14th International SedNet Conference

Healthy Sediments – Session 2: Sediment Flows

Analysis of sediment transport in Ebro Delta channels to optimise the efficiency of the irrigation network in diverting sediment to flood-prone areas under coastal retreat and land subsidence

Josep Coma Romera – Integrated Water Resources Engineer

Madrid, 7th October 2025

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GEOTOPSA
Geophysics and civil engineering consultancy

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Agència Catalana de l'Aigua
Finançat per la Unió Europea NextGenerationEU
Plan de Recuperación, Transformación y Resiliencia
Next Generation Catalunya
Generalitat de Catalunya

GENERAL INFORMATION

- **Nature:** Research project
- **Funding:** NextGenerationEU
- **Client:** Agència Catalana de l'Aigua
- **End beneficiaries:** Local irrigation-farming communities
- **Consortium:** HAEDES BV + Flumen Institute (UPC BarcelonaTech) + GEOTOPSA
- **Duration:** 2 years (June 2024 – June 2026)
- **Focus** on irrigation network supplying rice fields
- ***(~80Km) 2 main supply channels (start: ~30km upstream Delta)***
- ***(92Km) 5 conveyance channels "acequias principales"***
- ***(42Km) small irrigation channels to rice fields (concrete-lined)***

Funded by the European Union
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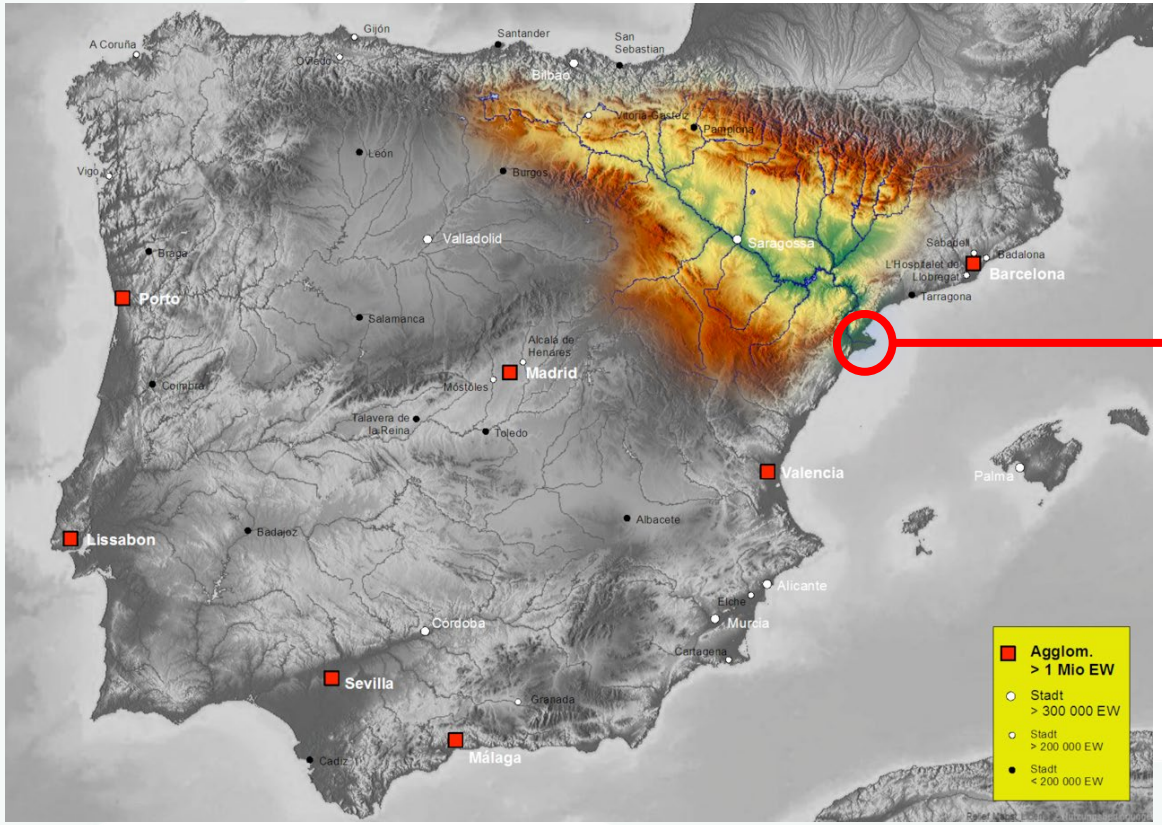
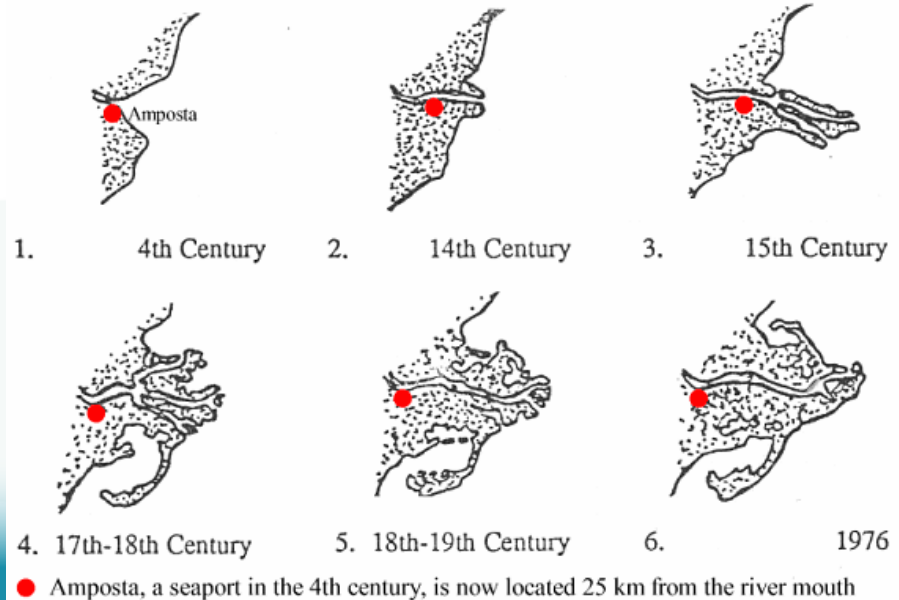
SETTING THE CONTEXT: THE EBRO DELTA

