Recommendations for a good sediment management practice in the Elbe – Methodology

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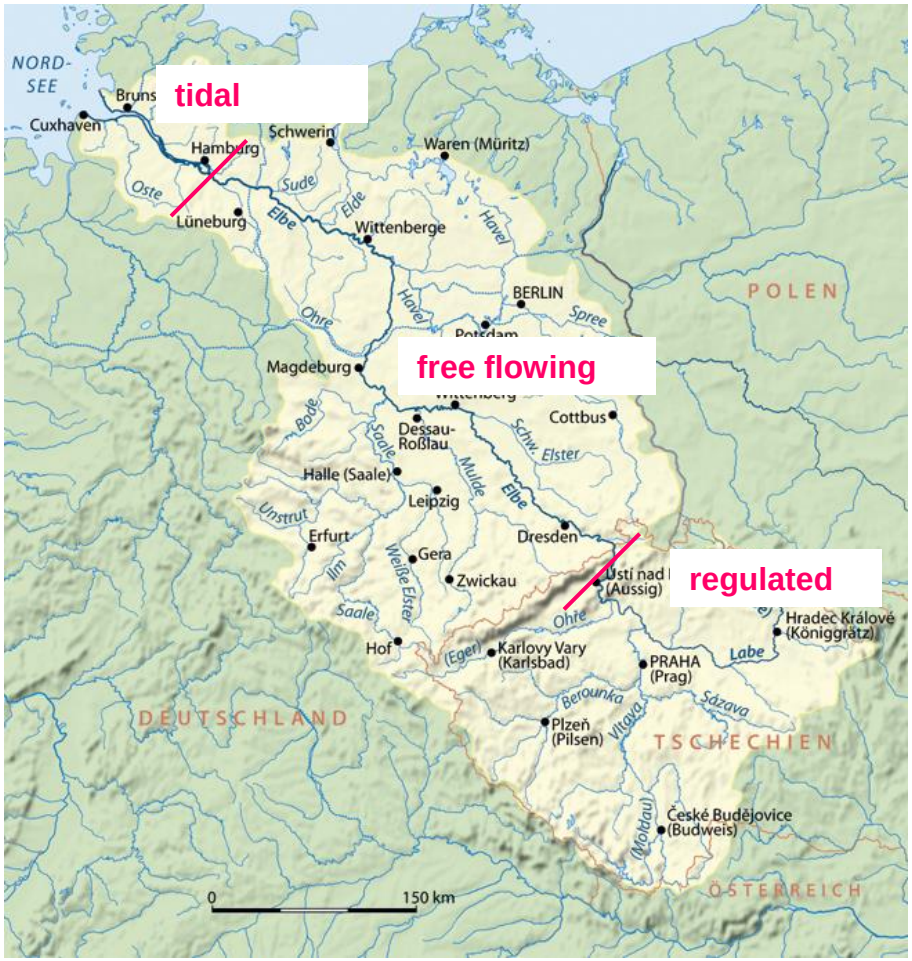
The Elbe



Length: 1,091 km

Area: 148,268 km²

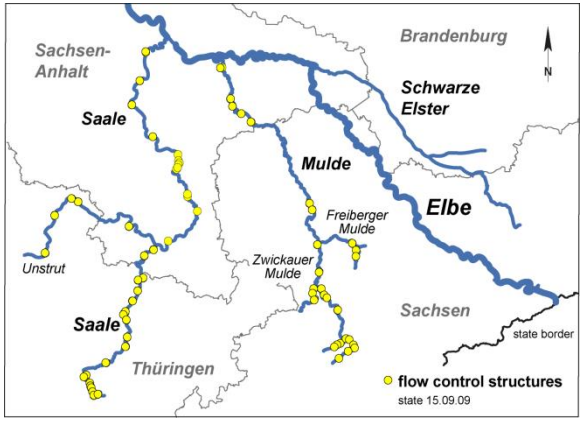
$MQ_{North\ Sea}$: 877 m³

Population: 25 Mio people (D, CZ)

Industry/Mining: over centuries

Agriculture: 56% of the catchment

Sediment Challenges
Quantity and Hydromorphology



- Impounded reach: 24 barrages and 4 weirs on 247.1 km
- Catchment : 292 dams / reservoirs; storage capacity ~ 4,000 mio m^3 (Simon et al. 2005)
- > 6,600 groyne fields - German free flowing reach
- 154 km tidal Elbe - basic morphological alterations - flood protection and navigation
- Area of active floodplains and marshes - loss to about 75% (Simon 1996)

- Sediment deficit of 0.45 million tons/year in the German inland reach (IKSE 2014)
- Mean erosion rates between 1.0 and 1.25 cm/year in wider parts of the lowland reach
- Significantly increased upstream transport of marine sediments in the tidal Elbe – factor 2.5 between dredged material amount and sediment input from inland (dry matter)

Sediment Challenges

Quality

- Ongoing sediment pollution from point sources (historical mining, old industrial sites, urban areas …)
- Sediments / old sediments act in turn as contamination source (floods!) for reaches downstream
- Consequences are:
  - Adverse effects on the aquatic community (ecological status)
  - Enhanced costs / limitations to secure services (agriculture in floodplains, dredging for navigation and flood protection, fish consumption)

ICPER and FGG Elbe

Integrated Sediment Management Concept (2014)

1st Elbe management plan (2010-15)

Deficient hydromorphological conditions and contamination as supra-regional issues

Unbalanced sediment conditions and contaminated sediments among main reasons

ICPER/FGG Elbe (2009): Sediment management concept in preparation of the 2nd management cycle (2016-2021)

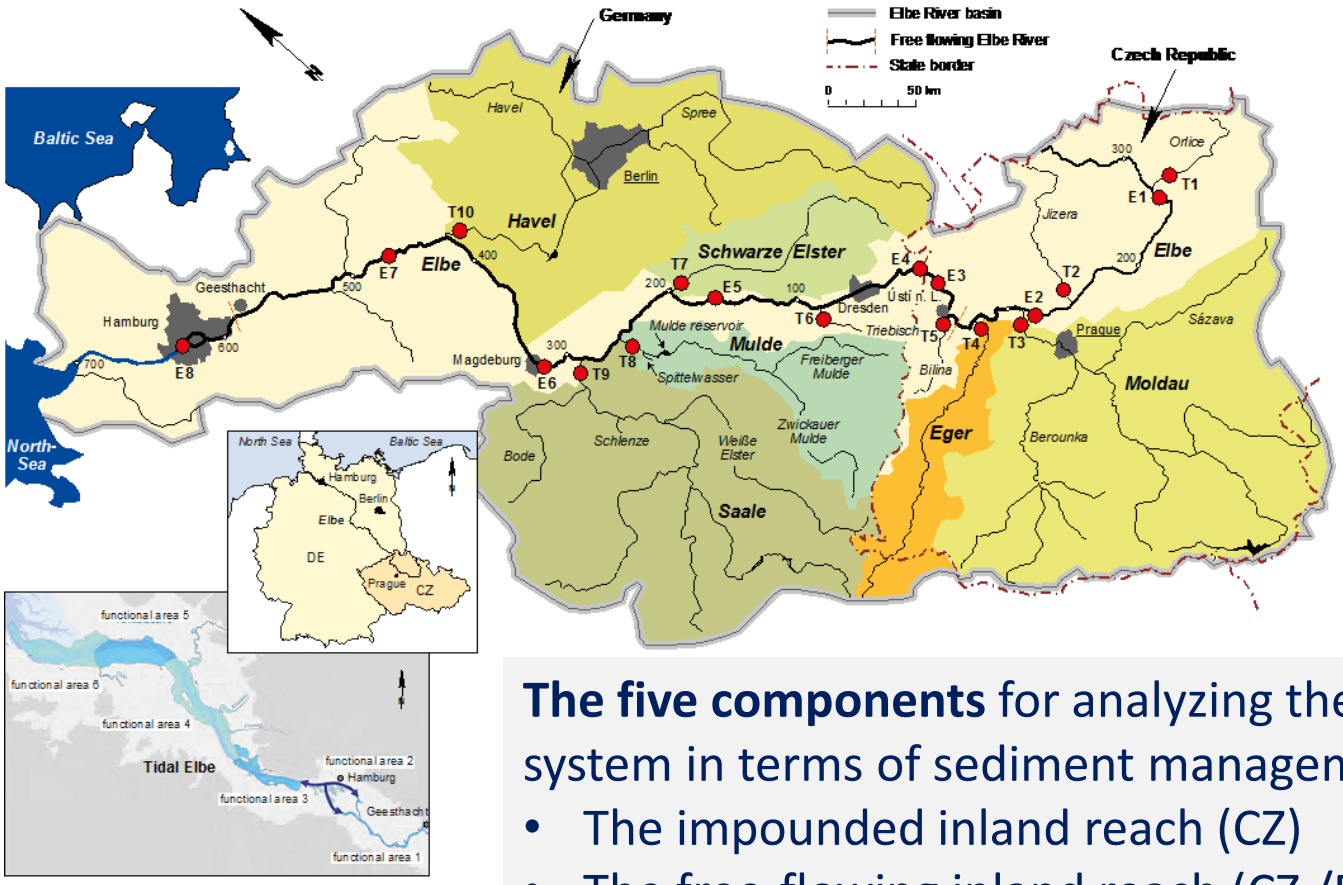
The Sediment Management Concept of the ICPER - Recommendations for a good sediment management practice in the Elbe

