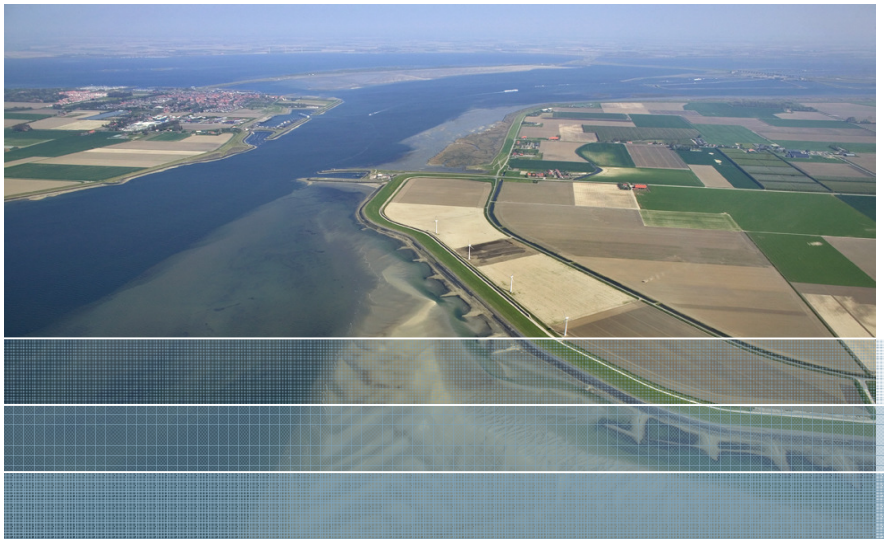


Deltares
Enabling Delta Life

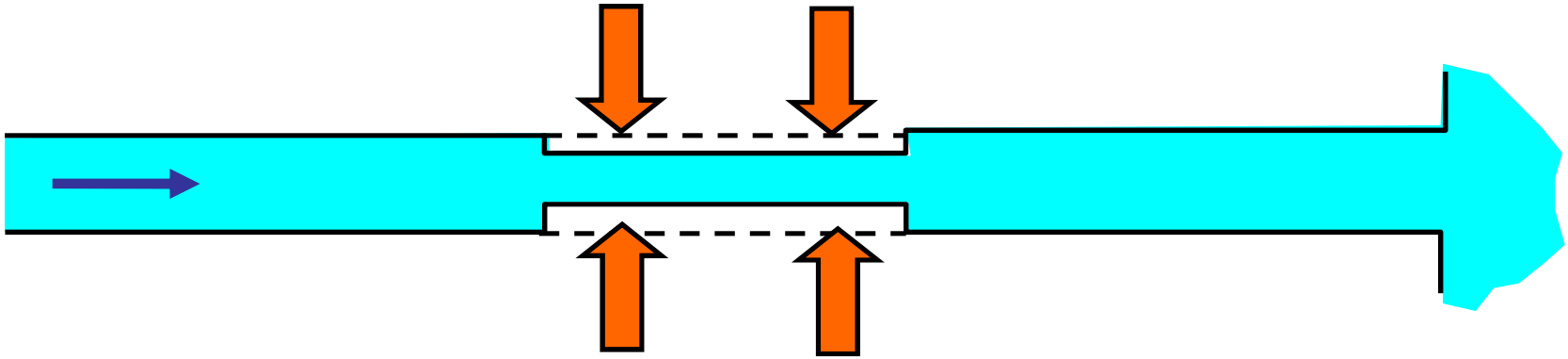
Engineered river systems

Erik Mosselman

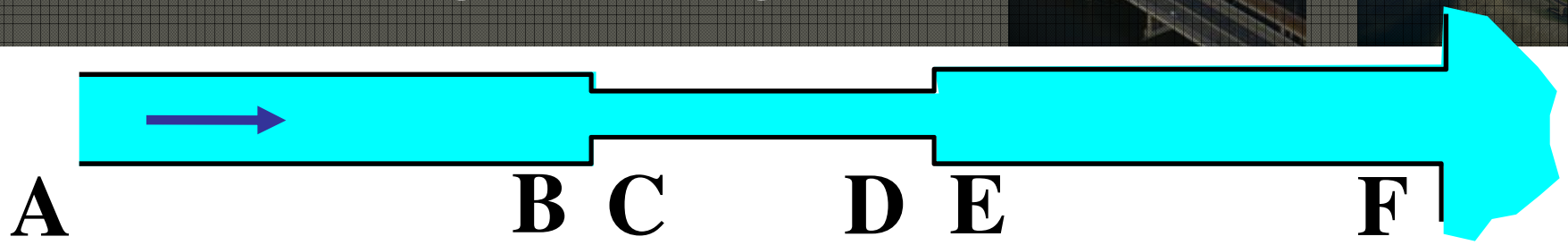
Practical training course on sustainable sediment management with the Sava River Basin as a showcase

Zagreb, Croatia, 16 October 2012

What happens with the river bed if a reach is trained?



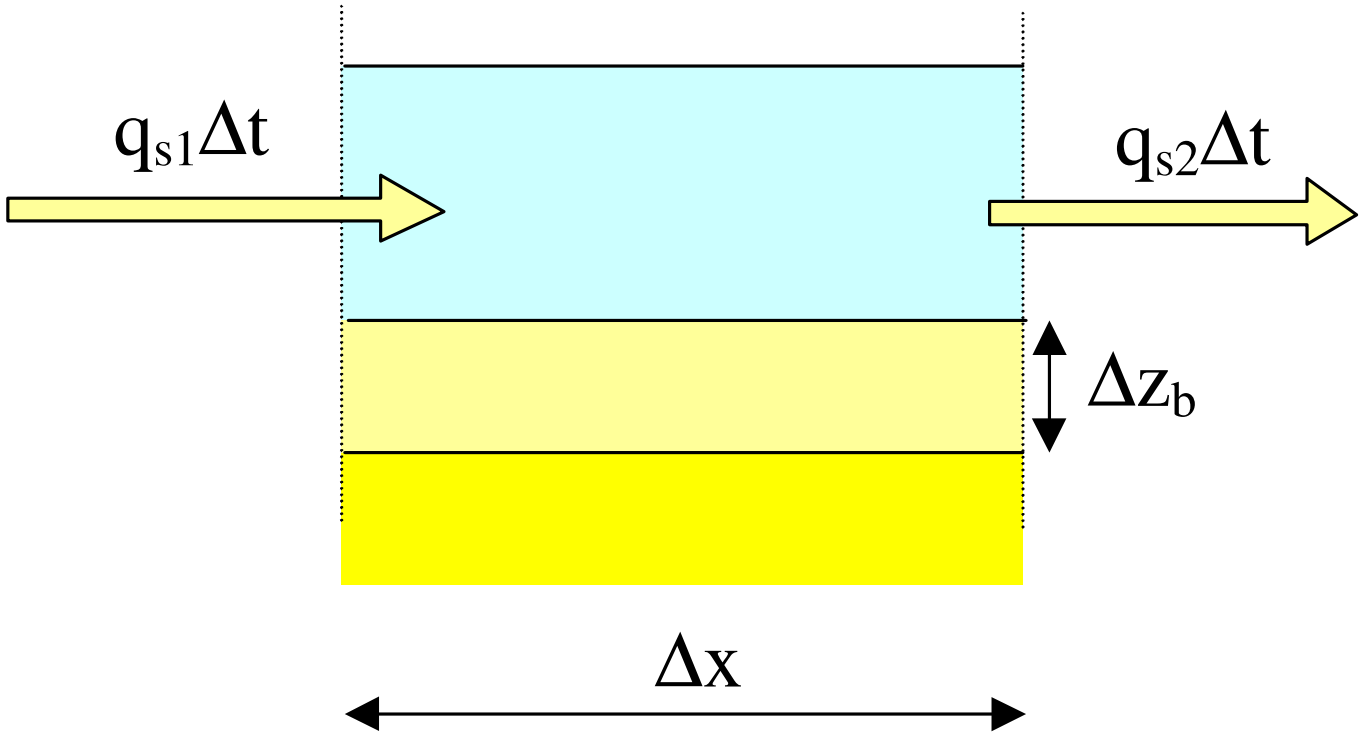
River training for navigation



River-bed response		A	B	C	D	E	F
initial	sedimentation						
	stable						
	erosion						
final	sedimentation						
	stable						
	erosion						

Deltares

Sediment balance



$$\Delta z_b \Delta x + \Delta q_s \Delta t = 0$$

Deltares

Sediment balance

$$\Delta z_b \Delta x + \Delta q_s \Delta t = 0$$

leads to partial differential equation

$$\frac{\partial z_b}{\partial t} + \frac{\partial q_s}{\partial x} = 0$$

Combination with sediment transport formula

$$q_s = q_s(u)$$

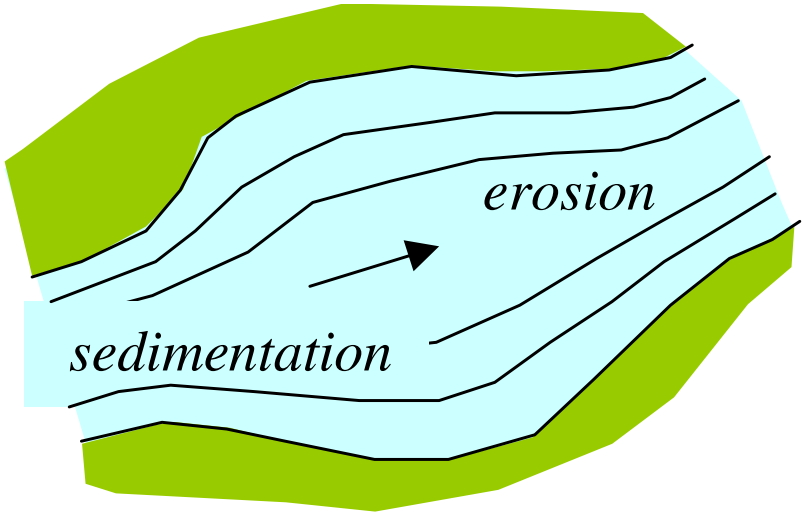
results in the Exner principle:

$$\frac{\partial z_b}{\partial t} + \left[\frac{dq_s}{du}\right]\frac{\partial u}{\partial x} = 0$$

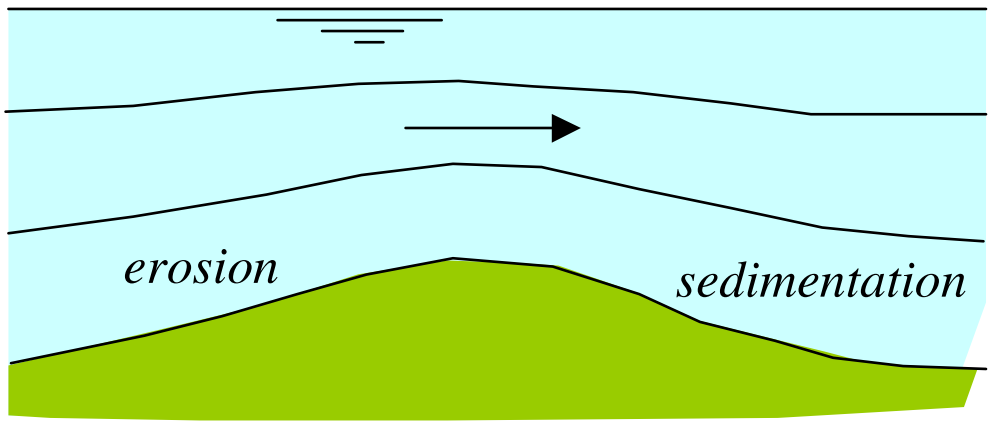
Deltares

Sediment balance: the Exner principle

$$\frac{\partial z_b}{\partial t} + \frac{\mathrm{d}q_s}{\mathrm{d}u}\frac{\partial u}{\partial x} = 0$$



