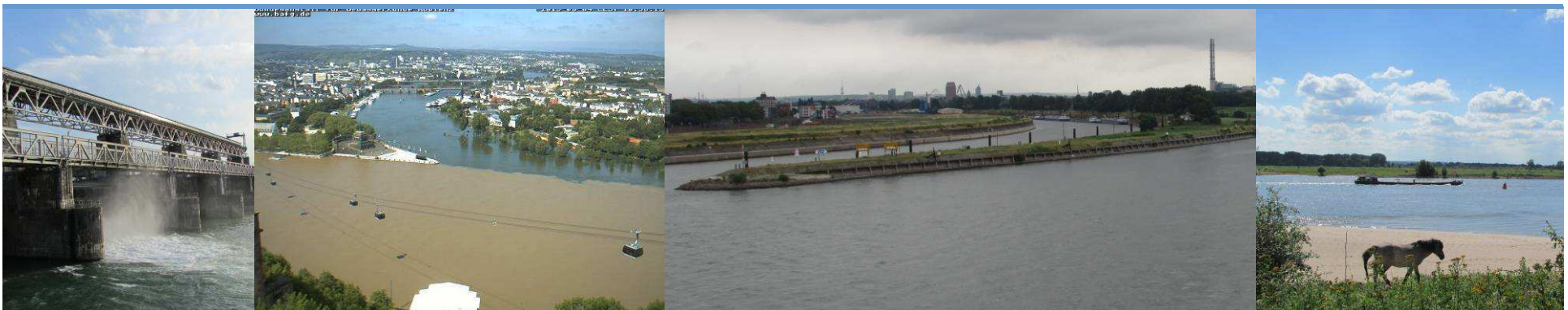# Sediment budget analysis – Method and data set
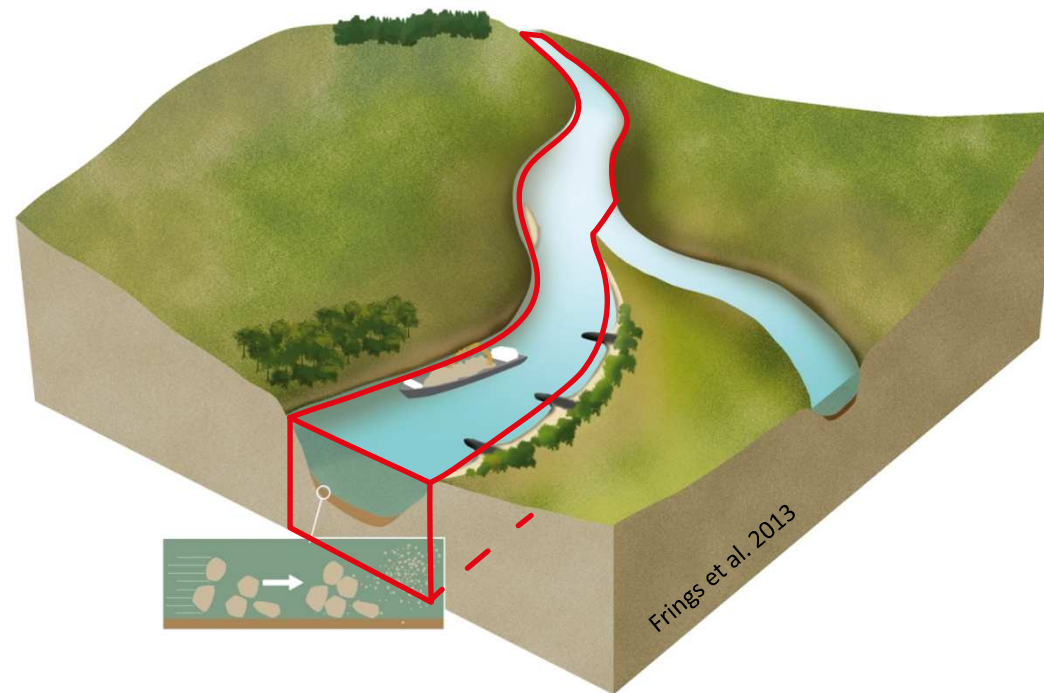
Dr. Gudrun Hillebrand

Federal Institute of Hydrology, Koblenz

Sediment budget - Method
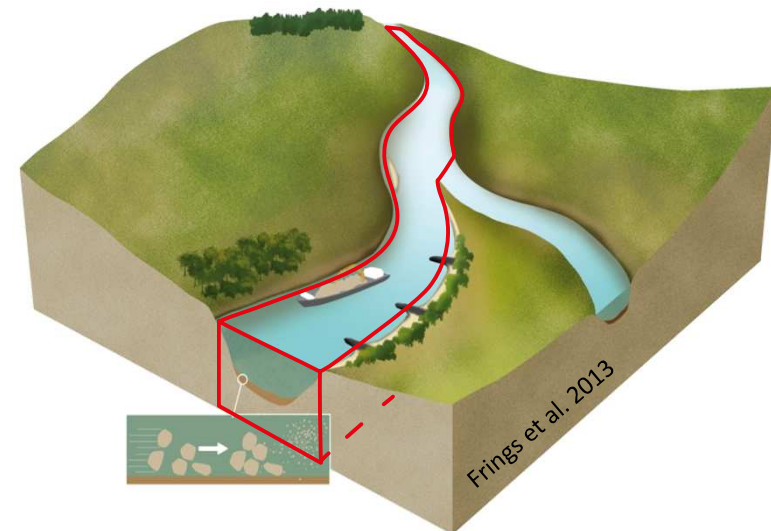
1. Define control volume and time period
2. Balance input and output