➡ IKSE / MKOL, Magdeburg, 2014 (DE/CZ)

➡ Heininger et al. in Heininger & Cullmann (Eds.) “Sediment matters”, Springer, 2015

The Concept
1. View on the Elbe catchment in the context of river basin sediment management

Five System Components



The five components for analyzing the Elbe system in terms of sediment management are:

- The impounded inland reach (CZ)
- The free-flowing inland reach (CZ /DE)
- The tidal reach (DE)
- Relevant tributaries
- Reference monitoring sites

System Components

Three Main Elbe Reaches (impounded, free-flowing, tidal) differ in their flow and sediment transport regime

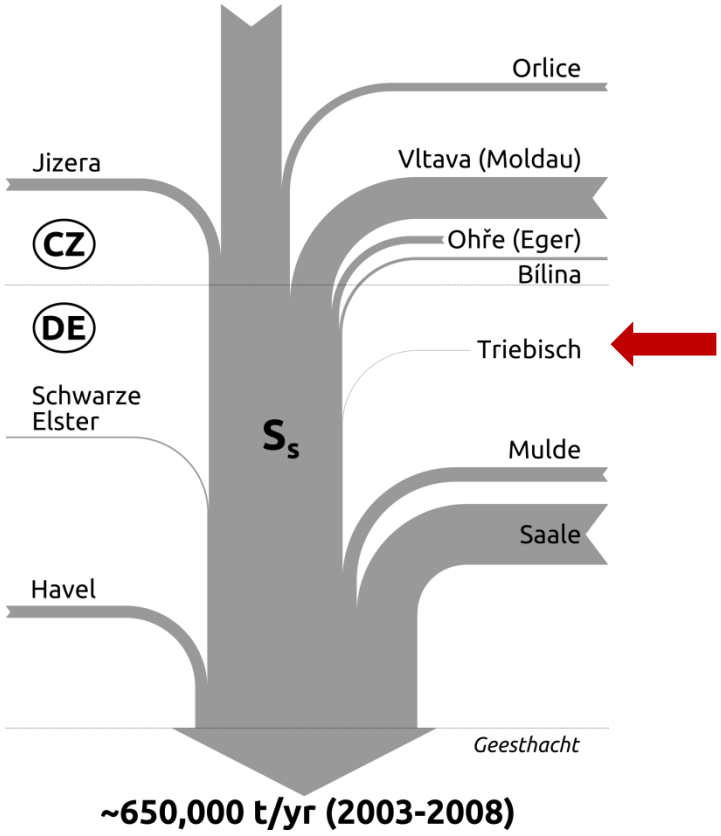
18 Reference Monitoring Sites (Elbe – 8; Tributaries – 10)

- Characterize a sub-basin in terms of sediment quantity and/or quality
- Provide (long-term) time series of data
- Represent the best available data basis in any case, what may mean that reference data in quantity and quality slightly differ geographically
- Provide data over a nine years period (2003 – 2011) including wet years with extreme floods (2006, 2010), drought (2003) and medium discharge conditions both in terms of discharge and sediment transport (2005)
- Balancing profiles:
  - CZ l Hrensko/Schmilka
  - DE = inland Elbe l Schnackenburg

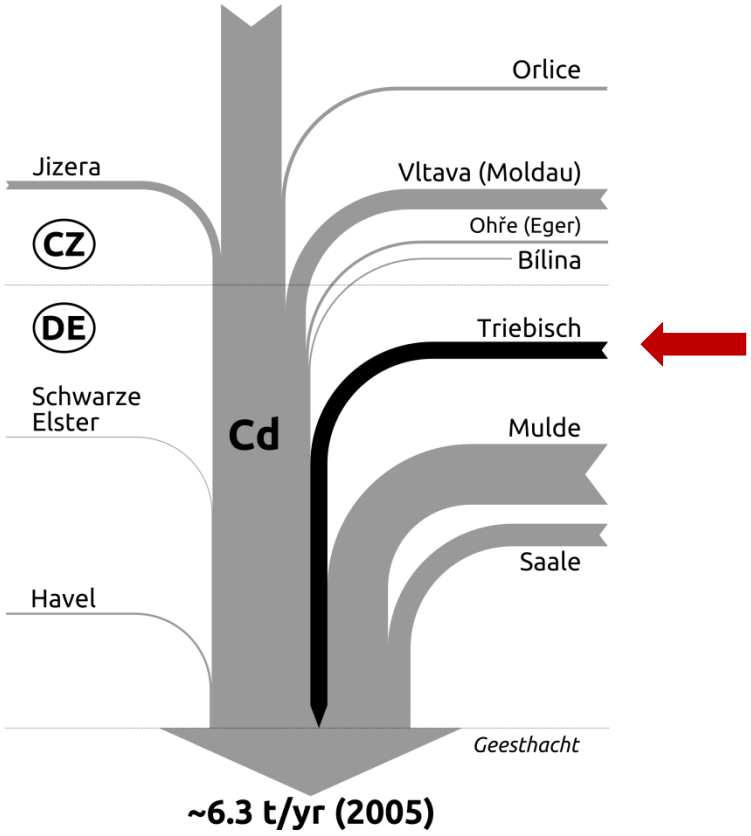
10 Relevant Tributaries are selected in two Categories

- Category 1: due to their basic characteristics **A, Q and S_S (>10% criterion at the reference site downstream)**
- Category 2: due to their **load of at least one relevant contaminant (>10% criterion at the reference site downstream)** although not meeting the quantity criteria
- Cat. 2 tributaries may occur either directly to the Elbe or to one of the Cat. 1 confluences

Role of Tributaries



~650,000 t/yr (2003-2008)