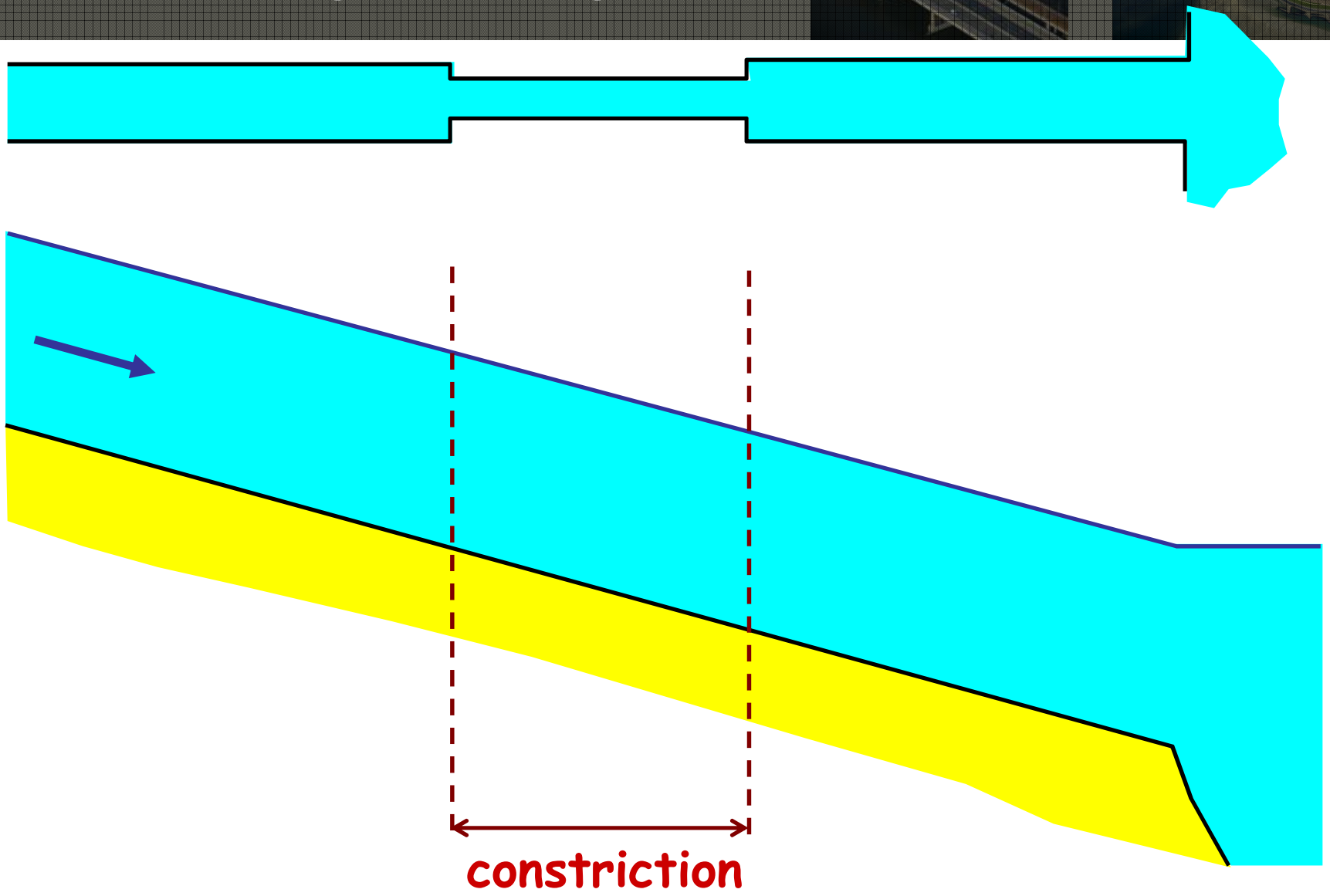
top view
of flow over horizontal bed



side view
of flow in channel with uniform width

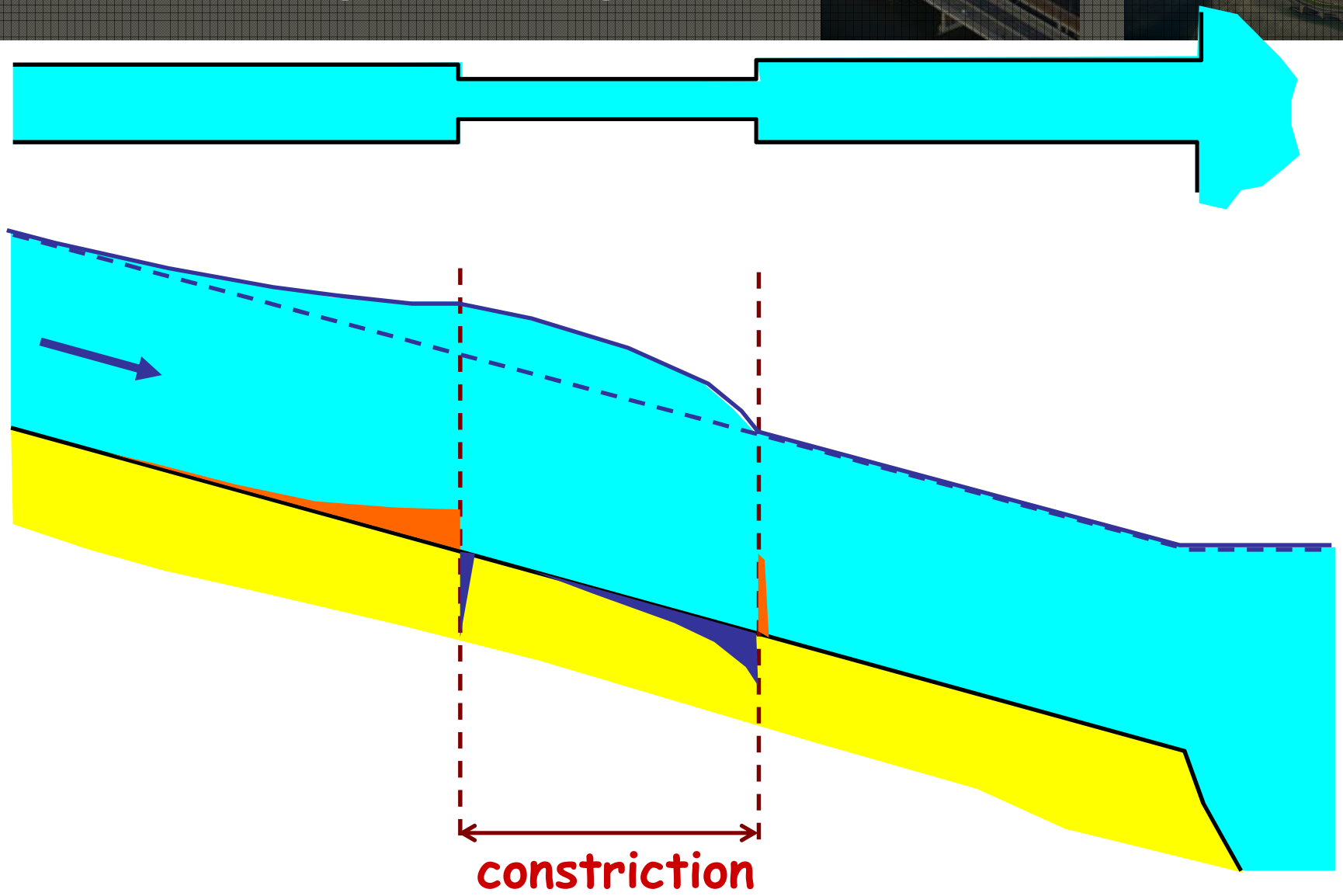
Deltares

River training for navigation



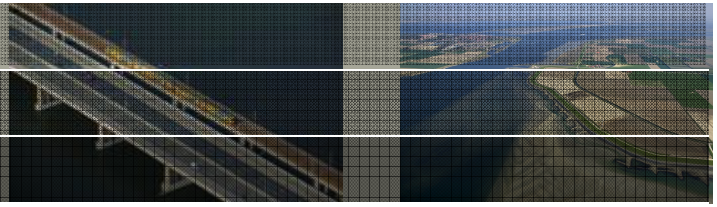
Deltares

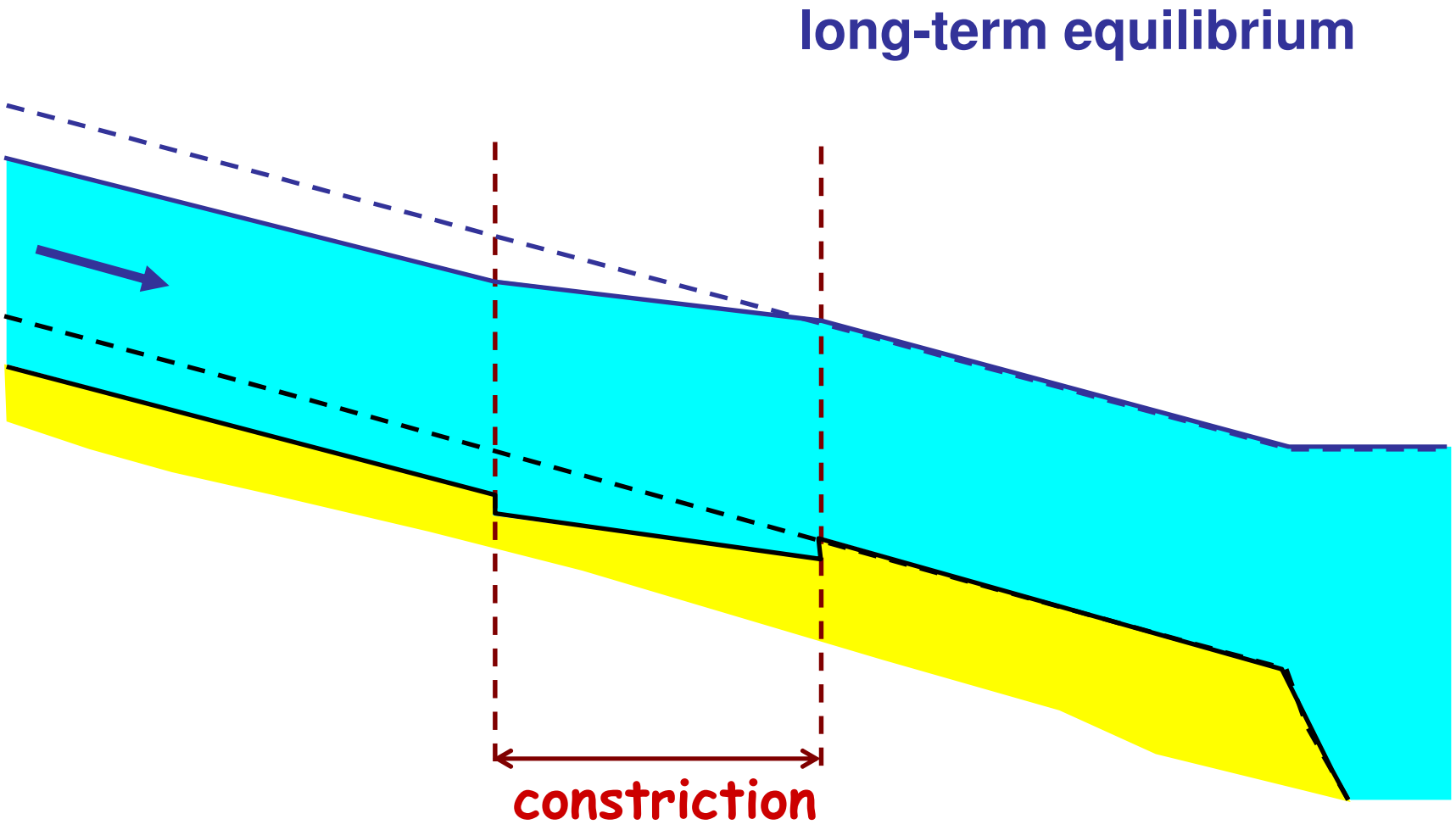
River training for navigation



Deltares

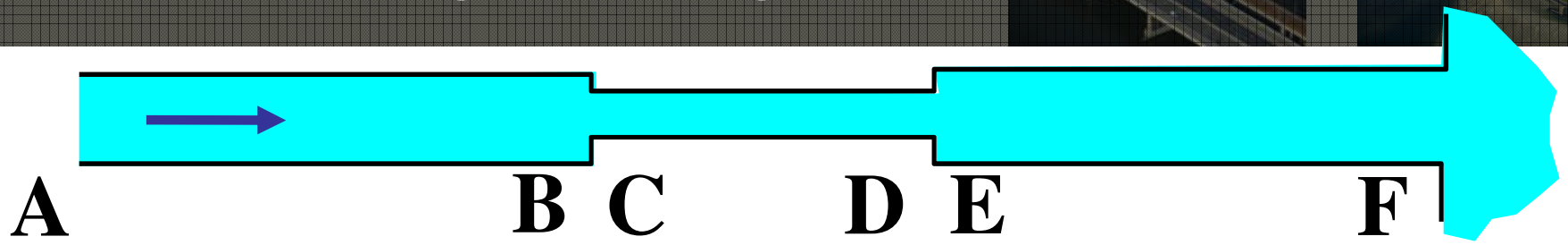
River training for navigation





Deltares

River training for navigation



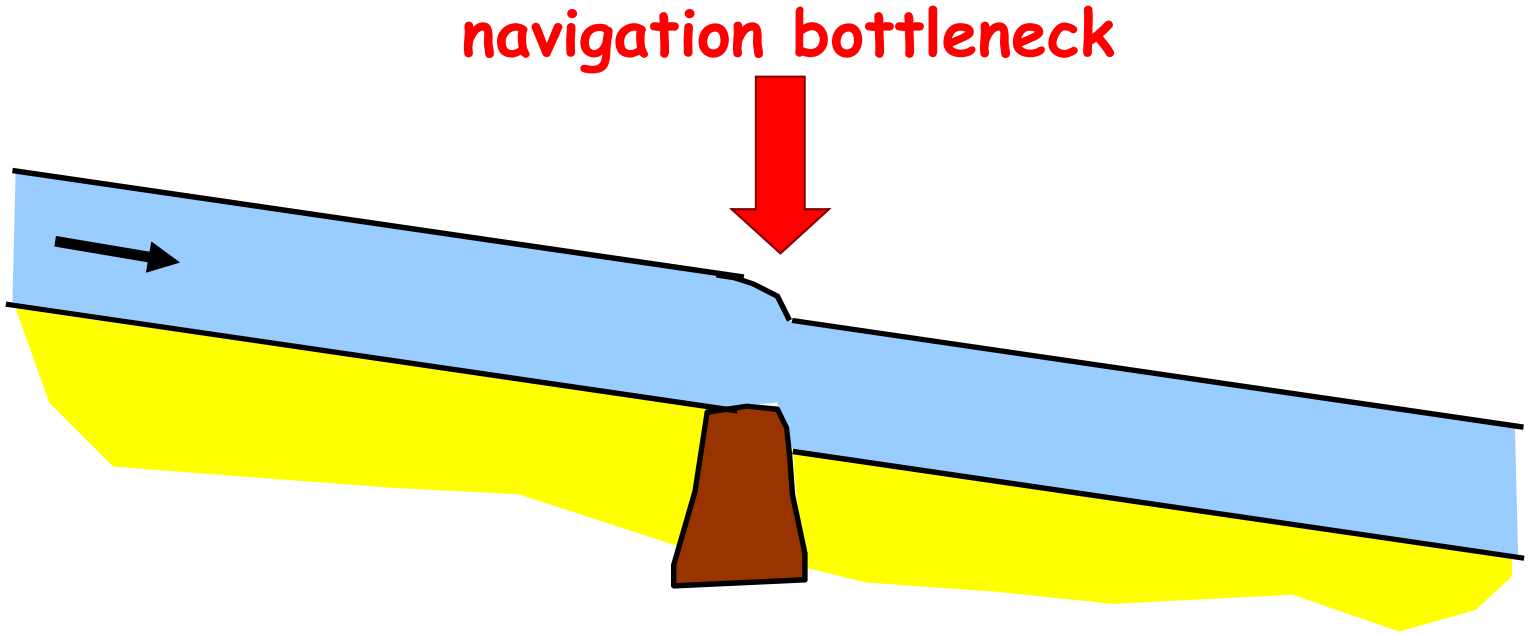
River-bed response		A	B	C	D	E	F
initial	sedimentation		▨			▨	
	stable	▨					▨
	erosion			▨	▨		
final	sedimentation						
	stable					▨	▨
	erosion	▨	▨	▨	▨		

Deltares

Bed degradation due to river training

Bed degradation: advantage of lower flood levels?

Bed degradation due to river training



Bed degradation due to river training

Bed degradation due to river training

River bed degradation:

- Limited depth above fixed layers
- Restrictions for sluices and river port entrances
- Instability of banks and hydraulic structures
- Shift in discharge distribution at bifurcations

- and for the Netherlands…
  angry Germans!

