BfG Federal Institute of Hydrology

BAW Federal Waterways Engineering and Research Institute

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Nature-Based Solutions for Bank Protection in Estuarine Waterways

Towards Best-Practice Guidance

ResiRiver Midterm Meeting

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Estuarine waterways in Germany



Challenges in estuarine waterways:

- Tidal fluctuations
- Limited space availabilty
- Ship-induced hydrodynamic loads

Bank protection that is as safe as necessary and as environmentally beneficial as possible.

Nature-based solutions for bank protection in estuaries

Nature-based solutions for bank protection as an alternative to riprap?

- **Factors limiting implementation** of nature-based solutions for bank protection (NbS-BP) in estuaries:
  - Limited technical guidance
  - Uncertainty in performance
  - Maintenance unpredictability
  - Planning and approval challenges

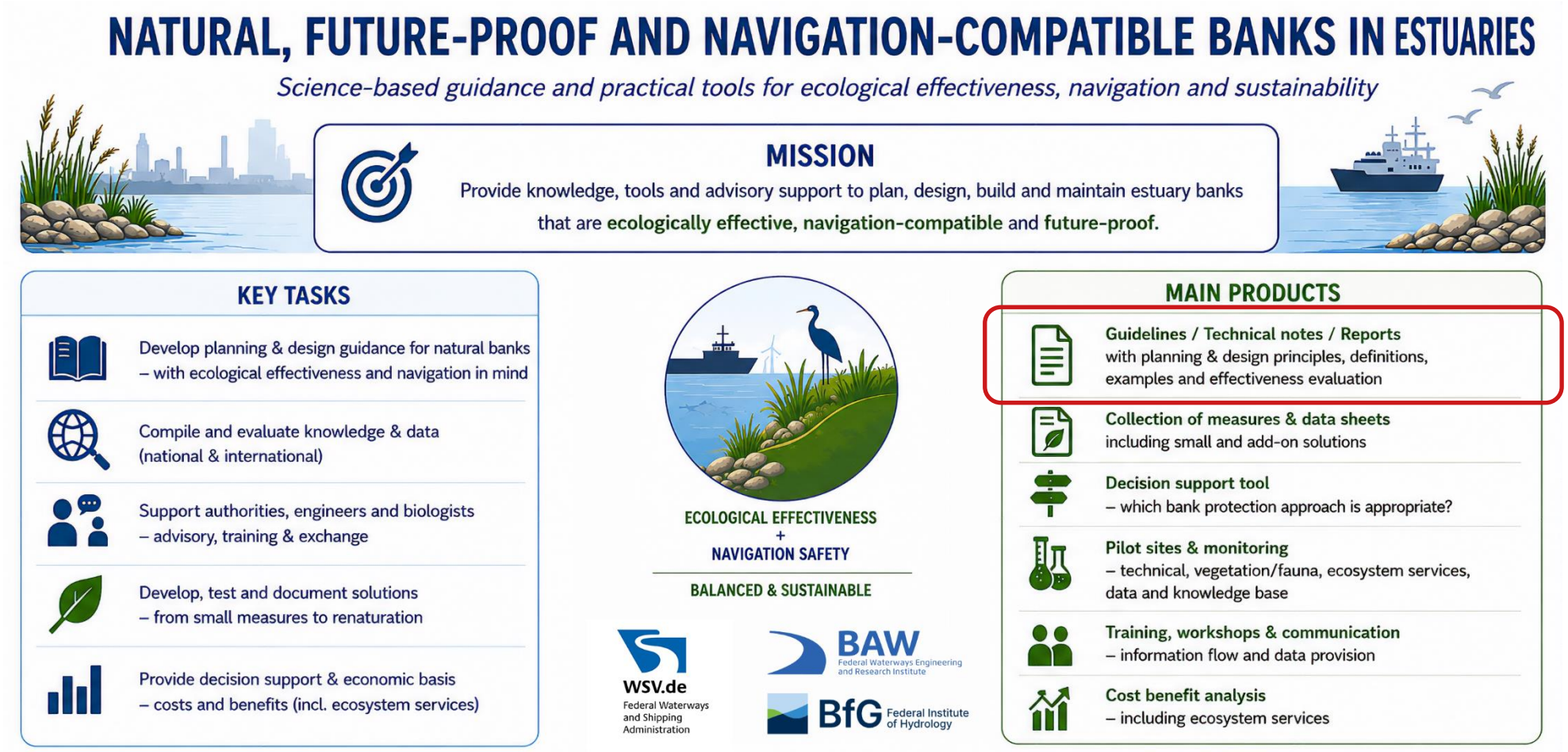

Natural bank development


Living measures


Dead wood measures


Structural improvement

Nature-based solutions for bank protection in estuaries



Collection of implemented measures









COLLECTION OF ALMOST 80 MEASURES









Collection of implemented measures