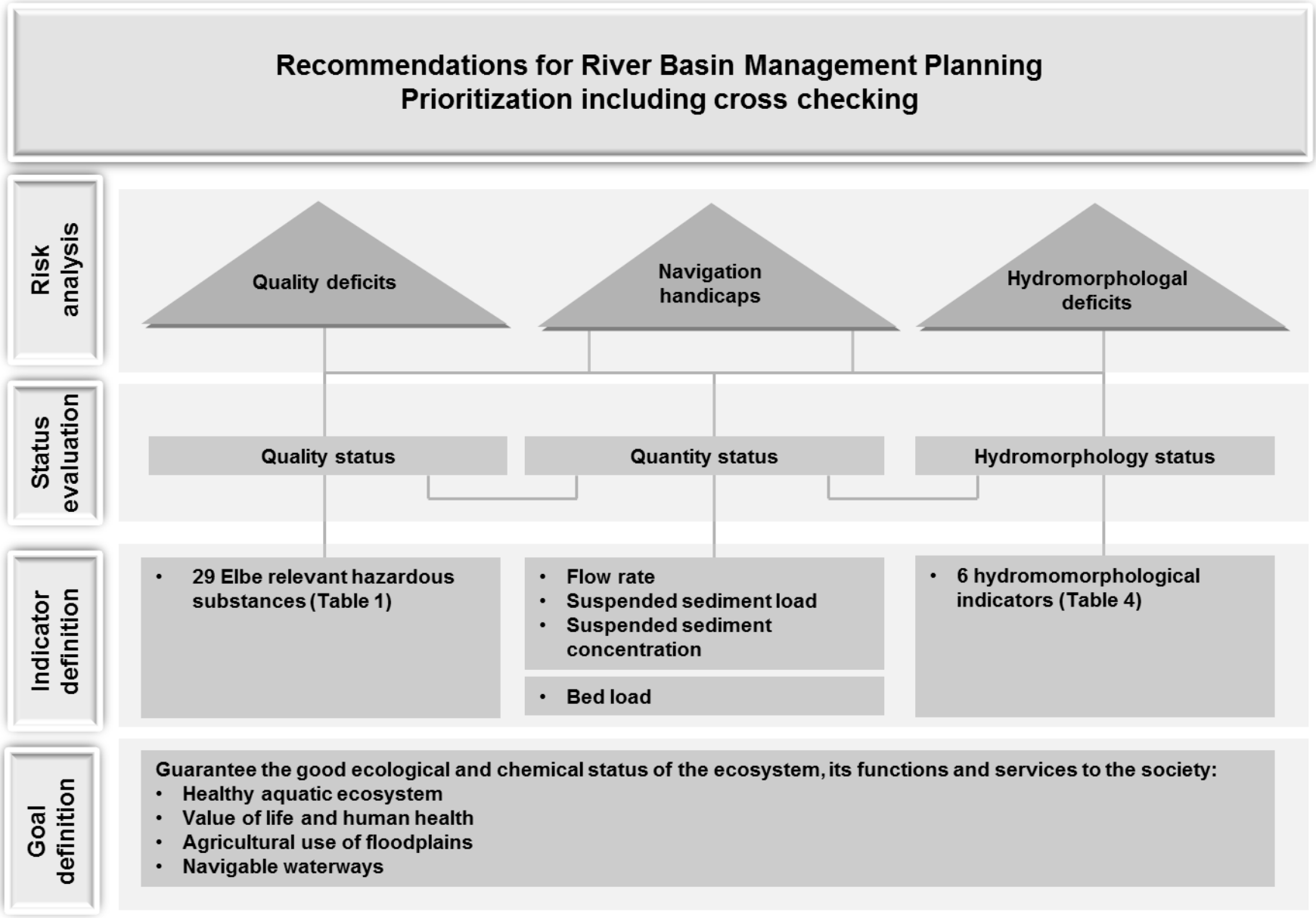


~6.3 t/yr (2005)

The Concept
2. General Approach

Integrated Concept
Related to the whole River Basin Elbe

- Developed along the chain of management goals – management planning – planning of measures – implementation of measures
- Risk-based, i.e. conclusions rely on the analyses of risks from insufficient status of the sediment budget, ecological functions, ecosystem services / uses depending on sediments
- Considers and integrates the spatial interdependencies of the catchment (upstream – downstream, main river - tributaries, river – sea, river – floodplain …)
- Considers sediment features and functions in terms of quantity, quality, and hydromorphology and their interaction
- Integrates environmental and use-oriented aspects [at the example of navigation]
- Takes a participative approach within institutional framework set by the WFD
- 1st priority is given measures fighting the causes of deficits rather than treating symptoms.

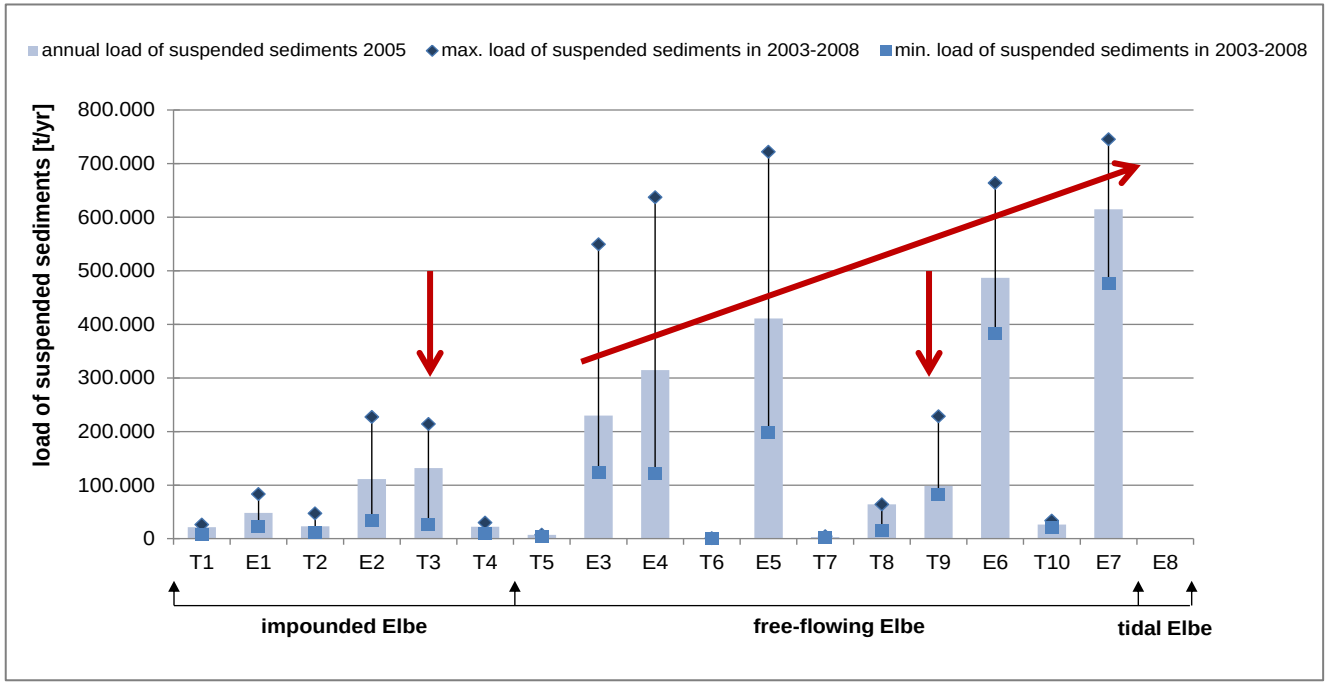


Conceptual Framework

The Concept
3. Sediment Quantity

Aspect Quantity - Suspended Sediment

Indicators Q, C_s, S_s



Deficit of 1,000 – 10,000 tons/year

Turbidity zone: 15% of the inland input; 50-80% marine

Input of 650,000 tons/year from the inland to the tidal Elbe

The Concept
4. Sediment Quality

Aspect Quality
Relevant issues and Indicators

Relevant Issues with regard to sediment quality

- Good chemical and ecological status / integrity of the aquatic community
- Protection of floodplain soils against pollution
- Protection of humans against contaminant uptake.