Deltares

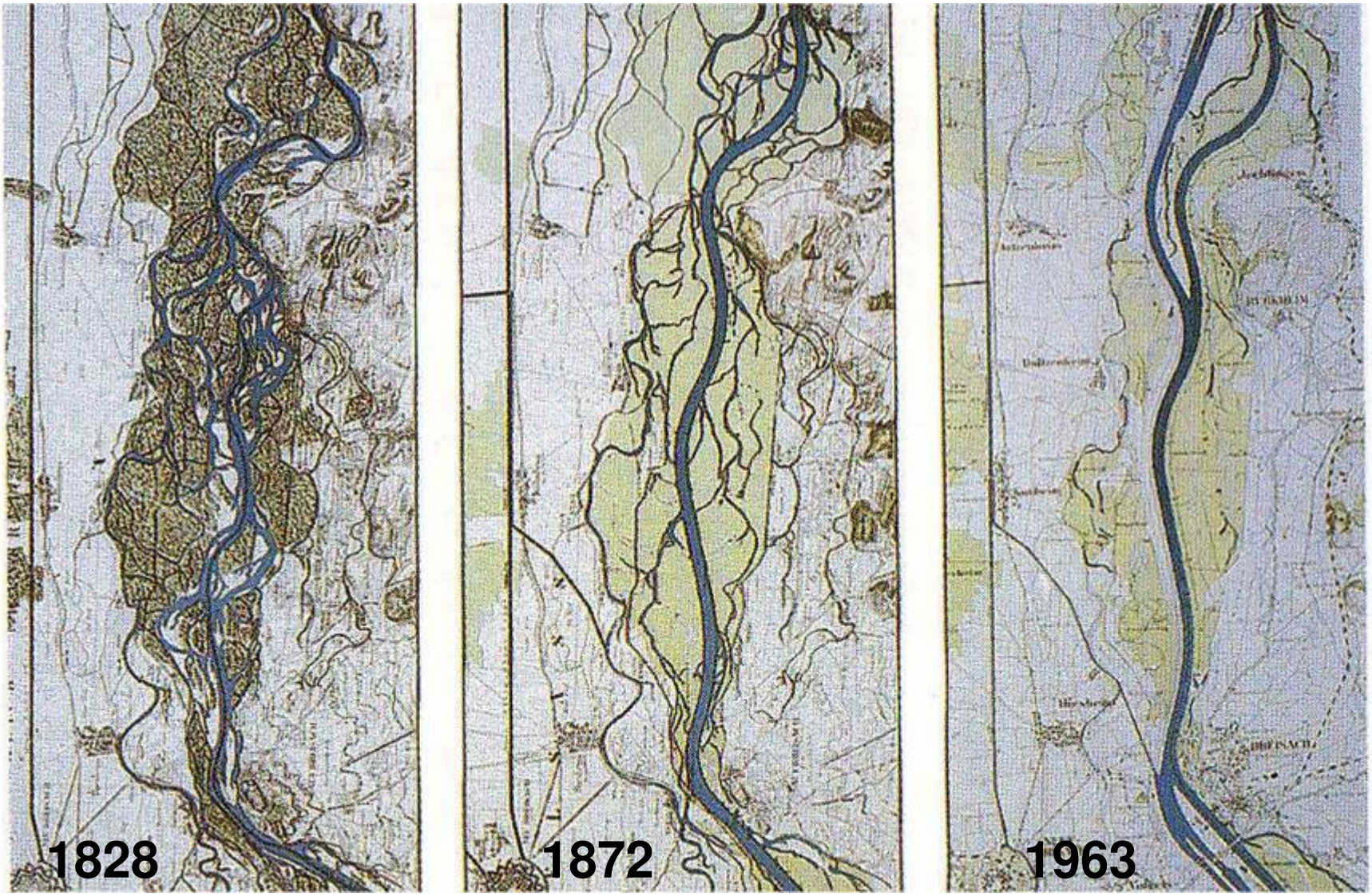
Bed degradation due to river training

Johann Gottfried Tulla

As a rule, no river or stream in the world needs more than one bed

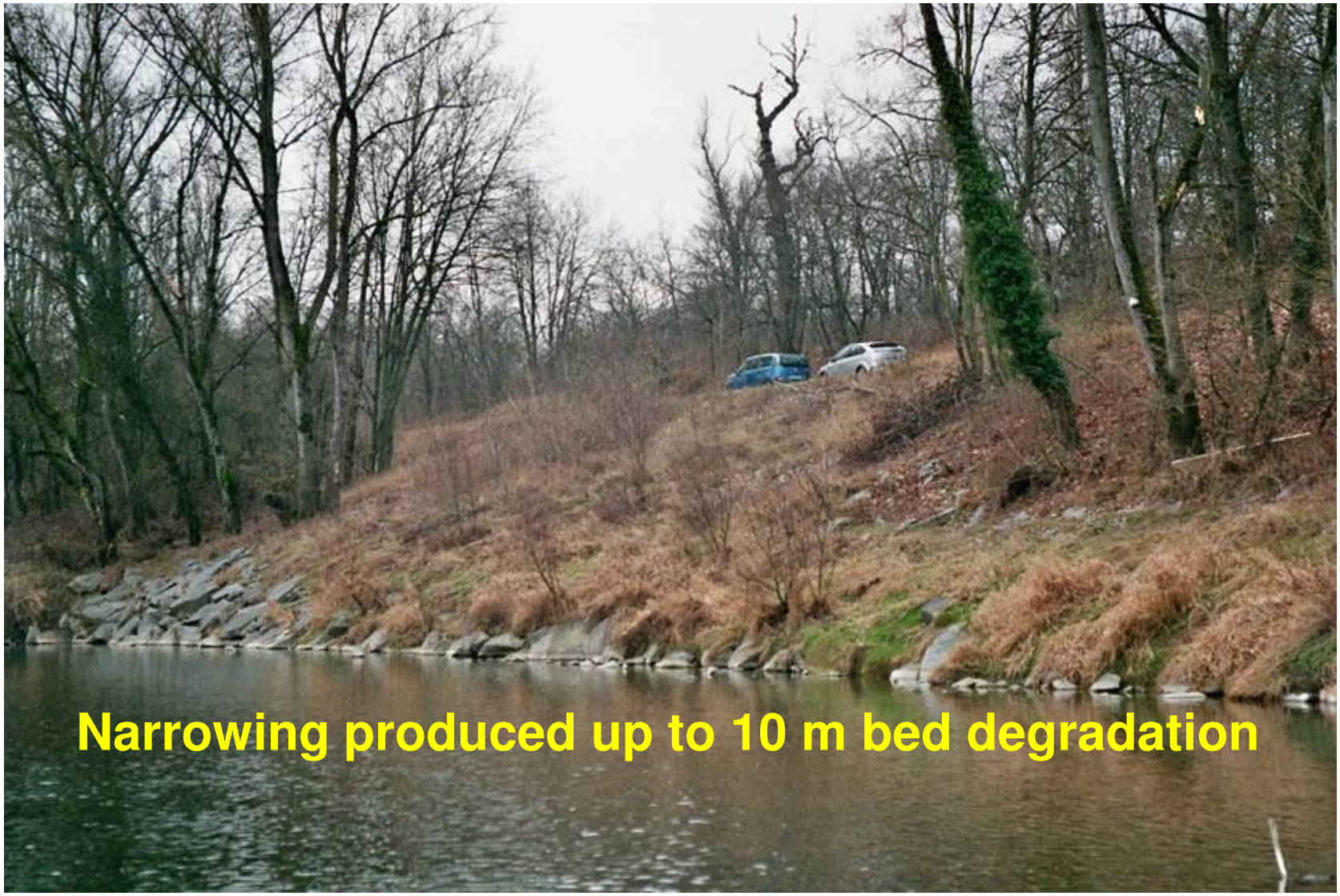
Bed degradation due to river training

Oberrhein below Basel



Deltares

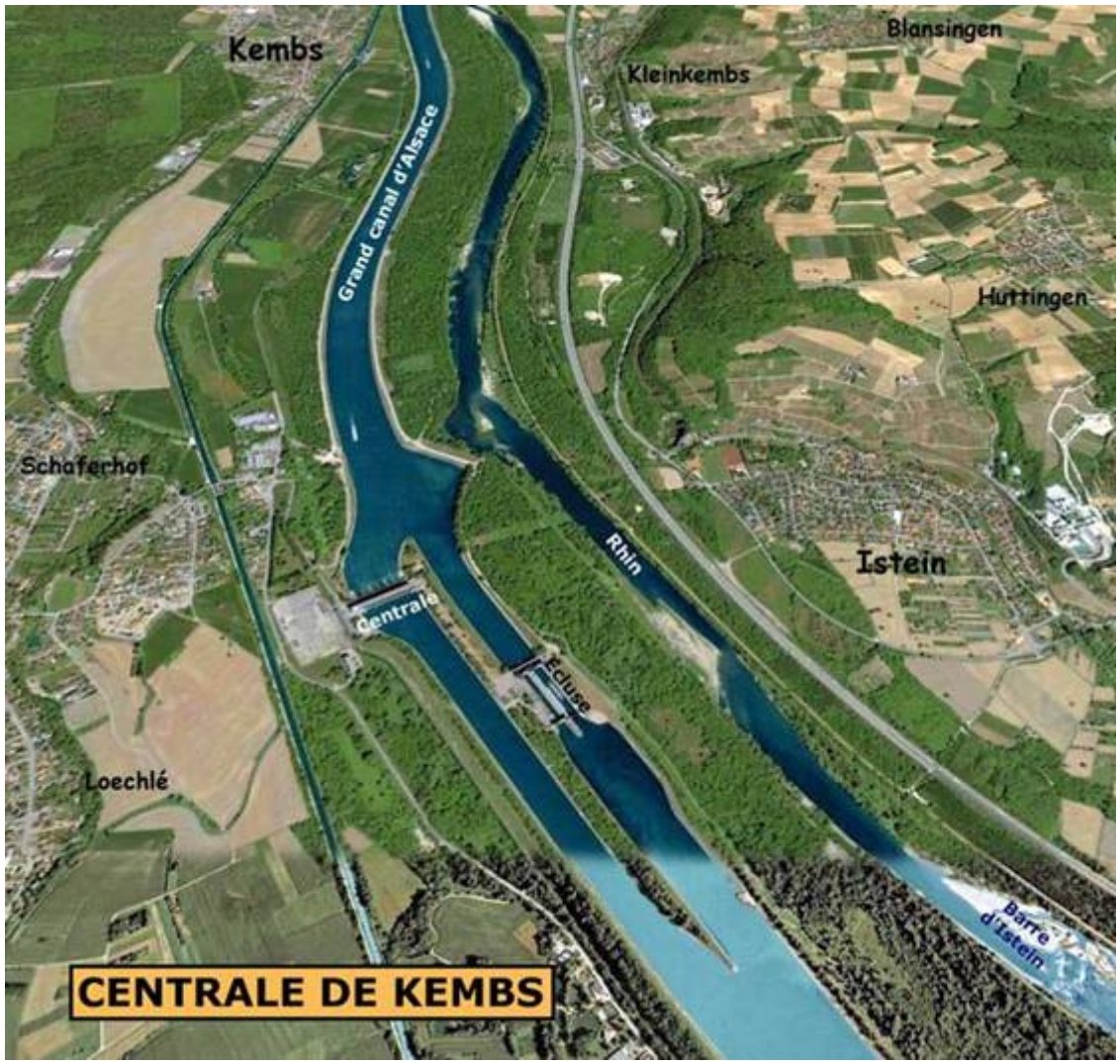
Bed degradation due to river training



Deltares

Bed degradation due to river training

Bed degradation due to river training



Navigation impossible …

Construction of lateral canal:

Grand Canal d'Alsace

Deltares

Bed degradation due to river training

Bed degradation due to river training

Bed degradation due to river training

Bed degradation due to river training

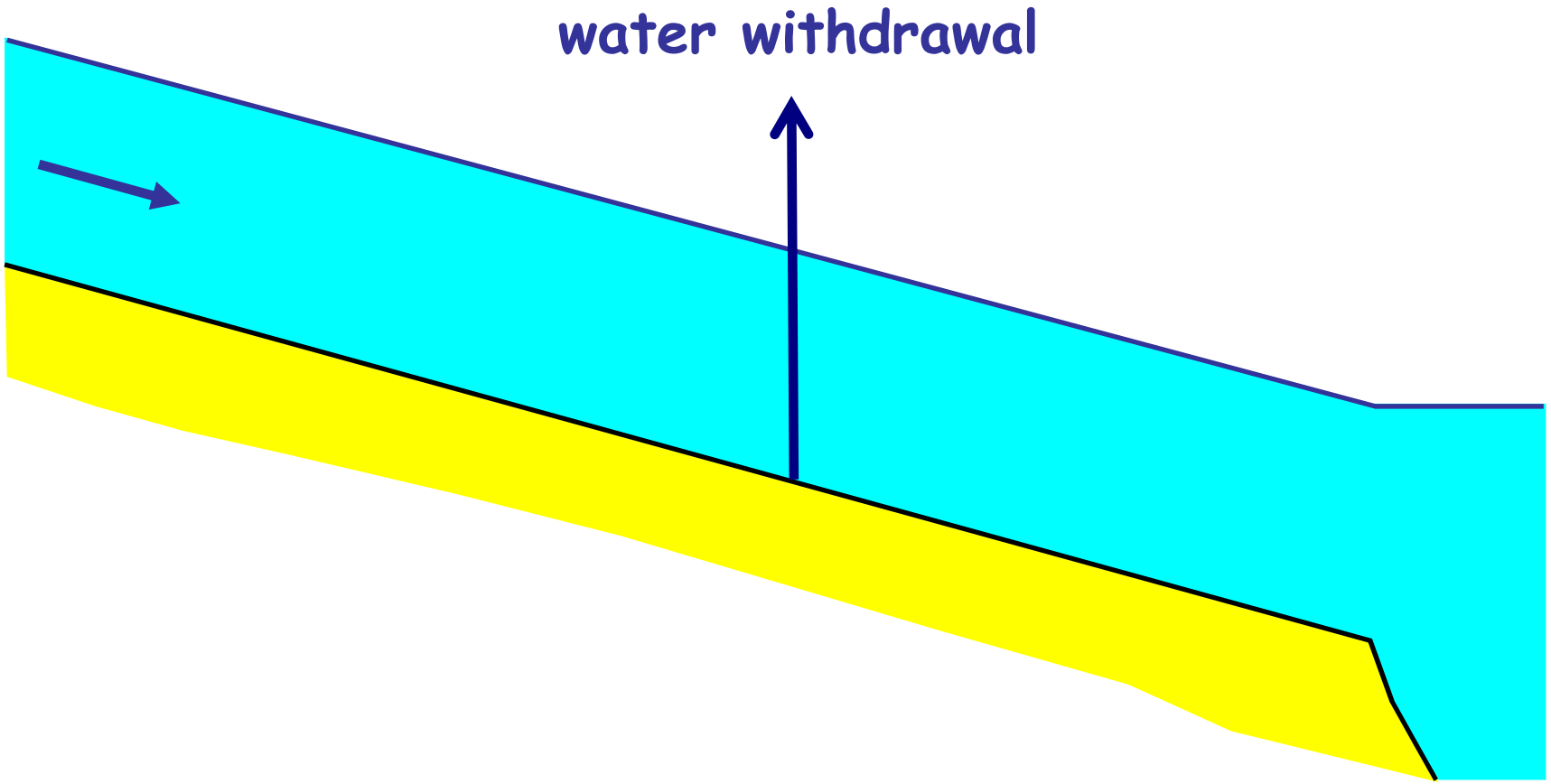
Lesson learned:

River narrowing to improve navigability:

- effective on a short term
- leading to expensive measures to maintain navigability on a long term
- **due to sediment**

Deltares

Water withdrawal for irrigation

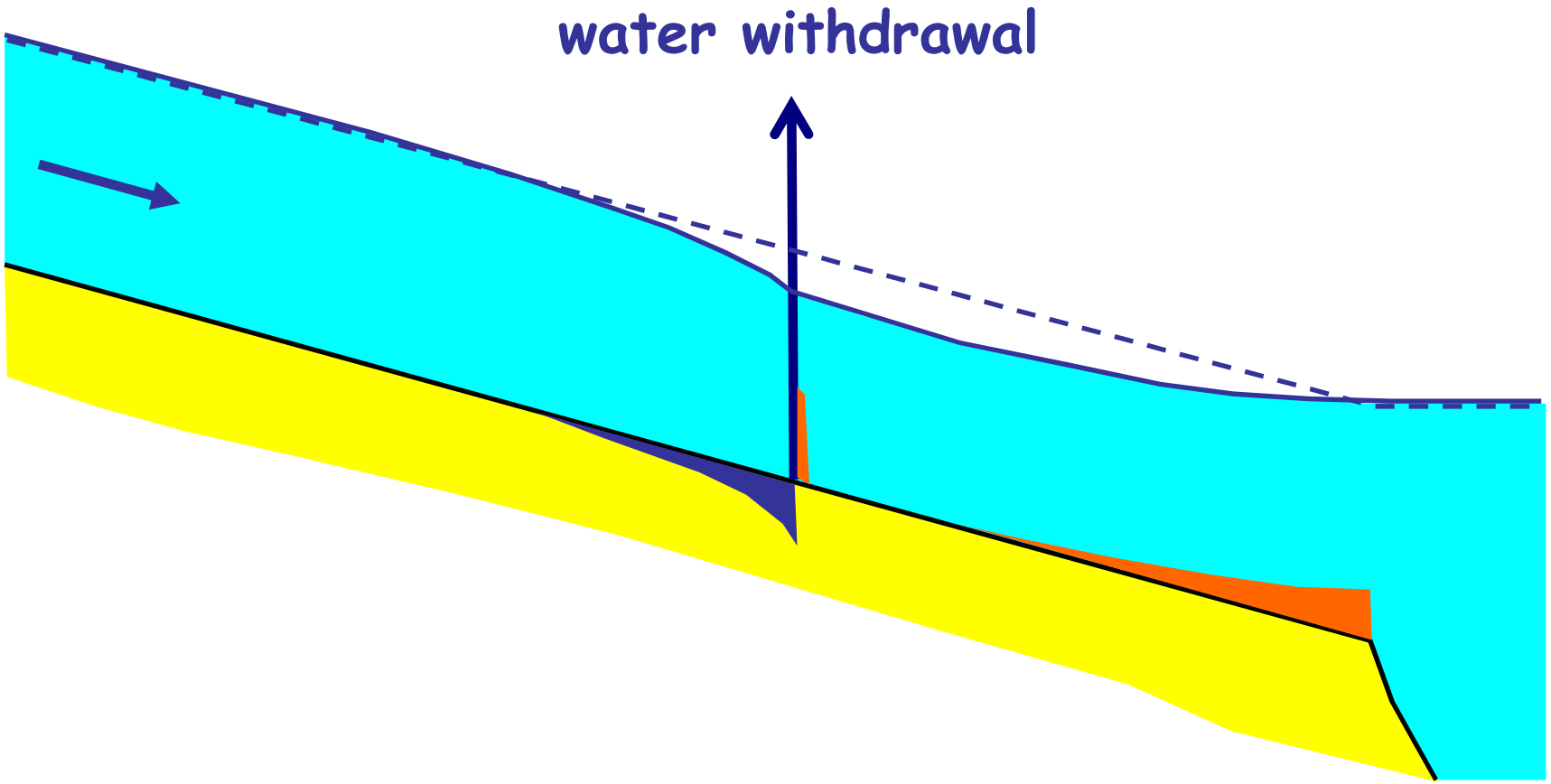


Deltares

What happens with the river bed if water is withdrawn?

