Fostering Danube Sediment Restoration in the Danube River Basin – DANSER project

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The most international river basin worldwide, the Danube River Basin, encompasses a diverse social, historic, economic, and cultural heritage as well as a vibrant biodiversity: a mosaic of aquatic and terrestrial habitats, floodplains and ecotone areas shelter numerous species, many of them rare or endangered at European or global level.

Sediments represent a key environmental component supporting the aquatic biodiversity by playing multiple roles, from defining the shape of ecosystems, taking active part in the biogeochemical cycles of nutrients, influencing water quality or provisioning habitats for billions of organisms (e.g. bacteria, macrophytes, benthic invertebrates and fish) (Sandu et al., 2025). In addition, sediments are essential for multiple human activities such as water management, flood and coastal protection or navigation (Apitz, 2012).

Many European wetlands experience negative changes due to the substantial reduction of natural hydrodynamic conditions (Schindler et al., 2016). Increased sedimentation and long-term low water levels, driven by climate change and anthropogenic impacts, have been observed in many river systems, leading to a dramatic loss of biodiversity, especially among sensitive species dependent on habitat availability during high and low water levels (Poff et al., 1997). In the Danube River Basin, anthropogenic changes, including dam construction, gravel exploitation, channelization, embankments, dikes and land use change have significantly altered the sediment balance, affecting sediment input to the adjacent floodplains and downstream ecosystems and leading to various impacts, such as river incision downstream the dams, problems for navigation, coastal erosion and impaired biodiversity.

To address some of these issues and foster sustainable sediment management in the Danube River Basin, the DANSER project (DANube SEdiment Restoration: towards deployment and upscaling of sustainable sediment management across the Danube River Basin), running between 2025-2028 and funded by Horizon Europe program, aims to apply several innovative and holistic solutions in selected sites comprising inter alia mapping of fluvial processes, sediment transport modelling, sediment budget analysis, investigating river-side arms connectivity and river-groundwater dynamics as well as the complex interrelationships with biodiversity. The project builds upon extensive knowledge acquired from previous sediment related projects and initiatives (SIMONA, Danube Sediment), while creating synergies with ongoing projects (e.g.: SUNDANSE, iNNO SED, DanubeSediment_Q2) and aims to enhance its contribution to the EU Digital Twin and to the EU Mission 'Restore our Ocean and Waters'. It aims to foster understanding of mechanisms governing sediment processes in the investigated sites, to identify suitable measures to be applied at the local level for sustainable sediment management and to increase cooperation with local stakeholders to promote the implementation of selected measures (*fig.1*)

From a global policy perspective, the project will contribute to several UN Sustainable Development Goals, such as SDG6 – Clean Water and Sanitation, SDG11 - Sustainable Cities and Communities, SDG13 - Climate Action, SDG14 - Life Below Water, SDG15 - Life on Land and SDG17 - Partnerships for the Goals. From a European perspective, the project will contribute to the implementation of EU water, flood protection and biodiversity policies, in particular the Water Framework Directive, the Floods Directive, the Green Deal, the Nature Restoration Law and the EU Biodiversity Strategy 2030.

Three Innovative Action DEMOs form the backbone of the DANSER project, where each DEMO will include pilot (actual intervention, real action) and sibling sites (where know-how will be used for complementary activities). These DEMO areas are located in the Upper, Middle and Lower Danube and are briefly presented below.

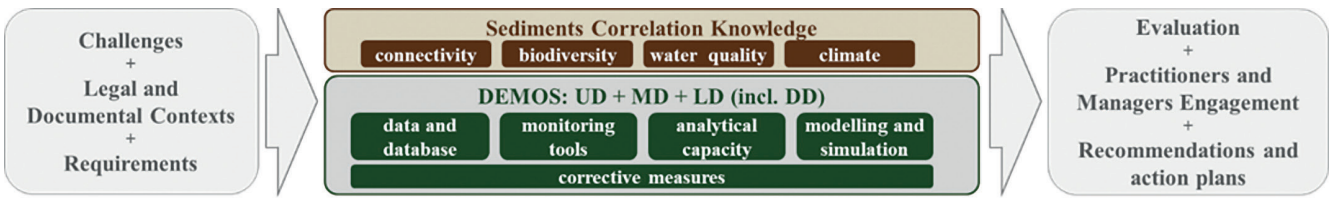

Figure 1. DANSER focus

Figure 2. Free-flowing section of the Danube (Donau-Auen Nationalpark) between Vienna and Bratislava (Photo: Nationalpark Donau-Auen/Kovacs, 2013)