Identification of indicators

Step 1 – potentially relevant contaminants

- Review of all Czech, German and international (e.g. OSPAR) regulations (laws, ordinances, guidelines) for their chemical risk requirements
- Resulting pool of chemicals which are persistent, bio-accumulative, adsorptive

Step 2 – Elbe-relevant contaminants

- Those contaminants from Step 1 which occur in the Elbe basin (data 2003 – 2008; reference monitoring sites; minimum one year (mean); at least one Elbe site or one site of Category 1 tributary)

Aspect Quality

Classification Scheme and Elbe-relevant contaminants

29 Elbe-relevant contaminants in the context of river-basin sediment management

- Hg, Cd, Pb, Cu, Ni, As, Cr
- x-HCH; DDX; PCBs; Pe-CB; HCB
- PAHs
- TBT
- PCDD/F

Classification scheme

- Three classes, two threshold values C1 and C2
- C1 (lower threshold) = lowest value in the row of all sediment-quality requirements of Step 1
- C2 (upper threshold) = EQS in either the Czech or the German national WFD regulations (Sb 2011; OGewV 2011) or comparable protection level

Aspect Quality
Approach to Risk Analysis

Risk Analysis was made

- For each of the 29 contaminants / contaminant groups
- In the impounded, free-flowing and tidal parts of the Elbe and in all relevant tributaries
- In two stages.

Stages of Risk Analysis

(1) Evaluation at the sub-basin level to identify the main source areas of particle-bound contaminants. As a result, the qualitative sediment conditions and the particulate contaminant fluxes in the catchment are described.

(2) Source-related evaluation within the source areas from Stage 1. As a result, the relevant sources in the respective basin districts are described and ranked.

Aspect Quality
Source Evaluation

Types of Sources

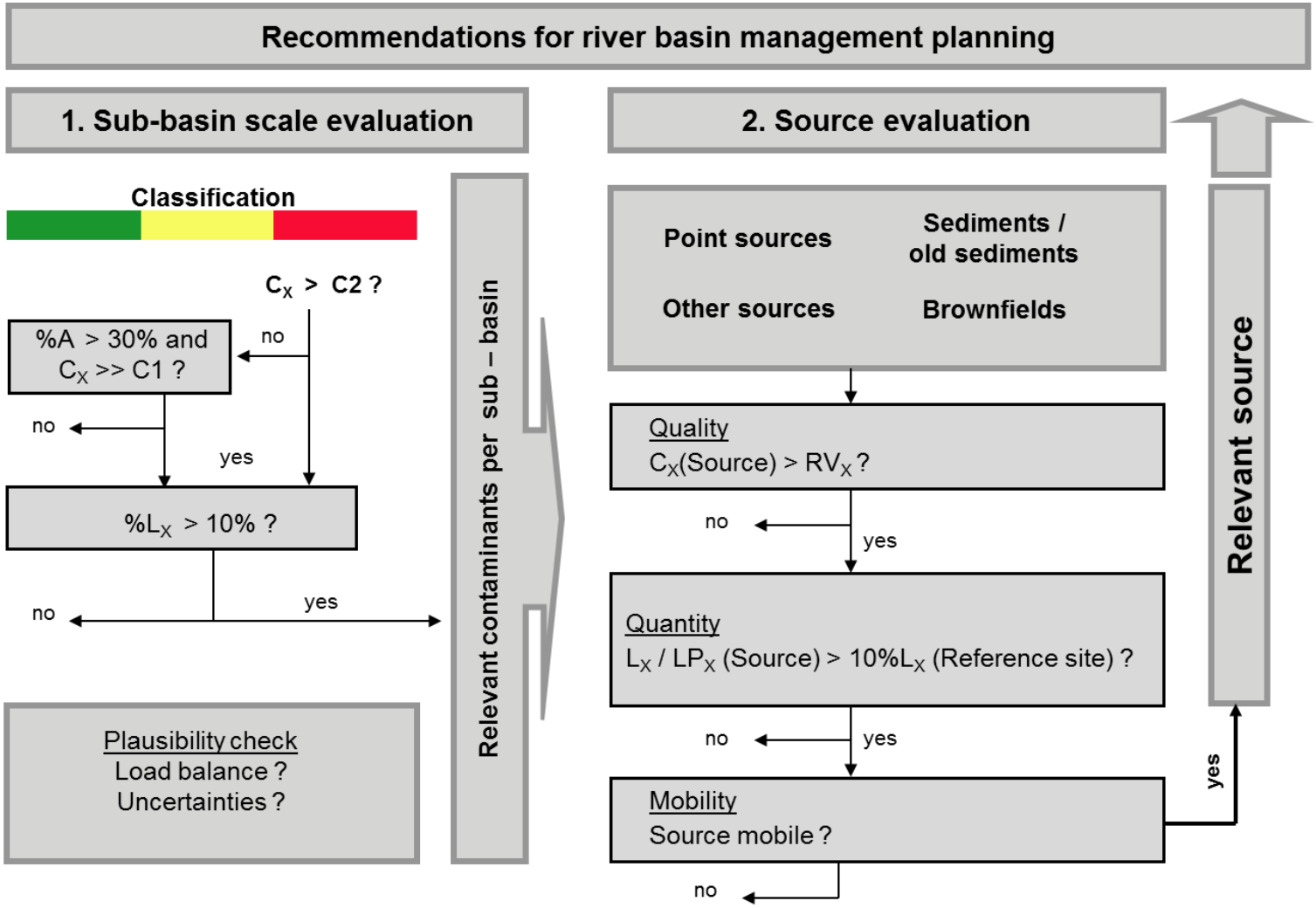
(1) Point sources. Sewage water and point discharges from historical mining.
(2) Sediments/historical sediments. Source function induced by floods.
(3) Historical contamination in adjacent zones to the river (old industry sites, brownfields …) with permanent (e.g. via groundwater) or episodic (e.g. via flood) contaminant emission
(4) Other sources, e.g. urban areas.

Three Criteria to estimate the relevance of a source (Data: 2003 – 2011) must all be met:

(1) Minimum concentration. At least one contaminant concentration exceeds the defined threshold (e.g. C2 in the case of particulate contaminant emission).
(2) Minimum amount. At least one contaminant annual load potentially exceeds a critical value. Expert estimation.
(3) Sensitivity to mobilization of the relevant contaminant(s) from the potential source – potential load is/may become a fact. Expert estimation.