A dynamic bio-cultural landscape under threat from sediment reduction and climate change



source: 2025, http://www.maps-for-free.com

source: 2024, ESA - Earth from Space: The Ebro Delta



source: 2025, Barcelona Field Studies Centre S.L. geographyfieldwork.com/Ebro-Delta-Storm-Gloria.htm

SETTING THE CONTEXT: THE EBRO DELTA

Tree-shaped gravity-fed irrigation network designed for paddy rice cultivation

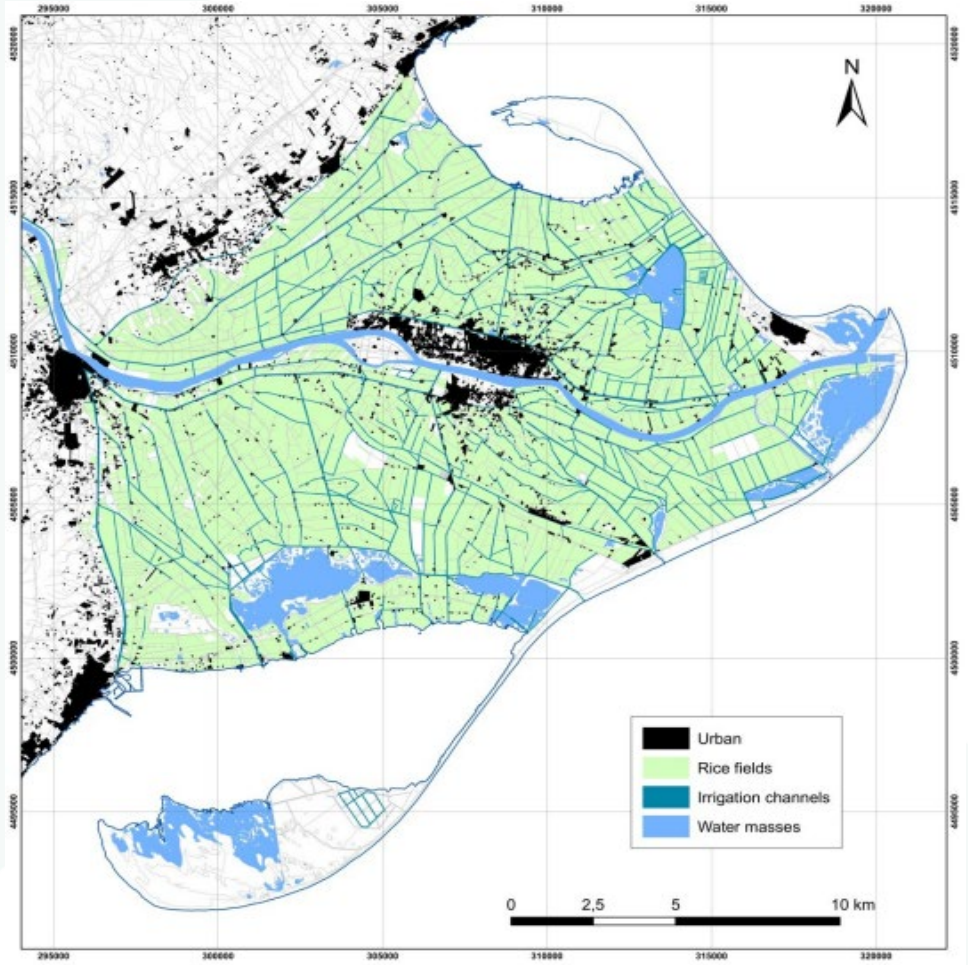
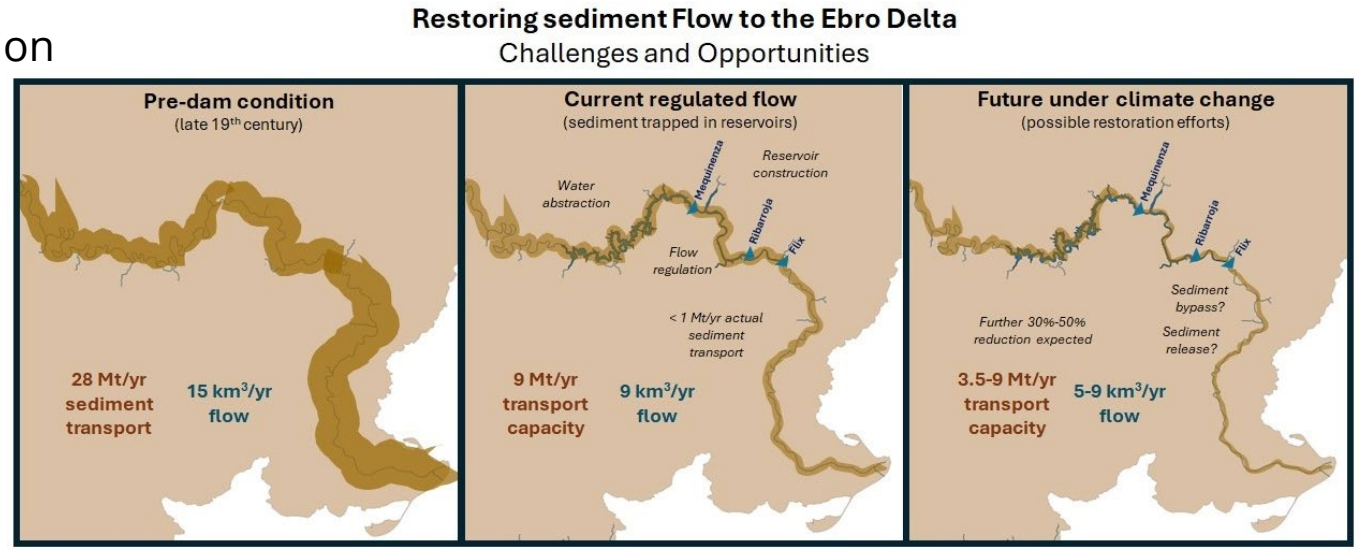


