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Deltas of the Anthropocene

Lessons from the Rhine

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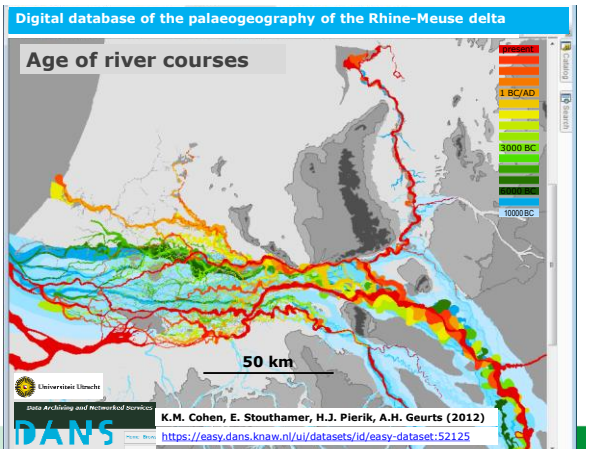
Deltas of the Anthropocene

'Man-made deltas'
'Anthropogenic Transformation'
'Sinking deltas'
'Deltas under pressure'

- Lessons from the Rhine delta history: a nutshell story
  - Heavily modified by humans
  - Detailed record of forcings and impacts
  - How, where, when have humans affected it?
  - Various options of sustainable management are tested
- What way to go for future deltas



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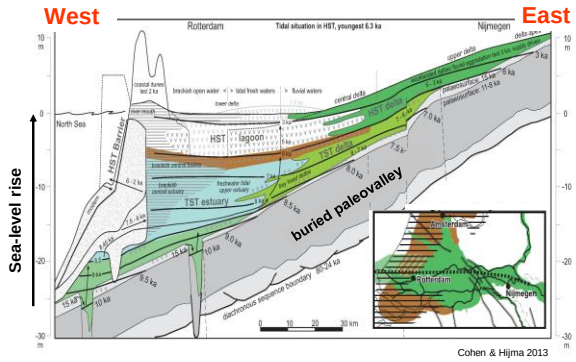
Back-barrier delta



Cohen & Hijma 2013

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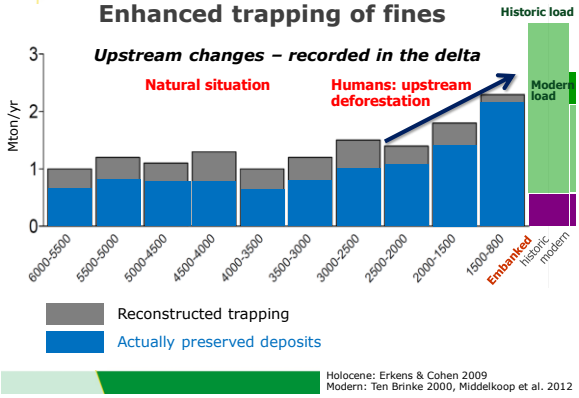
Enhanced trapping of fines



Holocene: Erkens & Cohen 2009
Modern: Ten Brinke 2000, Middelkoop et al. 2012

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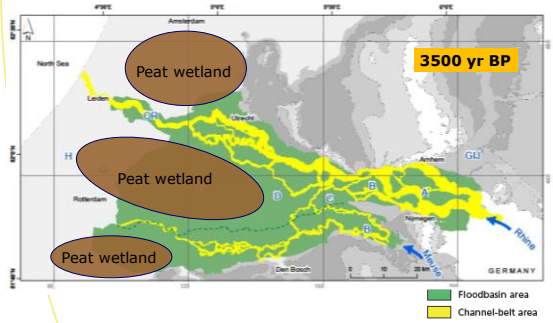
Changes start after 3500 BP



Erkens & Cohen 2009

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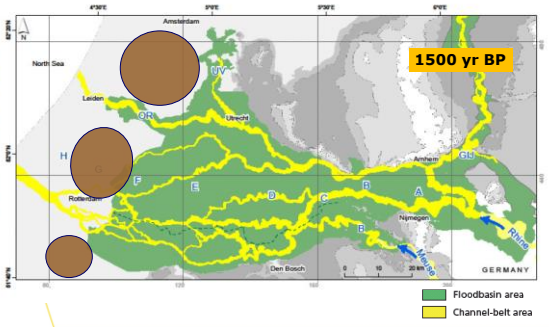
Enhanced clay deposition from upstream



Erkens & Cohen 2009

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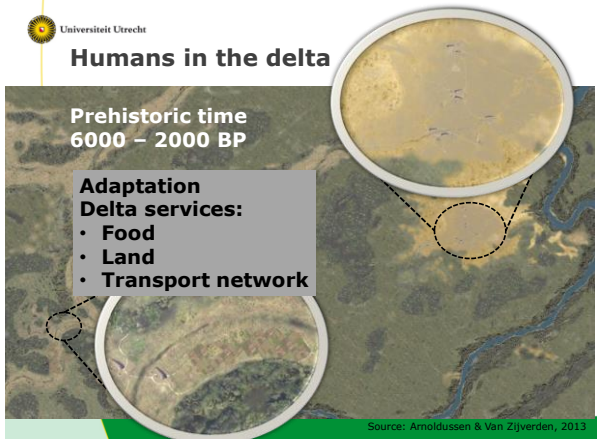
Humans in the delta