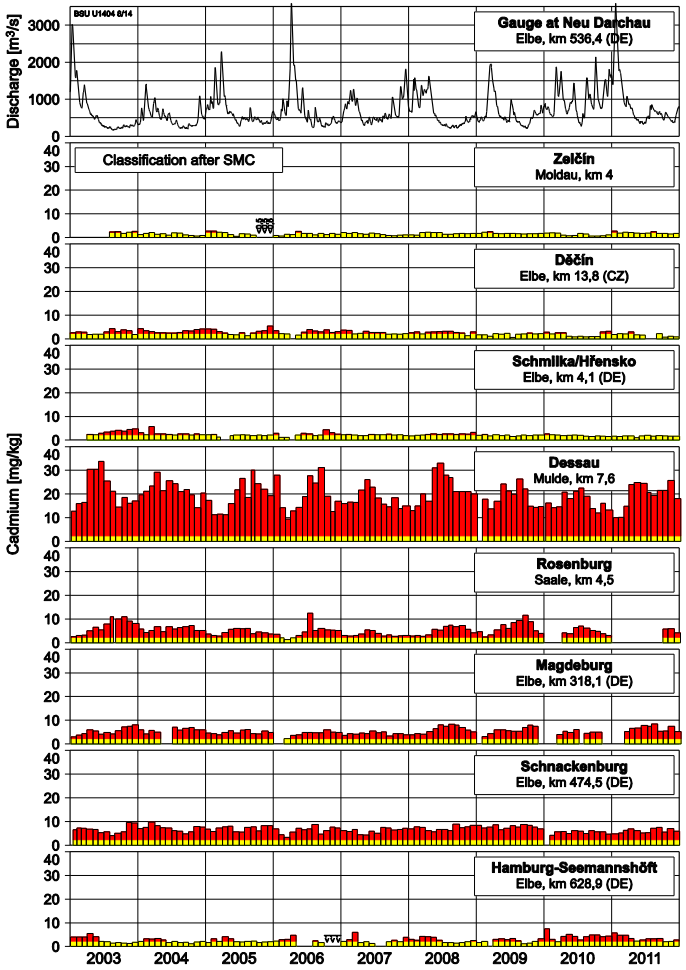
Aspect Quality

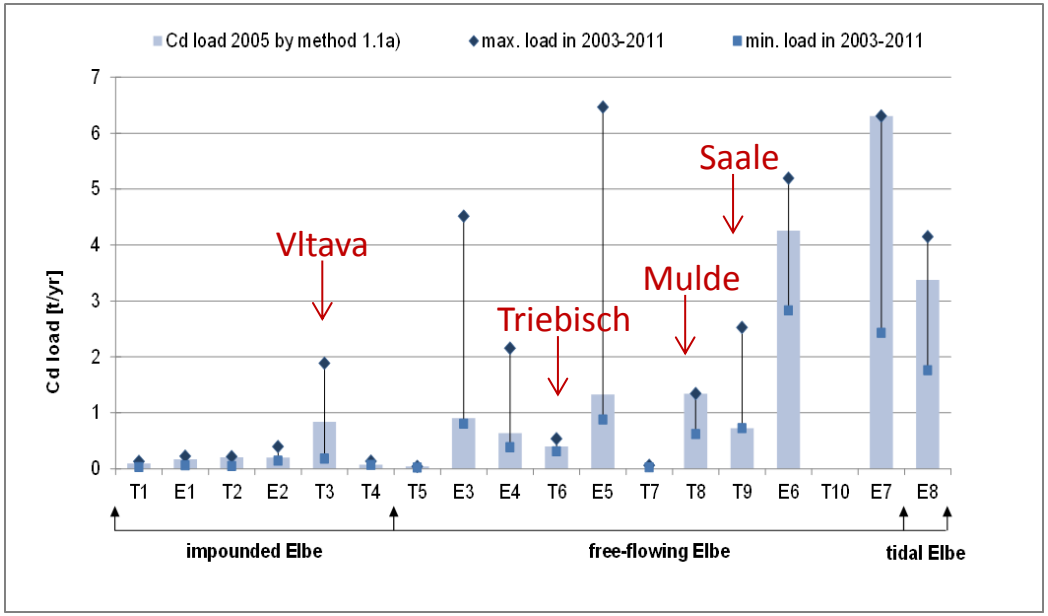
Overall Scheme of Risk Analysis



Aspect Quality

Results of Stage 1 – Example Cd





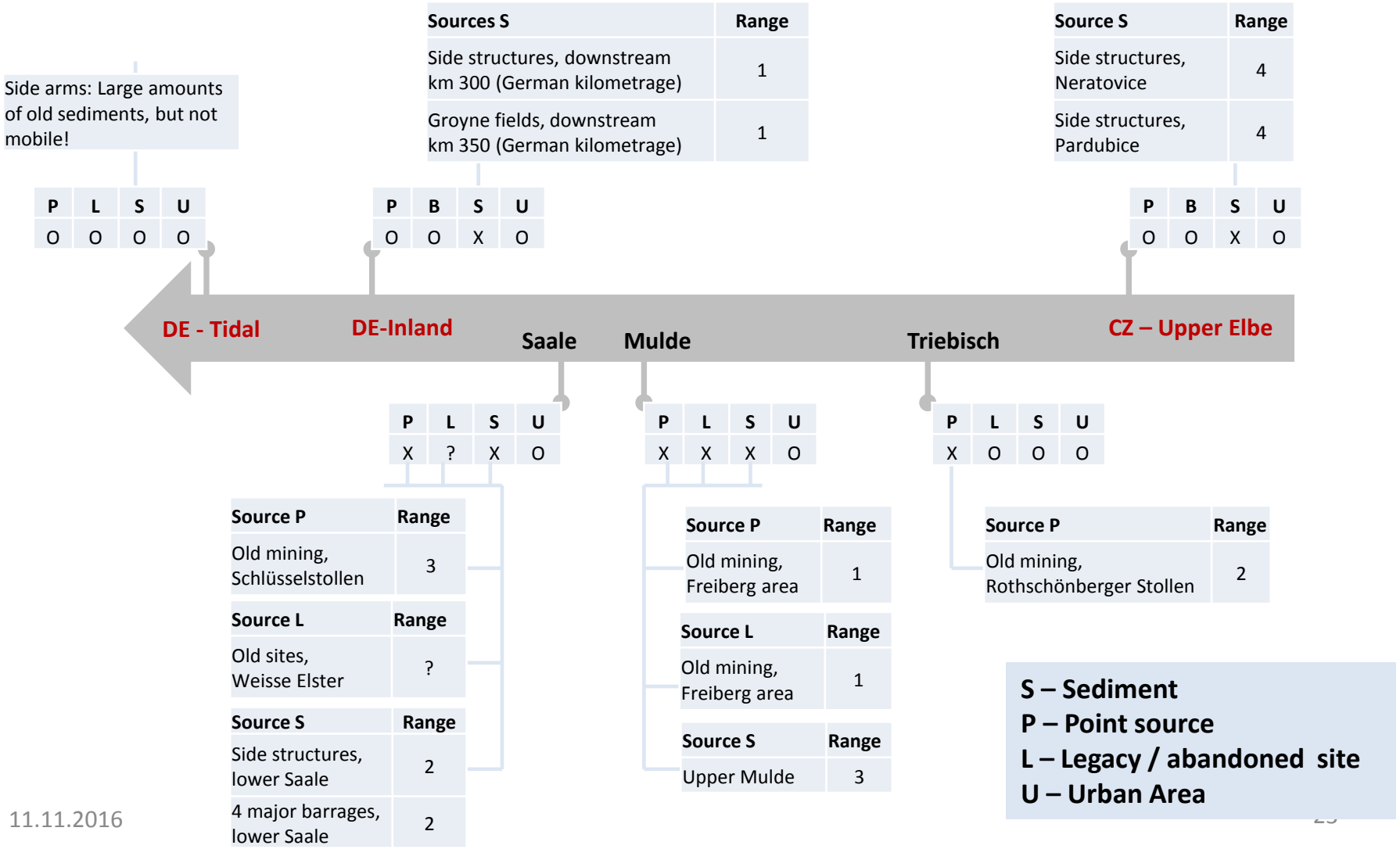
Aspect Quality

Step 1 – Sub-Basin Scale Evaluation

Sub-basin (Reference site)[2]	%A	Sub-basin-relevant contaminants[3] [Criteria: C > C2 and L >10% of L_{E7}]
Orlice (T1)	1.4	no
Jizera (T2)	1.4	no
CZ: Upper Elbe (E2)	9	I: Hg, Cd, Pb, α-HCH, γ-HCH, HCB, BaP, ∑5PAH II: Ni, p,p`DDT, p,p`DDE, 7 PCBs, fluoroanthene
Moldau / Vltava (T3)	19	I: Hg, Pb, BaP, anthracene, ∑5PAH II: Ni, p,p`DDT, p,p`DDE, PCBs, fluoroanthene
Eger / Ohre (T4)	4	I: As II: Ni
Bílina (T5)	0.7	I: As
CZ / DE: Border Profile (E4)	35	I: Hg, HCB, BaP, anthracene, ∑ 5PAK, TBT II: Zn, Ni, p,p`DDT, p,p`DDD, p,p`DDE, 7 PCBs, fluoroanthene
Triebisch (T6)	0.1	I: Cd II:Zn
Schwarze Elster (T7)	4	no
Mulde (T8)	5	I: Cd, Pb, As, α-HCH, β-HCH,γ-HCH, HCB, TBT, PCDD/F II: Zn, Ni, , p,p`DDT, p,p`DDD, p,p`DDE
Saale (T9)	16	I: Hg, Cd, Pb, α-HCH, γ-HCH, BaP, anthracene, ∑5PAK, TBT, PCDD/F II: Zn, Ni, p,p´DDE, p,p`DDT, fluoroanthene
Havel (T10)	16	no
DE and CZ/DE: Inland Elbe (E7)[5]	82.4[4]	I: Hg, Cd, Pb, As, α-HCH, β-HCH,γ-HCH, HCB, TBT, PCDD/F II: Zn, Ni, p,p`DDT, p,p`DDD, p,p`DDE, fluoroanthene
DE: Tidal Elbe (E8) [5]	10	I: Hg, Cd, Pb, α-HCH, HCB, ∑5PAK, TBT II: Ni, p,p`DDT, p,p`DDD, fluoroanthene