Figure 77. Reclassification of Ebro Delta soil uses, indicating Urban soil rice fiels irrigation channels and water masses, based on the Land Cover Map of Catalonia (CREAF, 2009).

source: 2025, Spain's official tourism website

PROJECT MOTIVATION AND RESEARCH QUESTIONS

- **Pressures:** **Land loss** due to
  - Coastal regression, coastal flooding, and salt intrusion
- **Drivers:**
  - Natural sediment flow disrupted (trapped in reservoirs ~200 km upstream)
  - Natural deltaic subsidence (1-3 mm/year)
  - Sea-level rise due to climate change
- **Impacts:**
  - Threats to agriculture, tourism, industry, and delta ecosystems
- **Responses & Potential Solutions (Ebro River Authority)**
  - Controlled floods (1–2 events/year, coordinated with dam)
  - Sediment bypass at Riba-Roja reservoir (under study)
  - Optimized irrigation network operation to mobilize sed



- Significant decline in flow and sediment transport capacity due to anthropogenic interventions
- Flow conditions still offer sufficient capacity to transport more sediment than is currently available
- Enhancing sediment supply could be effective if synchronized with appropriate flow management

source: Martin-Carrasco, F.; Santillán, D.; López-Gómez, D.; Iglesias, A.; Garrote, L. Sediment Transport Constraints for Restoration of the Ebro Delta. Water 2025, 17, 1620. https://doi.org/10.3390/w17111620

