), total length 144.5 km (2023–2025, 13.2 billion UAH, of which 8.5 billion already allocated from the liquidation fund). Explicit purpose: minimise consequences of the Kakhovka destruction and ensure livelihood under critically reduced water levels in the former reservoir.
- Broader experimental water-supply project for Dnipropetrovsk, Kherson, Zaporizhzhia and Mykolaiv regions (2024).
- Reconstruction of water-supply and drainage facilities in Mykolaiv (2024–2025, ≈695 million UAH).
- Construction/reconstruction of wastewater treatment facilities and sewage networks in Kherson and Dnipropetrovsk settlements (2023–2025).

Complementary measures for local well-being include one-off financial assistance to affected populations (564.9 million UAH), restoration of social-service providers, medical facilities (e.g., polyclinic in Kherson's Korabel district), schools, administrative service centres (TsNAPs), youth and cultural institutions, and demining of territories. The Plan does not decide on long-term reconstruction of the Kakhovka Reservoir itself; it focuses on rapid alternative water-delivery systems and restoration of basic services so that hromadas can continue to function under the new hydrological conditions.

The plan is operational and infrastructure-focused rather than strategic on landscape futures. It does not explicitly recommend full reservoir restoration or alternative ecological scenarios; the emphasis is on restoring pre-disaster connectivity, navigation capacity and basic services in de-occupied or accessible areas.

Malchykova, D. & Pylypenko, I. (2025).Post-war reconstruction and urban planning in the Kakhovka Reservoir disaster region. *Ekonomichna ta Sotsialna Geografiya*, 93,. Pp. 31–49. [In Ukrainian] **Мальчикова, Д & Пилипенко І.** (2025). Повоєнне відновлення та просторове планування у зоні катастрофи Каховського водосховища. *Економічна та соціальна географія*, 9. С.31–49. Available at: https://doi.org/10.17721/2413-7154/2025.93.31-49.

This interdisciplinary study by Kherson State University geographers synthesises expert discourse from the university's dedicated Kakhovka platform, open digital data (including DREAM recovery platform) and multi-criteria analysis. Scope covers ongoing reconstruction efforts, water-supply projects in affected hromadas, and design of alternative post-disaster spatial strategies. Main findings: any recovery depends first on security and de-occupation; existing water-supply projects are designed only for minimal household needs and suffer extremely low funding/implementation rates. Alongside scenarios of reservoir rebuild and Velykyi Luh ecosystem restoration, the authors propose an alternative model of comprehensive agro-economic transformation: redesign of pre-war hydrosocial networks, promotion of small-scale farming with innovative low-water irrigation, and return to dryland farming patterns. This is presented as the pathway that best ensures social and environmental sustainability of hromadas and inclusive urban development. The paper explicitly weighs reservoir restoration against renaturalisation and the dryland-farming alternative, favouring adaptive, water-minimising transformation under continued uncertainty.

Treffers F., Korchagin A., Usychenko S., Mnatsakanyan V., Van Epp T., Buckley N., Panchev H., Bondov A. (2024). *Dnipro River Integrated Vision*. Ro3kvit Urban Coalition for Ukraine & Greenpeace. 251 p. [In Ukrainian & English] **Трефферс Ф., Корчагін А., Усиченко С., Мнацаканян В., Ван Епп Т., Баклі Н., Панчев Х., Бондов А.** *Інтегрована Візія Річки Дніпро*. Ro3kvit Urban Coalition for Ukraine & Greenpeace. 251 с. Available at: https://ro3kvit.com/projects/dnipro-river-integrated-vision and https://dniproriver.greenpeace.ua/en (full report downloadable in English and Ukrainian). Chapter about Kakhovka resevoir: https://dniproriver.greenpeace.ua/kakhovka-en/.

This large collaborative vision document (research, scenarios, layer mapping) treats the Dnipro as a multi-scalar system linking ecology, water supply, agriculture, energy, mobility, culture and urban life. Triggered partly by the Kakhovka destruction, it analyses pre-war functions, wartime weaponisation and threats, then proposes integrated recommendations across underground, nature, water, roads and built layers. Three future scenarios are outlined: (1) "Back to 2021" (restore dams, bridges and 2021 state with ecological upgrades); (2) environmentally friendly redesign (sustainable reconstruction of infrastructure, new solutions around former Kakhovka site, enhanced nature and reduced pollution); (3) further nature-oriented variants.

The authors currently view Scenario 2 as most promising. Local case studies (e.g., Kremenchuk energy modelling) and a dedicated Kakhovka chapter one year after the breach emphasise green recovery, decentralised solutions and dialogue among stakeholders. Reservoir restoration is one option among layered alternatives; preference is given to integrated, climate-resilient redesign that maximises ecological and social co-benefits.

Government of Ukraine & United Nations (2023) *Post-Disaster Needs Assessment: 2023 Kakhovka Dam Disaster*, Ukraine. Available at: https://ukraine.un.org/en/248860-post-disaster-needs-assessment-report-kakhovka-dam-disaster and https://reliefweb.int/report/ukraine/post-disaster-needs-assessment-2023-kakhovka-dam-disaster-ukraine-enuk.

This official PDNA (UN-EU-WB methodology, led by Ministry of Economy with KSE data support) quantifies damage, losses and recovery needs across social, productive, infrastructure and cross-cutting (especially environment) sectors. Direct damage ≈ US$2.79 billion; total losses > US$11 billion (environment the largest long-term component); total recovery/reconstruction needs ≈ US$5.04 billion (of which US$1.82 billion immediate/short-term 2023–24). It covers housing, health, education, agriculture, energy, water & sanitation, municipal services and environment under a "Build Back Better" lens. Recommendations form a recovery framework prioritising resilient reconstruction of critical services, water security, and environmental remediation. The document does not prescribe full reservoir restoration versus renaturalisation; needs are framed around restoring essential services and building resilience, leaving strategic landscape choices for subsequent planning.

Zhavzharova, T. (ed.) (2024). Green Book of Zaporizhzhia Recovery: Roadmap for City Restoration. Zaporizhzhia: EcoSense. 60 p. [In Ukrainian] **Жавжарова Т. (ред.)** (2024) Зелена книга відновлення Запоріжжя: Дорожня карта відновлення міста. Запоріжжя. ГО "Екосенс". 2024. 60 с. Available at: https://vidnova.info/wp-content/uploads/2024/02/Zelena_karta_vidnovlennya_Zaporizhzhya_ukr-versiya.pdf (In Ukrainian); https://vidnova.info/wp-content/uploads/2024/02/GREEN-BOOK-of-Zaporizhzhia-recovery_eng-final.pdf (In English).

Collective roadmap for green post-war recovery of Zaporizhzhia city territorial community. Based on population surveys of recovery priorities, European Green Deal alignment, and multi-sector analysis. Priority directions include mental health, ecological security, green energy infrastructure, economic recovery & entrepreneurship, culture, inclusive infrastructure, housing modernisation, IDP integration and climate adaptation. Structural-logical schemes and sectoral roadmaps are provided. The document is city-focused and does not centre on Kakhovka reservoir decisions; recommendations emphasise sustainable, inclusive, climate-adapted reconstruction of urban systems rather than large-scale river engineering choices.