COLLECTION OF ALMOST 80 MEASURES

- Many NbS-BP measures already exist along the estuarine waterways*
  - Different functionalities
  - Different spatial extensions
  - Different settings
- **Experience is project- and site-specific!**



Living measures (8 %)



Dead wood measures (74 %)



Structural improvement (18 %)

**Available online: https://ufersicherung-baw-bfg.baw.de/aestuarbereich/en/massnahmen*

Schreiber et al. (under review): Nature-Based Bank Protection in Practice: Experiences from German Estuarine Waterways.

From individual projects to generalized measure types





DATA SHEETS





Development of technical data sheets

DATA SHEETS



- Data sheets of most commonly implemented types of measures
  - convert experience into **practice oriented actionable guidance**
  - support practitioners in planning and implementing

Content of data sheets

- **Overview**
  - Bank protection functionality
  - Advantages and disadvantages
- **Ecological benefit** for vegetation, fauna, ecosystem services, habitats
- **Range of applications**
- **Dimensioning and design**
- **Maintenance**
- **Examples**

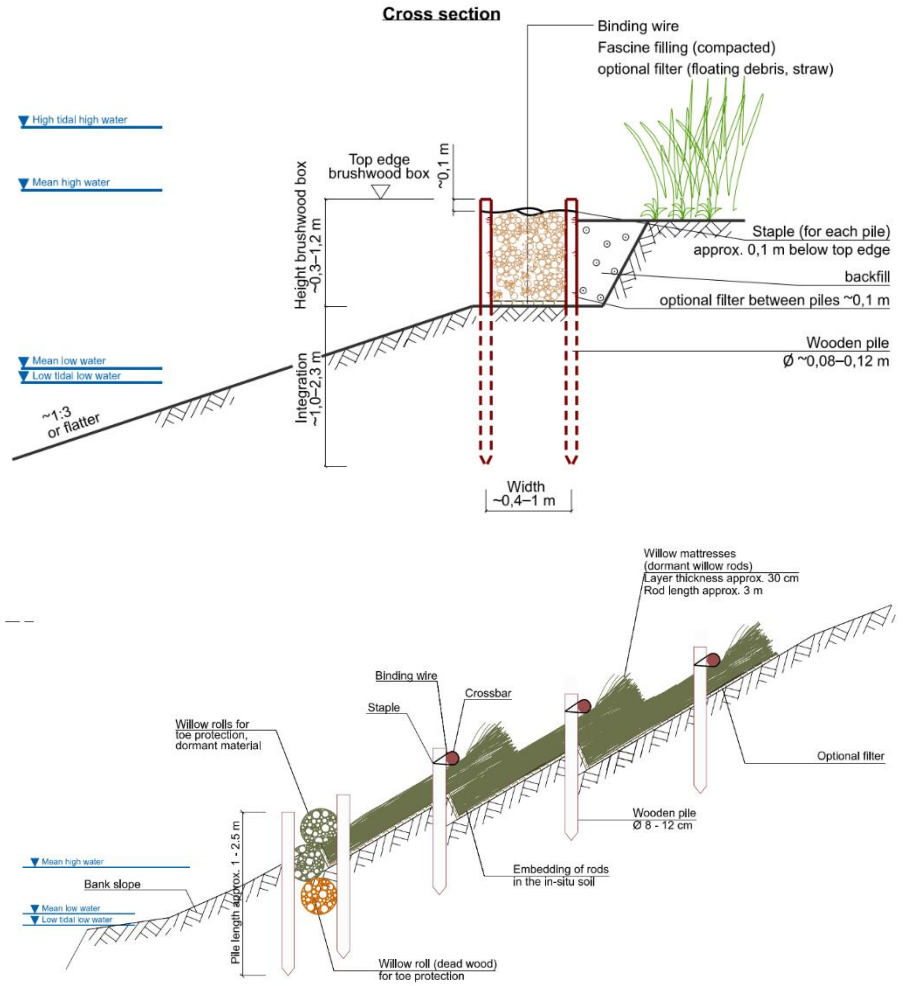
Available online: https://ufersicherung-baw-bfg.baw.de/aestuarbereich/en/arbeitshilfen/kennblaetter