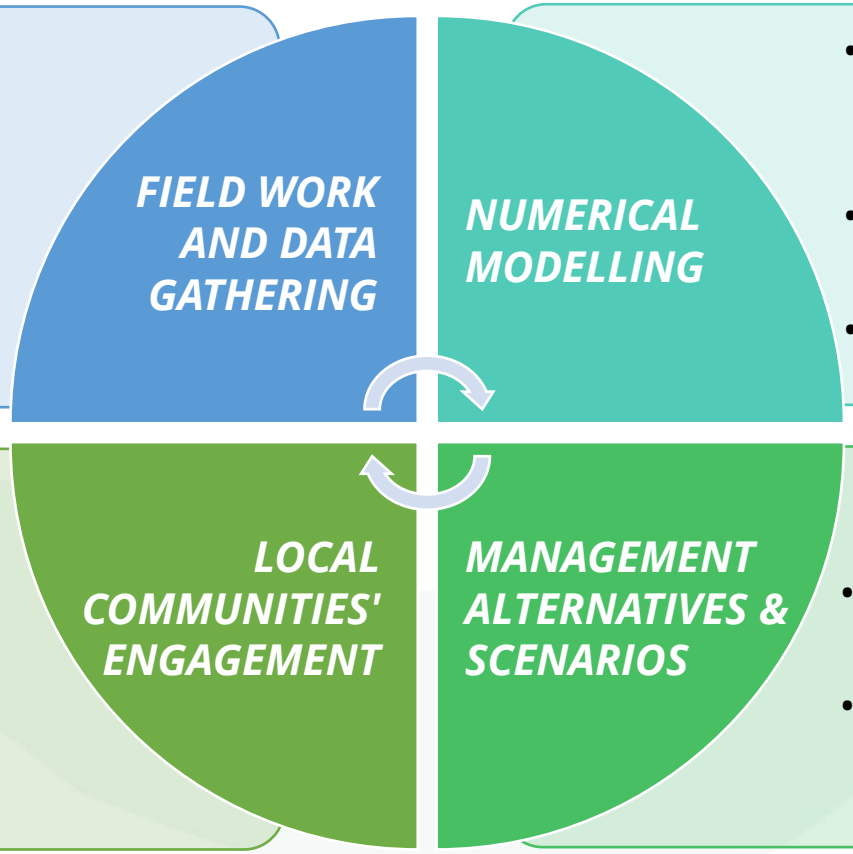
RESEARCH QUESTIONS

- ***What is the sediment transport capacity of the Ebro Delta irrigation network?***
- ***How should the network be managed to efficiently transfer sediments from the river to the delta plain?***

OBJECTIVES AND METHODOLOGY

1. ***Assess sediment transport capacity of the irrigation network (hydro-sedimentary modelling).***
2. ***Estimate sediment volumes transferable from river to delta plain under varying flow, concentration & D50***
3. ***Define irrigation network management strategies to direct sediment to the most vulnerable areas.***

- Channel topography surveys.
- Sediment injection experiment.
- Data during 3 controlled floods.



- Adaptation of IBER model → channel flow + sed. suspension transport
- High-resolution in terms of wide range of channel geometries.
- Junctions in tree-shaped network

- Field visits & on-site meetings.
- End-product: tools to support decisions on irrigation network operation.

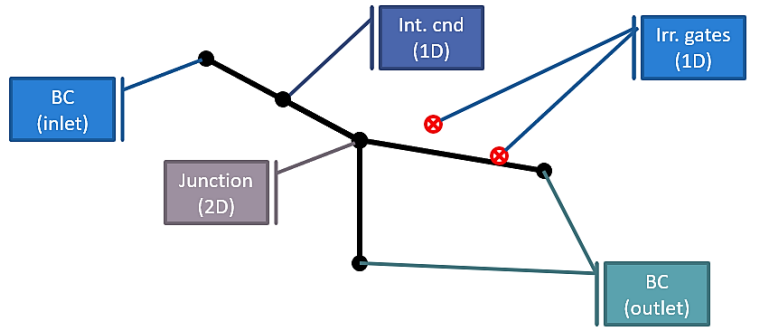
- Simulation of irrigation network operation.
- Identification of high-sedimentation points→reduce maintenance costs.

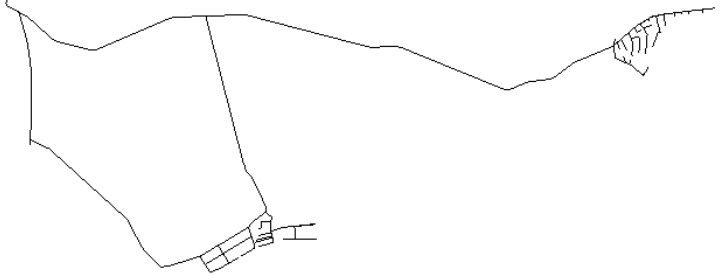
NUMERICAL MODELLING WITH IBER1D HYDRO-SED MODEL

- Adapted from IBER 1D urban drainage module
→ open-channel flow + suspended sediment transport (1D).
- **Hydrodynamics:** solves depth-averaged 1D Saint-Venant Eqs.
- **Sediment transport:** (coupled with hydrodynamics) depth-averaged convection–diffusion Eqs.
- **Numerical solver:** finite volume method, first-order scheme.
- **Project-specific model characteristics/adaptations:**
  - 200 km of channels modelled, covering > 4,000 ha irrigated area.
  - Channel junctions: hybrid approach – 1D network connected via 2D domains at junctions.
  - 1,200 irrigation gates integrated (geo-located & linked to nearest channel).
  - Wide range of cross-sections dimensions and geometries: triangular, rectangular, trapezoidal.

source: www.iberaula.es
Model reference: Bladé et al. (2014)

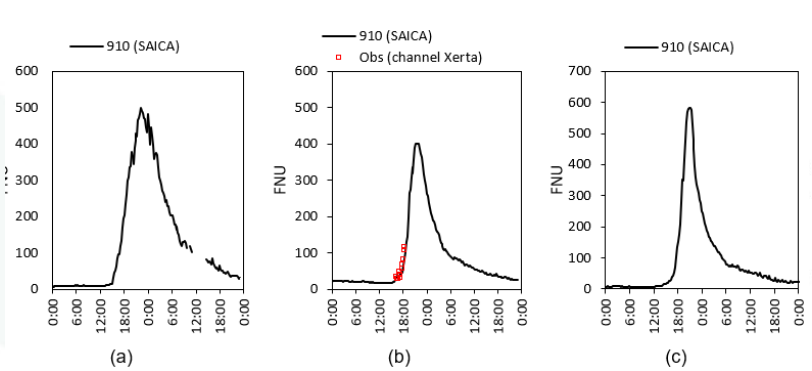
Development of a free surface 1D/2D model integrated in a GUI