Frings et al. 2013

Sediment budget - Method

1. Define control volume and time period
2. Balance input and output
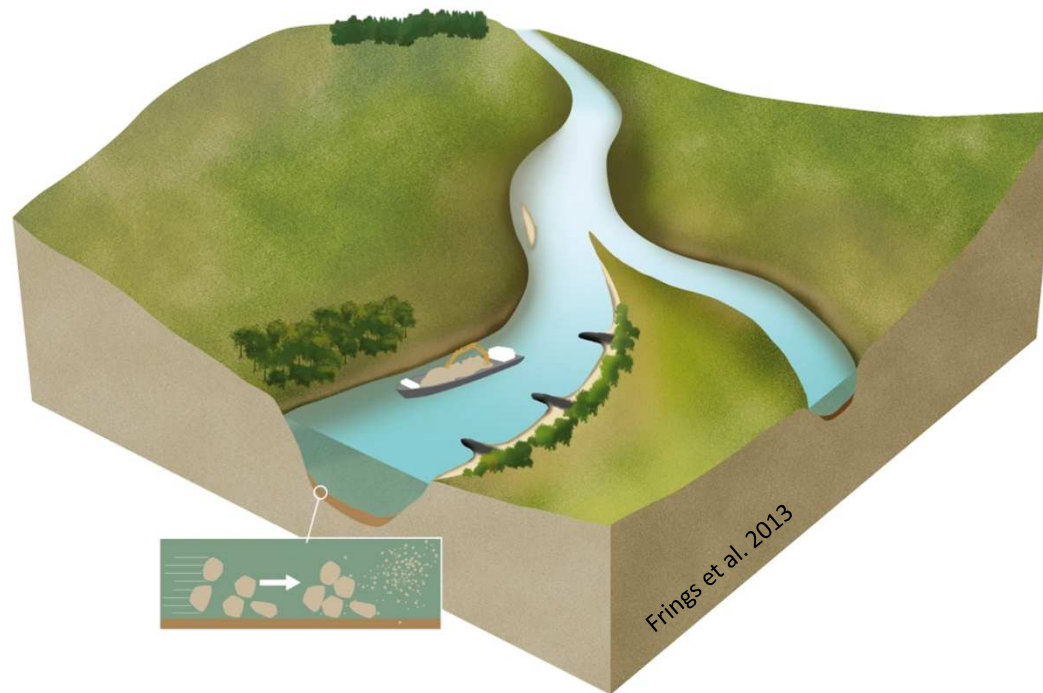
- Time period:
  - 1991 – 2010
- Size fractions:
  - stones   (> 63 mm)
  - coarse gravel   (16 – 63 mm)
  - fine gravel   (2 – 63 mm)
  - sand   (0.063 – 2 mm)
  - silt/clay   (< 63 μm)

Frings et al. 2013

Balance input and output

$$\left(I_{up} + I_{tr} + I_{se} + I_{di} + I_{ar} + I_{ab} + I_{do}\right)$$

$$- \left(O_{do} + O_{se} + O_{dr} + O_{gr} + O_{fl} + O_{po} + O_{ab}\right) = \Delta S$$
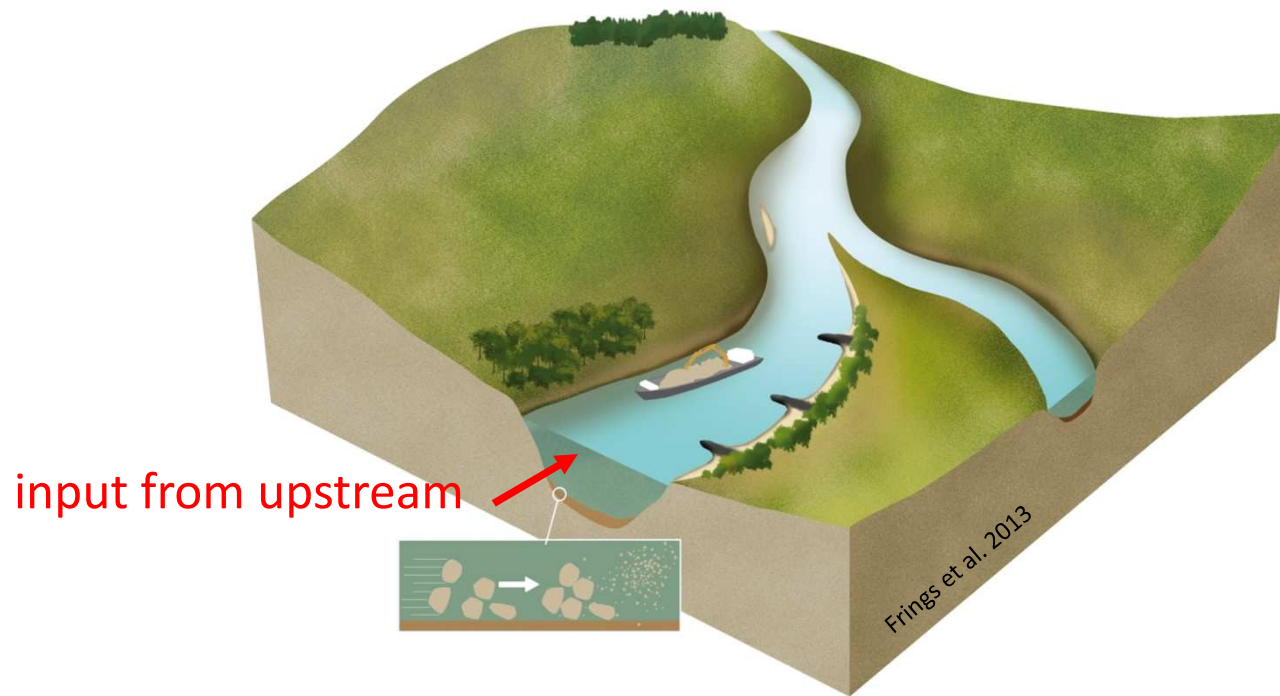

Frings et al. 2013

Assumption: tectonic bed evolution is negligible

Balance input and output

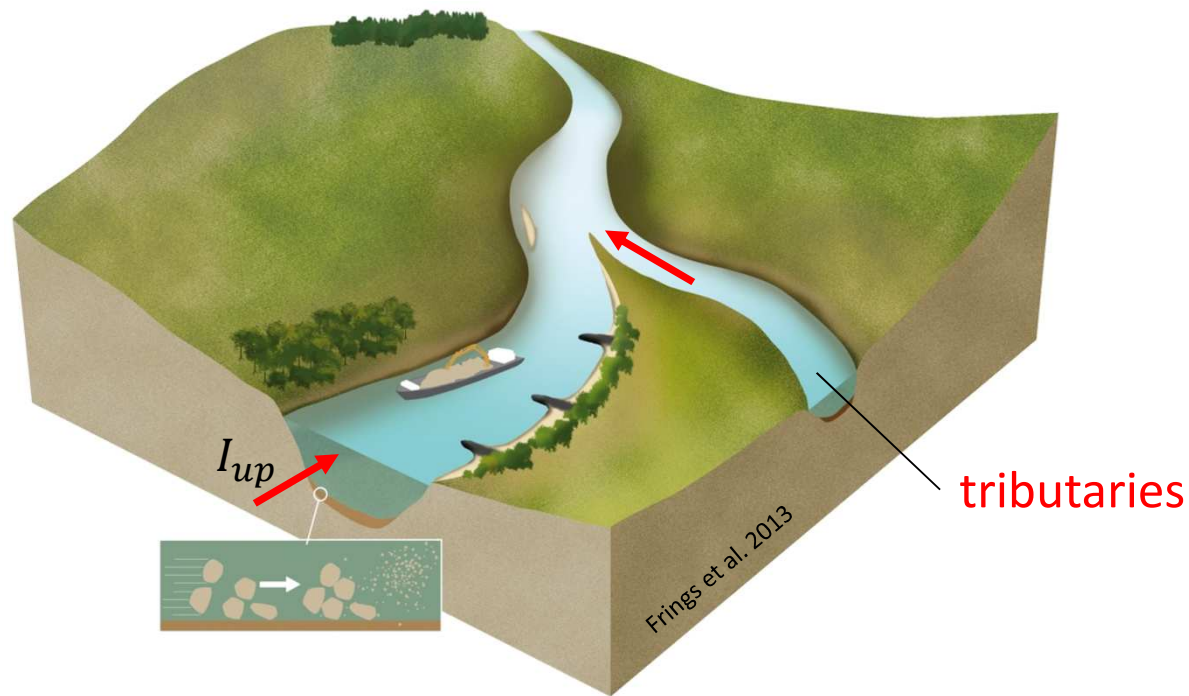$$\left(I_{up} + I_{tr} + I_{se} + I_{di} + I_{ar} + I_{ab} + I_{do}\right)$$