Kherson City Military Administration (2025). *Draft Programme of Comprehensive Restoration of the Territory of Kherson City Territorial Community for the Period until 2027.* Kherson. 194 p. [In Ukrainian] *Проєкт Програми Комплексного відновлення території Херсонської міської територіальної громади на період до 2027 року.* Херсон. 194 с. Available via Kherson city administration portals: https://miskrada-ks.gov.ua/wp-content/uploads/2025/10/proiekt-prohramy-kompleksnoho-vidnovlennia-terytorii-khersonskoi-miskoi-terytorialnoi-hromady-na-period-do-2027-roku.pdf.

Local comprehensive recovery programme (passport, socio-economic and ecological assessments, damage analysis, prioritised measures). Covers administrative-territorial structure, economy, employment, climate/water/soils, pollution, housing and social infrastructure, and negative impacts of hostilities and the dam disaster. Goal: prioritise recovery measures, attract investment and international/state aid, plan concrete restoration and development actions to 2027. Funding from local/regional/state budgets and donors. The programme is practical and service-oriented; it addresses water resources and environmental state but does not explicitly choose between full reservoir rebuild and alternative landscape models.

Kherson State University (2025). *Recovery Strategy for the De-Occupied Territories of Ukraine: Post-Conflict Development Challenges and Ways to Overcome Them. Collective monograph.* Ivano-Frankivsk. 721 p. [In Ukrainian] **Херсонський державний університет** (2025). *Стратегія відновлення деокупованих територій України: виклики постконфліктного розвитку та шляхи їх подолання.* Івано-Франківськ. 721 с. Available at: https://doi.org/10.5281/zenodo.15190154.

This 721-page collective monograph, examines theoretical-methodological foundations of post-conflict economic recovery, investment and financial mechanisms, the role of SMEs, infrastructure and industrial restoration, socio-economic aspects, economic security and environmental policy. Chapters address behavioural challenges, sustainable development integration, green financing, smart infrastructure and institutional reforms. The work is framed at a strategic and institutional level rather than as a site-specific engineering or hydrological study. The only explicit treatment of the Kakhovka reservoir destruction appears in **Chapter 6.5 "Державна екологічна політика в умовах деокупації: нові підходи для стійкого розвитку"** (State Ecological Policy under Conditions of Deoccupation: New Approaches for Sustainable Development) by K.A. Riabets (pp. 669–679, DOI: https://doi.org/10.5281/zenodo.15189641). The chapter places the event within a wider category of damage to critical infrastructure (water-treatment plants, dams and sewage systems) that caused massive pollution of water bodies and groundwater, disruption of water-supply systems and elevated risks of infectious disease. No quantitative data on flooded area, irrigation losses, sediment volumes or water-supply shortfalls are provided in the chapter or elsewhere in the monograph. Recommendations in Chapter 6.5 focus on the need for a fundamentally new adaptive and integrated state ecological policy. Concrete proposals include: adoption of a special Law of Ukraine "On the Restoration of Ecological Infrastructure and Rehabilitation of Affected Territories";

creation of a state fund for ecological reconstruction with defined financing sources and methodologies for assessing war-related environmental damage; legislative regulation of environmental monitoring tools (including drones equipped with sensors for water quality, temperature and chemical composition); integration of ecological goals into all recovery programmes; community participation in ecosystem restoration planning; green financing instruments (green bonds, tax incentives); and alignment with sustainable-development goals and international partners.

The destruction is treated as a paradigmatic example of war-induced technogenic catastrophe that necessitates new legal, institutional and monitoring frameworks, rather than as a site-specific recovery planning problem. The work does not explicitly recommend full Kakhovka reservoir restoration or alternative landscape scenarios; it treats ecological recovery as an integrated component of broader post-conflict economic and institutional rebuilding without locking in a single hydrological model.

Mokhnenko A., Melnikova K., Petrenko V., Kovaliov V. (2025). *Methodological Recommendations. Programme for the Restoration of the Potential of De-Occupied Territories*. Ivano-Frankivsk: Kherson State University. 50 pp. [In Ukrainian] **Мохненко А., Мельникова К., Петренко В., Ковальов В.** (2025). *Методичні рекомендації. Програма відновлення потенціалу деокупованих територій*. Івано-Франківськ: Херсонський державний університет. 50 с. Available at: https://kspu.edu/FileDownload.ashx?id=92e2914d-a747-4c3f-8aca-1ae7486da10a.

These methodological recommendations provide a practical template for designing comprehensive recovery programmes for de-occupied hromadas. Scope includes assessment of destruction levels, prioritisation of measures, financing mechanisms (state, private, international), and strategic approaches to housing, industrial, social and communal infrastructure. Methods recommended: statistical analysis of losses, economic-mathematical modelling of recovery scenarios, SWOT analysis and expert assessments. The structure of a model programme covers: general territorial description, review of existing urban-planning documentation, analysis of economic/social/ecological consequences of hostilities, strategies for restoring housing/transport/communal/social infrastructure, economic-growth stimulation proposals, financing mechanisms and effectiveness evaluation. Specific quantified water-supply solutions or Kakhovka-linked irrigation volumes are not provided; communal infrastructure restoration (including water systems) is listed among priority strategic directions without detailed engineering or cost figures. Recommendations focus on creating favourable conditions for economic development, infrastructure modernisation, social stability and ecological security through coordinated multi-source funding and clear prioritisation. No explicit stance is taken on full reservoir restoration versus renaturalisation or dryland alternatives; the document remains a general methodological framework for local programme design.

Odesa Oblast Military Administration (2025). *Strategy for Recovery and Development of Odesa Oblast. Action Plan for 2025–2027.* [In Ukrainian] **Одеська обласна військова адміністрація** (2025). *Стратегія відновлення та розвитку Одеської області. План заходів на 2025–2027*. Available at: https://rdaod.com.ua/3d-flip-book/action-plan-for-implementing-the-strategy/ (Page 473).

Odesa Oblast is classified as a zone of risky agriculture where drought and dry winds recur every 2–3 years, causing annual losses of 6.6 billion UAH to the agrarian sector. Irrigation systems built 40–50 years ago are 100 % worn out and require urgent modernisation. The Plan explicitly states that after the destruction of the Kakhovka HPP an acute need arose to restore water supply and expand irrigated areas in order to improve agricultural productivity, including in Odesa Oblast.

Under Programme 3 (economic transformation) the largest irrigation-related measures are capital repair and reconstruction of inter-farm canals, hydraulic structures and pumping stations (indicative cost ≈1.23 billion UAH, Development horizon). The stated goals are minimisation of water losses and increase of irrigated land, with expected gains of 15–20 % in gross agricultural production. Complementary actions include introduction of efficient irrigation technologies and climate-oriented farming. The document therefore treats modernisation of the regional melioration system as a direct response both to long-term climatic risks and to the water-supply disruption caused by the loss of the Kakhovka Reservoir.

Russian Federation Government (2025). *Strategy for Sustainable Development of the Azov Region for the Period until 2040.* Moscow. 58 p. [In Russian] *Стратегия устойчивого развития Приазовья на период до 2040 года* (утверждена распоряжением Правительства Российской Федерации от 29 декабря 2025 г. № 4140-р. Available at: http://government.ru/docs/57500/ and http://static.government.ru/media/files/6XCp9L2g4ZjmwwxpHTWoFI3DoLa3SdPe.pdf.

This rare example of official (but illegitimate) Russian Federation strategy and accompanying action plan covers seven regions under Russian occupation — Donetsk and Luhansk "people's republics", Republic of Crimea, Krasnodar Krai, Rostov Oblast, and the temporarily occupied parts of Zaporizhzhia and Kherson oblasts — collectively termed the "Azov Region" (Приазовье). Its stated goals are restoration of favourable ecological conditions for aquatic biological resources of the Azov Sea and coast, development of fisheries, tourism and recreation, and improvement of population welfare. The document analyses current economic and environmental conditions, identifies problems and challenges, and sets long-term targets to 2040. Data sources include official statistics on emissions, water abstraction, waste, forest cover, protected areas, tourism capacity and fisheries potential.