DEMO activities in the Upper Danube

Location: National Park Donau-Auen, Wachau, Morava mouth, Traisen mouth

The Danube section between Vienna and Bratislava (*fig. 2*) is one of the few free-flowing river sections in the Upper Danube, hosting a high biodiversity. However, excessive downcutting of the main channel and aggradation of sediments in the floodplains are currently reducing the lateral connectivity between the main arm and floodplain waterbodies, accelerating the conversion of aquatic to terrestrial ecosystems. To stop this trend, different management strategies have been implemented over the past decades, such as side arm reconnection, optimised bedload management, and riprap removal. To create a holistic picture of the riverscape evolution, a multi-disciplinary approach will be followed by combining sedimentary archives analysis, spatio-temporal mapping, hydromorphological modelling, and hydrological and habitat-related connectivity models, to understand human interventions on river morphology, sediment dynamics and biodiversity on the local to regional scale.

The activities foreseen to be developed at these sites encompass:

- Establishing a best practice template for sustainable sediment management by characterisation and quantification of sediment dynamics and water level fluctuations as a function of hydro-geomorphic system change and human interventions beyond the times of direct observation.
- Regressive iterative (historical) mapping of the area between Vienna and Bratislava to reconstruct channel evolution at several points in time in response to human interventions (river channelization, hydropower plants, maintenance dredging for inland navigation, renaturation and removal of river-bank stabilization).
- Hydromorphological and sediment connectivity modelling
- Biodiversity analysis and correlation of endangered and indicator species, considering changes due to human interventions and connectivity changes, taking into account network approaches and establishing monitoring of indicator groups

DEMO activities in the Middle Danube

Location: Terezino Polje, Drava River; Kopački Rit Nature Park

The Drava River system is of great importance for the local community due to its geographic position and multiple ecosystem services provided. In the last decade, climate change, anthropogenic activities and ecological succession have influenced this area, changing its original conditions and affecting particularly the connectivity of wetlands and floodplains of this system with the main river and water source. To improve their reconnection, the sedimentation regime, water quality and biodiversity, the activities planned at these sites include:

- Monitoring of key habitat parameters (sedimentation/erosion, water/groundwater levels, water quality/quantity) and biodiversity
- Characterization of spatio-temporal changes and dynamics of the water connectivity between the river/canal bed and hydrological restoration works

- Use of nature-based solutions to improve wetland biodiversity, with a particular focus on fish and waterfowl species
- Enhance biodiversity protection and conservation by wetland ecosystem restoration and increased community involvement

The DANSER project will implement its DEMO activities at two pilot sites in the Middle Danube region: the Terezino Polje site along the Drava River in northern Croatia and the Kopački Rit Nature Park along the Danube River. A recent field survey of the Drava River's oxbow channel Gradac near Terezino Polje revealed that the channel has become inactive due to progressive sediment infilling, primarily as a result of long-standing hydrotechnical activities (*fig.3*). Similarly, previous studies conducted in Kopački Rit have indicated increased sedimentation throughout the park, which could potentially have negative impacts on biodiversity as well as on tourism and local economic activities within the nature park. These findings confirm that such degradation processes are widespread and require systematic monitoring and management.

Effective monitoring and the development of management guidelines for these areas are essential, as past research has shown the cumulative impacts of human activity and climate change such as accelerated sedimentation in channels, reduction or alteration of water surfaces, long-term low water levels, excessive vegetation growth, loss of biodiversity, the spread of invasive species, and significant morphological changes – all contributing to the disruption of the ecosystem's natural balance.

Planned field activities include using a drilling rig for undisturbed sediment sampling, along with geophysical surveys – bathymetry, subbottom profiling, and LiDAR – complemented by biodiversity assessments. These advanced, non-invasive methods will provide a comprehensive understanding of current conditions. The project's innovation lies in combining these techniques with geological, hydromorphological, and ecological data, enhanced by numerical modelling and a real-time dashboard to support targeted restoration efforts. Communication and outreach will involve stakeholder engagement, educational dissemination, and visual documentation to ensure broad public awareness and participation.