Aspect Quality

Results of Stage 2 – Example Cd



Aspect Quality
The Role of Contaminant Sinks

A list of sinks of supra-regional importance was compiled

- Floodplains
- Storage reservoirs
- Dams
- Riverine lakes
- Hamburg harbour

As showcases were considered in detail

- Floodplains of the German Middle Elbe (Krüger et al. 2014)
- Large storage reservoir ‘Muldestausee’ (Junge 2013)
- Hamburg habour (elsewhere, long-term studies of the City of Hamburg)

The Concept
5. Hydromorphology

Aspect Hydromorphology
Principles and Technical Approach

The concept considers

- the close interrelationship between sediment budget and hydromorphological status
- that hydromorphological features are indicators of the sediment budget and *vice versa* hydromorphological characteristics influence sediment conditions
- hence, risk analysis should couple the assessment of the sediment budget as part of the hydromorphological status with recommendations to improve this status.

Boundary conditions were

- The assessment scheme should as much as possible fit into to the “world of WFD”
- Existing national assessment methodologies, models, data and historical data should be used (CZ: HEM, HEM-S; DE: INFORM, ValMorph; FGG 2013, IMP 2012)
- The comparability of assessment results between CZ and DE should be ensured.

While for the inland parts (CZ and DE) a combination of modeling and expert assessment is applied, for the tidal reach (DE) exclusively expert assessment is used.

Aspect Hydromorphology
Indicators

Overall six indicators were defined

(1) Impact on the morphological regime (CZ) vs. Mean river bed changes / sediment balance (DE) – due to the different flow regimes!
(2) Sediment continuity
(3) Width variation / Depth variation
(4) Grain size distribution of the river bed substrate
(5) Bank stability (CZ) vs. Bank structure (DE)
(6) Ratio of recent to morphological floodplain / marsh

- Indicators (1) and (2) have a key function for the sediment budget
- Four indicators correspond to the hydromorphological component groups (WFD) 'sediment continuity' and 'river morphology'
- On the one hand, focusing on sediment budget means a restriction with respect to the more general feature "hydromorphology"
- On the other hand, an extension is made with the indicators 'sediment balance' and 'recent to morphological floodplain ratio'.

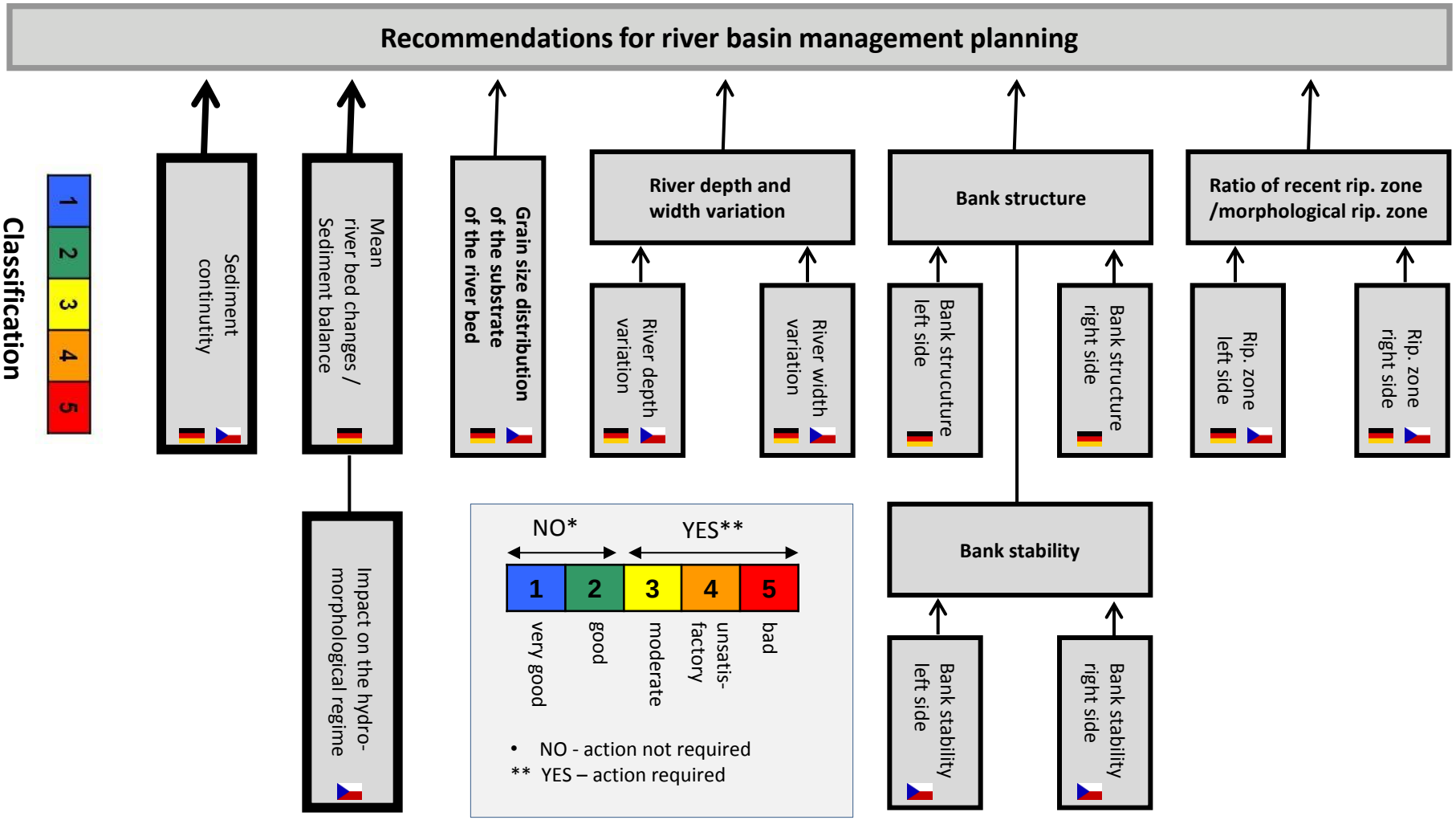
Aspect Hydromorphology
Classification and risk assessment

Classification

- Five classes in the inland Elbe (Class 1, best level to Class 5, worst level)
  - Class 1 – best available historical data (*inter alia* consistency for the whole river; time horizon approx. 110 years)
  - Classes 2-5 based on expert assessment
  - Class 1, 2 – no action required
  - Class 3, 4, 5 – action required with growing urgency
- Four classes in the tidal Elbe (HMWB)
  - Class 1 is missing (HMWB)
  - Gradual application on the basis of the present-day natural potential of water bodies (German: *Leitbild*) in four classes via expert assessment
- Each indicator is classified individually
- In a first step, the two key indicators are considered for recommending actions
- In a second step, the other hydromorphological indicators are checked for synergies in combination with step one and whether specific recommendations must be given.