The Strategy explicitly links the destruction of the Kakhovka Reservoir dam in 2023 to concrete agricultural and hydrological consequences in the regions (including Kherson and Zaporizhzhia). It states that after the dam breach "irrigation of fields from artificial canals ceased, and the possibility of using medium-depth wells became substantially limited because of a decline in groundwater levels

and an increase in their mineralisation." It further notes that the destruction caused wind erosion of contaminated bottom sediments, resulting in pollution of part of the agricultural lands. Broader context provided: arable land in the Azov Region reaches up to 30 million hectares (9.6 % of the total area of the seven regions), creating preconditions for irrigated agriculture; total water abstraction from natural sources in 2024 was 11.1 billion m^3 , of which 5.2 billion m^3 returned as wastewater; climate-driven aridification and reduced river runoff into the Azov Sea are raising salinity (currently 14.8–14.9 ‰) and threatening freshwater availability for housing, industry and agriculture. The Strategy treats these water-supply and irrigation disruptions as part of a wider set of ecological problems (soil salinisation, chemical pollution, loss of river flow) that must be addressed to restore Azov Sea bio-potential and support agriculture.

Recommendations centre on ecological monitoring and remediation of the Azov Sea and its tributaries, reconstruction of fish-reproduction facilities (target release of 20 million sturgeon juveniles by 2030 and 40 million by 2040), expansion of protected areas, modernisation of communal water-supply and sewerage systems in the coastal zones of the occupied regions, reduction of diffuse agricultural pollution, and measures to increase river runoff into the Azov Sea in order to lower salinity. Tourism and recreation infrastructure (beach capacity, accommodation, transport corridors) are prioritised as economic drivers. The document does **not** recommend reconstruction of the Kakhovka Reservoir or dam. It registers the cessation of canal irrigation and the resulting groundwater and soil problems as irreversible facts of the post-2023 situation and focuses instead on adaptation through alternative water management, ecological restoration of the Azov basin, and development of non-irrigation-dependent sectors (fisheries, tourism). No alternative future hydrological scenarios for the former reservoir bed itself (renaturalisation of Velykyi Luh, hybrid systems, or full rebuild) are discussed; the Strategy simply operates on the premise that the reservoir no longer exists and that irrigation systems dependent on it have stopped functioning.

(10) CULTURE AND HISTORY

Collected sources about impacts of Kakhovka Dam blast on cultural and historic values of the region are rather scarce. The sources converge on a shared recognition that the Lower Dnipro / Velykyi Luh constitutes one of Ukraine's densest and most symbolically charged cultural landscapes — a continuum from Scythian "Golden Belt" barrows and early medieval settlements through the Zaporozhian Cossack heartland to mid-20th-century Soviet industrial heritage (Nova Kakhovka). The 2023 dam breach is treated simultaneously as catastrophic loss (flooding of urban ensembles, accelerated erosion of hill-forts, exposure to looting) and as an unprecedented research window that has already yielded significant finds (dugout canoe, coins, previously submerged layers).

A clear divergence appears in proposed futures. Official Ukrainian planning documents and early government statements leaned toward reconstruction of the hydraulic system. In contrast, the Institute of Archaeology report, the Atlas Obscura investigation, Sushko's essay, ecological-heritage advocacy groups, and UNESCO's emergency programmes emphasise documentation, preventive archaeology and, in several cases, explicit non-reconstruction so that the restored floodplain can remain accessible for research and as a living cultural landscape. Ablyakimova et al. and the Swedish/UNESCO support packages focus on immediate wartime protection and international accountability rather than long-term landscape choice.

The range of alternatives therefore spans: (1) full or partial reconstruction of the reservoir (implied in early official planning); (2) systematic archaeological survey and conservation of newly exposed sites while leaving the river free-flowing; (3) integrated natural-cultural restoration of Velykyi Luh as a national memory landscape; and (4) international emergency funding and technical assistance for documentation under conflict conditions. The dominant scholarly and heritage-advocacy position emerging from this collection privileges the second and third options, treating the cultural values of the pre-reservoir landscape as sufficiently high to outweigh the hydraulic and agricultural arguments for rebuilding the dam.

KEY PUBLICATIONS:

Boltryk, Yu., Chabay, V., Karyaka, V. & Pavlova, M. (2024). *Report on Analytical Studies of the State of Archaeological Sites in the Zone of the Kakhovka Reservoir.* Kyiv: Institute of Archaeology, National Academy of Sciences of Ukraine. 86 pp. [In Ukraine] *Звіт про аналітичні дослідження стану археологічних пам'яток в зоні Каховського водосховища.* Available via institutional channels of the Institute of Archaeology NASU.

This analytical report by the Institute of Archaeology of the National Academy of Sciences of Ukraine systematically inventories and assesses the condition of

archaeological sites along both banks of the former Kakhovka Reservoir (Zaporizhzhia, Dnipropetrovsk and Kherson oblasts). It draws on archival data, previous excavation reports, cartographic materials and post-breach observations. The preface and introductory sections frame the Lower Dnipro / Velykyi Luh as a unique natural-cultural landscape — a giant riverine oasis celebrated since Herodotus, the heartland of Zaporozhian Cossack identity ("Sich is the mother, the Great Meadow is the father"), and a dense concentration of Scythian, medieval and early-modern sites.

Main findings emphasise that virtually the entire shoreline of the former reservoir was occupied by ancient settlement structures or burial monuments. The report documents sites on the right and left banks, notes accelerated erosion and exposure of previously submerged layers after the 2023 breach, and highlights the sozoological and cultural value of the exposed landscape.

Recommendations (section 4.7) call for urgent systematic survey, preventive archaeology, documentation of newly accessible sites, and integration of cultural-heritage protection into any future land-use decisions for the former reservoir bed. The authors treat the post-breach exposure as both a threat (erosion, looting) and an unprecedented research opportunity; they do not advocate reconstruction of the reservoir.

Cherevko, R. (2023). The Kakhovka Dam Disaster Revealed an Archaeological "Goldmine", *Atlas Obscura*, 26 September. Available at: https://www.atlasobscura.com/articles/kakhovka-dam-chaika-cossack-archaeology.

This journalistic investigation recounts the sudden appearance of archaeological finds after the reservoir emptied, focusing on a 6.7 m dugout canoe recovered on Khortytsia Island in late June 2023. Drawing on interviews with Khortytsia National Reserve archaeologists (notably Oleh Tuboltsev), the article situates the find within the longer search for early Cossack *chaika* vessels and the broader cultural landscape of the Lower Dnipro.

The main cultural values identified are the island's multi-layered heritage (Stone Age to Mennonite colony, Zaporozhian Cossack base) and the potential for further discoveries of pre-Cossack and early-modern watercraft and settlements previously inaccessible under the reservoir. The article notes that while the Ukrainian government initially planned to rebuild the dam, ecologists and heritage advocates (Ukrainian Nature Conservation Group) argue against reconstruction, proposing instead restoration of the pre-Soviet floodplain landscape precisely because of its combined natural and cultural significance. Future solutions emphasised are urgent documentation, conservation of recovered objects, and non-reconstruction of the reservoir to keep the newly exposed cultural landscape accessible for research and heritage protection.