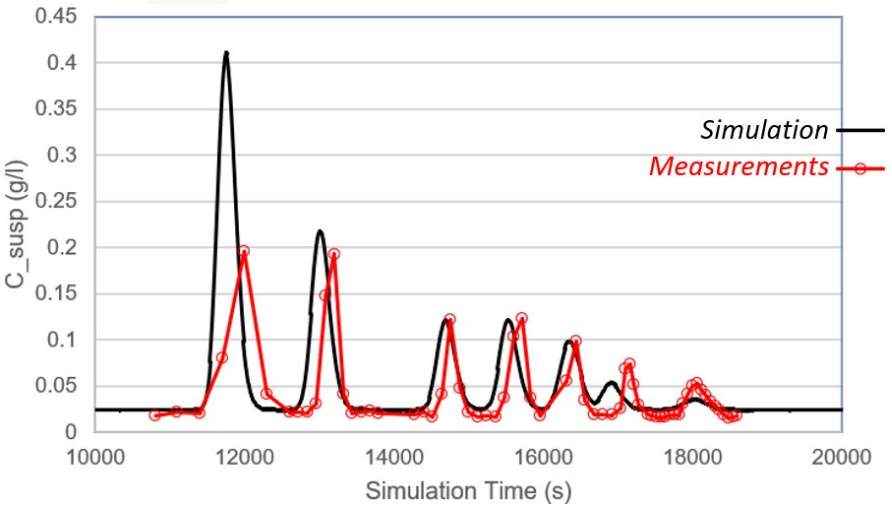




DATA GATHERING AND FIELD WORK

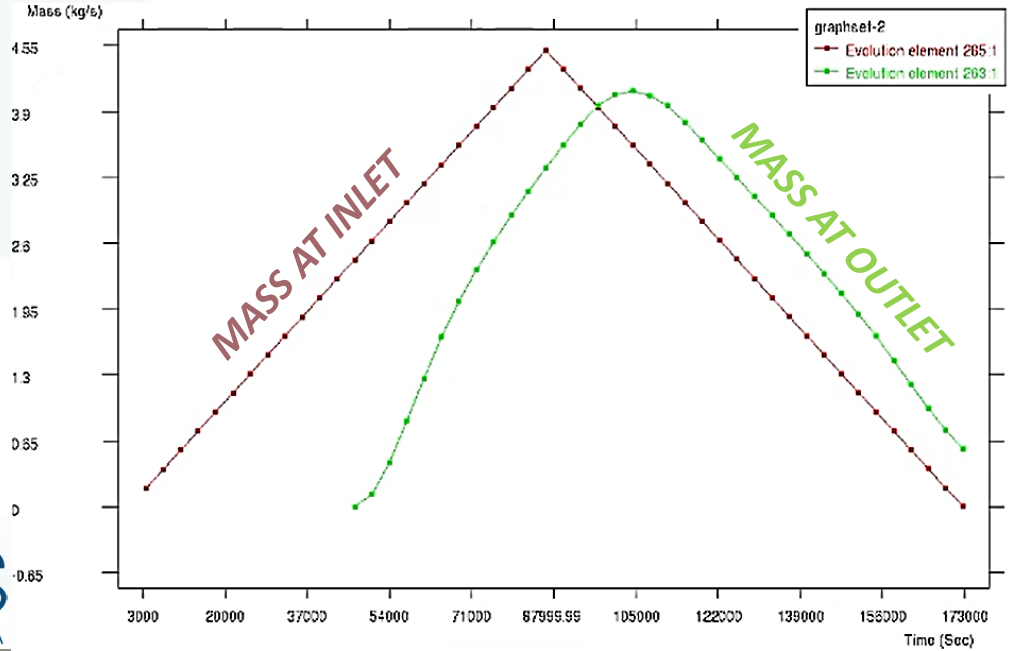
- **Channel Geometry**
  - Topography surveys: 75 km of channels
- **Sediment Injection Experiment**
  - Purpose: model verification
  - Measure: turbidity → concentration
  - Outcome: correct peak representation
- **Controlled Floods (CHE, 3 events)**
  a) 30/01/2024: Qp = 1,600 m³/s
  b) 21/11/2024: Qp = 1,400 m³/s
  c) 07/05/2025: Qp = 1,500 m³/s
- **Sediment Characteristics**
  - Grain size: < 0.150 mm
  - Relatively cohesive (>80% organic)