DEMO activities in the Lower Danube

Location: Iron Gates, Belene Island, Friendship Bridge, Danube Delta

The activities planned at these sites comprise:

- Comprehensive overview of upstream land management and inventory of sediment resources to identify sustainable solutions for minimizing soil erosion
- Exploring different strategies for sediment replenishment to reduce the negative effects on biodiversity
- Investigating dam management strategies to facilitate the passage of sediments and monitor the restoration of affected habitats

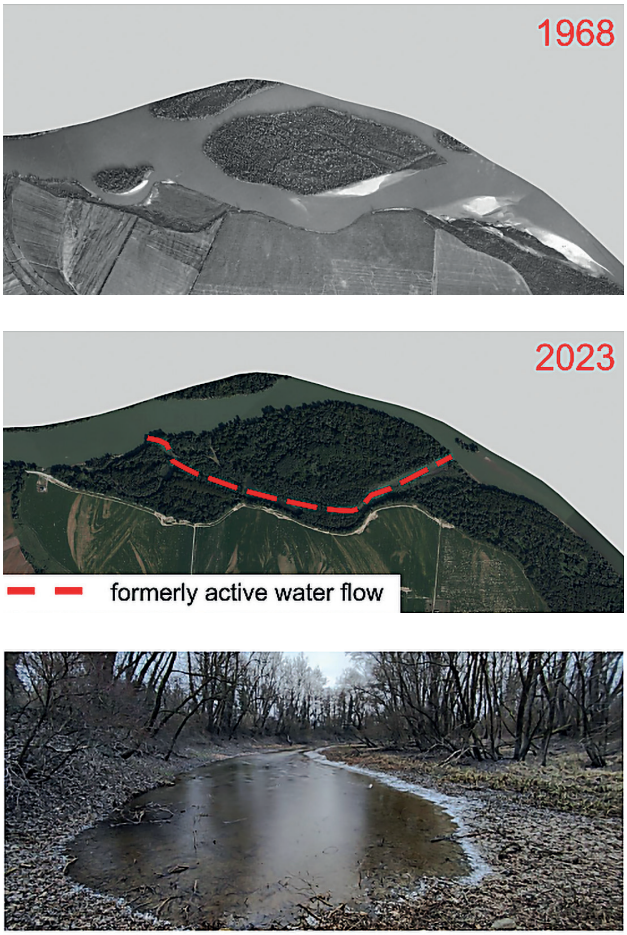

Figure 3. The previous and current state of the Gradac oxbow in Terezino Polje (adapted from Croatian Waters)

- Investigate the connectivity between surface water and groundwater to understand the water circulation pattern and sediment transport dynamics
- Improving the knowledge base regarding sediment management from multi-connectivity restoration works
- Foster community engagement for the implementation of sustainable sediment management measures.

DANSER innovative activities

DANSER's innovation package couples state-of-the-art science with hands-on river-basin governance, aiming that new datasets, model- or pilot actions feed into the decision-making process at the three Danube DEMO sites and their sister locations. Several novelty elements will be in focus, such as:

- Integrated riverscape 'time-machine': dated sediment cores, historical maps and LiDAR surveys will be combined to reconstruct more than a century of channel-floodplain evolution, highlighting connectivity break-points that need to be tackled by restoration activities.
- 3-D Site-evolution Models: drill-hole stratigraphy, geophysical sonar and UAV bathymetry are merged into interactive tools that managers can query in real time to test

different options such as cutoff reconnection or gravel replenishment.

- Basin-linked Hydro-morphodynamic Toolbox: physics-based and AI tools will be combined to facilitate planners in comparing restoration scenarios across all pilot and sibling sites quickly.
- Digital Sediment Portal & Citizen Observatory: web dashboards will emphasize monitoring data and model outputs, while a low-threshold Sediment Café app will provide the residents the possibility to upload water transparency readings that loop straight back into the models for quality-checked assessment.
- Transnational Sediment Task Force & Living Labs: practitioners, authorities and NGOs co-design measures in iterative workshops, fostering the implementation of Danube Sediment Management Guidance from paper to riverbank and aligning with the requirements of EU Nature Restoration Law.
- Nature-based Connectivity Solutions: side-arm reopening, floodplain lowering and bed-load replenishment are piloted in the Lower, Middle and Upper Danube, generating in-situ evidence that restored sediment regimes boost both biodiversity and climate resilience.
- Open-source Training Suite: micro-credential courses, hackathons and summer schools transfer the toolbox to young professionals, ensuring the know-how spreads beyond the consortium to water authorities and engineering consultancies.
- Data-rich link to the EU Digital Twin of the Ocean: harmonized datasets, uncertainty metadata and code containers are delivered through EMODnet nodes, standing ready for integration into Europe's wider ocean-river digital twin ecosystem.