Ablyakimova, E., Symonenko, O., Telizhenko, S. & Yashny, D. (2024). Russian-Ukrainian War: The Tragedy of the Cultural Heritage of Ukraine. *Baltic Worlds*, 17(4). Pp. 14–22. Available at: https://balticworlds.com/wp-content/uploads/2024/12/BW-2024.4.p.14_22.Ablyakimova.et_.al_.pdf.

Based on data collected by the Crimean Institute for Strategic Studies, this article surveys the systematic destruction, looting and appropriation of Ukrainian cultural heritage since 2014, with a dedicated section on the Kakhovka dam explosion. Methods combine field reports, museum inventories and satellite/observational evidence of site damage.

Key findings for the Kakhovka zone include: approximately 95 known archaeological sites in the reservoir area alone (nearly 200 when including the Dnipro-Bug and Berezan estuaries); intensification of coastal erosion destroying Late Scythian hill-forts and burial grounds; complete flooding of 78 monuments of history, monumental art and archaeology (including the historic centre of Nova Kakhovka, a mid-20th-century urban complex of national importance); and the exposure of sites to "black diggers". The authors frame the dam breach as both an ecological and a cultural catastrophe that permanently alters or erases markers of regional historical development. Preservation solutions stressed are documentation under wartime conditions, international pressure against illicit excavations and transfers, and post-deoccupation recovery of looted collections; the article does not discuss long-term reservoir reconstruction versus renaturalisation.

Dayneko, P., Moysiyenko, I., Sudnik-Wójcikowska, B., Dembicz, I., Zachwatowicz, M. & Skobel, N. (2023). Ancient settlements as natural heritage sites: the first occurrence dataset on vascular plant species from ancient settlements in the Lower Dnipro region (Ukraine). *Biodiversity Data Journal*, 11: e99041. Available at: https://doi.org/10.3897/BDJ.11.e99041.

This data paper presents a georeferenced occurrence dataset of vascular plants recorded on 18 ancient settlements (kurgans, hill-forts, etc.) in the Lower Dnipro region (2015–2020 fieldwork). Although primarily botanical, the authors explicitly link the high floristic richness and presence of protected species to the cultural value of these sites as long-term refugia created by human activity.

Main cultural-natural values identified are the dual heritage status of ancient settlements: they function simultaneously as archaeological monuments and as islands of steppe biodiversity (including species listed in the Bern Convention, Red Data Book of Ukraine and regional lists). The paper argues that protection of these sites must integrate cultural and natural heritage regimes. Future solutions proposed are recognition of ancient settlements as natural heritage sites and coordinated conservation planning that preserves both archaeological integrity and associated steppe flora.

Bazhan, O. (2025). People and Buildings. Construction of the Kakhovka HPP through the Prism of Private Correspondence. Southwest. Odesyka: Historical and Local Studies Scientific Almanac. Odesa. Pp. 193-208 [In Ukrainian] **Бажан О.** (2025). Люди та будови. Спорудження Каховської ГЕС крізь призму приватного листування. Південний захід. Одесика. Історико-краєзнавчий науковий альманах. Одеса. С. 193-208. Available at: https://resource.history.org.ua/cgi-bin/eiu/history.exe?C21COM=2&I21DBN=ELIB&P21DBN=ELIB&Image_file_name=book/0018599_1.pdf&IMAGE_FILE_DOWNLOAD=1.

Using private correspondence and archival materials, this historical study reconstructs the human and political dimensions of the 1950s construction of the Kakhovka HPP. It documents the Soviet decision-making process, the mobilisation of scientific institutions, and the lived experience of builders, while situating the project within the broader transformation of the Lower Dnipro landscape. Cultural values highlighted are the erasure of pre-existing settlement patterns and the imposition of a new industrial-hydraulic landscape that submerged the historic Velykyi Luh. The text itself does not propose post-2023 preservation solutions, but supplies the historical context against which contemporary calls for renaturalisation are framed.

Sushko, K. (2024). *The Return of the Dnipro: Where Does the Kakhovka HPP Come From?*. 2nd expanded edition. Chernivtsi: Druk Art. 87 p. [In Ukrainian] **Сушко К.** (2024). *Повернення Дніпра: звідкіль родом Каховська ГЕС?* Вид. 2-ге, допов. й розшир. Чернівці: Друк Арт, 2024. 87 с. Available at: https://drive.google.com/file/d/1DDNLrQxvB8CPIP18g9WRVoD8PwFQBf6M/view?usp=sharing.

This historical-essayistic work by the Zaporizhzhia writer and former director of the Khortytsia National Reserve traces the creation of the Kakhovka "sea", the flooding of Velykyi Luh, and the cultural memory of the lost landscape. Drawing on historical sources, oral testimony and post-2023 observations, Sushko presents the return of the river as both ecological recovery and cultural restitution. Future solutions advocated centre on non-reconstruction of the reservoir and conscious restoration of the historic floodplain as a space of national memory and identity.

Government of Ukraine & United Nations (2023) *Post-Disaster Needs Assessment: 2023 Kakhovka Dam Disaster, Ukraine* (sections on municipal services, public spaces and cultural infrastructure). Available at: https://ukraine.un.org/en/248860-post-disaster-needs-assessment-report-kakhovka-dam-disaster (accessed 5 August 2026).

Within the broader PDNA, the municipal-services chapter quantifies damage to public spaces, libraries, cultural facilities, administrative buildings, parks, recreation areas and sports infrastructure caused by the flooding (total municipal damage estimated at approximately US$128 million, overwhelmingly concentrated in Kherson Oblast). It documents disruption of local cultural life, including flooded libraries, damaged recreational zones and limited access to administrative and community facilities.

The assessment treats restoration of public and cultural spaces as a priority for social recovery and as a "pull factor" for the return of displaced families and youth. **Recommendations** include Build-Back-Better reconstruction of cultural and recreational infrastructure, digitisation of administrative services, creation of modular service centres, and integration of cultural institutions into local recovery plans. The document does not take a position on long-term reconstruction of the reservoir versus renaturalisation of Velykyi Luh.

> **UNESCO & Ministry of Culture and Information Policy of Ukraine** (2024). UNESCO will assist in conducting archaeological research in areas affected by the destruction of the Kakhovka HPP dam (press release, 6 August 2024). Available at: https://mincult.gov.ua/en/news/unesco-will-assist-in-conducting-archaeological-research-in-areas-affected-by-the-destruction-of-the-kakhovka-hpp-dam/.

These official communications record the agreement between UNESCO's Ukraine office, the Institute of Archaeology of the National Academy of Sciences of Ukraine, and the National Reserve "Khortytsia" to organise urgent archaeological research in the zones exposed or threatened by the dam breach. Support is provided through the UNESCO Heritage Emergency Fund and contributions from the Government of Japan. Activities include documentation of newly accessible sites, underwater surveys, capacity-building for local specialists, and stabilisation of vulnerable heritage under wartime conditions.

The cultural values emphasised are the multi-layered archaeological and historical significance of the Lower Dnipro and Khortytsia (from prehistoric settlements to Cossack and later periods). The preferred future actions are emergency documentation, professional conservation of recovered objects, and sustained research programmes that keep the newly exposed cultural landscape accessible rather than allowing uncontrolled looting or irreversible damage.

> **Government of Sweden** (2026). Government approves support to cultural heritage preservation in Ukraine. Press release, Ministry of Culture and Ministry for Foreign Affairs, 20 April 2026. Available at: https://www.government.se/press-releases/2026/04/government-approves-support-to-cultural-heritage-preservation-in-ukraine/.