Development of technical data sheets

DATA SHEETS

- Data sheets are as detailed as possible to be directly applicable:
  - E.g. detailed **material dimensions** (length, diameter, etc.)
  - **installation steps** and important considerations
  - **Technical drawings**
  - **Range of application** (e.g. suitable implementation height for different willow species)

Available online: https://ufersicherung-baw-bfg.baw.de/aestuarbereich/en/arbeitshilfen/kennblaetter

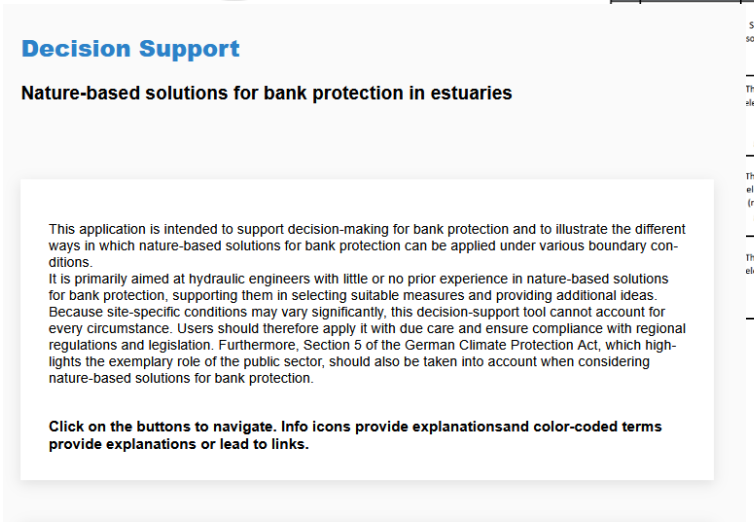


Technical drawings of brushwood box and willow mattress.

Decision support tool



- **User group**: primarily new hydraulic engineers with little experience in NbS-BP
- facilitate decision-making for bank protection
- highlight ways in NbS-BP can be used in a variety of ways under a wide range of boundary conditions



Decision Support

Nature-based solutions for bank protection in estuaries

This application is intended to support decision-making for bank protection and to illustrate the different ways in which nature-based solutions for bank protection can be applied under various boundary conditions.
It is primarily aimed at hydraulic engineers with little or no prior experience in nature-based solutions for bank protection, supporting them in selecting suitable measures and providing additional ideas. Because site-specific conditions may vary significantly, this decision-support tool cannot account for every circumstance. Users should therefore apply it with due care and ensure compliance with regional regulations and legislation. Furthermore, Section 5 of the German Climate Protection Act, which highlights the exemplary role of the public sector, should also be taken into account when considering nature-based solutions for bank protection.

Click on the buttons to navigate. Info icons provide explanationsand color-coded terms provide explanations or lead to links.