Together, these activities will deliver ready-to-replicate blueprints for two additional European biogeographic regions and provide the knowledge backbone for a Danube Sediment Observatory that will continue informing Mission Ocean and regional RBP targets long after the project ends.

Communication activities

Effective communication is essential for ensuring the success and long-term impact of the DANSER project. A comprehensive and integrated communication strategy has been developed to disseminate project results, engage local communities, and foster collaboration among stakeholders across the Danube River Basin. The project will leverage a variety of channels and tools to ensure that its objectives reach and resonate with a wide range of audiences, such as:

- Branding and Communication Materials: DANSER will adopt an engaging and consistent branding strategy, including the production of printed and digital materials, tailored to local contexts and available in multiple languages. These materials will ensure that stakeholders at each site are well-informed and aligned with the project's goals.
- Project Website and Social Media: A dedicated website will serve as the central hub for all project-related information. It will feature comprehensive resources, including reports, research findings, and key documents, accessible to the public. In addition, DANSER will engage audiences through social media platforms like LinkedIn and Facebook, providing updates, sharing progress, and fostering online discussions with stakeholders, policymakers, and the general public.
- Publications and Scientific Outreach: DANSER will publish its findings in reputable peer-reviewed journals and sectoral magazines. Project results will also be presented at key conferences to ensure that the insights gained from the project are integrated into broader discussions on sediment restoration and environmental management.
- Public Events and Webinars will be central to the communication strategy, providing platforms for direct engagement with stakeholders, the wider public, and the scientific community. These forums will be designed to present results, exchange best practices, and discuss innovative solutions for sediment management across the Danube River Basin.
- Educational Outreach and Summer Schools: DANSER is committed to raising environmental awareness, particularly among young people. Educational materials, such as children's books and colouring books focused on sediment importance for the aquatic communities, will be made available online. These resources will offer an interactive and engaging way for younger audiences to learn about the importance of sediment restoration. Additionally, summer schools will be organized to educate students about sediment dynamics and biodiversity, fostering the next generation of experts in the field.
- Community and Stakeholder Engagement: A key element of DANSER's communication strategy is the establishment of a Community of Practice (CoP), bringing together stakeholders from various sectors – local communities, policy-makers, researchers, and environmental organizations – to share knowledge and experiences. The CoP will also support the development of collaborative solutions to sediment management and contribute to the broader objectives of the EU Mission 'Restore our Ocean and Waters'. Furthermore, citizen science initiatives will empower local communities to participate in water transparency monitoring through an easy-to-use app.
- Synergies with Parallel Projects: Collaboration is central to DANSER's approach. The project will work closely with other ongoing sediment-related initiatives, sharing knowledge, enhancing synergies, and amplifying the impact of its activities. DANSER will also contribute to the EU Digital

Figure 4. DEMO Pilot site in the Danube Delta

Twin of the Ocean initiative, supporting efforts to digitize and model sediment processes on a larger scale.

Key takeaway message

By placing sediment at the centre of river-basin planning, DANSER shows that restoring the Danube's 'moving bed' is not a niche technical exercise but a keystone for biodiversity, climate resilience and local prosperity. The three DEMO sites will illustrate how science-guided, community-owned measures can move whole reaches from diagnosis to action within a single project cycle. Key messages are briefly summarised below:

- What DANSER delivers on the ground: Pilot side-arm reopenings, gravel re-charges and floodplain lowering begin reestablishing natural transport corridors, cutting erosion hotspots and boosting habitat complexity. Early model runs point to a 10–15% drop in sediment deficit at the Iron Gates reach and measurable gains of in-stream diversity once replenishment starts in 2026.
- Broader impacts unlocked: Environmental: healthier flow of sediments that underpins endangered fish nurseries and riparian wetlands. Social: Living Labs and 'Sediment Café' workshops grow a basin-wide constituency of residents who can read turbidity trends and lobby for best practice. Economic: smoother navigation channels reduce dredging costs, while more resilient floodplains lower damage bills and open new eco-tourism niches.
- Scaling beyond the Danube: A suite of open-source tools, micro-credential courses and a repository of Key Exploitable Results will be packaged for at least six Associated Regions and two further EU biogeographic zones, fostering the Mission Ocean lighthouse knowledge transfer.

DANSER thus paves the way for the successful implementation of sustainable sediment practices: data-driven measures restore local sediment balance; visible benefits mobilize community and policy support; and the resulting know-how feeds Europe's Digital Twin of the Ocean, ensuring that the Danube system continues to act as a living laboratory for river restoration long after 2028.

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