The Swedish Government allocated SEK 12 million for 2026–2027, channelled through UNESCO, specifically for the protection and long-term preservation of cultural heritage sites in Ukraine threatened by the war, including those affected by the Kakhovka dam destruction. The funding supports documentation, emergency conservation, capacity-building and safeguarding of at-risk movable and immovable heritage.

The measure recognises the heightened vulnerability of sites in the former reservoir zone and the Lower Dnipro region. It does not prescribe a particular landscape scenario (reconstruction versus renaturalisation) but prioritises immediate protection and professional preservation so that cultural values can be maintained regardless of the final hydrological decision.

Rozhko, V., Yamelynets, A., Honek, Y. et al. (2023). *Rapid Preliminary Report: Flooding of Cultural Heritage Repositories Due to the Destruction of the Nova Kakhovka Dam on 6 June 2023*. Smithsonian Cultural Rescue Initiative, Ukrainian Heritage Monitoring Lab / HeMo, PlanetScape Ai, CIDCM, Virginia. Available at: https://culturalrescue.si.edu/what-we-do/research/scri-research-reports?page=0.

Using high- and moderate-resolution satellite imagery (Maxar, Planet Labs) cross-checked with Ukrainian Heritage Monitoring Lab inventories, the report confirms flooding at seven cultural repositories in the inundation zone. Publicly released examples include the Novokakhovsk Art Gallery named after Albin Havdzynskyi, the Museum of History of Nova Kakhovka, the Museum of Battle Glory of the Danube Military Flotilla in Kherson, the Literary and Memorial Museum of Anatolii Bakhuta, and the House-Museum of Ostap Vyshnia in Krynky.

The principal finding is the immediate physical threat to museum buildings and collections from rising water. The report functions as an emergency monitoring product; its implicit recommendations are continued satellite and ground-based monitoring, rapid-response conservation, and post-flood damage assessment of cultural repositories. It does not address long-term landscape alternatives.

Tymoshenko, M., Hontsa, F. & Kelm, N. (2024). Velykyi Luh: Map of the Great Meadow — Land of Ukrainian Cossack State, the Mongol Khan's headquarters and more, *Texty.org.ua*, 28 January. Available at: https://texty.org.ua/projects/111631/velykyi-luh-map-great-meadow/.

This interactive cartographic project reconstructs the pre-1950s landscape of Velykyi Luh by overlaying 1940s German topographic maps with the post-June 2023 riverbed of the Dnipro. It locates historic Cossack sites, medieval settlements, archaeological landmarks, forests, swamps and islands that were submerged by the Kakhovka Reservoir.

The cultural values stressed are Velykyi Luh as the geographic and symbolic heart of the Zaporozhian Host, a cradle of Ukrainian statehood, and a dense concentration of historical and archaeological heritage. By making the lost landscape visible again, the map serves as a public-education and advocacy tool that supports arguments for non-reconstruction of the reservoir and for the recognition of the restored floodplain as a cultural-memory landscape.

Bernhardt, J., Koller, M. & Lichtenberger, A. (eds.) (2019). *Mediterranean Rivers in Global Perspective*. Mittelmeerstudien, Band 19. Paderborn: Ferdinand Schöningh / Brill. Available at: https://brill.com/edcollbook/title/52841?srsltid=AfmBOopBEDuJ_463Vfgxa5uwBMsFz1fa3BWoFl5fshicBbNPHMcc85dJ.

This edited volume places major rivers, including the Dnipro, in a comparative Mediterranean and global historical framework. The relevant chapter on the Zaporozhian Cossacks and the Dnipro examines the river as a cultural, military and ecological frontier that shaped Cossack identity, settlement patterns and symbolic geography from the late medieval period onward.

Main cultural values identified are the Dnipro rapids and floodplain (later submerged by the Kakhovka Reservoir) as the spatial core of Zaporozhian autonomy, self-governance and martial tradition. The text treats the pre-dam landscape as an integral part of Cossack historical memory. No post-2023 recommendations are offered; the work supplies the long-term historical baseline against which the loss and potential recovery of Velykyi Luh are now evaluated.

> **Kondriko, A.** (2012). The Spiritual-Knightly Aspect of the History of the Zaporozhian Sich. *Vlast'*, 10. Pp. 65–68. [In Russian] **Кондрико А.** (2012). Духовно-рыцарский аспект истории Запорожской Сечи. *Власть*, 10. С. 65-68.

The article analyses structural, ritual and ethical parallels between the Zaporozhian Sich and European spiritual-military orders (Templars, Hospitallers, etc.). It draws on historical sources concerning organisation, celibacy rules, election of atamans, regalia, religious symbolism and the "brotherhood" ethos.

Key values highlighted are the Sich as a quasi-monastic military brotherhood whose ideals of chastity, collective decision-making, sacralised warfare and contempt for worldly wealth were rooted in the specific geography of the Lower Dnipro and Velykyi Luh. The author concludes that while the Sich was never a formal Orthodox military-monastic order, its "steppe knighthood" ideals remained constant. The text contains no recommendations concerning the post-2023 landscape, but reinforces the cultural centrality of the flooded territory to Cossack spiritual identity.

(11) ECOLOGY AND CONSERVATION

Significant portion of literature on ecology and conservation related to Velykyi Luh has been co-authored by the members of UNSG team, who authored reports presented in **section (0)**. Therefore we skipped comparison between these publications and the UNCG volumes.

Empirical evidence across the botanical and ecological studies converges on rapid, spontaneous recovery of the drained reservoir bed. Kuzemko et al. (2024 preprint; 2025 Ukrainian Botanical Journal; 2026 Chornomorski Botanical Journal) document an exponential rise in vascular-plant richness — from roughly ten taxa weeks after the breach to 68–147 species within the first year and 343 by late 2025 — together with the swift formation of willow–poplar thickets, marsh communities and habitats already qualifying under the Bern Convention and EU Habitats Directive. Mikhailyuk, Leonov & Khodosovtsev (2026) show that cyanobacteria and green algae dominated early biological soil crusts on both takyr-like silt and sand, stabilising surfaces against deflation and initiating succession, while bryophytes and lichens remained minor. Lisovets et al. (2025) confirm, through hemeroby and phytoindication analysis on Khortytsia Island, that moisture regime is the primary driver of community change, with coastal zones becoming highly hemerobic and interior areas retaining higher naturalness. These findings collectively refute earlier forecasts of permanent desertification or mass invasion on dried reservoir bottom.

Biodiversity values are framed at multiple scales. Locally, the recovering bed already supports rare native taxa, newly described cryptogams (Khodosovtsev et al. 2024 on *Circinaria ucrainica*) and functional biocrusts (Mikhailyuk et al. 2026). Regionally, Manyuk (on Velykyi Luh wetlands), Moskalenko & Plyushch (on Tendrivska and Yahorlytska Bays) and Demchenko (on ichthyofauna of the Azov–Black Sea basin) record both acute losses — disrupted spawning, salinity shifts, pollutant pulses — and the potential for secondary recovery once hydrological regimes stabilise. The Ramsar COP15 assessment (2025) and the Kamianska Sich monograph (Khodosovtsev et al. 2025) embed these changes within wartime damage accounting and protected-area planning, emphasising the dual natural–cultural significance of the former Great Meadow.