No.	Risk	Risk description	Probability of occurrence	Severity of potential damage		
			Unlikely = 0 % - 20 % Likely = 20 % - 75 % Very likely = 75 % - 100 %	minor	moderate	severe
		Surface erosion occurs due to soil conditions, bank slope, and the forces acting on it.	Unlikely	No	No	Yes
			Likely	No	Yes	Yes
			Very likely	No	Yes	Yes
		The absence of bank protection elements causes the soil to slide parallel to the slope (not relevant for embankment gradients flatter than 1:10).	Unlikely	No	No	Yes
			Likely	No	Yes*	Yes
			Very likely	No	Yes*	Yes
		The absence of bank protection elements causes a slope failure (not relevant for embankment gradients flatter than 1:10).	Unlikely	No	No	Yes
			Likely	No	Yes*	Yes
			Very likely	No	Yes*	Yes
		The absence of bank protection elements causes damage to the bank structure due to the impact of currents/waves.	Unlikely	No	No**	Yes**
			Likely	No	Yes**	Yes**
			Very likely	No	Yes**	Yes**

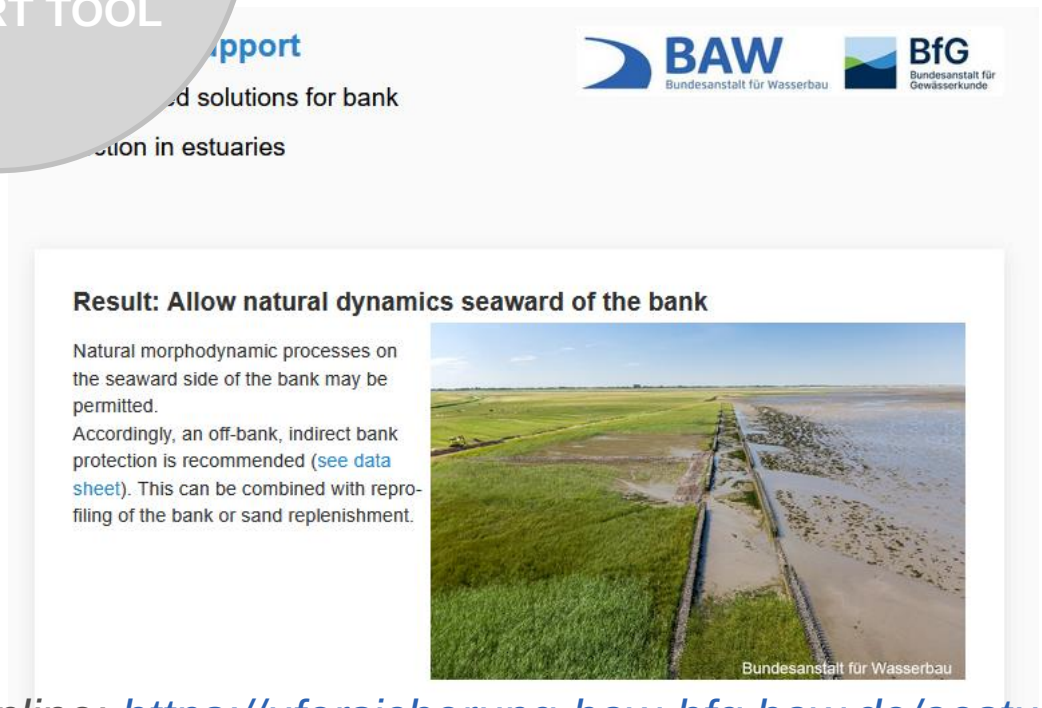
Input

- Land ownership
- Land usability
- Space availability on waterward side
- Risk assessment for negative development of the bank
- Presence and height of an erosion edge
- Allowability of dynamic development of the shore line
- Necessity of weight per area

Available online: https://ufersicherung-baw-bfg.baw.de/aestuarbereich/en/arbeitshilfen/entscheidungshilfe

Decision support tool

DECISION SUPPORT TOOL



Input

Output

Recommended bank protection with reference to data sheets (if available)

- Direct bank protection with NbS-BP: brushwood boxes, brushwood mattresses, willow mattresses
- Indirect bank protection with NbS-BP
- Direct bank protection with riprap (integration of ecological stepping stones)

Available online: https://ufersicherung-baw-bfg.baw.de/aestuarbereich/en/arbeitshilfen/entscheidungshilfe

What has been achieved?