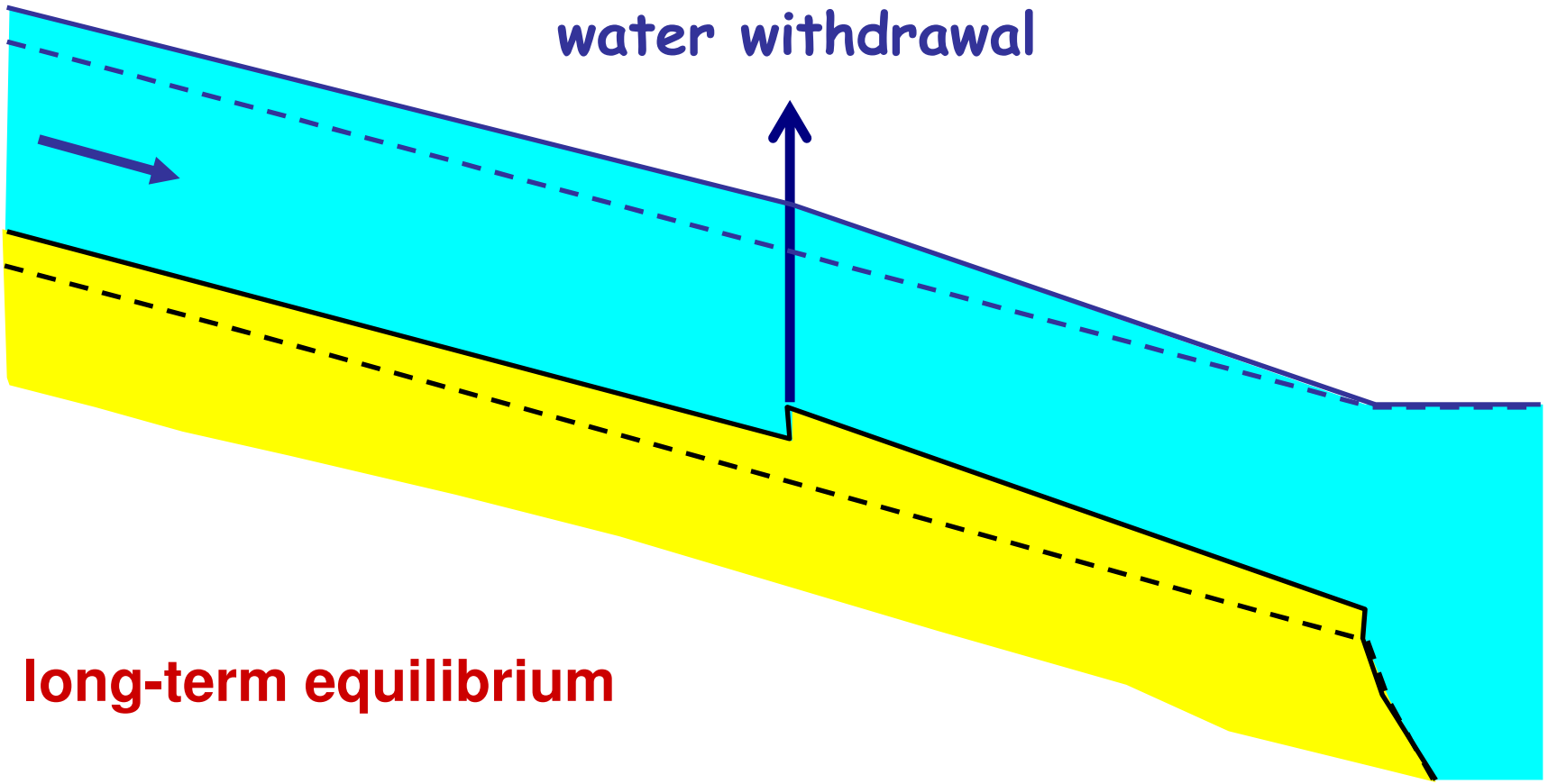
Who dares?

Water withdrawal for irrigation



Deltares

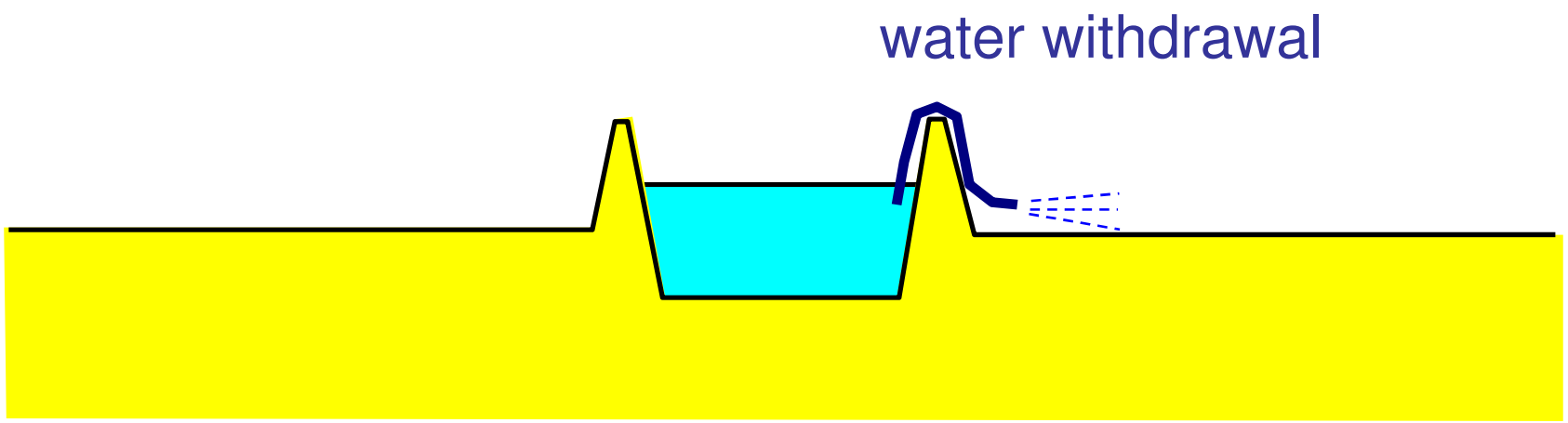
Water withdrawal for irrigation



long-term equilibrium

Deltares

Water withdrawal for irrigation

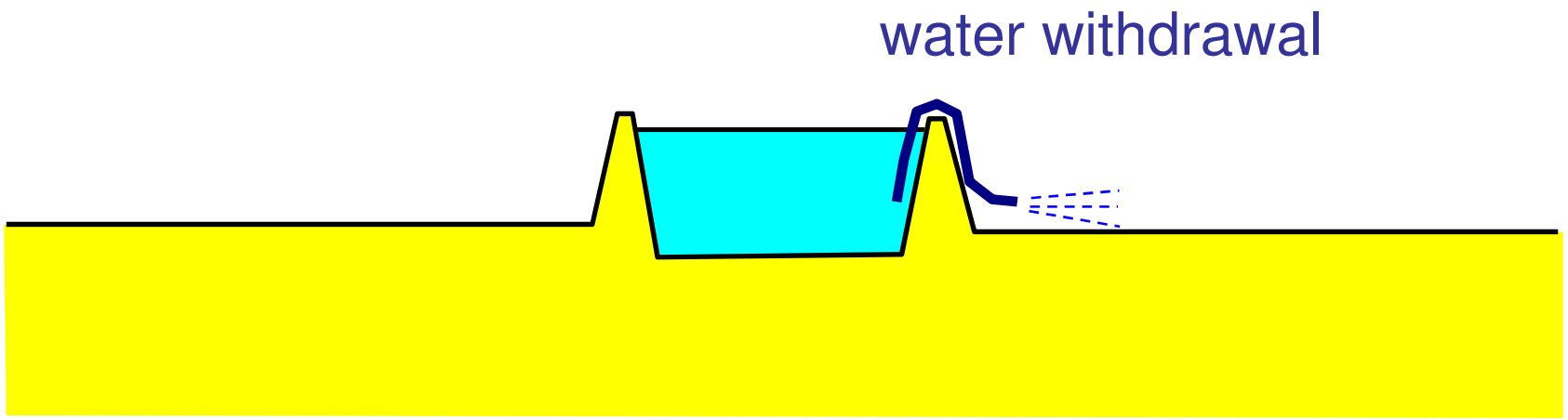


Deltares

Water withdrawal for irrigation

sedimentation:

- rise in bed levels
- rise in water levels

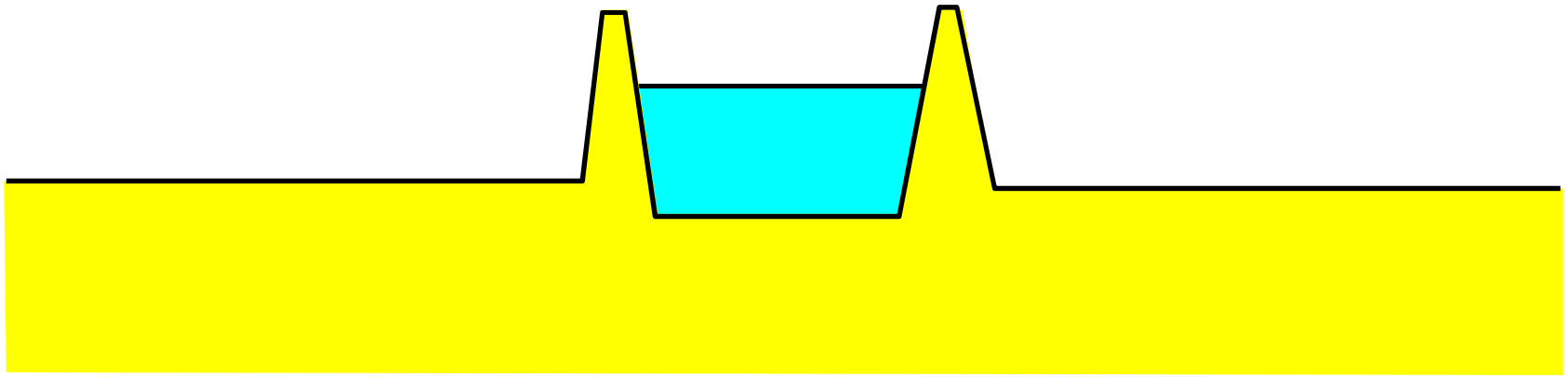


Deltares

Water withdrawal for irrigation

sedimentation:

- rise in bed levels
- rise in water levels
- raised embankments

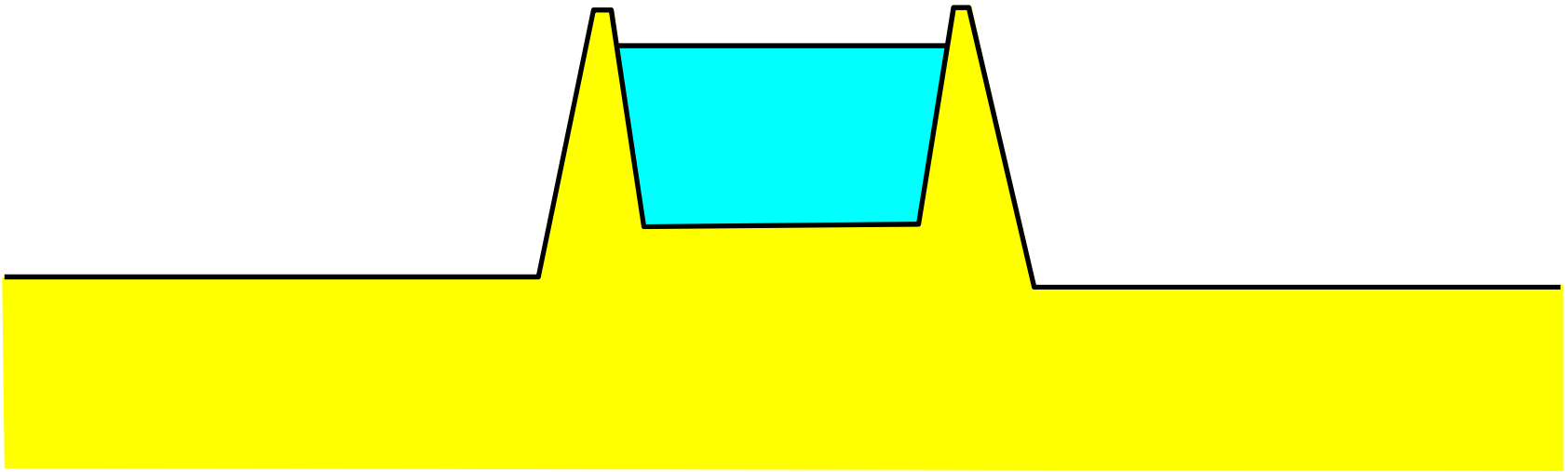


Deltares

Water withdrawal for irrigation

sedimentation:

- rise in bed levels
- rise in water levels
- raised embankments



Deltares

Water withdrawal for irrigation

sedimentation:

- rise in bed levels
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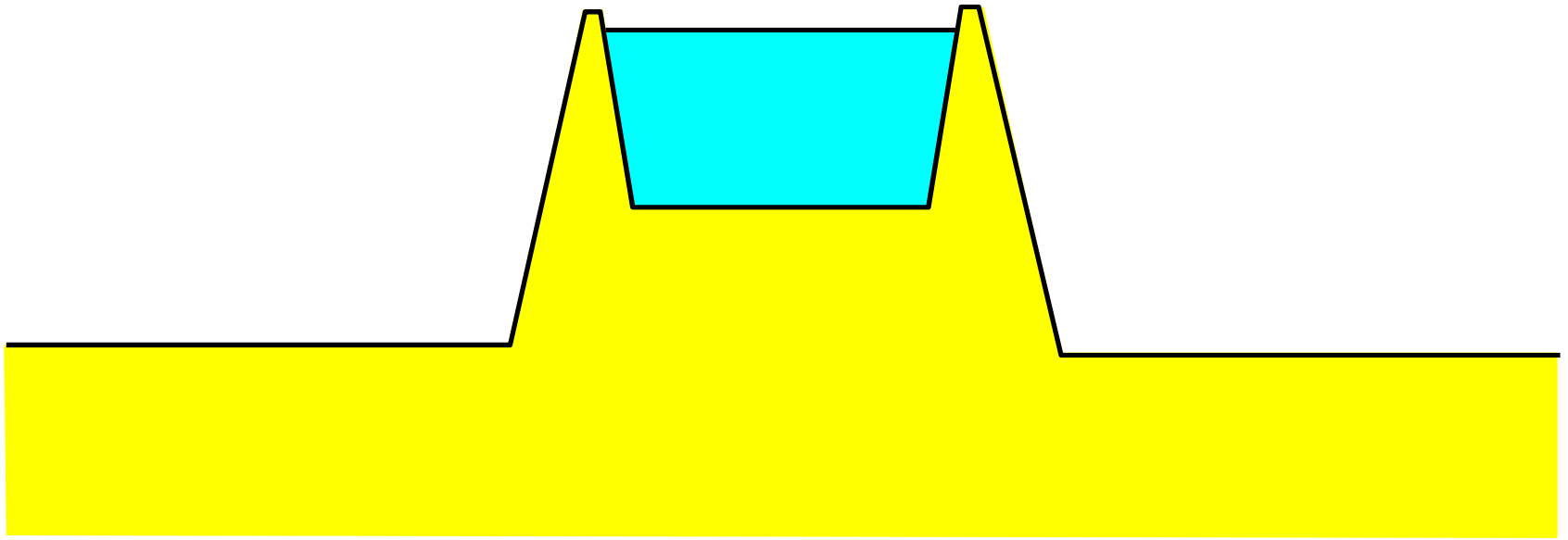
- raised embankments