Aspect Hydromorphology

Overall Scheme of Risk Analysis



Aspect Hydromorphology
Recent status

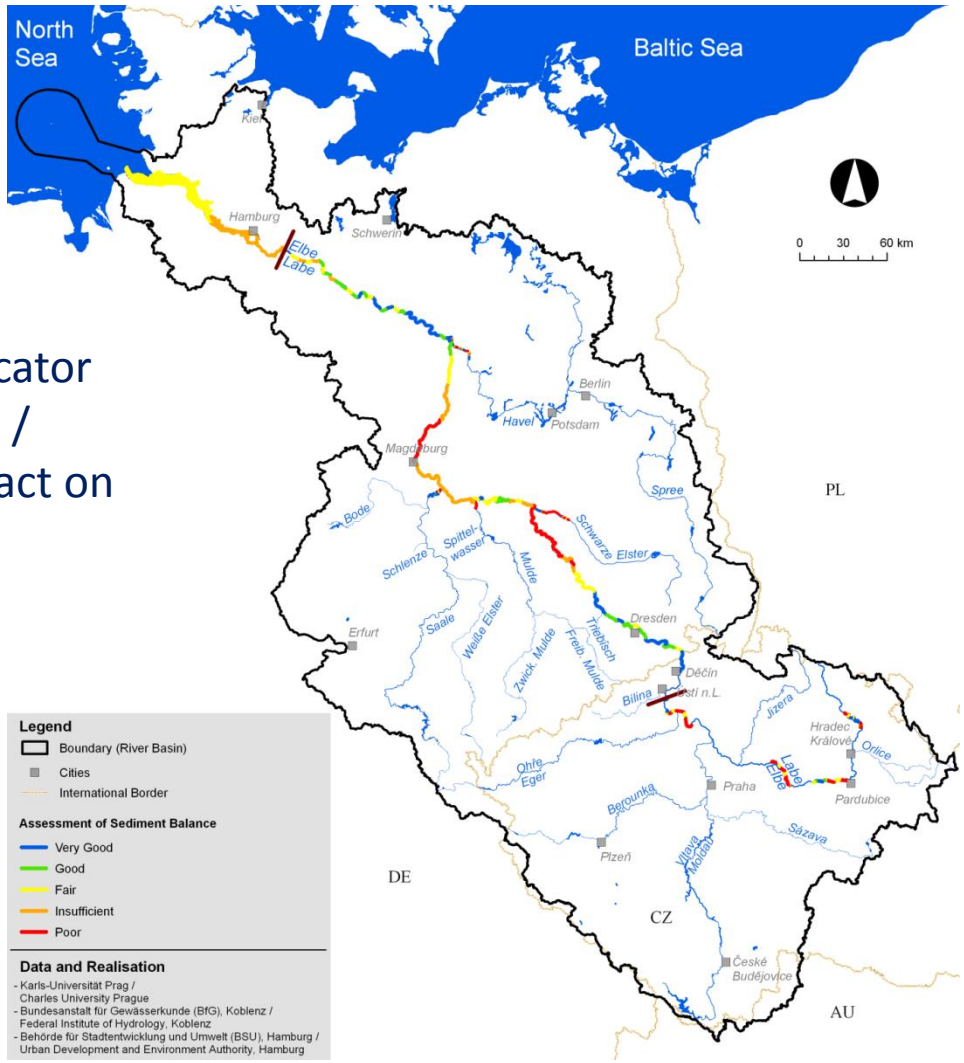
CZ – Main River Elbe
- Five representative pilot reaches, including the CZ-DE cross-border section of a length between 30 and 80 km
- Hydro-ecological monitoring approach (HEM, HEM-S)
- No aggregation of indicators is made.

DE – Complete Inland Reach and mouth reaches of Category 1 tributaries
- Cartographic, geodetic, aerial photograph data (INFORM, ValMorph)
- Integration of 5 km steps (depending on the indicator separately for the left and right banks)
- No aggregation of indicators is made.

DE – Tidal Reach
- Six functional areas of 20 – 30 km length each
- Four zones in each area
- The most unfavorable result of a zone is decisive for the whole area.

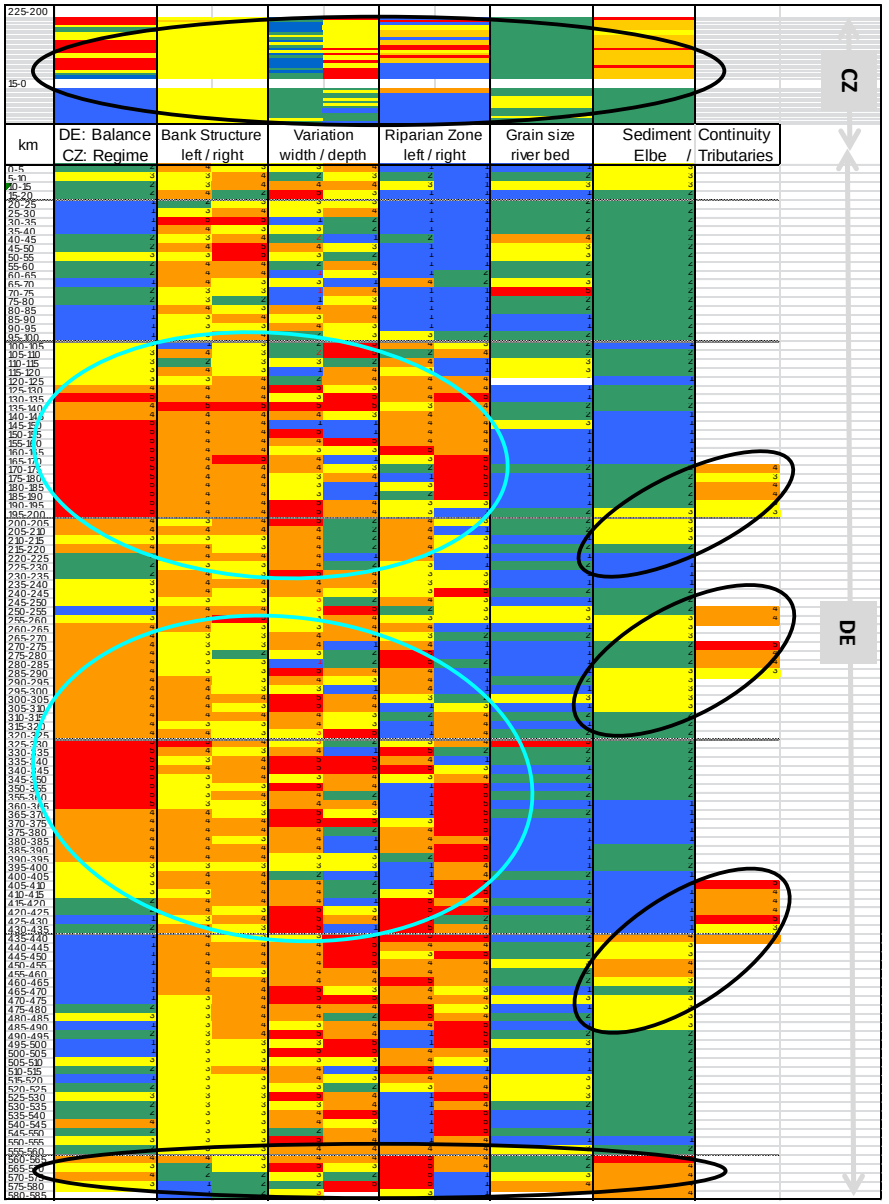
Aspect Hydromorphology

Overview of the key indicator ‘Mean river bed changes / sediment balance’ / Impact on the hydromorphological regime’ (IKSE 2014)



Aspect Hydromorphology

Hydromorphological risk analysis - Overview of the results for the inland Elbe (IKSE 2014)



Reaches with advancing river bed incision

Impact of bad sediment continuity

The Concept
6. The Example of Navigation

The Example of Navigation
Motivation and risk analysis

Motivation for including navigation from the beginning

- Sediment management is an integral part of the maintenance of the Elbe River for navigation
- Water ways construction / river training impacts the sediment regime
- Thus, navigation both may be a reason for and suffer from (e.g. quality!) an insufficient sediment status
- Navigation may serve as an example for including other forms of use.