But implementation confidence is still limited by remaining uncertainties.

Knowledge gap 1: Hydrodynamic loads

- **Current status:**
  - mostly qualitative description of tolerable loads in data sheets

- **Needed:**
  - Quantitative thresholds
  - Tolerable hydrodynamic loads
  - Data on performance in reducing hydrodynamic loads

- **Measuring campaigns of hydrodynamic loads on existing and future measures:**
  - Investigate performance
  - Develop application boundaries
  - Understand failure mechanisms
  - Optimization potential



Set-up for wave and current measurements in bank areas using pressure sensors and acoustic doppler velocimeters.

Knowledge gap 2: Material durability and maintenance

- **Uncertainty exists** regarding:
  - Material durability
  - Maintenance intervals
  - Long-term performance

- **Continuous monitoring** improves the evidence base:
  - standardized monitoring to complement practitioner-derived insights with quantitative data
  - annual site visits documenting material condition, structural integrity and overall development of the protection measure and the surrounding area



Brushwood fascines ready for implementation.

Knowledge gap 2: Material durability and maintenance

- **Maintenance intervalls** differ significantly depending on the **boundary conditions**
  - Brushwood structures typically require maintenance after approximately five years or earlier, depending on site-specific conditions.
  - Under suitable conditions the durability of dead wood measures can be longer or maintenance can be discontinued.

- A **better understanding of the factors controlling durability** is essential to establish dead wood-based NbS-BP as a reliable alternative to riprap.



Brushwood boxes where the Oste river flows into the Elbe, with a maintenance intervall of 1-2 years.

WSA Elbe-Nordsee



Brushwood mattress in a tidal tributary (Pinnau) with no maintenance need.

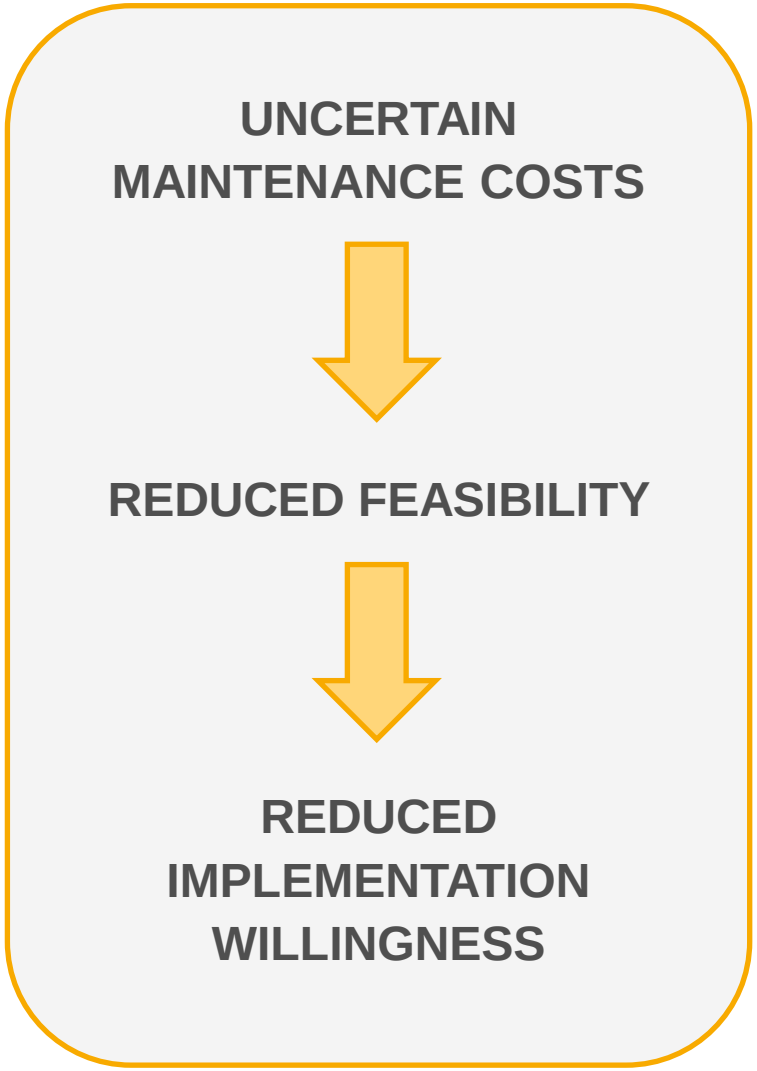
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Technical uncertainty becomes economic uncertainty