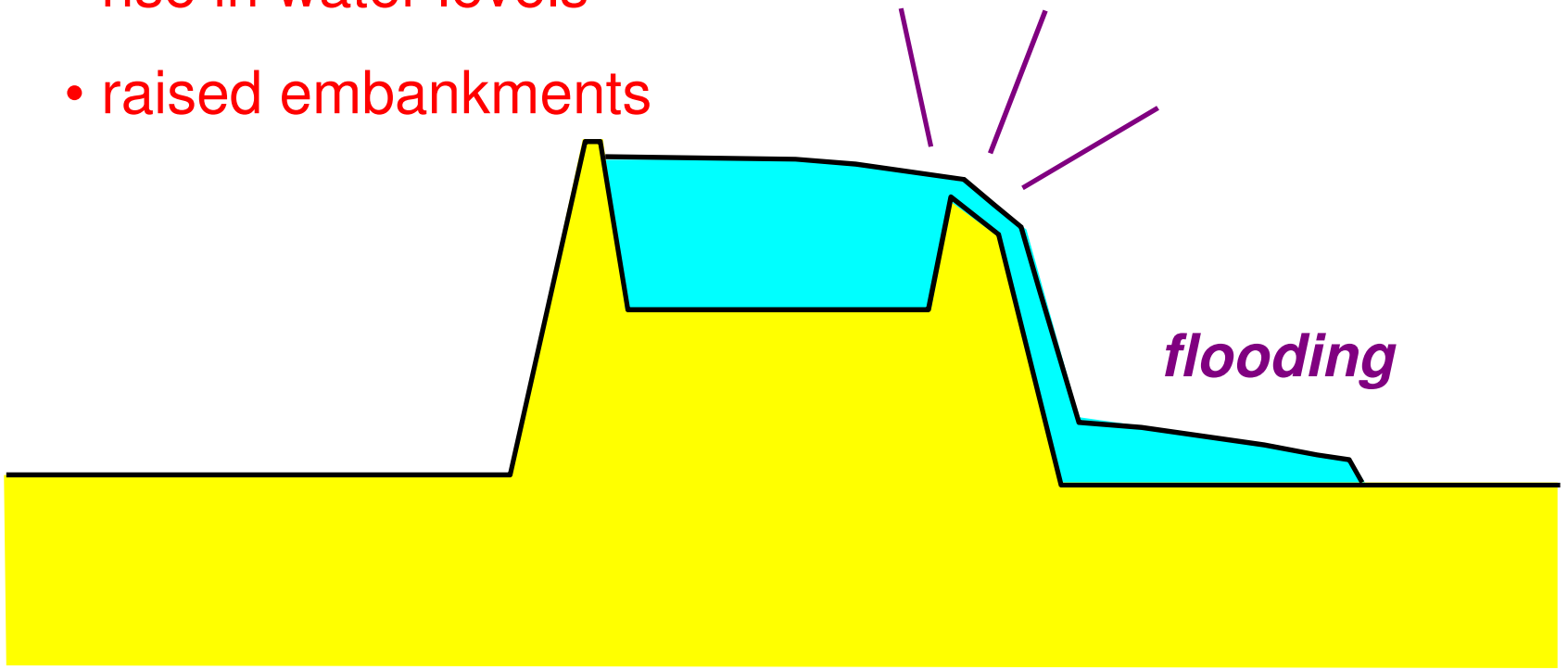


Deltares

Water withdrawal for irrigation

sedimentation:

- rise in bed levels
- rise in water levels
- raised embankments

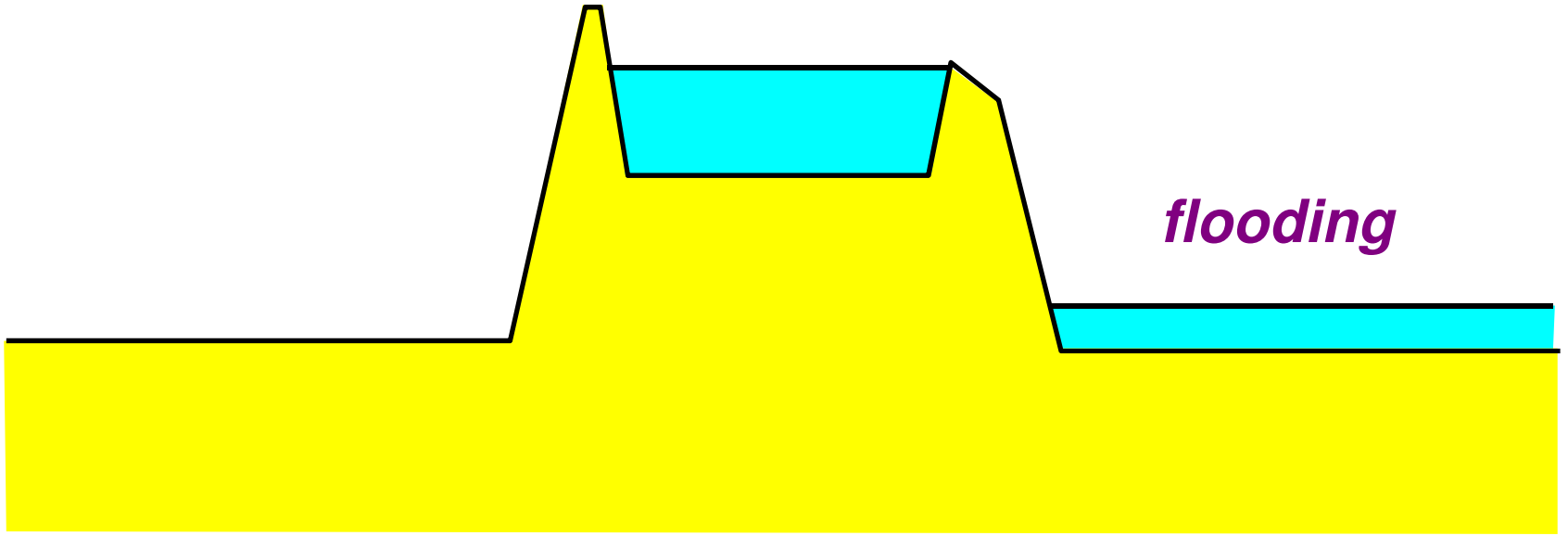


Deltares

Water withdrawal for irrigation

Effect of water withdrawal

made worse in case of barrages and subsidence



Deltares

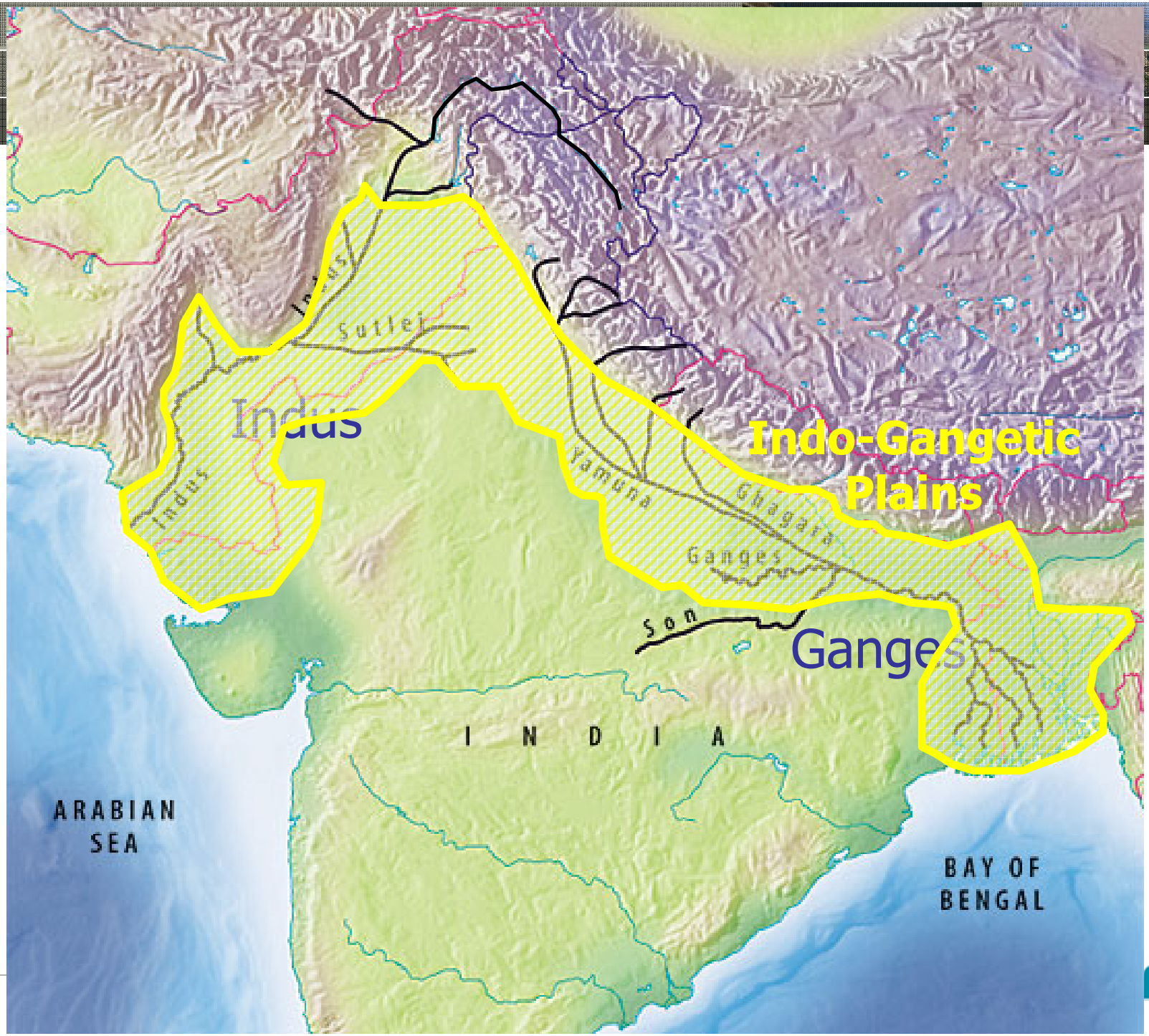
Water withdrawal for irrigation

Lesson learned:

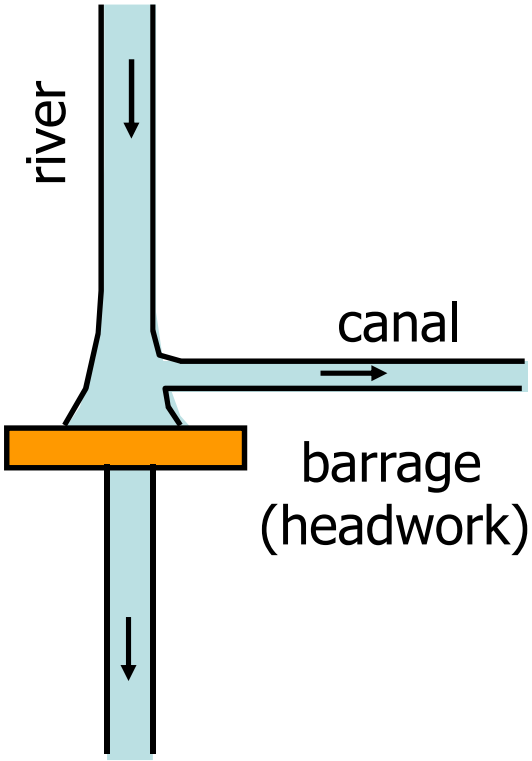
Water withdrawal for irrigation:

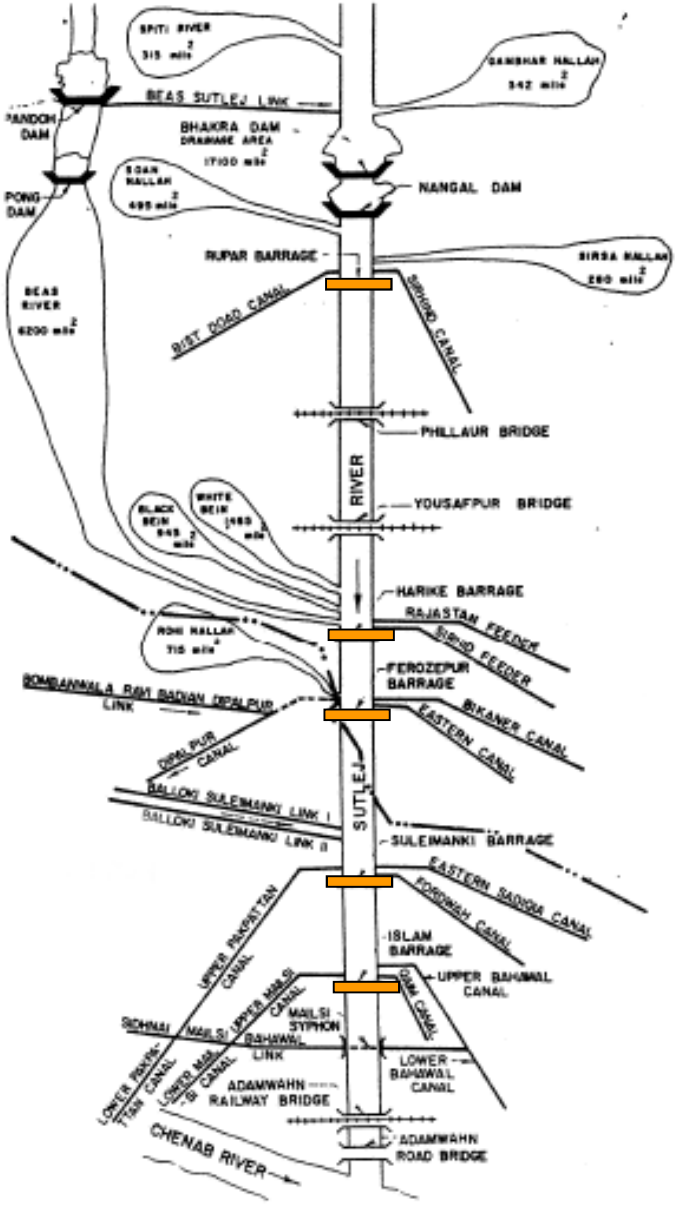
- lowers water levels on a short term
- raises flood water levels on a long term
- **due to sediment**