$$- \left(O_{do} + O_{se} + O_{dr} + O_{gr} + O_{fl} + O_{po} + O_{ab}\right) = \Delta S$$

input from upstream

Frings et al. 2013

Balance input and output

$$\left(I_{up} + \textcolor{red}{I_{tr}} + I_{se} + I_{di} + I_{ar} + I_{ab} + I_{do}\right)$$

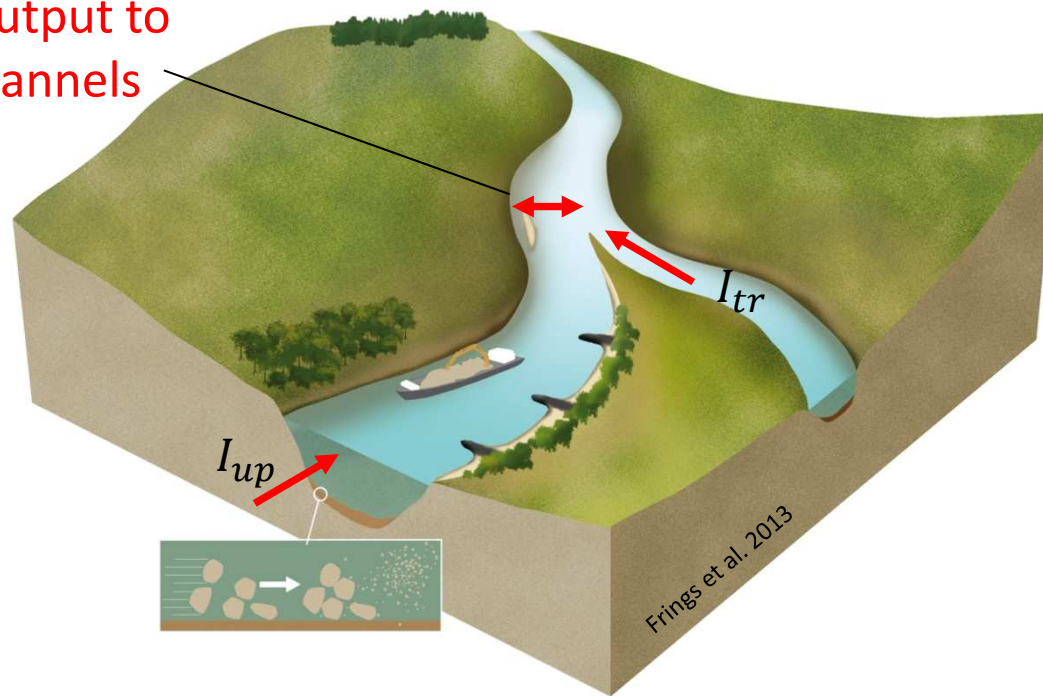$$- \left(O_{do} + O_{se} + O_{dr} + O_{gr} + O_{fl} + O_{po} + O_{ab}\right) = \Delta S$$

I_{up}

Frings et al. 2013

tributaries

Balance input and output

$$\left(I_{up} + I_{tr} + \textcolor{red}{I_{se}} + I_{di} + I_{ar} + I_{ab} + I_{do}\right)$$

$$- \left(O_{do} + \textcolor{red}{O_{se}} + O_{dr} + O_{gr} + O_{fl} + O_{po} + O_{ab}\right) = \Delta S$$

input from/output to
secondary channels

I_{tr}

I_{up}

Frings et al. 2013

Balance input and output

$$\left(I_{up} + I_{tr} + I_{se} + {\color{red}I_{di}} + I_{ar} + I_{ab} + I_{do} \right)$$

$$- \left(O_{do} + O_{se} + O_{dr} + O_{gr} + O_{fl} + O_{po} + O_{ab} \right) = \Delta S$$

diffuse inputs

I_{se}/O_{se}

I_{tr}

I_{up}

Frings et al. 2013

Balance input and output

$$\left(I_{up} + I_{tr} + I_{se} + I_{di} + \textcolor{red}{I_{ar}} + I_{ab} + I_{do}\right)$$

$$- \left(O_{do} + O_{se} + \textcolor{red}{O_{dr}} + O_{gr} + O_{fl} + O_{po} + O_{ab}\right) = \Delta S$$

I_{se}/O_{se} I_{di}

I_{tr}

artificial input/ dredging

I_{up}

Frings et al. 2013

Balance input and output

$$\left(I_{up} + I_{tr} + I_{se} + I_{di} + I_{ar} + {\color{red}I_{ab}} + I_{do}\right)$$

$$- \left(O_{do} + O_{se} + O_{dr} + O_{gr} + O_{fl} + O_{po} + {\color{red}O_{ab}}\right) = \Delta S$$

I_{se}/O_{se} I_{di}

I_{ar}/O_{dr} I_{tr}

I_{up}

Frings et al. 2013

abrasion (input/output)