Risk analysis from the navigation perspective

- Comparison of the recent situation in terms of fairway width and depth with the defined maintenance objectives

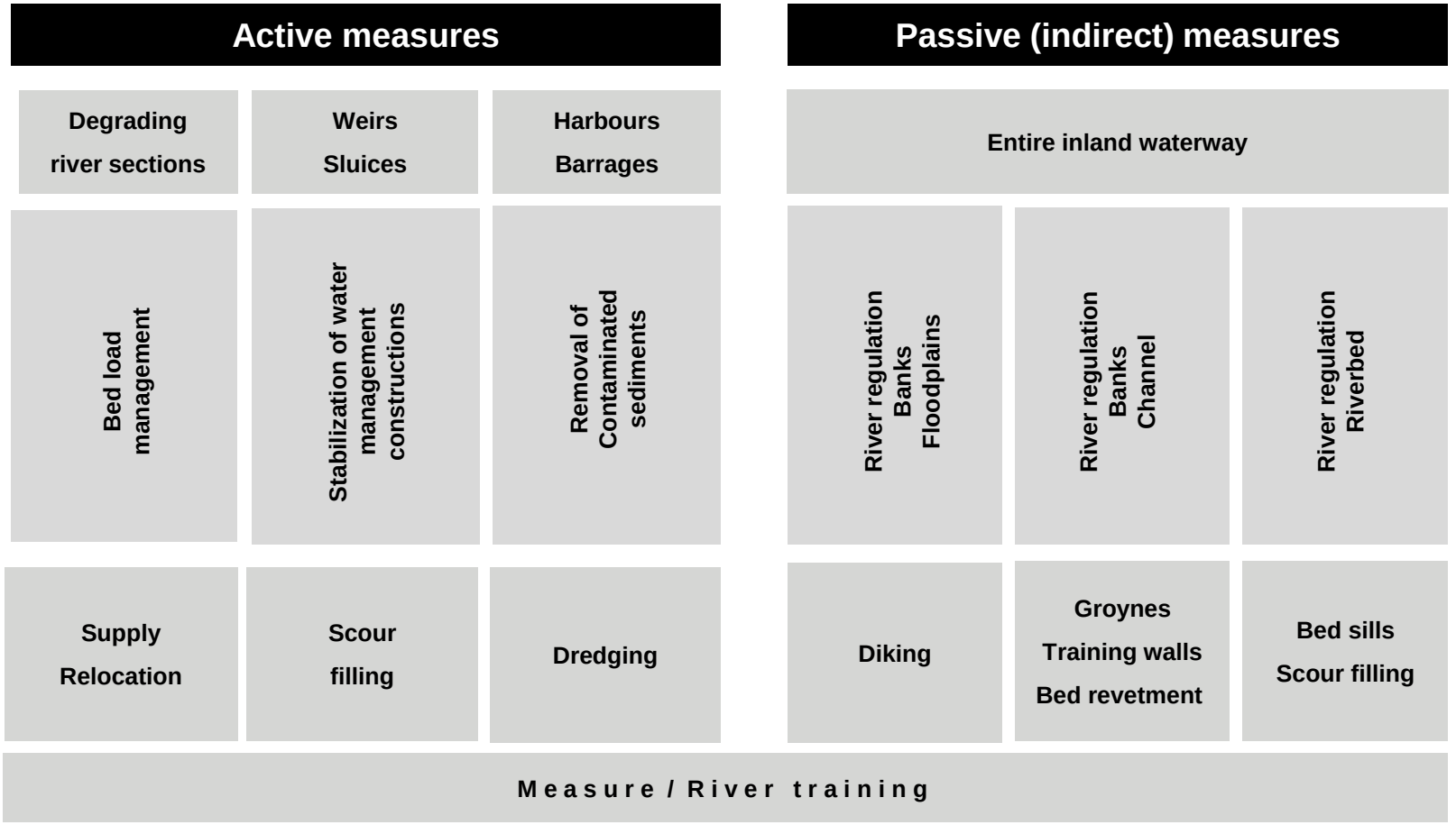
The Example of Navigation
Navigation Risks

Sediment risks from the navigation perspective

- Impounded reaches – sedimentation as the most critical effect (water depth, construction stability)
- Free-flowing inland reaches – dysfunction of the regulating system, bed incision, sedimentation require for a permanent sediment and bedload management
- Tidal Elbe – wide areas of fine sediment deposition (sand) drifting in from outside the Elbe channel and local shoals in form of ripples and dunes of medium and coarse sand
- General problem – contaminant levels of cohesive sediments.

The Example of Navigation

Sediment Management Options (Inland Elbe)



The Concept
7. Prioritization and Recommendations for Action

Prioritization

Criteria

General criteria

1. Solving a problem at source or elimination of the underlying cause.
2. If the underlying cause (source) does not exist anymore, the problem should be solved possibly near to the source (“Sweeping the stairs from the top down“).
3. The recommendation has positive effect on one or both of the other aspects.
4. A single investment causes lower follow-up costs in the long run.
5. Degree of difficulty/costs of implementation.
6. Safety/uncertainty in the assessment of success, e.g. because of variability of the system.
7. The criterion for exclusion “Absence of appropriate options for solution“ is applied only in exceptional cases when the level of knowledge is very well based/substantiated.

Recommendations for River Basin Management as the Final Step

Recommendation for actions

- Are given from the perspective of each of the three aspects – quality, hydromorphology, navigation
- The recommendations for action developed from one specific perspective are assessed with view to mutual synergies or conflicts with the two others

Types of action – example quality

(1) Reduction / restoration of point sources
(2) Reduction / restoration of historical contaminations
(3) Removal of historical sediment deposits sensitive to remobilization
(4) Management of fine sediments in the river combined with the optimization of maintenance strategies
(5) Reduction of fine sediment imports from urban areas
(6) Utilization and management of contamination sinks.

Management Options and their Mutual Impacts

Recommendation vs. Response			Conclusion(synergy – conflict)
Quality	**Hydromorphology**	**Navigation**	
Recommendation: Removal and management of fine contaminated sediments in Elbe side structures downstream E6	**Response**: relief to the river bed particularly with higher discharges; improvement of the river morphology	**Response**: reduced contaminant loads into the reaches downstream and into the tidal Elbe	• High synergy due to double positive response
Recommendation: Enhancement of fine sediment deposition in Elbe floodplains downstream T9	**Response**: deposition may apply not only to fine sediment but also to gravel and sand, thus increasing the sediment deficit downstream. Prognosis difficult due to poor knowledge of underlying processes.	**Response**: reduced contaminant loads into the reaches downstream and into the tidal Elbe	• Potential conflict with hydromorphology • Synergy with navigation • Detailedevaluationrequired
Response: Potential conflicts may be avoided if restricted (1) to natural substrates and (2) to predominantly uncontaminated source areas.	**Recommendation**: increasing the sediment supply by bed load feeding and dredging and dumping, e.g. by reactivating from the riparian zone	**Response**: May be beneficial for maintaining the navigation channel by steering the measures in terms of location, time, amount	• Synergy with navigation may be reached • Conflict with quality may be avoided
Response: Potential conflicts due to expected enhanced mobilization of contaminated fine sediments at least in a transition time; conflicts may be avoided by removal of hot spots before	**Recommendation**: Improvement of the sediment continuity (cross structures; tributaries)	**Response**: Potential conflict with maintenance of the navigation channel when sediments are supplied by tributaries non-controllable	• Potential conflict with quality • Detailed evaluation required
Response: neutral, potential benefit if measures are combined with the removal of contaminated fine sediments, e.g. from groyne fields	**Response**: potential decrease of the transport capacity	**Recommendation**: maintenance and restoration of the river training system in the free flowing reach of the inland waterway Elbe (E3 to E7)	• Neutral • Synergy both with hydromorphology and quality may be reached
Response: potential conflict due to an accelerated transport of contaminated fine sediments to the sea.	**Response**: neutral when restricted to the fine fraction	**Recommendation**: Scenario-oriented fine sediment management in the tidal Elbe	• Potential conflict with quality • Detailed evaluation required

Thank you!

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