Deltares

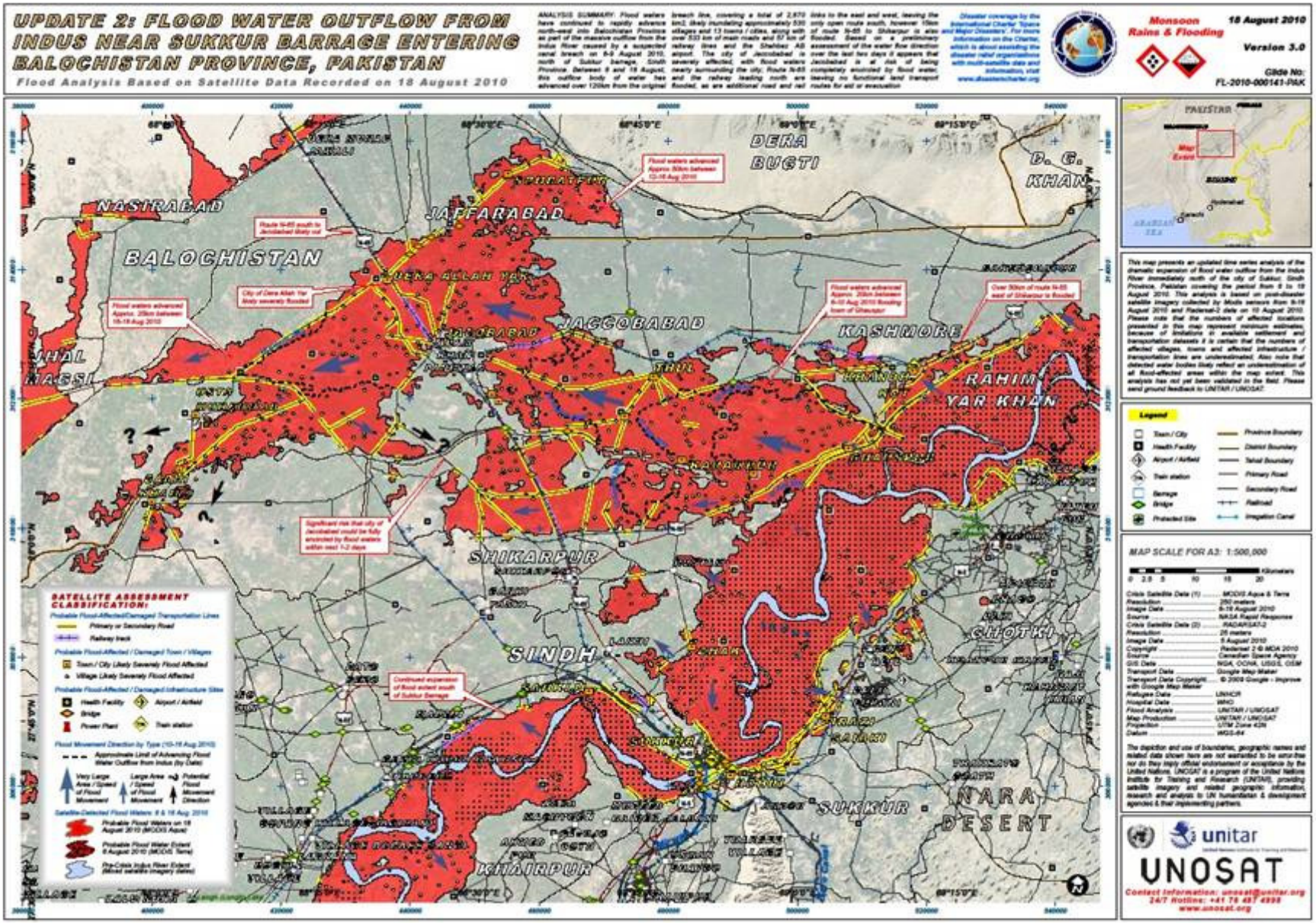

Indus
Sutlej
Indus
Yamuna
Ghaggar
Ganges
Son
Indo-Gangetic
Plains
Ganges
I N D I A
ARABIAN
SEA
BAY OF
BENGAL

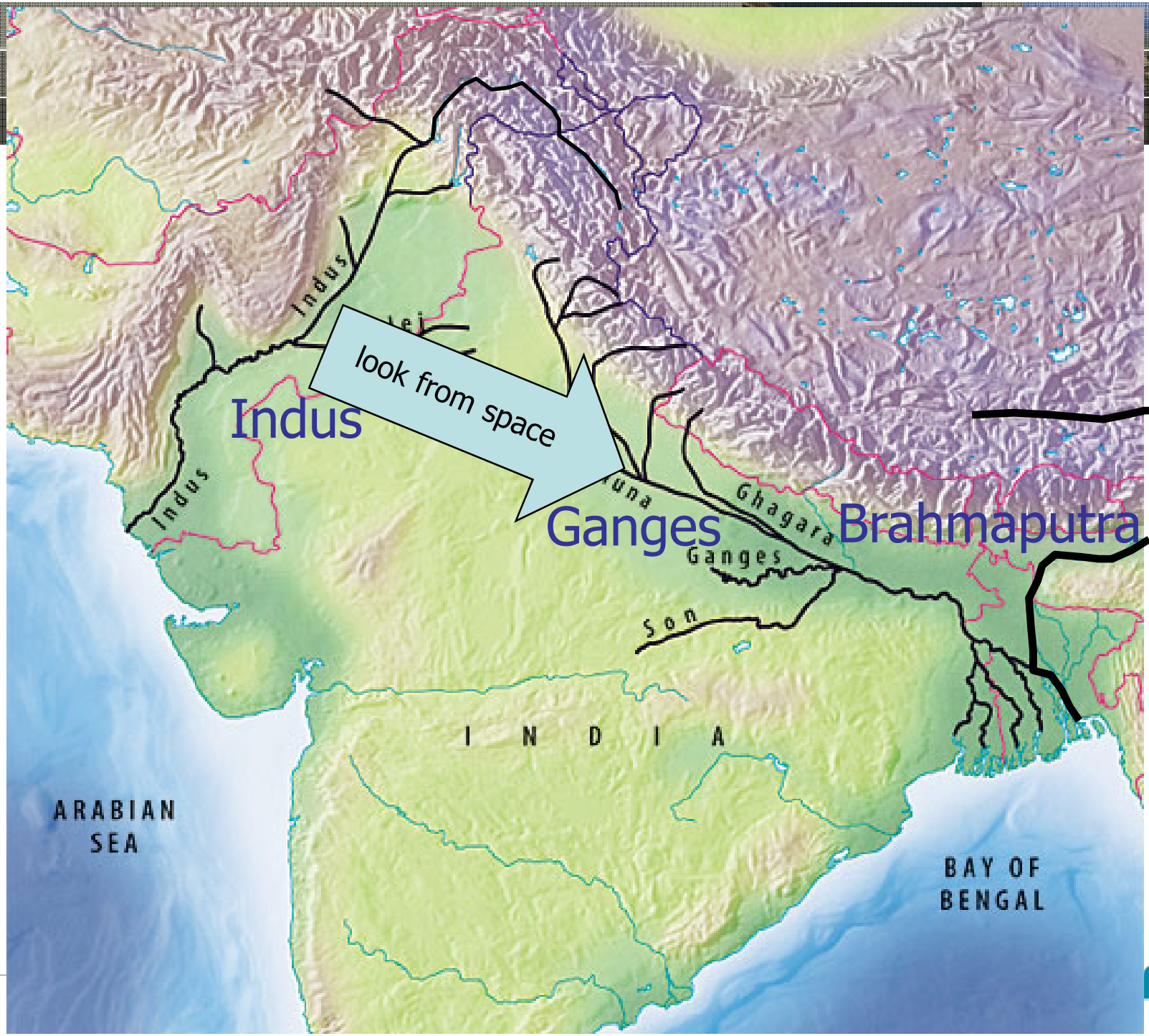
Irrigation on Indo-Gangetic Plains

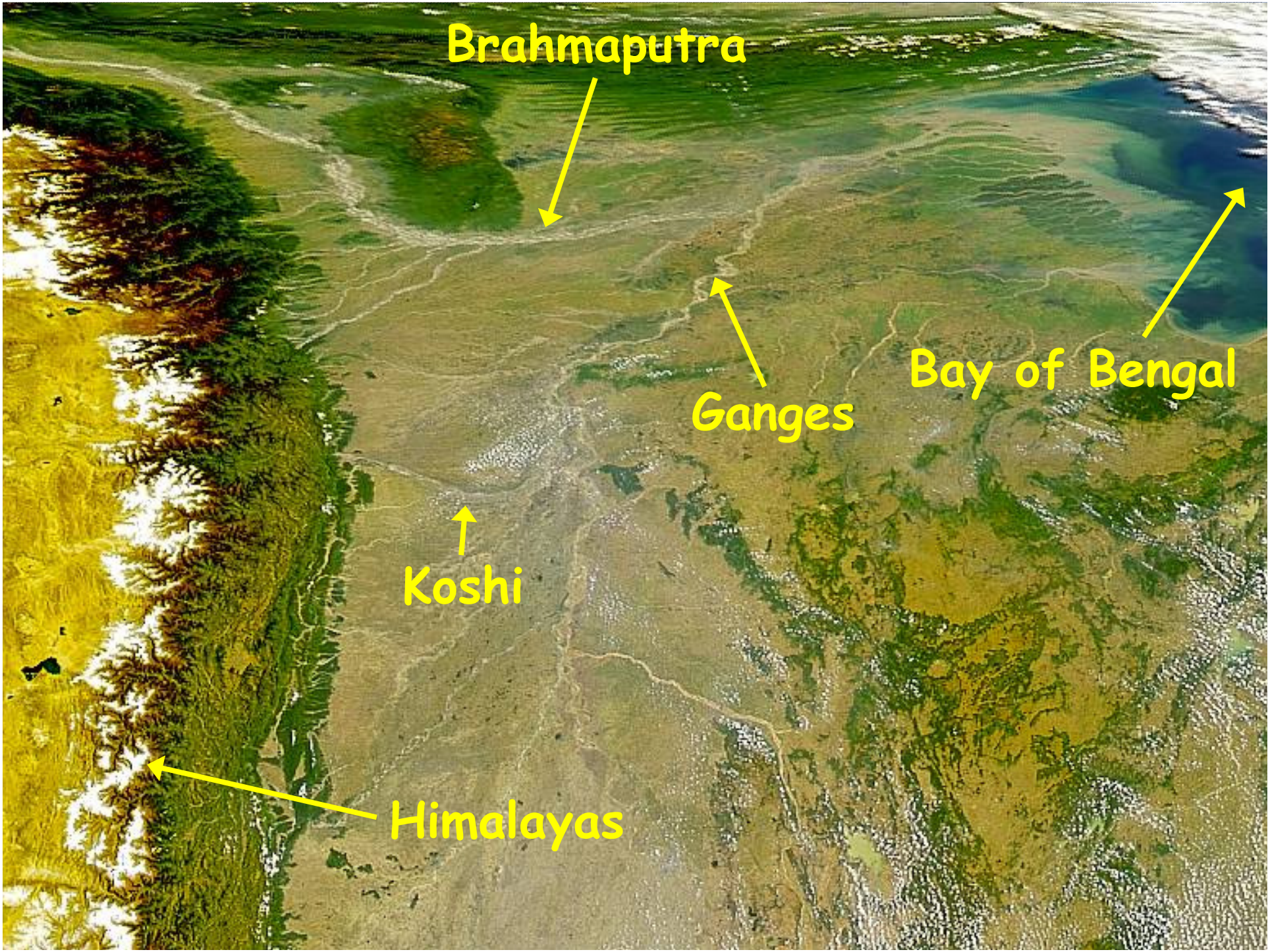




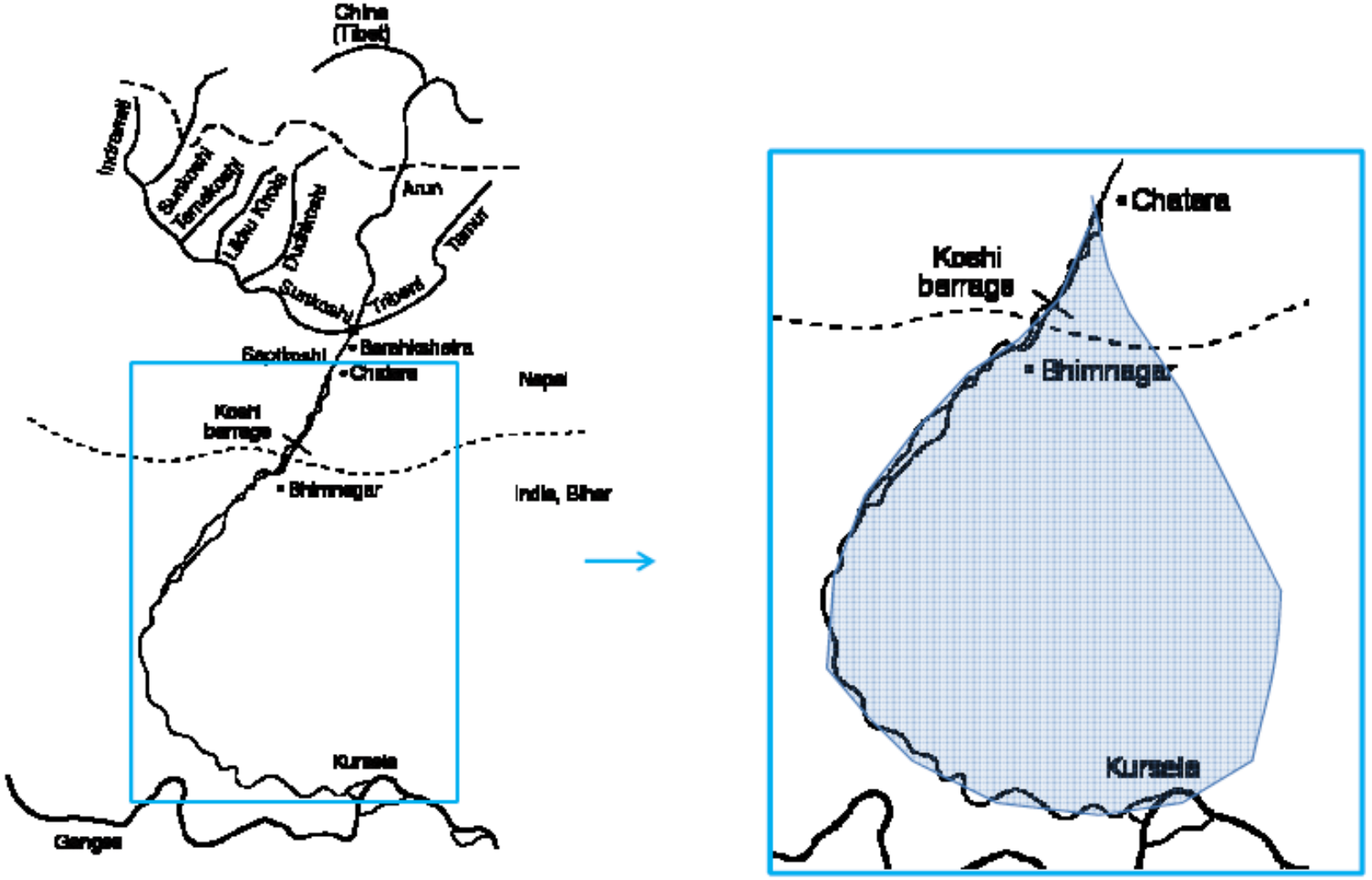
Water withdrawal for irrigation




look from space
Indus
Ganges
Brahmaputra
Indus
Indus
Ganges
Ghagara
Son
I N D I A
ARABIAN SEA
BAY OF BENGAL