Balance input and output

$$\left(I_{up} + I_{tr} + I_{se} + I_{di} + I_{ar} + I_{ab} + \textcolor{red}{I_{do}}\right)$$
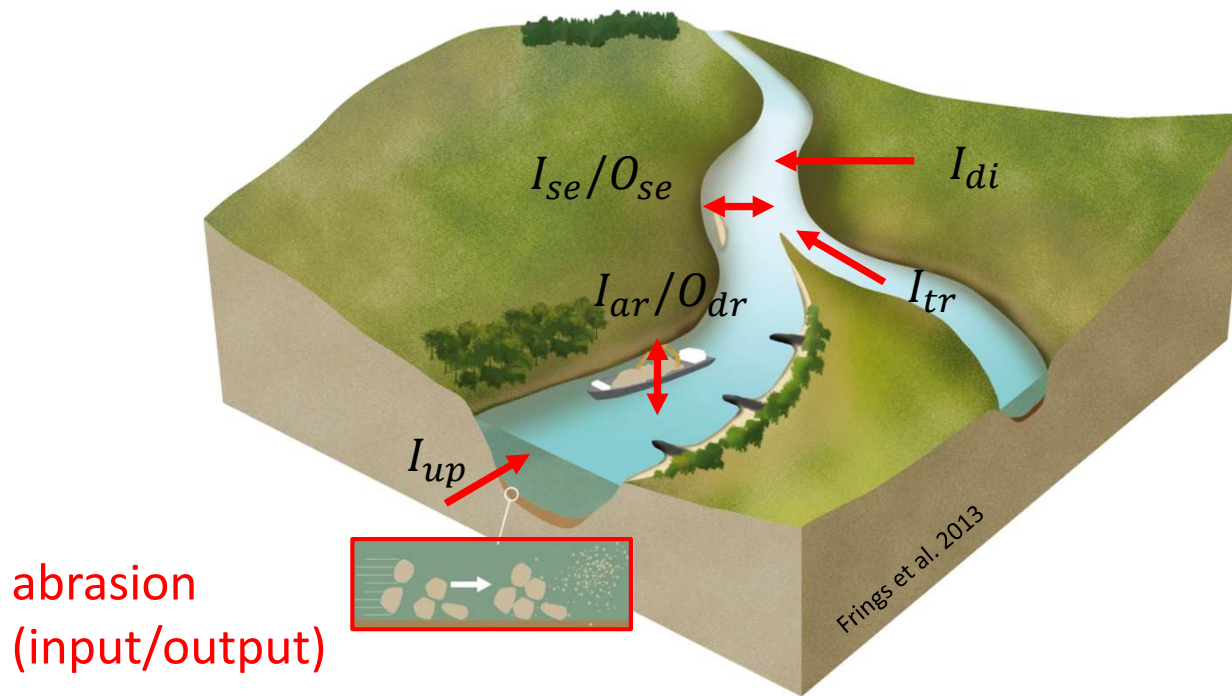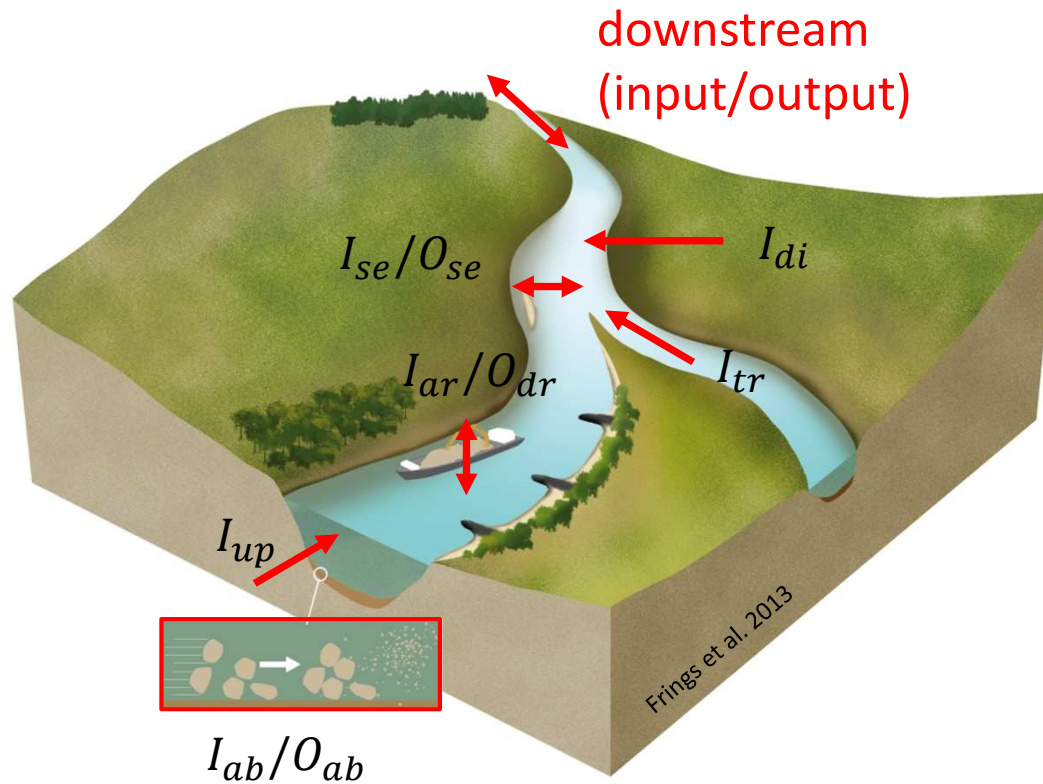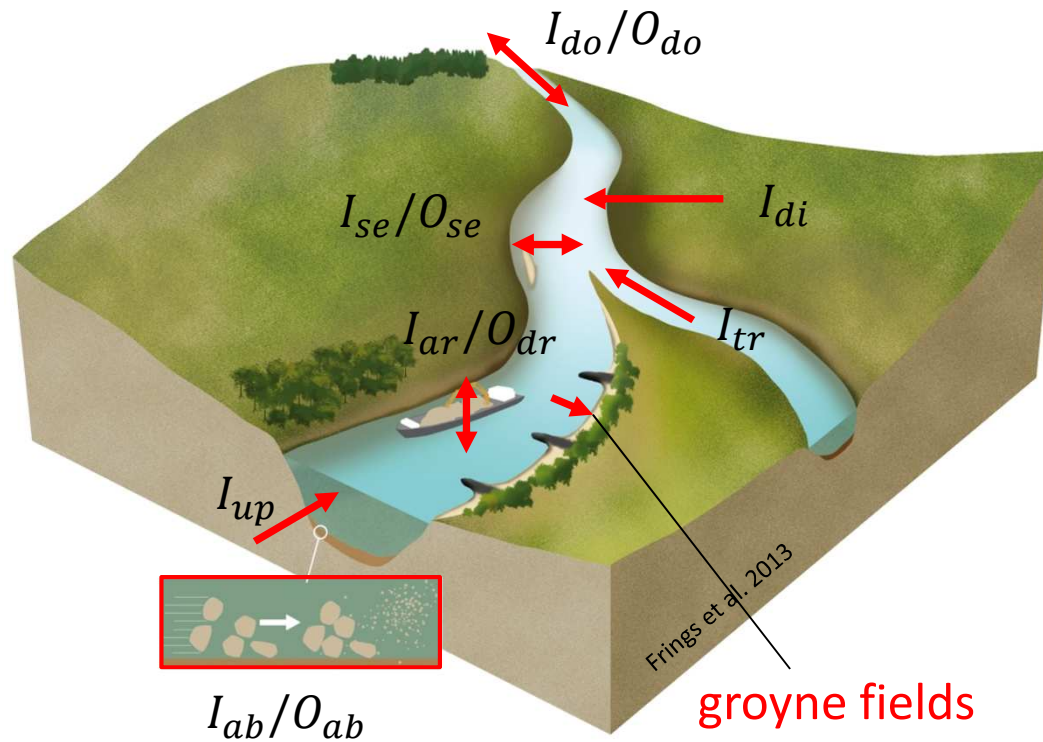
$$- \left(\textcolor{red}{O_{do}} + O_{se} + O_{dr} + O_{gr} + O_{fl} + O_{po} + O_{ab}\right) = \Delta S$$