Source: Arnoldussen & Van Zijverden, 2013

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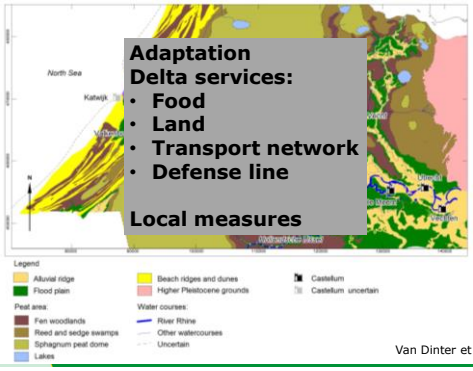
Adapted occupation: Roman Limes



Van Dinter et al., 2013

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Land reclamation: drainage

- Pressure on land
- Organisation - governance
- Power / money
- Knowledge and system understanding
- People and windmills to do the work

Drainage: subsidence!

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Peat mining, resulting in lakes

~1400 – 1800 AD

- Economic development
- Urban growth
- Need for fuel
- Over-exploitation

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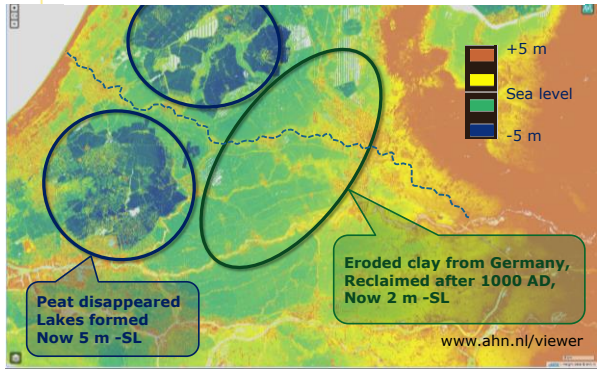
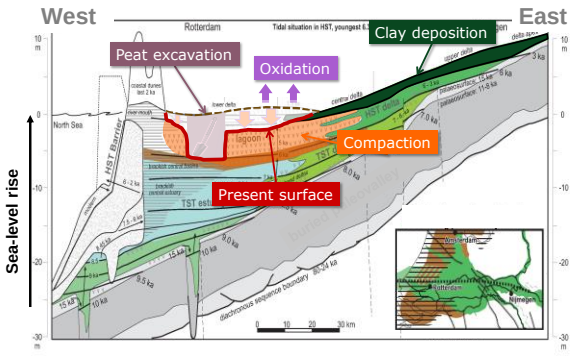
Lidar delta elevation: artificial surface



Longitudinal section delta wedge



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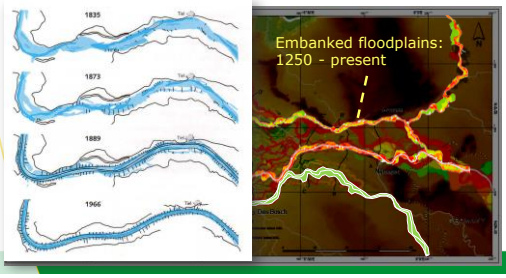
Embanked rivers in the delta

- Disruption of channel – floodplain connection
- No more natural avulsions
- Sediment deposition only along rivers and in estuary



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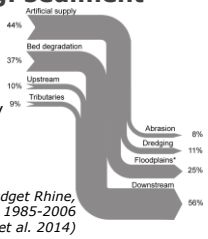
20th century engineering: sediment

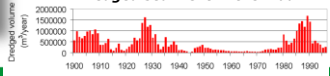
- Upstream weirs trap sediment
- Excessive gravel dredging
- Result = reduced sediment delivery to the delta

Weir at Iffesheim – Germany



Sand+gravel budget Rhine, mid-Germany, 1985-2006 (Frings et al. 2014)

Dredged sediment in the Waal



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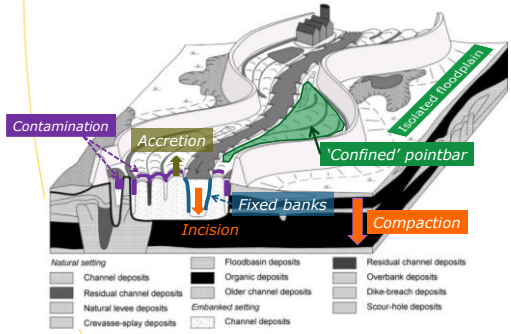
Man-made channel-belt architecture