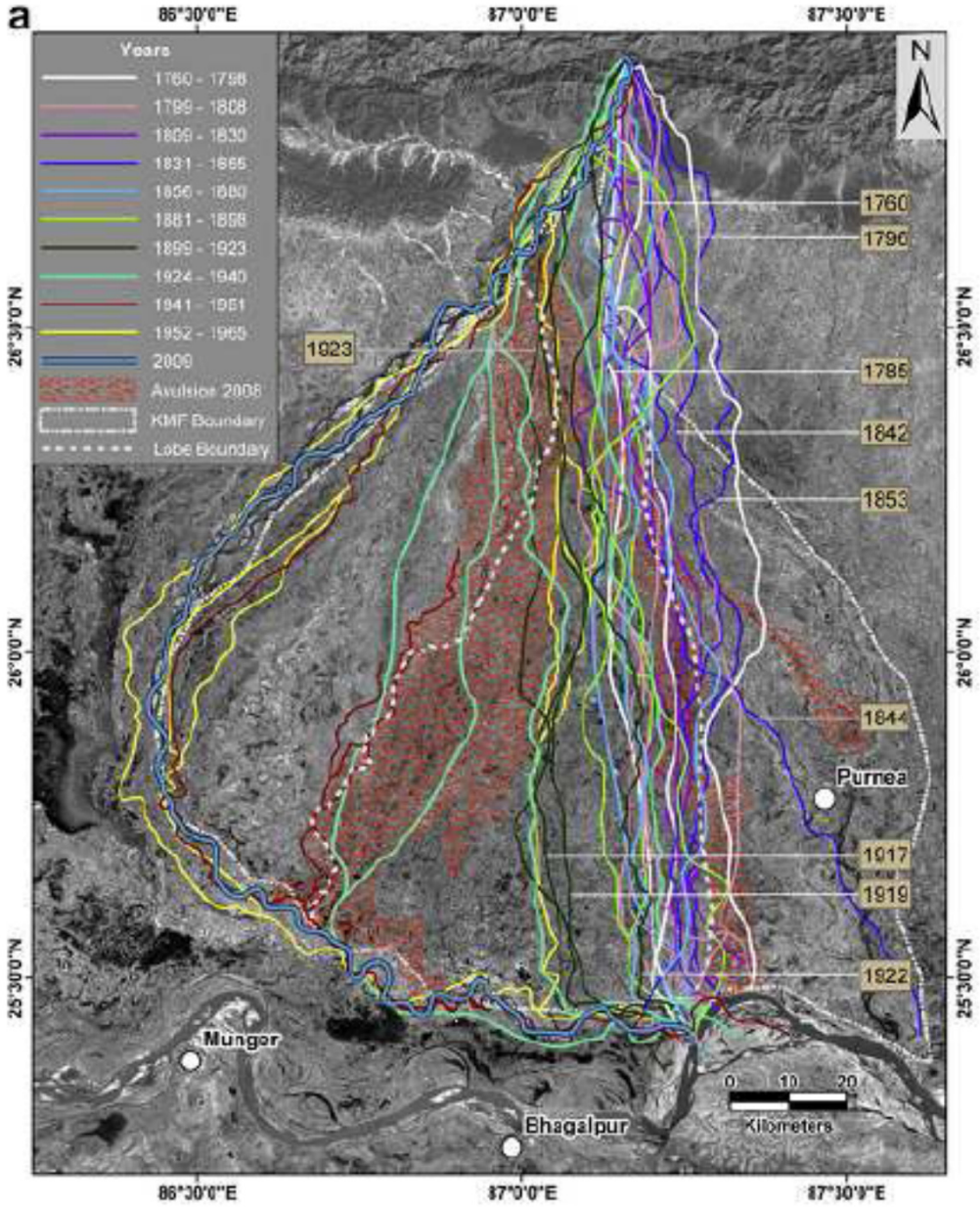

Brahmaputra
Ganges
Bay of Bengal
Koshi
Himalayas

Koshi river megafan



Deltares

Koshi river megafan

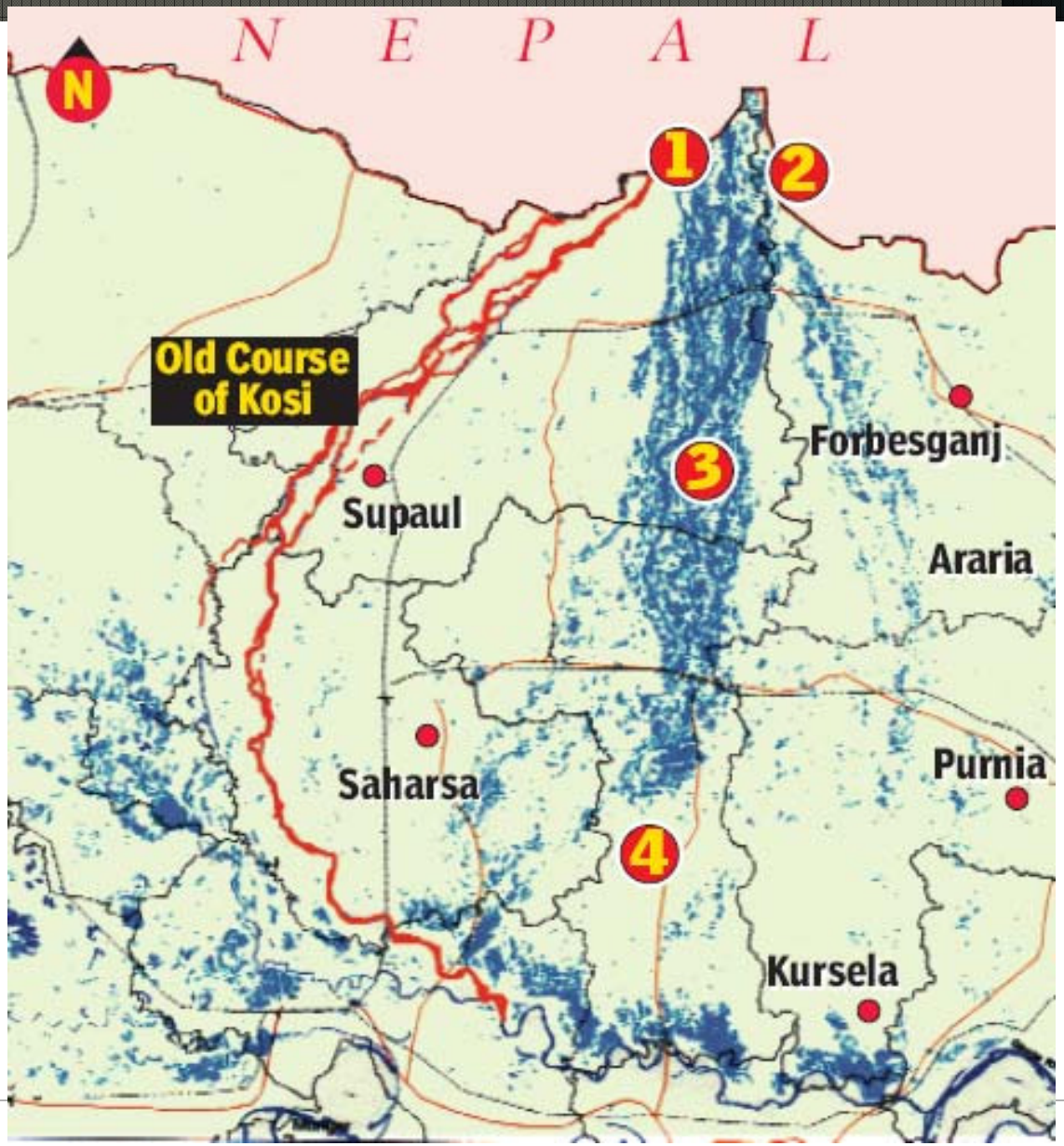


Chakraborty et al, 2009

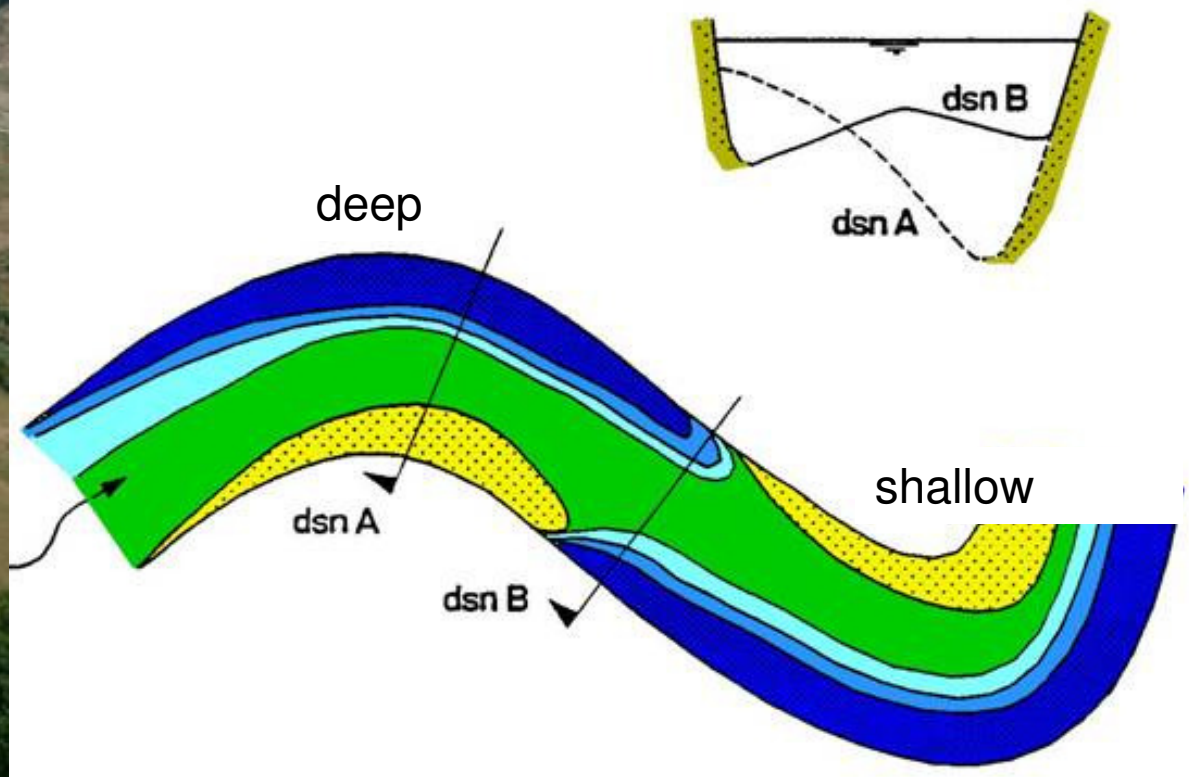
Deltares

Koshi river megafan

Koshi river megafan: 2008 flood

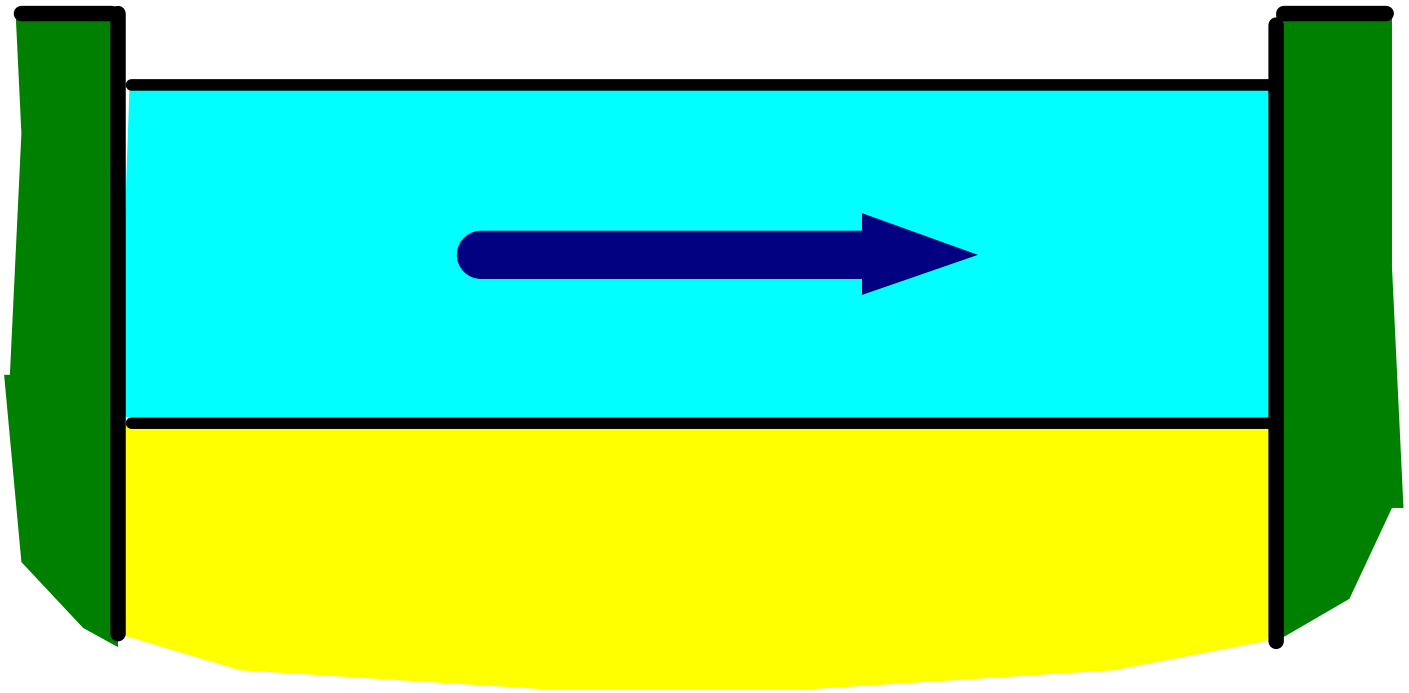


Engineering of river bends



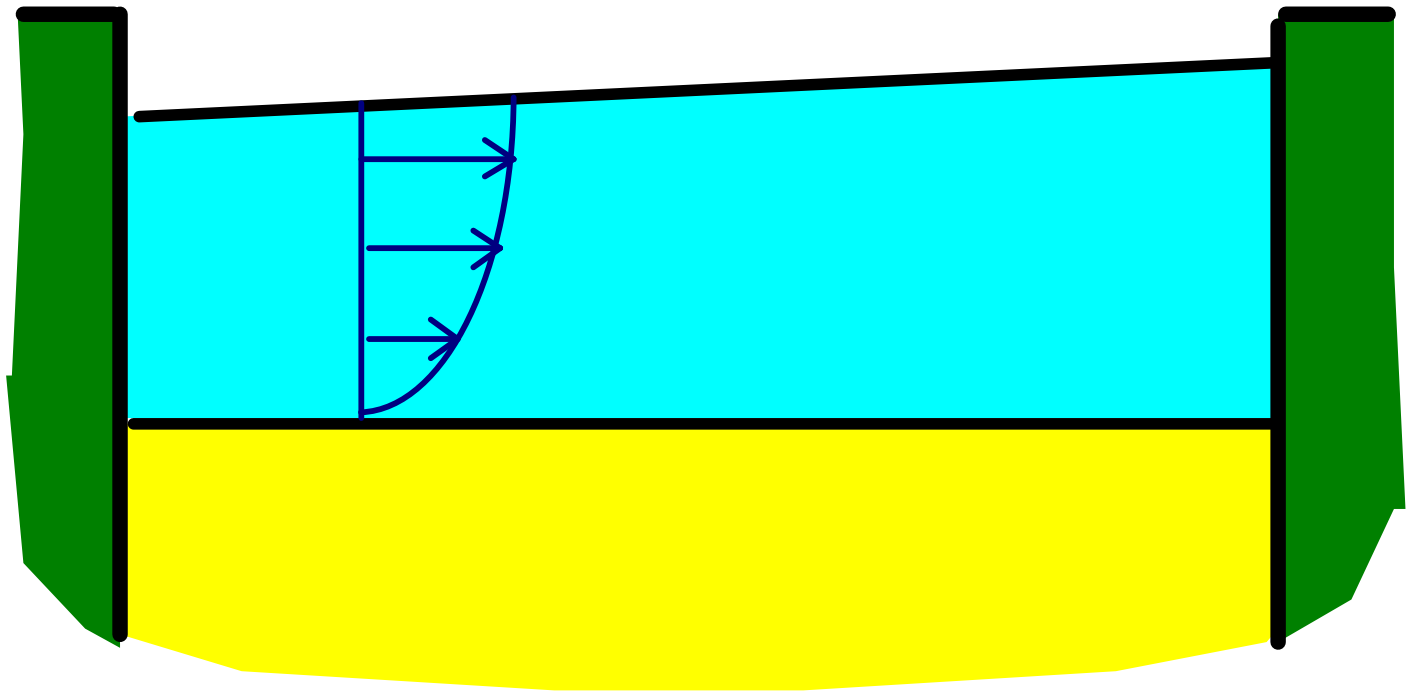
Deltares

Engineering of river bends