Balance input and output

$$\left(I_{up} + I_{tr} + I_{se} + I_{di} + I_{ar} + I_{ab} + I_{do}\right)$$
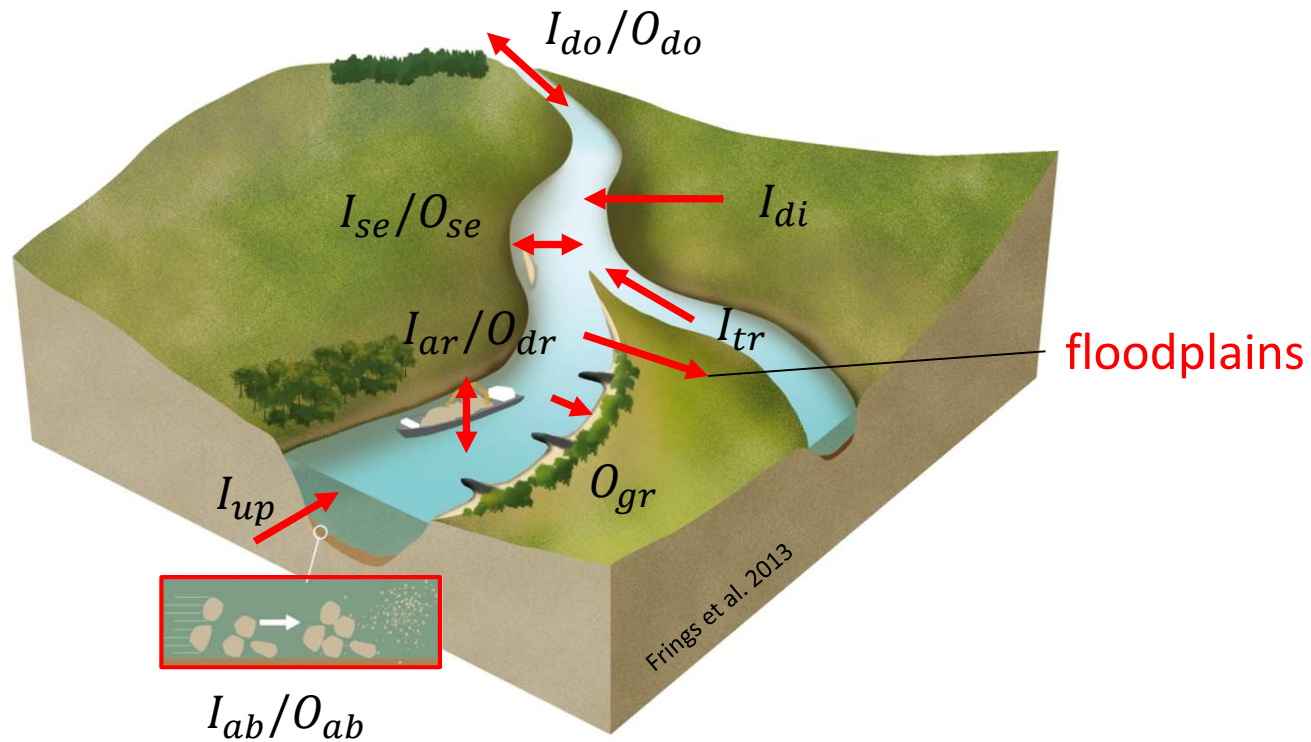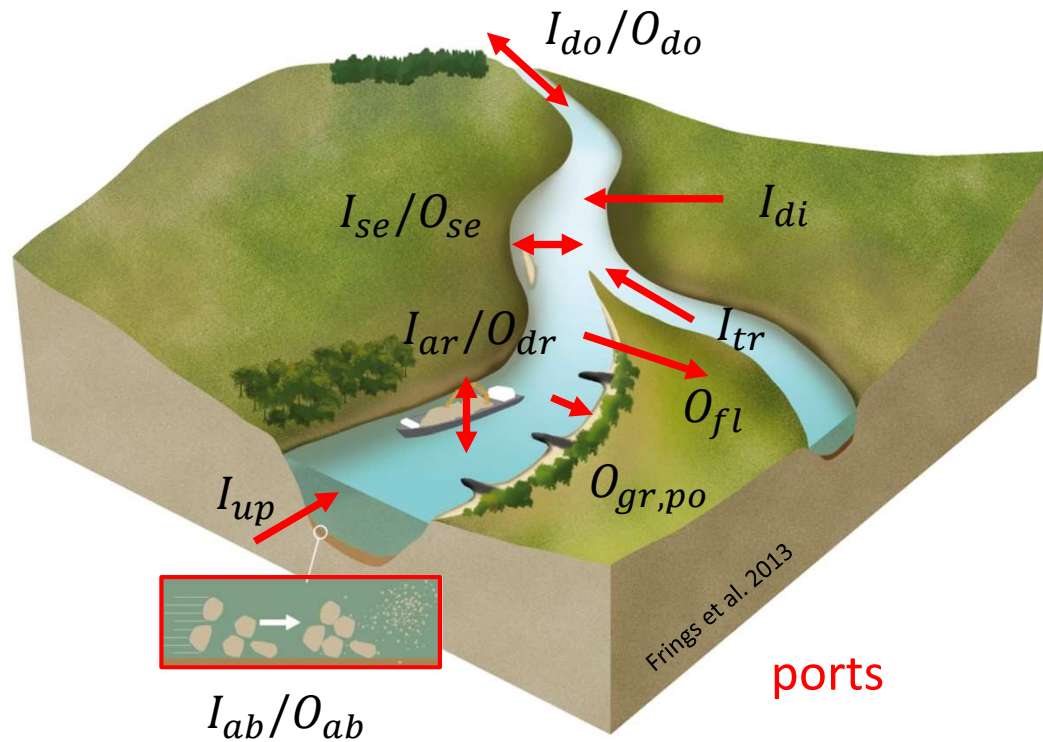
$$-\left(O_{do} + O_{se} + O_{dr} + O_{gr} + O_{fl} + O_{po} + O_{ab}\right) = \Delta S$$