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Sediment dynamics

	Natural delta	Present Rhine
Total deposition suspension load	2 – 3 Mton/yr	2.5 Mton/yr
Main depo zones	Flood plain	Channel
Avulsions	Large-scale shifts in deposition areas	No change
Pacing in sediment dynamics	Channel belt life cycles Erosion, deposition reworking	Flood pulses only
Residence/ preservation	Downstream increase Half lives: 10^2 – 10^5 yr	Waal before normalisation: ~90% reworked 'Reworking' to date: Floodplains = clay excavation Channels = dredging

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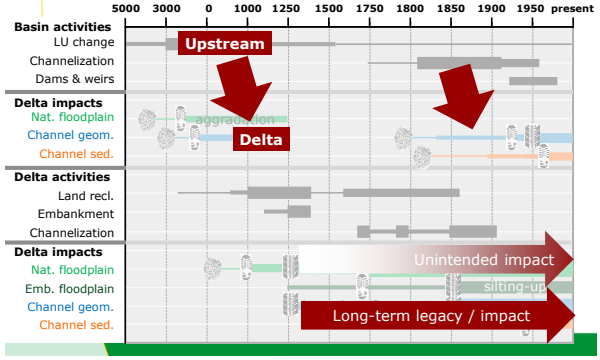
Impacts across scales



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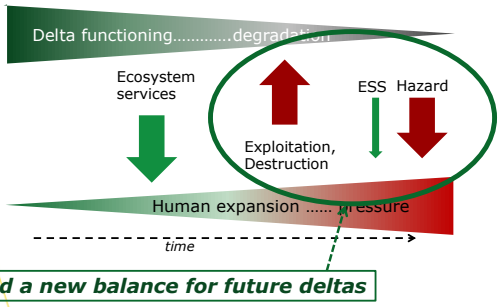
What happened – the challenge



Find a new balance for future deltas

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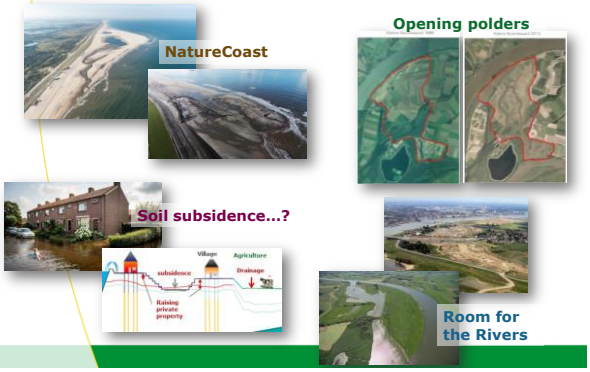
Solutions? - Pilots in the Rhine delta



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Scientific challenges

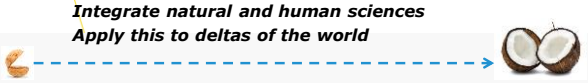
Understand the physical system:

- Causes and mechanisms underlying the problem
- Longer-term and larger-scale impacts of measures
- Options for sustainable restoration

Understand the societal system:

- The problem is 'new' and not well incorporated in current governance / legislation
- Who has the problem, who caused it, who solves it?
- Conflicting interests across spatial scales and time
- Identification of adaptation capacity and options

Integrate natural and human sciences
Apply this to deltas of the world



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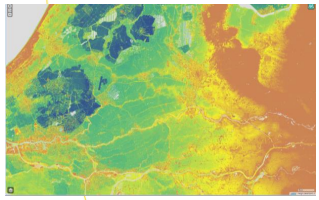
Thank you!



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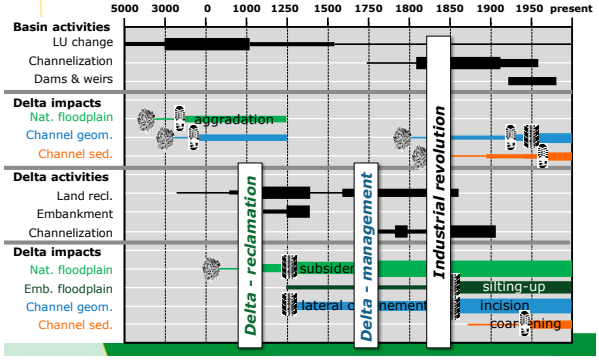
Synthesis – Rhine delta



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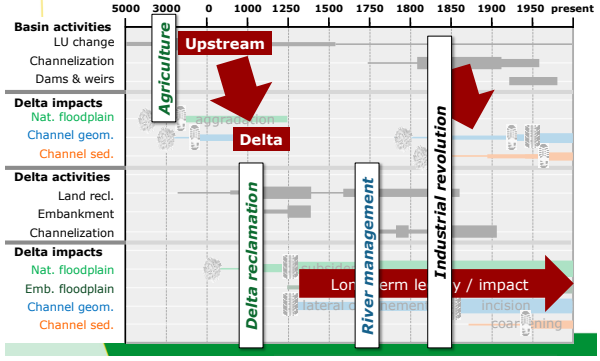
Synthesis – Rhine delta



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Natural delta

High-stand sediment trapping

Trapping of fines
Break down
- 500 year time slices
- Spatially explicit

Erkens (2009)