Positions on the future of the reservoir favor restoration of Velykyi Luh ecosystem. Kuzemko and co-authors (all three vascular-plant papers), Didukh's 2024 conference volume, the Dnipro Rapids seminar materials (2025), Manyuk, Suriadna ("The death of the Great Meadow"), Mikhailyuk et al., Lisovets et al. and the Kamianska Sich book treat natural succession toward pre-reservoir floodplain ecosystems as both feasible and desirable. They recommend continued multi-taxon monitoring, legal protection or expansion of existing reserves (Kamianska Sich, Khortytsia, Dnipro Rapids) and recognition of the newly formed habitats as conservation assets;

none of these works advocates reconstruction of the dam or re-impoundment. Roman (2024) frames the drainage explicitly as a potential "chance" for ecological recovery rather than a catastrophe requiring reversal. The Ramsar COP15 report is concentrating on mitigation and restoration of damaged Wetlands of International Importance regardless of the long-term hydrological configuration chosen for the former reservoir bed. However, it explicitly hints that post-blast wetland values reviving now on the Kakhovka reservoir bottom are likely more significant than those possessed by original Ramsar sites at the Kakhovka reservoir.

KEY PUBLICATIONS:

Didukh, Ya., Moysiyenko, I., Kravchenko, O., Mulenko, M., Polyanska, K., Chusova, O. & Hetman, P. (2025). Initial stages of formation of floodplain forests on the bed of the Kakhovka Reservoir and forecast of their development. *NaUKMA Research Papers. Biology and Ecology*, 8. Pp. 70–80. [In Ukrainian] **Дідух Я., Мойсієнко І., Кравченко О., Муленко М., Полянська К., Чусова О., Гетьман П.** (2025). Початкові етапи формування заплавних лісів днища Каховського водосховища та прогноз їхнього розвитку. *Наукові записки НаУКМА. Біологія і екологія*. 8. С. 70-80. Available at: https://doi.org/10.18523/2617-4529.2025.8.70-80.

Field surveys in 2023–2024 on the drained bed (primarily within Kamianska Sich National Nature Park and near Zaporizhzhia) documented extremely rapid growth of *Salix×rubens*, later joined by *Populus alba* and *P. nigra*. Mean shoot density of willow declined from ~90 individuals m^{-2} in the juvenile stage (three weeks after the breach) to 23 individuals m^{-2} by the end of 2023 and 10.3 individuals m^{-2} in 2024, while mean height increased from 190 cm to 350 cm. Biomass partitioning in the first year was approximately 0.45 : 0.16 : 0.18 : 0.21 (stems : branches : leaves : roots). The authors project phytomass, energy stores and supporting/regulating ecosystem services at 10, 20 and 50 years, estimating monetary values of 825, 1 338 and 1 523 conventional units respectively under the assumption that floodplain forests occupy 30 % of the former reservoir bed.

The paper emphasises the high water-regulation, soil-forming and remediation value of the emerging poplar–willow habitats, which are protected at the European level and currently constitute only ~0.1 % of Ukraine's forest area. It explicitly questions the expediency of reconstructing the Kakhovka Reservoir and calls for a balanced decision that fully accounts for the ecological and historical-cultural value of the recovering floodplain ecosystems rather than automatic re-impoundment.

Kuzemko, A., Prylutskyi, O., Kolomytsev, G., Didukh, Ya., Moysiyenko, I., Borsukevych, L., Chusova, O., Splodytel, A. & Khodosovtsev, O. (2024). Reach the bottom: plant cover of the former Kakhovka Reservoir, Ukraine. Research Square preprint. Available at: https://doi.org/10.21203/rs.3.rs-4137799/v1.

Field surveys in June and October 2023 within Kamianska Sich National Nature Park (two one-day visits to accessible right-bank bays) combined with Sentinel-2

remote sensing and machine-learning habitat classification documented the earliest stages of revegetation on the drained reservoir bed. Vascular-plant richness rose from 10 to 68 species in 3.5 months; perennials and short-lived species were almost equally represented, wind dispersal dominated (83 %), and neophytes comprised only 16 %. Four habitat types were delineated: dense willow thickets (Salix alba × fragilis), marshy reedbeds, muddy sediments with sparse vegetation, and shell/sand deposits. Willow seedlings densified to ~90 individuals m^{-2} and reached average heights of 190 cm (max. 309 cm) by October, covering large areas.

The study demonstrates rapid spontaneous restoration of floodplain vegetation and the formation of habitats protected under the Bern Convention and EU Habitats Directive (G1.11 / 91E0, C3.2). Low alien-species pressure and the stabilising effect of willow cover contradict earlier predictions of desertification, dust storms and neophyte invasion. The authors argue that the emerging landscape already resembles pre-reservoir Velykyi Luh communities and provide a high-resolution habitat map as a baseline for monitoring; they do not support reservoir reconstruction and treat continued natural succession as the preferred trajectory.

Kuzemko, A., Prylutskyi, O., Kolomytsev, G., Didukh, Ya., Moysiyenko, I., Borsukevych, L., Chusova, O. & Khodosovtsev, O. (2025). Initial stages of revegetation at the bottom of the drained Kakhovka Reservoir (Ukraine): synthesis of field surveys and remote sensing. *Ukrainian Botanical Journal*, 82(5). Pp. 488–501. Available at: https://doi.org/10.15407/ukrbotj82.05.488.

Building on the 2024 preprint, this peer-reviewed synthesis incorporates a third field campaign (May 2024) and refined Random-Forest classification of Sentinel-2 imagery. Vascular-plant taxa increased nearly fourteen-fold within the first year. Habitat maps for October 2023 and May 2024 show closed vegetation (willow–poplar thickets and marshes) occupying roughly half the former bed; spring flooding temporarily expanded open-water surfaces to ~48 % while sparse-sediment habitats contracted.

The paper confirms the resilience of native floodplain succession, the limited role of invasive aliens, and the structural importance of softwood alluvial forests. It supplies open-access habitat maps and code as a foundation for adaptive management and explicitly frames natural revegetation as a scientifically valuable alternative to any reconstruction of the reservoir.

Kuzemko, A., Borsukevych, L., Didukh, Ya., Manyuk, V., Mulenko, M., Skobel, N., Chusova, O. & Moysiyenko, I. (2026). Vascular plant diversity in the former Kakhovka Reservoir area: two years after the dam breach. *Chornomorski Botanical Journal*, 22(1). Pp. 23–45. Available at: https://doi.org/10.32999/ksu1990-553X/2026-22-1-2.

Seven field campaigns (June 2023–October 2025) across Kherson, Zaporizhzhia and Dnipropetrovsk oblasts, supplemented by iNaturalist and GBIF records, tracked floristic change on the exposed bed. Species richness rose exponentially from 11 (June 2023) to 343 (October 2025); genera increased from 11 to 212 and families from 8 to 60. Taxonomic structure stabilised rapidly around Compositae, Poaceae and Brassicaceae.

Life-form and dispersal spectra shifted from early dominance of annuals and anemochorous woody pioneers (*Salix, Populus nigra*) toward perennial herbs and mixed zoochorous/autochorous strategies. Phytoindication revealed a progressive transition from hygrophytic to mesophytic conditions while willow–poplar forests remained the structural backbone. Neophyte proportion peaked early and then declined; rare species such as Carex secalina appeared, indicating high conservation value.

The authors conclude that the flora is rapidly converging on natural Lower-Dnipro floodplain assemblages. They present the spontaneous recovery as evidence of ecosystem resilience and do not advocate rebuilding the dam; continued monitoring and protection of the emerging habitats are recommended as the primary management pathway.