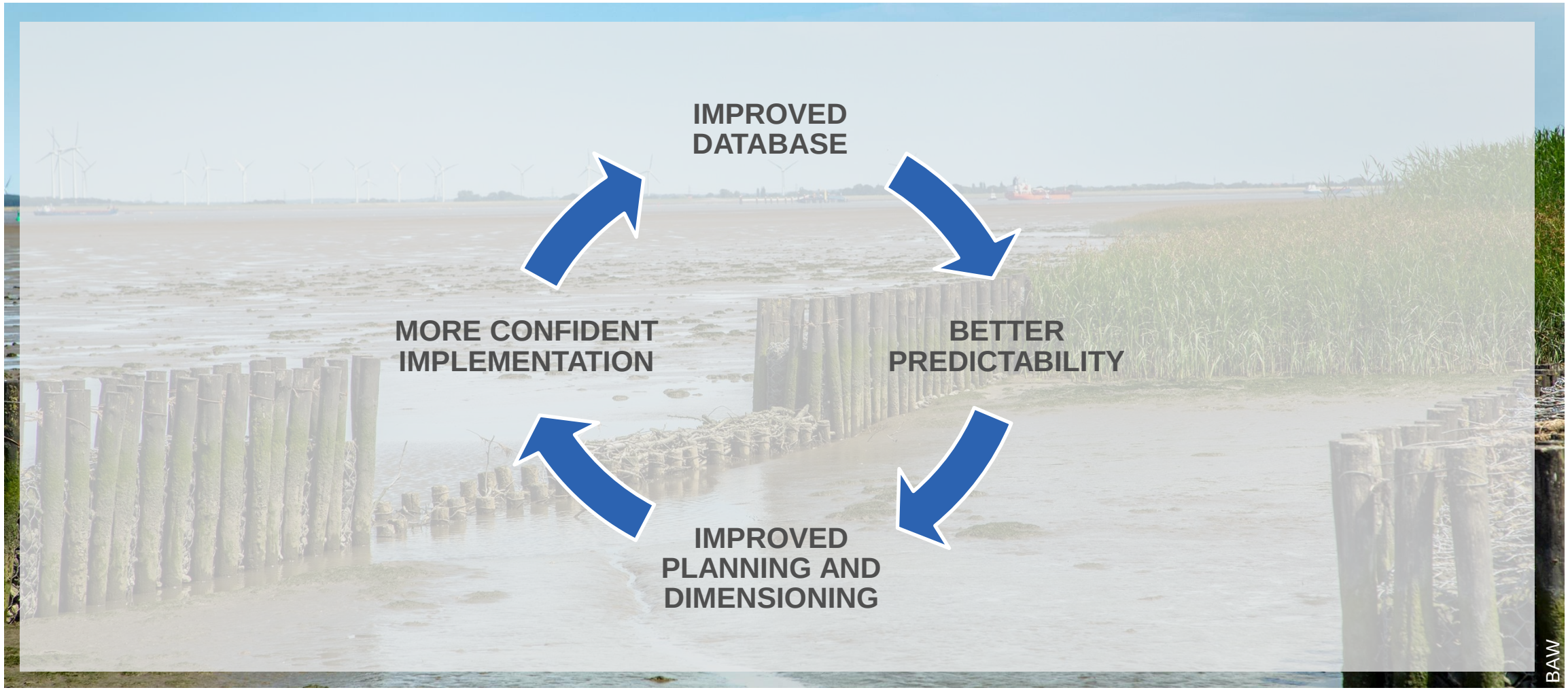
- **Cost-Benefit-Analysis** of nature-based solutions for bank protection vs. riprap*
  - **Lower construction costs but higher maintenance costs** for NbS-BP in comparison to riprap
    - Maintenance costs are site-specific and data base is small: **suitable boundary conditions → lower maintenance → higher feasibility**
    - **Monetarized ecological benefits** of NbS-BP are not included and could potentially shift feasibility