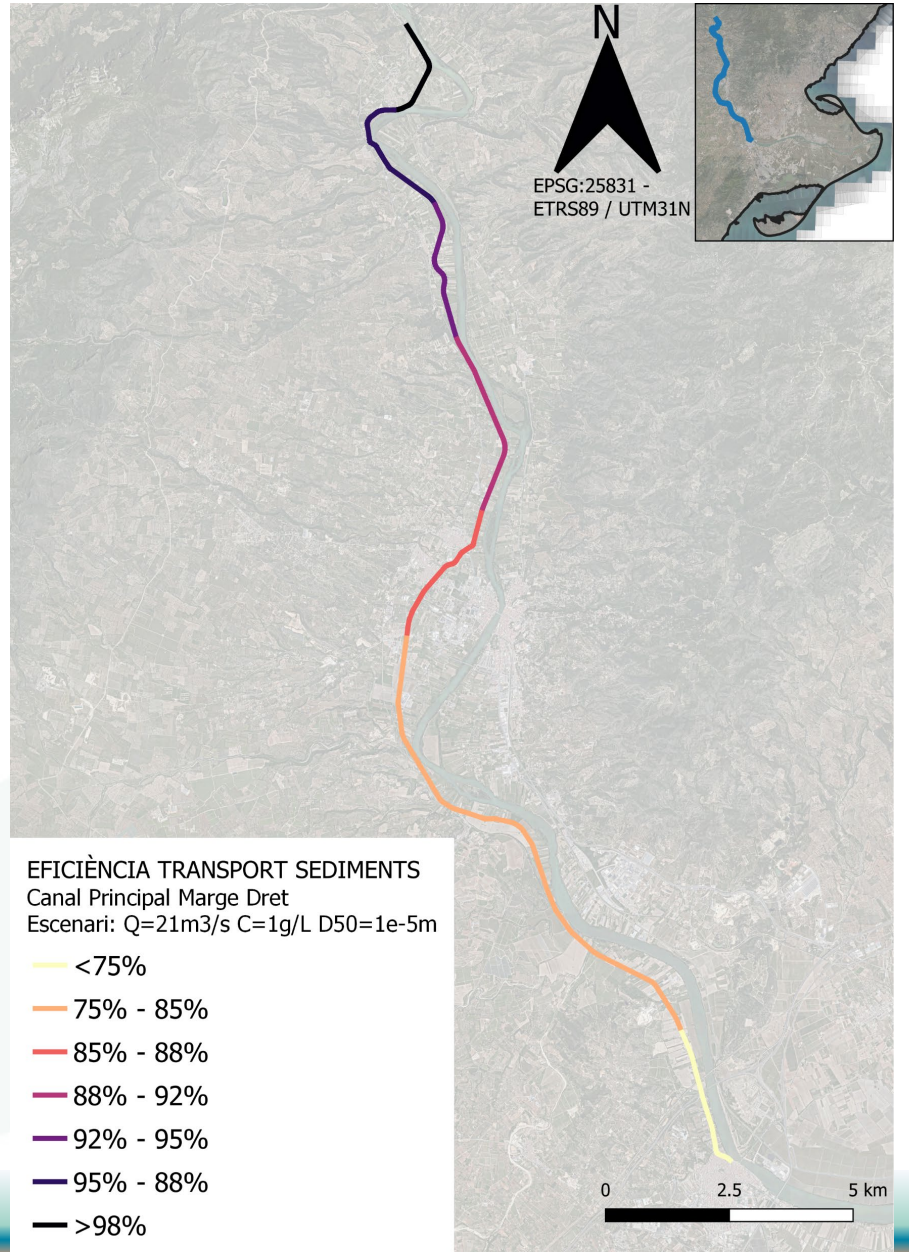




BASELINE SCENARIOS: TEORETICAL TRANSPORT EFFICIENCY

- **Efficiency = Mass transported at outlet / Mass at inlet**
- **Scenarios: synthetic approach**
  - **Flow (Q):**
    - Supply channels 28 / 21 m³/s (Right) • 19 / 17 m³/s (Left)
    - Conveyance: Qmax (no overflow) • 50% Qmax
  - **Sediment concentration (C):**
    - 0.3 g/L (observed) • 1.0 g/L (hypothetical)
  - **Grain size (d_{50}):**
    - 0.01 mm (field ref.) → 0.09 mm (test limit)





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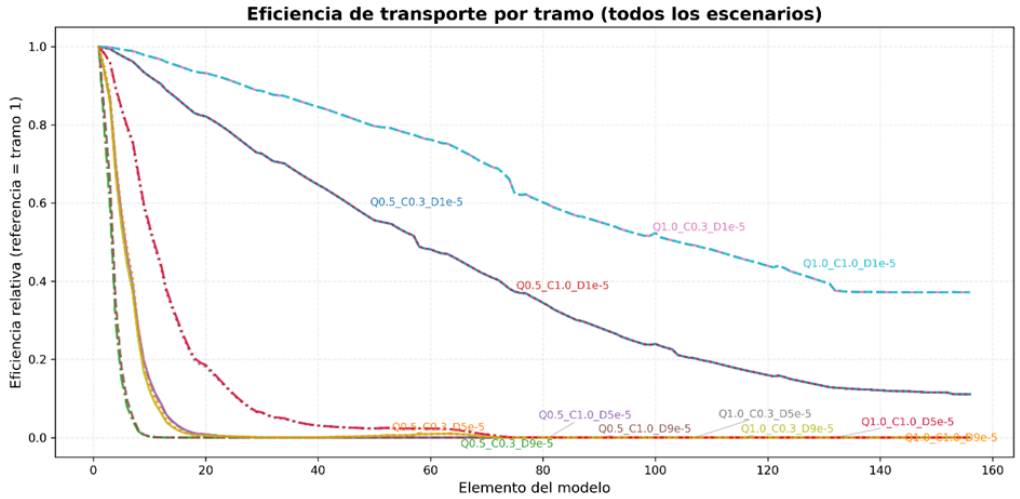
SEDIMENT TRANSPORT EFFICIENCY: KEY FINDINGS