Khodosovtsev, O., Moysiyenko, I., Kuzemko, A. at all. (2025). *National Nature Park "Kamianska Sich": War against Nature*. Lviv: Company "Manuscript" Publishing. 184 pp. [In Ukrainian] **Ходосовцев О., Мойсієнко І., Куземко А. та ін.** (2025) *Національний природний парк «Кам'янська Січ»: війна проти природи*. Львів : Видавництво «Компанія "Манускрипт"», 2025. 184 с. Available at: https://ekhsuir.kspu.edu/handle/123456789/22405.

This multi-author monograph documents the full impact of Russian military occupation and the 2023 dam breach on Kamianska Sich National Nature Park. A dedicated chapter analyses the hydrological and ecological consequences of reservoir drainage for the park's biotopes, recording rapid colonisation by willow thickets, marsh communities and pioneer vegetation on former bay bottoms. Legal sections address ecocide, environmental war crimes and compensation mechanisms.

Biodiversity values highlighted include the park's residual steppe, petrophytic and floodplain habitats that have been both damaged by hostilities and partially restored by the natural draw-down. The authors outline scenarios for park expansion that incorporate the recovering reservoir bed and treat natural succession, rather than reservoir reconstruction, as compatible with long-term conservation goals.

Manyuk, V. (2024). Ecological consequences of the explosion of the Kakhovka HPP for wetlands of the Velykyi Luh ("Great Meadow"): losses and further prospects. Presentation / Workshop «Environmental emergency in Ukraine relating to the damage of its Wetlands of International Importance (Ramsar Sites) stemming from the Russian Federation's aggression» 31 May 2024. [In Ukrainian] **Манюк В.** (2024) Екологічні наслідки підриву Каховської ГЕС для водно-болотних угідь Великого Лугу: втрати і подальші перспективи. Презентація / Робоча зустріч «Надзвичайна екологічна ситуація в Україні, пов'язана з пошкодженням водно-болотних угідь міжнародного значення (Рамсарських угідь) внаслідок агресії Російської Федерації» 31 травня 2024 року. Available at: https://drive.google.com/file/d/1fyPHHVCIRv1ouaGlpUl-FbW1Dhxal_sF/view?usp=sharing.

The work places the 2023 drainage in long-term historical context. It recalls that the construction of the Kakhovka Reservoir in the 1950s–60s flooded approximately 200 000 ha of one of Europe's largest riverine floodplain–terrace complexes, destroying a high-biodiversity wetland landscape that functioned as a coherent system. The author argues that the Great Meadow was not permanently destroyed

but merely submerged for six decades; the rapid appearance of pioneer willow thickets and young floodplain forests in 2023–2024 demonstrates that the underlying landscape and its recovery potential remained intact.

Biodiversity and ecosystem values are framed as the restoration of a historically significant wetland of European importance. The paper rejects the Soviet-era and later myths that drainage would produce irreversible catastrophe, notes that such narratives were revived in recent decades to justify continued operation or expansion of the hydropower complex, and presents the spontaneous formation of dense willow stands as the early stage of Velykyi Luh recovery. It implicitly and explicitly opposes reconstruction of the reservoir, treating the drainage as an opportunity to restore the pre-reservoir floodplain ecosystems rather than reverse the process.

Moskalenko, Yu. & Plyushch, S. (2024).Consequences of Russian aggression for the Wetlands of International Importance "Tendrivska Bay" (768) and "Yahorlytska Bay" (116). Black Sea Biosphere Reserve, NAS of Ukraine. Presentation / Workshop «Environmental emergency in Ukraine relating to the damage of its Wetlands of International Importance (Ramsar Sites) stemming from the Russian Federation's aggression» 31 May 2024 [In Ukrainian] **Москаленко Ю., Плющ С.** (2024). Наслідки російської агресії для водно-болотних угідь міжнародного значення „Тендрівська затока" (768) і „Ягорлицька затока" (116). Презентація / Робоча зустріч «Надзвичайна екологічна ситуація в Україні, пов'язана з пошкодженням водно-болотних угідь міжнародного значення (Рамсарських угідь) внаслідок агресії Російської Федерації» 31 травня 2024 року. Available at: https://drive.google.com/file/d/1EiCWsvzMFIVgua3eO-Y3H-_EkzRyPvc6/view?usp=sharing.

Focusing on two coastal Ramsar sites, the authors assess secondary effects of the dam breach (altered freshwater inflow, salinity shifts, pollutant pulses) on waterbird and fish habitats. They document both immediate impacts and early signs of ecological adjustment, advocating continued monitoring and protection of the Ramsar network as part of regional recovery.

Demchenko, V. (2024). Risks for the ichthyofauna of wetlands of the Azov–Black Sea region under conditions of war. Presentation / Workshop «Environmental emergency in Ukraine relating to the damage of its Wetlands of International Importance (Ramsar Sites) stemming from the Russian Federation's aggression» 31 May 2024. [In Ukrainian] **Демченко В.** (2024). Ризики для іхтіофауни водно-болотних угідь Азово-Чорноморського регіону в умовах. Презентація / Робоча зустріч «Надзвичайна екологічна ситуація в Україні, пов'язана з пошкодженням водно-болотних угідь міжнародного значення (Рамсарських угідь) внаслідок агресії Російської Федерації» 31 травня 2024 року. Available at: https://docs.google.com/presentation/d/1lhtbjBfjLcV22tedt0sPVtX1ZMoYFgiV/edit?usp=sharing&ouid=109574388265892571827&rtpof=true&sd=true.

The report evaluates war-related and dam-breach-related risks to fish assemblages of Azov–Black Sea wetlands, including changes in spawning grounds, salinity regimes and connectivity caused by the loss of the Kakhovka Reservoir. It stresses the need for habitat protection and adaptive management to safeguard remaining ichthyofauna.

Roman, A. (2024). Kakhovka HEPP explosion: a man-made disaster or a chance for the environmental future of Ukraine. *Scientific Journal of Metinvest Polytechnic*. Series: Technical Sciences, No. 2. Pp.98-104. [In Ukrainian] **Романь А.** (2025). Підрив Каховської ГЕС: техногенна катастрофа чи шанс на екологічне майбутнє України. *Науковий Журнал Метінвест Політехніки*. Серія: Технічні науки, 2. С.98-104. Available at: https://doi.org/10.32782/3041-2080/2024-2-15.

The article frames the dam breach as both catastrophe and potential ecological opportunity, arguing that spontaneous renaturalisation of the reservoir bed offers a pathway toward a more resilient environmental future for southern Ukraine if reconstruction is not pursued.

Khodosovtsev, A., Darmostuk, V., Dembicz, I., Dengler, J., Moysiyenko, I. & Kuzemko, A. (2024). *Circinaria ucrainica* sp. nov., a new species from sand dunes of the Lower Dnipro valley (Ukraine). *The Lichenologist*, 56.Pp. 159–167. Available at: https://doi.org/10.1017/S0024282924000197.

During the 2021 Eurasian Dry Grassland Group expedition to the Lower Dnipro sand dunes, a sterile crustose aspicilioid lichen with rhizomorphs was discovered and described as the new species *Circinaria ucrainica* (Megasporaceae). Phylogenetic analysis (nrITS, nrLSU, mtSSU) places it close to C. reptans, from which it differs by narrower rhizomorphs, spicate prothalline tips and ecological preferences. The species forms part of biological soil crusts on stable sand dunes, co-occurring with mosses (*Syntrichia ruraliformis*) and other lichens.