I_{do}/O_{do}

I_{se}/O_{se}

I_{di}

I_{ar}/O_{dr}

I_{tr}

I_{up}

Frings et al. 2013

groyne fields

I_{ab}/O_{ab}

Balance input and output

$$\left(I_{up} + I_{tr} + I_{se} + I_{di} + I_{ar} + I_{ab} + I_{do}\right)$$

$$-\left(O_{do} + O_{se} + O_{dr} + O_{gr} + \textcolor{red}{O_{fl}} + O_{po} + O_{ab}\right) = \Delta S$$

I_{do}/O_{do}

I_{se}/O_{se}

I_{di}

I_{ar}/O_{dr}

I_{tr}

floodplains

O_{gr}

I_{up}

Frings et al. 2013

I_{ab}/O_{ab}

Balance input and output

$$\left(I_{up} + I_{tr} + I_{se} + I_{di} + I_{ar} + I_{ab} + I_{do}\right)$$

$$- \left(O_{do} + O_{se} + O_{dr} + O_{gr} + O_{fl} + \textcolor{red}{O_{po}} + O_{ab}\right) = \Delta S$$

I_{do}/O_{do}

I_{di}

I_{se}/O_{se}

I_{ar}/O_{dr}

I_{tr}

O_{fl}

$O_{gr,po}$

I_{up}

Frings et al. 2013

ports

I_{ab}/O_{ab}

Balance input and output

$$\left(I_{up} + I_{tr} + I_{se} + I_{di} + I_{ar} + I_{ab} + I_{do}\right)$$

$$-\left(O_{do} + O_{se} + O_{dr} + O_{gr} + O_{fl} + O_{po} + O_{ab}\right) = \Delta S$$

change in sediment storage (river bed)

I_{do}/O_{do}

I_{di}

I_{se}/O_{se}

I_{tr}

I_{ar}/O_{dr}

O_{fl}

$O_{gr,po}$

I_{up}

ΔS
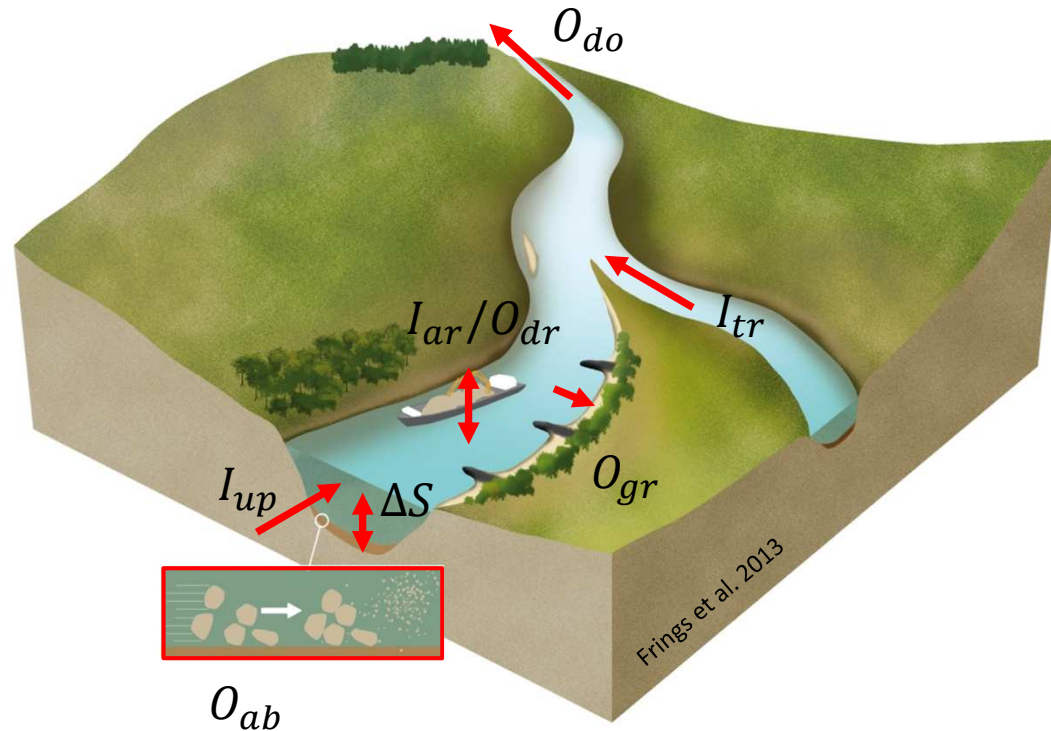
I_{ab}/O_{ab}

Frings et al. 2013

Budget equation = f(study section, grain size)

$$\left(I_{up} + I_{tr} + \cancel{I_{se}} + \cancel{I_{di}} + I_{ar} + \cancel{I_{ab}} + \cancel{I_{do}} \right)$$

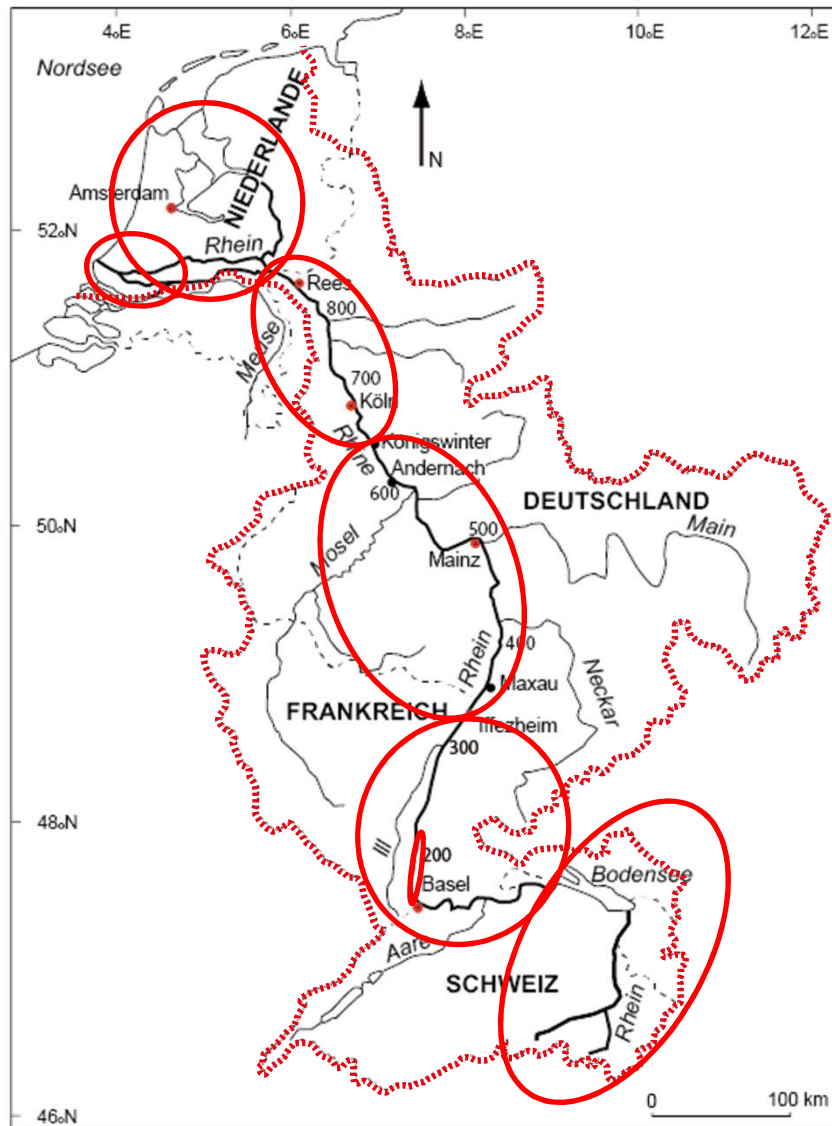$$- \left(O_{do} + \cancel{O_{se}} + O_{dr} + \boxed{O_{gr}} + \cancel{O_{fl}} + \cancel{O_{no}} + O_{ab} \right) = \Delta S$$