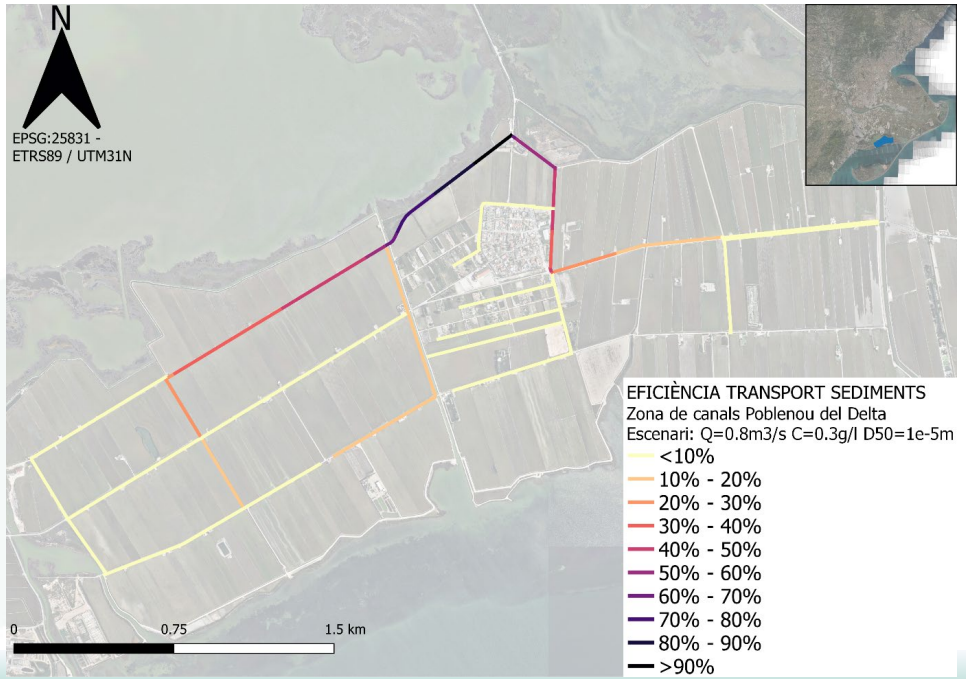
- **Main supply channels ("canales principaes")**
  - High sed transport capacity - theoretical efficiency ~70%
  - Flow (Q) → decisive factor
  - Particle size (d_{50} = 0.01–0.09 mm) → transported
  - Limited effect of slopes or minor geometry changes

- **Conveyance channels ("acequias principales")**
  - Grain size (D50) → decisive factor
  - Coarser particles (d_{50} ≥ 0.05 mm) → deposit early, even at Qmax
  - Straight channels → high efficiency
  - Complex geometries (bends, bifurcations, counter-slopes) → deposition

- **Small irrigation channels to rice fields**
  - Low sed transport capacity
  - Hydraulic structures further reduce transport
  - Sediments rarely reach them

  → upstream losses + weak inflows at small derivations





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SOCIAL DIMENSION IN PRACTICE

Hands-on engagement with rice producers and farmers: key to understand the challenges on current irrigation management and develop solutions that are both practical and beneficial for the community

TOOLS FOR INFORMED IRRIGATION NETWORK OPERATION

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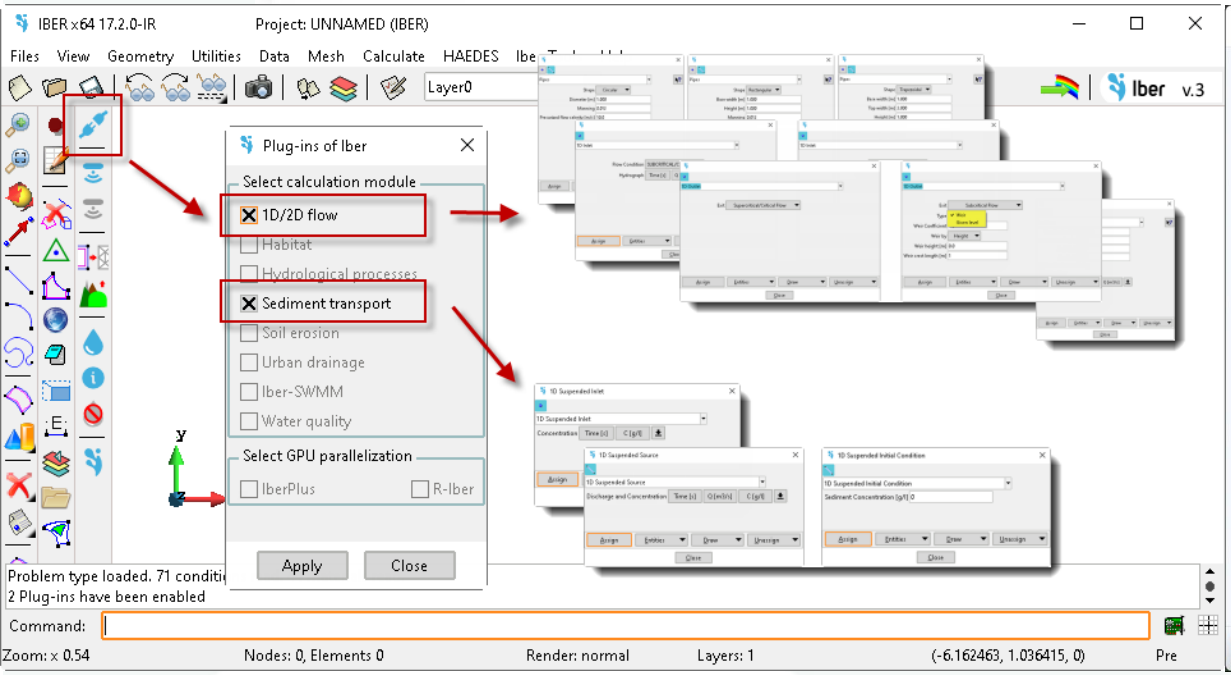