Although collected before the dam breach, the paper documents a previously unknown lichen component of the Lower Dnipro dune biota that is now relevant to post-drainage succession on exposed sandy substrates of the former reservoir. It underscores the conservation value of these biological crusts and the need for continued taxonomic inventory of the recovering landscape. No position is taken on reservoir reconstruction.

Mikhailyuk, T., Leonov, A. & Khodosovtsev, O. (2026). Terrestrial algae, bryophytes, and lichens of biological soil crusts and corticolous biofilms on the bed of the former Kakhovka Reservoir. *Chornomorski Botanical Journal*, 22(1). Pp. 46–65. Available at: https://doi.org/10.32999/ksu1990-553X/2026-22-1-3.

Three-year field and laboratory study (2023–2025) of biological soil crusts and willow-bark biofilms on the exposed reservoir bed identified 55 terrestrial algae (17 Cyanobacteria, 27 Chlorophyta, 4 Charophyta, 7 Heterokontophyta), two bryophytes (*Marchantia polymorpha, Funaria hygrometrica*) and one lichen (*Physcia adscendens*). Fifty algal species occurred in soil biocrusts; cyanobacteria and green algae dominated, with *Phormidium takyricum*, *Chlorosarcinopsis* cf. *aggregata*, *Microcoleus vaginatus* and *Klebsormidium* cf. *flaccidum* among the most frequent. Takyr-like silt substrates hosted 30 algal species; sands hosted 36 and frequently supported *Funaria biocrusts*. Willow-bark biofilms contained ten algal species (green algae dominant) plus the first recorded epiphytic lichen.

The work demonstrates that biological soil crusts were the primary stabilisers of exposed silt and sand in the first years after drainage, preventing deflation and initiating succession. Algal diversity increased over the three years. Bryophytes and lichens remain minor components at this early stage. The findings support natural recovery pathways and highlight the functional importance of microbial and cryptogamic communities for ecosystem restoration on the former reservoir bed.

Lisovets, O., Podorozhniy, S., Tutova, H., Molozhon, K., Kunakh, O. & Zhukov, O. (2025). Hemeroby reveals the dynamics of vegetation cover following the destruction of the Kakhovka Reservoir. *PeerJ,* 13:e19607. Available at: https://doi.org/10.7717/peerj.19607.

Phytosociological mapping and phytoindication on Khortytsia Island assessed vegetation response to the altered hydrological regime after the 2023 dam breach. Twelve plant-community associations were identified. Principal-component analysis showed that gradients of humidity, trophic status and light availability, closely linked to hemeroby and naturalness indices, explain most of the variation in community composition. Coastal zones experienced the strongest transformation: newly exposed sandy substrates were rapidly colonised by xerophytic and ruderal species, forming highly hemerobic assemblages, while more stable central areas retained relatively undisturbed communities.

The study demonstrates that the collapse of the reservoir triggered rapid shifts in floodplain vegetation, with moisture regime acting as the primary filter. Hemeroby and naturalness indices are shown to be effective tools for monitoring post-catastrophic change and prioritising restoration. The authors do not advocate reconstruction of the reservoir; they emphasise the need for adaptive management of the new terrestrial and semi-terrestrial habitats.

Ramsar Convention Secretariat (2025). *Implementation of Resolution XIV.20: Final assessment report of environmental damage on Wetlands of International Importance in Ukraine stemming from the Russian Federation's aggression*. COP15 Inf.2. Gland: Ramsar Convention Secretariat. Available at: https://www.informea.org/en/decision/resolution-xiv20-ramsar-conventions-response-environmental-emergency-ukraine-relating.

This official assessment, prepared pursuant to Resolution XIV.20, consolidates Earth-observation data, literature, site-manager reports, stakeholder workshops and field visits to evaluate war-related (including Kakhovka-related) damage to Ukraine's Ramsar Sites. It documents impacts on hydrological regimes, water quality, migratory-bird and fish habitats, and provides recommendations for immediate, short-, medium- and long-term rehabilitation and restoration measures.

Biodiversity values emphasised are the role of southern Ukrainian wetlands in the African–Eurasian Flyway and as critical fish habitats. The report advises on mitigation and restoration without prescribing a single hydrological future for the former Kakhovka Reservoir, but stresses the need to protect and restore remaining wetland functions and connectivity.

Didukh, Ya. (ed.) (2024). *Vegetation and biotopes of Ukraine: materials of the fifth scientific-theoretical conference* (Kyiv, 18–19 April 2024). Kyiv: M.G. Kholodny Institute of Botany, NAS of Ukraine. 63 p. [In Ukrainian] **Дідух Я.** (ред.) (2024) *Рослинність та біотопи України: матеріали п'ятої науково-теоретичної конференції*. Київ, 2024. 63 с. Available at: https://www.researchgate.net/publication/382250473_Biotopi_dolini_r_Dnipra_do_stvorenna_ta_pisla_zniknenna_Kahovskogo_vodoshovisa.

Conference proceedings that include contributions on the classification of vegetation and biotopes and on the impact of military actions on Ukraine's natural ecosystems. Several abstracts address the early stages of habitat formation on the drained Kakhovka Reservoir bed and the broader consequences of the dam breach for floodplain and steppe biotopes.

The volume reinforces the scientific priority of documenting and protecting the newly forming biotopes and supports research-based approaches to their long-term conservation rather than automatic reconstruction of the former reservoir.

Suriadna, N., Yosipenko T., Gorbenko O. (2024). The death of the Great Meadow . Presentation at Ramsar convention mission consultations. May 31, 2024. [In Ukrainian] **Сурядна Н., Йосипенко Т., Горбенко О.** (2024). Погибель Великого Лугу. Презентація на консультаціях Рамсарської конвенції. 31 травня 2024. Available at: https://drive.google.com/file/d/1ouBstIoZcf6vJIsxmPT5lDP1oqPF55lY/view?usp=sharing.

A popular-scientific or advocacy text that frames the historical flooding of Velykyi Luh by the Kakhovka Reservoir as a cultural and ecological loss and interprets the 2023 drainage as a potential (if tragic) opportunity for partial restoration of the Great Meadow landscape and its associated biodiversity and heritage values. It argues against re-impoundment.

Vasyliuk, O., Kuzemko, A. and Shapoval, V. (2024). Habitats of the Dnipro River valley before the creation and after the disappearance of the Kakhovka Reservoir. *The Biosphere Reserve "Askania-Nova" Reports*, 26, pp. 57–67. [In Ukrainian] **Василюк О., Куземко А., Шаповал В.** (2024). Біотопи долини річки Дніпра до створення та після зникнення Каховського водосховища. *Вісті Біосферного заповідника «Асканія-Нова»*, 26. С.57-67. Available at: https://doi.org/10.53904/1682-2374/2024-26/4.

The study combines field surveys conducted during the 2023–2024 growing seasons on the exposed bed of the former Kakhovka Reservoir with historical sources to reconstruct pre-flooding biotopes of the Dnipro River valley. Six main groups comprising 36 biotope types were identified across different periods: at least 32 types existed before the reservoir was created, 12 types formed after its disappearance (observed in 2023–2024), and at least five types appear to be new to the area. The results clarify the processes of natural succession following the dam's destruction and enable forecasts of further biotope development on the former reservoir lands; no explicit management recommendations are stated beyond the value of continued monitoring of these successional dynamics.

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(IN ALPHABETICAL ORDER)

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