- **Investigation of threshold values** for successful and low-maintenance implementation **improves economic predictability** of NbS-BP**.**

** Eltzsch et al. (under review): Cost analysis of nature-based solutions for bank protection compared to rock armor revetments under consideration of embodied CO2 emissions.*

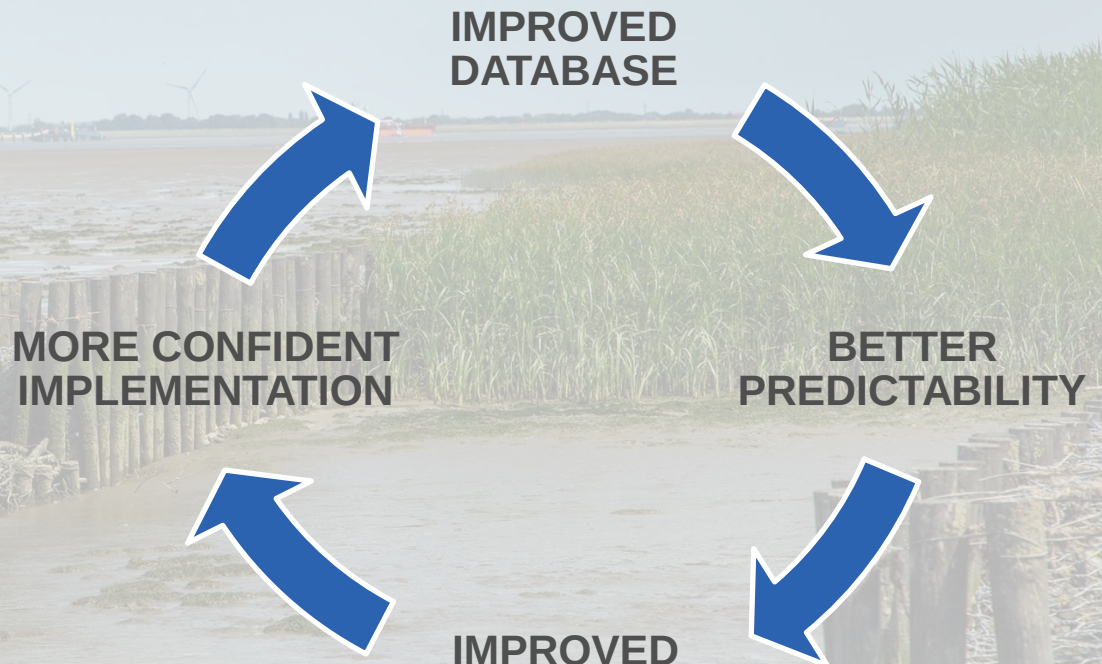


Conclusion


IMPROVED DATABASE
BETTER PREDICTABILITY
IMPROVED PLANNING AND DIMENSIONING
MORE CONFIDENT IMPLEMENTATION
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Conclusion

- **What we achieved**
  - Structured implementation knowledge
  - Practical guidance tools
  - Decision-support framework
  - Cost-benefit analysis
- **What we are improving**
  - Hydrodynamic threshold data
  - Durability understanding
  - Maintenance predictability
- **What still needs to change**
  - Acceptance of uncertainty:
    - understand it, quantify it where possible, and integrate it transparently into planning and approval processes.



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