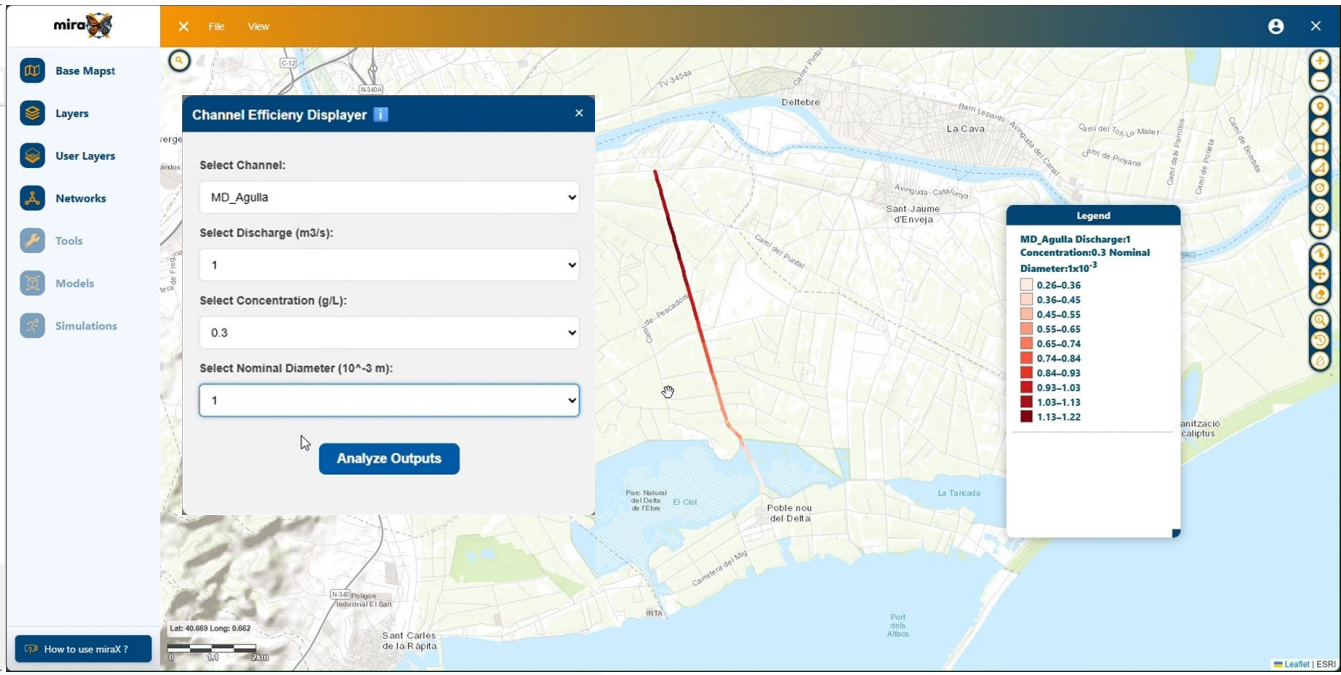

Support Decision-making for local irrigator communities:

- Reduce maintenance costs through lower sediment removal requirements.
- Improve hydraulic management to direct sediments toward vulnerable areas.

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FUTURE STEPS OF THE PROJECT

- Identify irrigation network high-sedimentation points
  - Corrective measures and cost/benefit estimation
- Rice parcel-level analysis: estimate sediment volumes to offset subsidence and sea-level rise
- Deploy the model for scenario simulations:
  - Controlled floods
  - Irrigation gate management
  - Hypothetical increased sediment concentrations via reservoir bypass
- Develop a channel hydraulic operational strategy: optimize flows to route sediment to vulnerable parcels
- Validation & knowledge transfer:
  - Present results and validate assumptions with irrigators
  - Deploy modelling tool for operational decision support

TAKE-HOME MESSAGES

- Ebro Delta is a dynamic morphological system, vulnerable due to a disrupted natural hydrosedimentary regime → solutions are being considered.
- Paddy rice sector is threatened by land loss from sea-level rise, salinity, and subsidence.
- Extensive irrigation network of concrete-lined channels requiring annual sediment cleaning.
- Sediment characteristics: very fine (D50 < 0.15 mm); effectiveness for land restoration remains uncertain.
- Controlled floods: promising solution to mobilize trapped sediment in upstream reservoirs; channels can distribute sediments across the deltaic plain.
- Cross-sector collaboration between Ebro River Authority (CHE) + local irrigator communities + wetland protection entities.

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