e. g. gravel budget

Usually, not all terms are known. Unknown term = closing term.

e.g. sedimentation in groyne fields
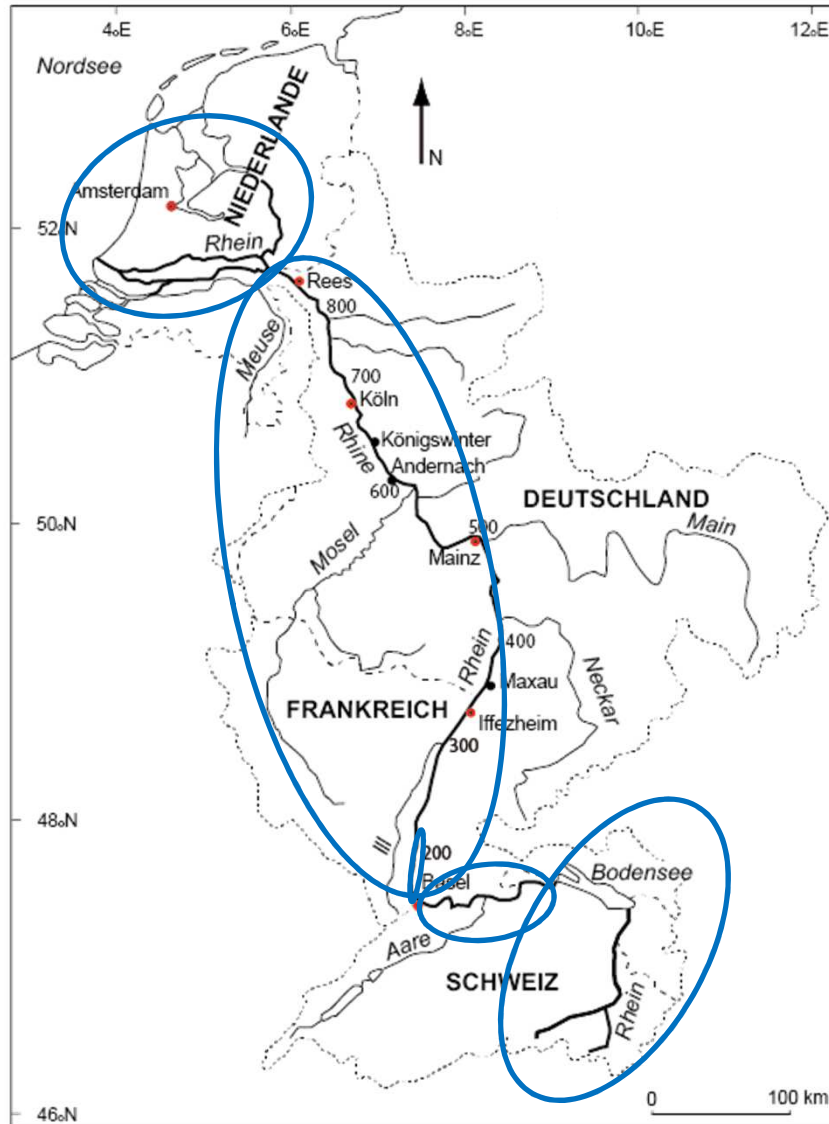

Frings et al. 2013

Study sections

- **complete Rhine basin**

- **Alpine section:**
  - Alpine Rhine and Lake Constance

- **Impounded section:**
  - Konstanz to Iffezheim
  - Restrhein

- **Free-flowing section:**
  - Iffezheim to Bonn
  - Bonn to D/NL border

- **Delta section:**
  - Upper Rhine Delta
  - Lower Rhine Delta

Data sets

Alpine section:

- Literature, e.g. Zarn et al. (1995)/(2010)

Konstanz to Basel:

- Literature, e.g. Abegg (2013)

Restrhein:

- Literature, e.g. Dittrich (2013)
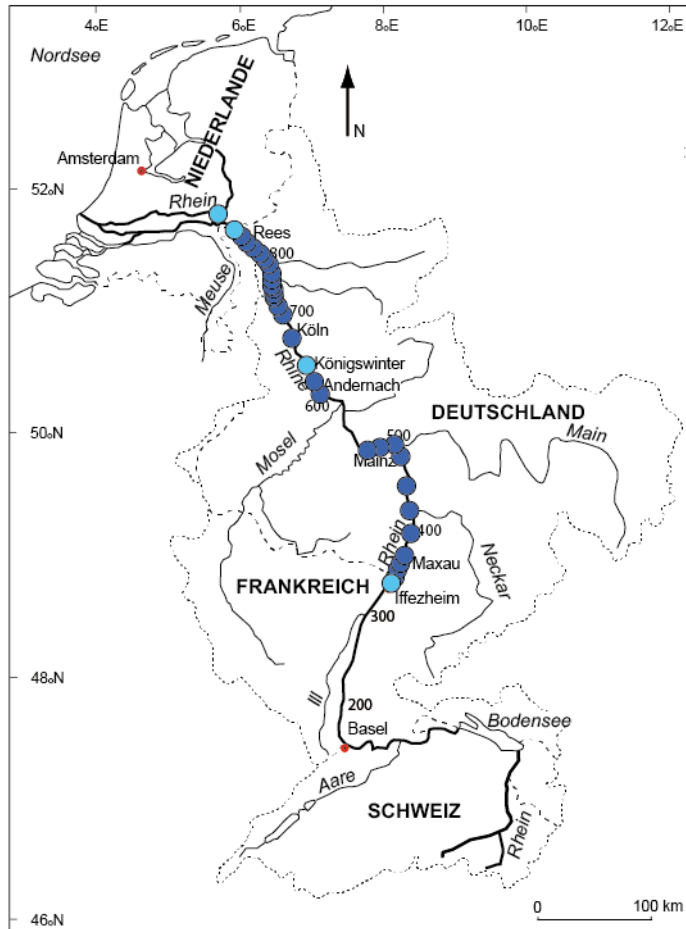
Basel to D/NL-border (w/o Restrhein)**:**

- Existing budgets
- WSV data

Rhine Delta:
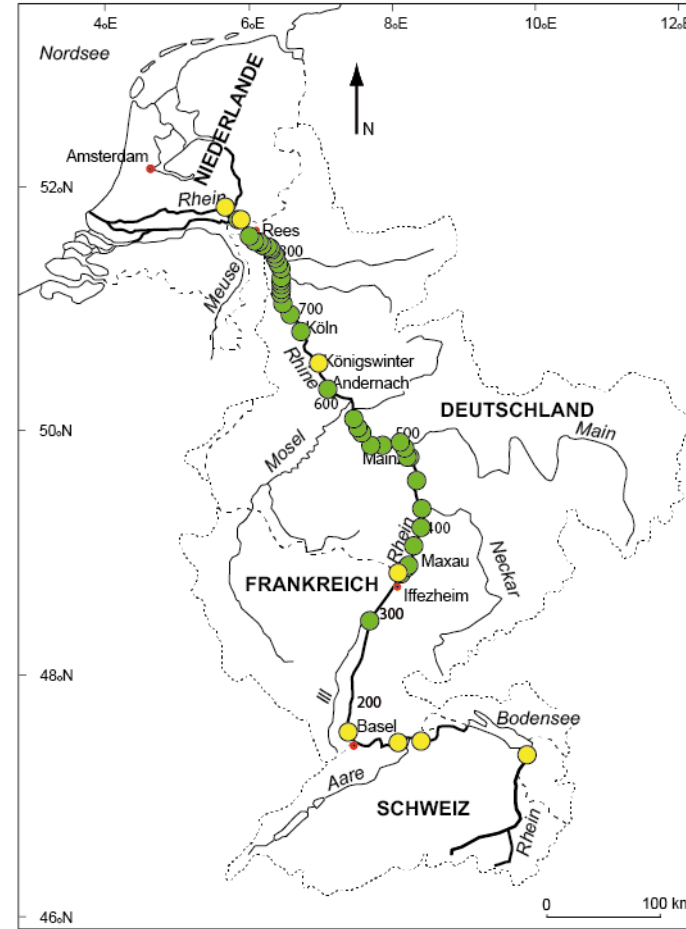
- Literature
- Existing budgets, Ten Brinke (2001), van Deumel (1995)
- Rijkswaterstaat data

Bed load measurements in the Rhine

Suspended load measurements in the Rhine

Data types

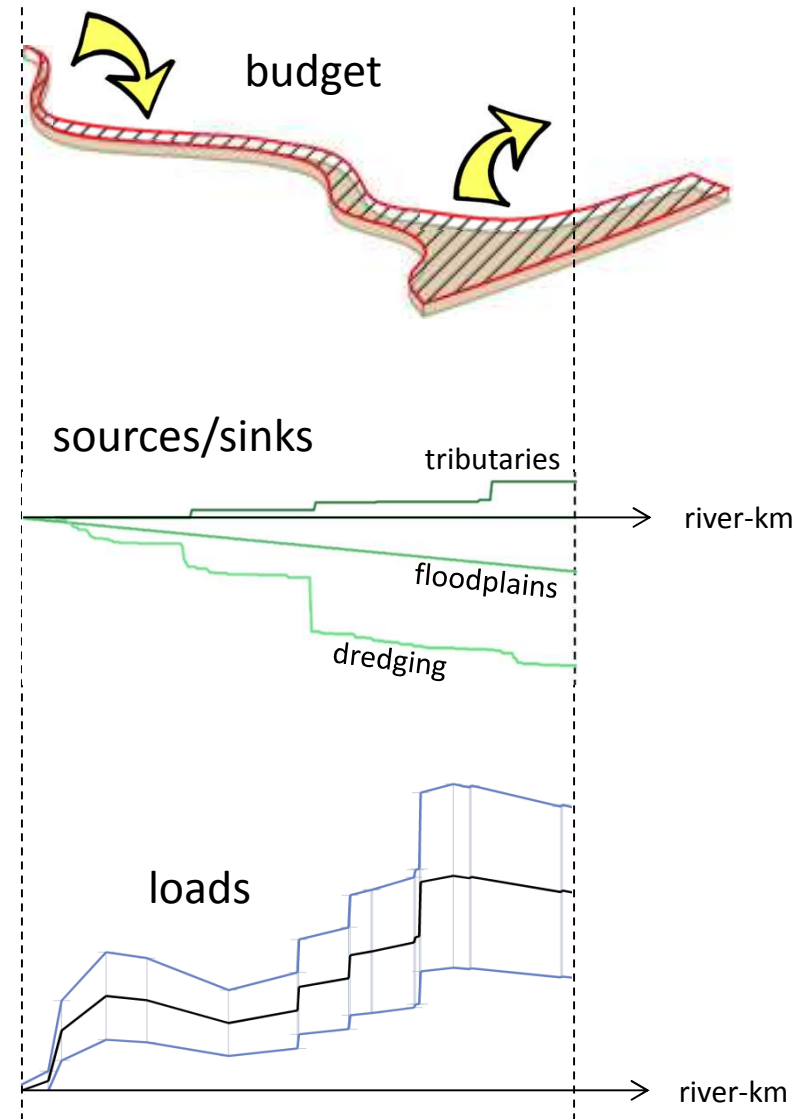**Existing measurements and/or literature values:**

- Bed load (gravel, sand) *≈ 1400 measurements*
- Suspended load (sand, clay/silt) *≈ 500 cross-sectional + 50000 point measurem.*
- Amount and composition of artificial inputs
- Dredging volumes *≈ 3000 measures*
- Bed elevation (echo-soundings)
- Bed grain size composition *≈ 10000 sieve curves*
- Abrasion rates
- Sedimentation rates on floodplains

Additional measurements:

- Sedimentation rates on floodplains
- Grain size composition of suspended loads **Session 2**
- Sand loss in bed load measurements

Steps towards the final budget

1. Collect data:
   - literature
   - database systems
   - field measurements
2. Plausibility check of data, data correction if necessary and possible
3. Convert and aggregate all data to mean annual loads
4. Sediment budget
5. Validation (load data that was not used in budget)
6. Accuracy analysis

Thank you!

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