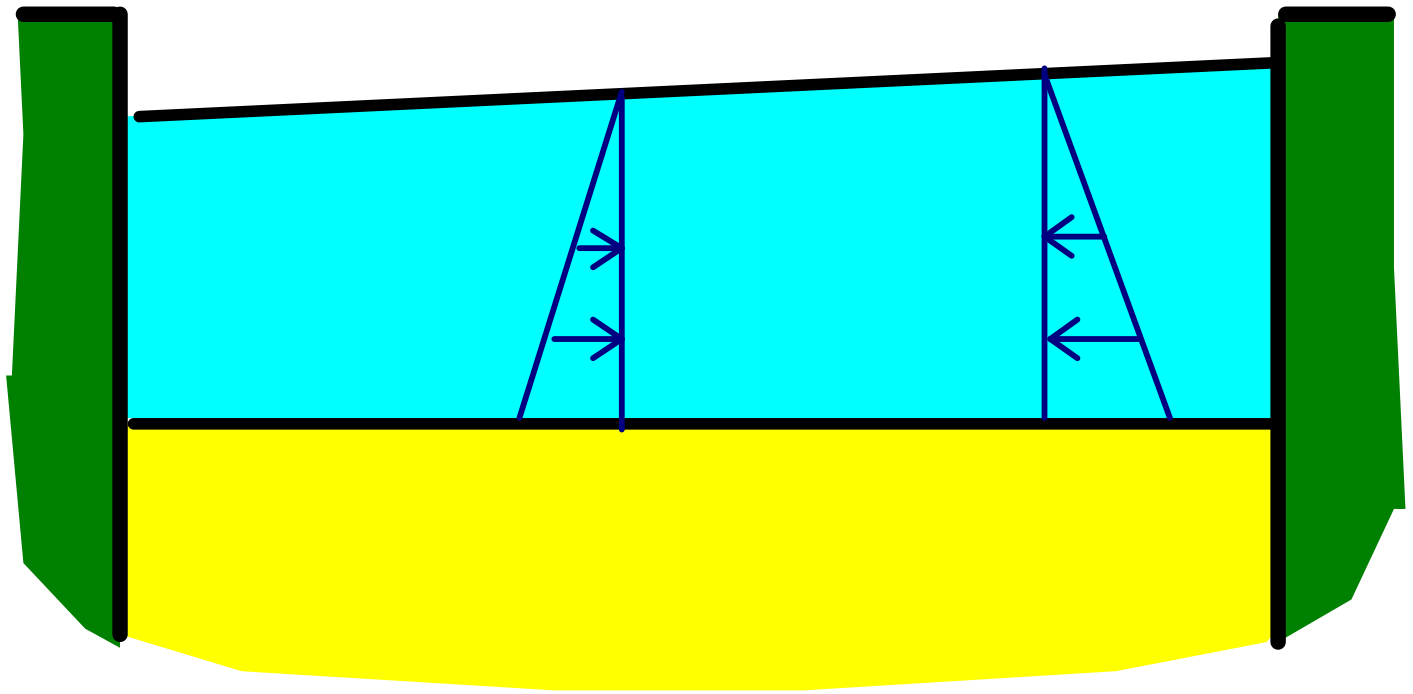


Deltares

Engineering of river bends

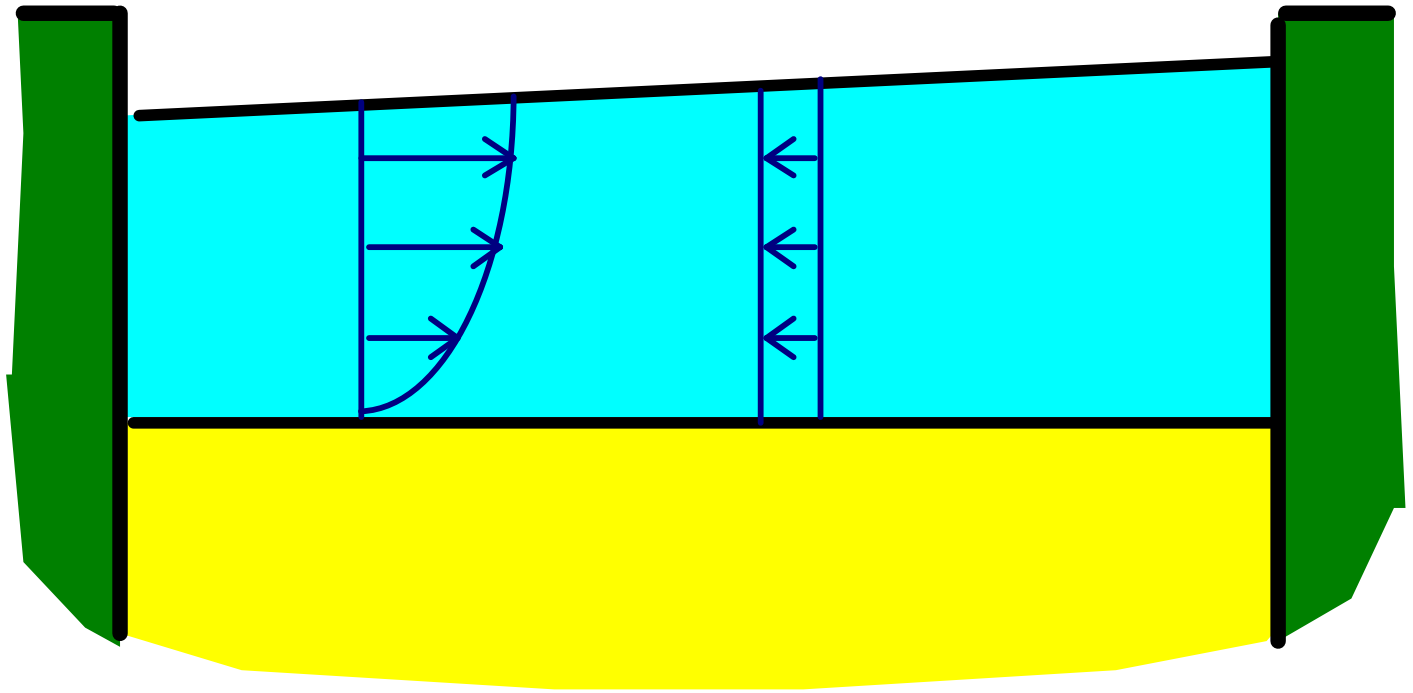


Engineering of river bends



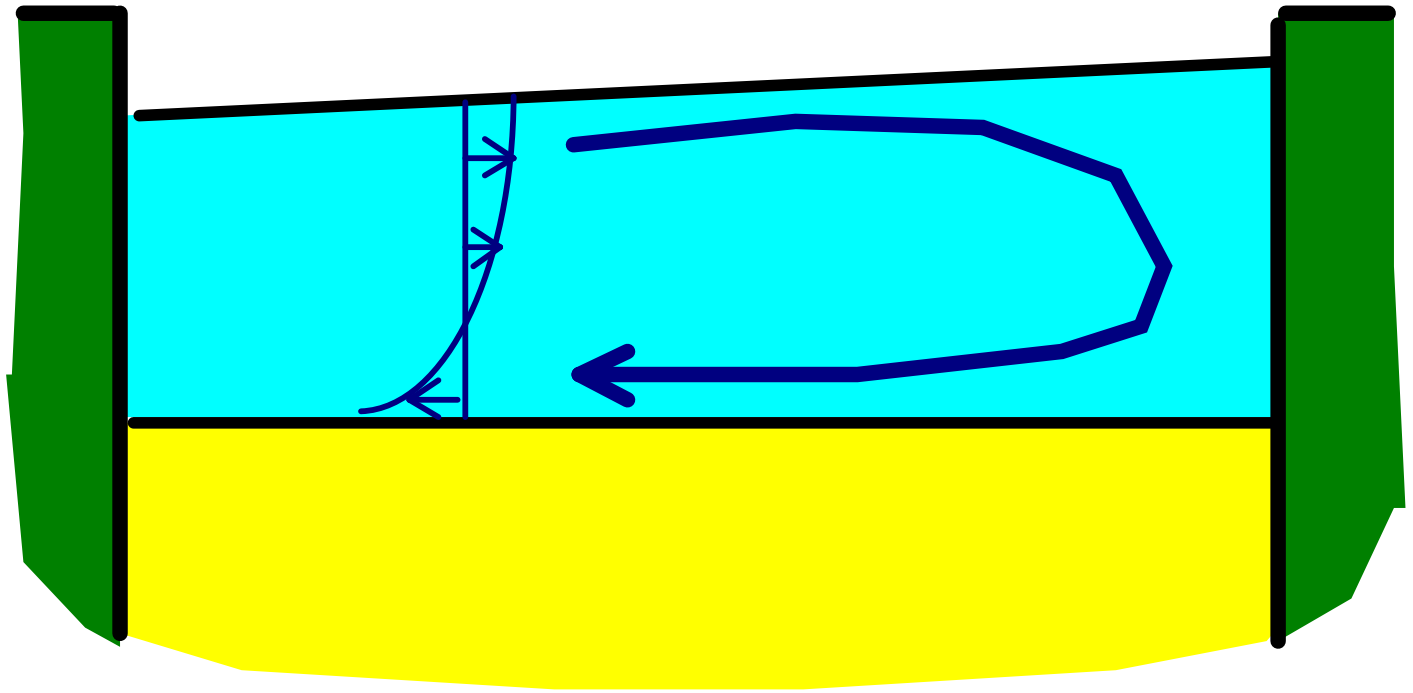
Deltares

Engineering of river bends



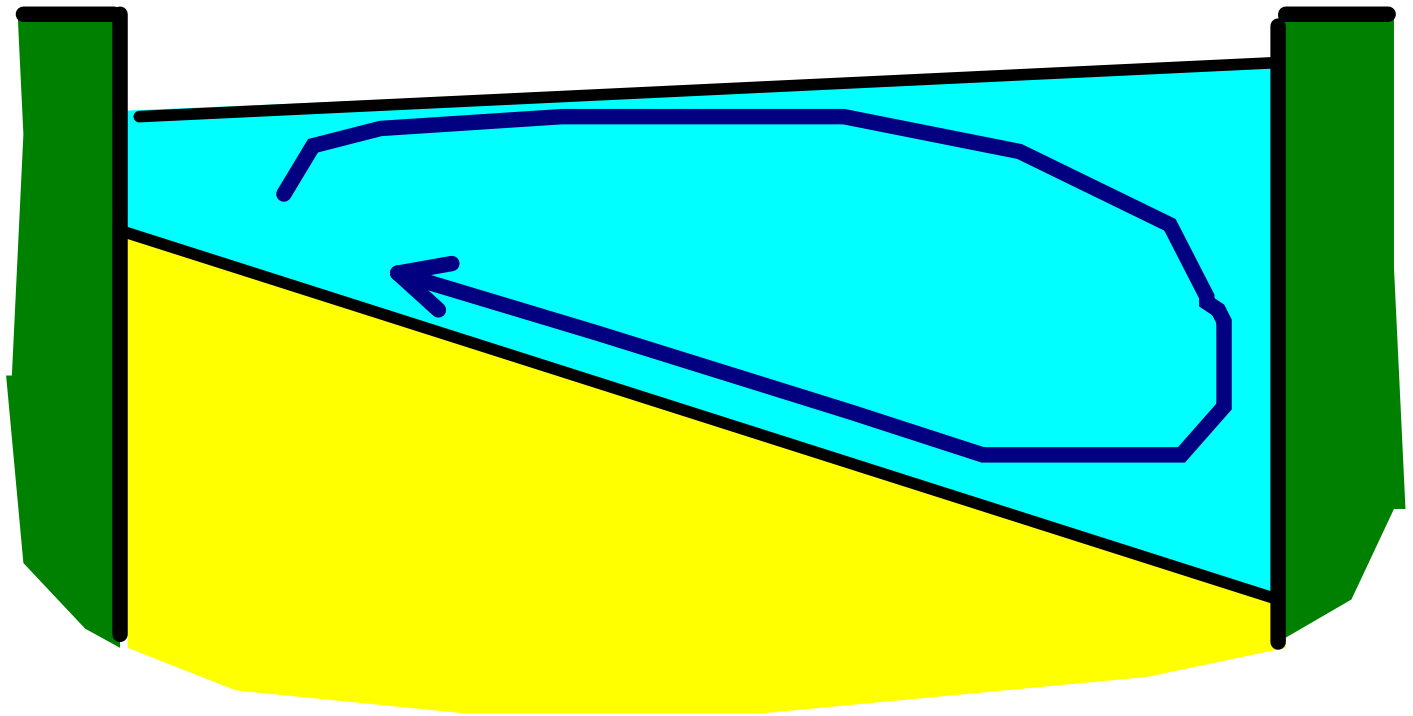
Deltares

Engineering of river bends



Deltares

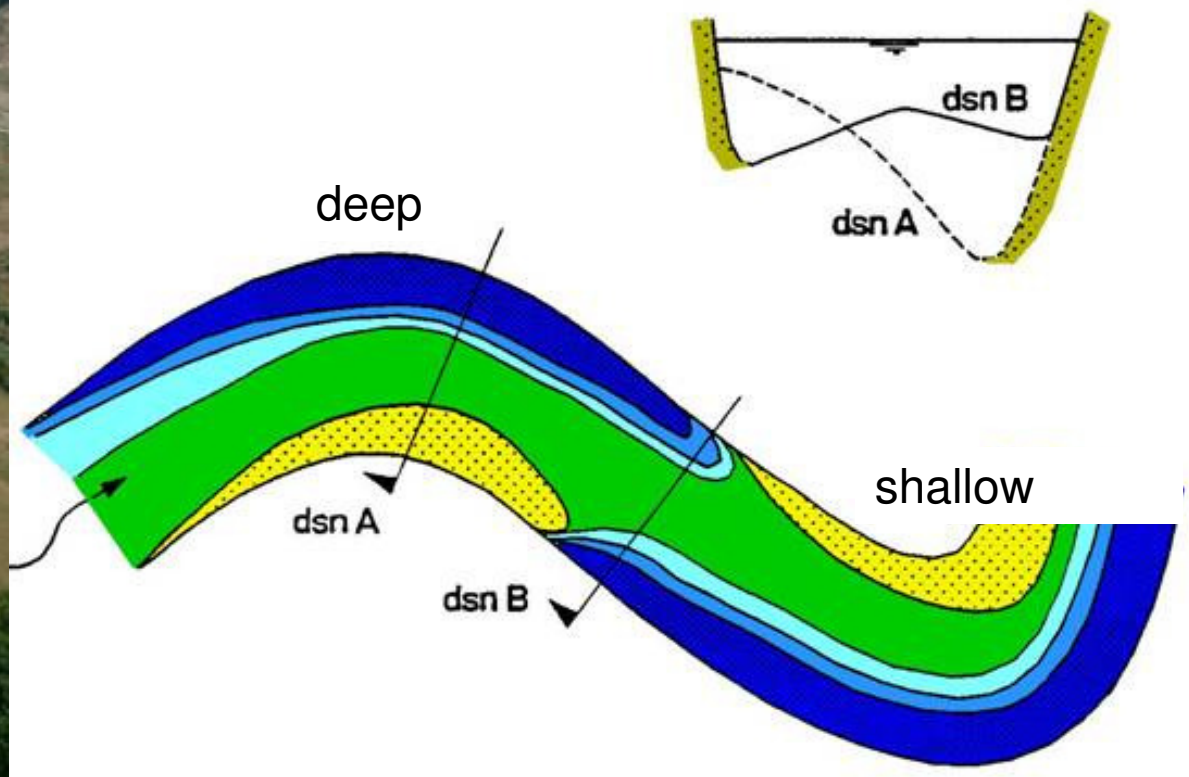
Engineering of river bends



Deltares

Engineering of river bends

Engineering of river bends



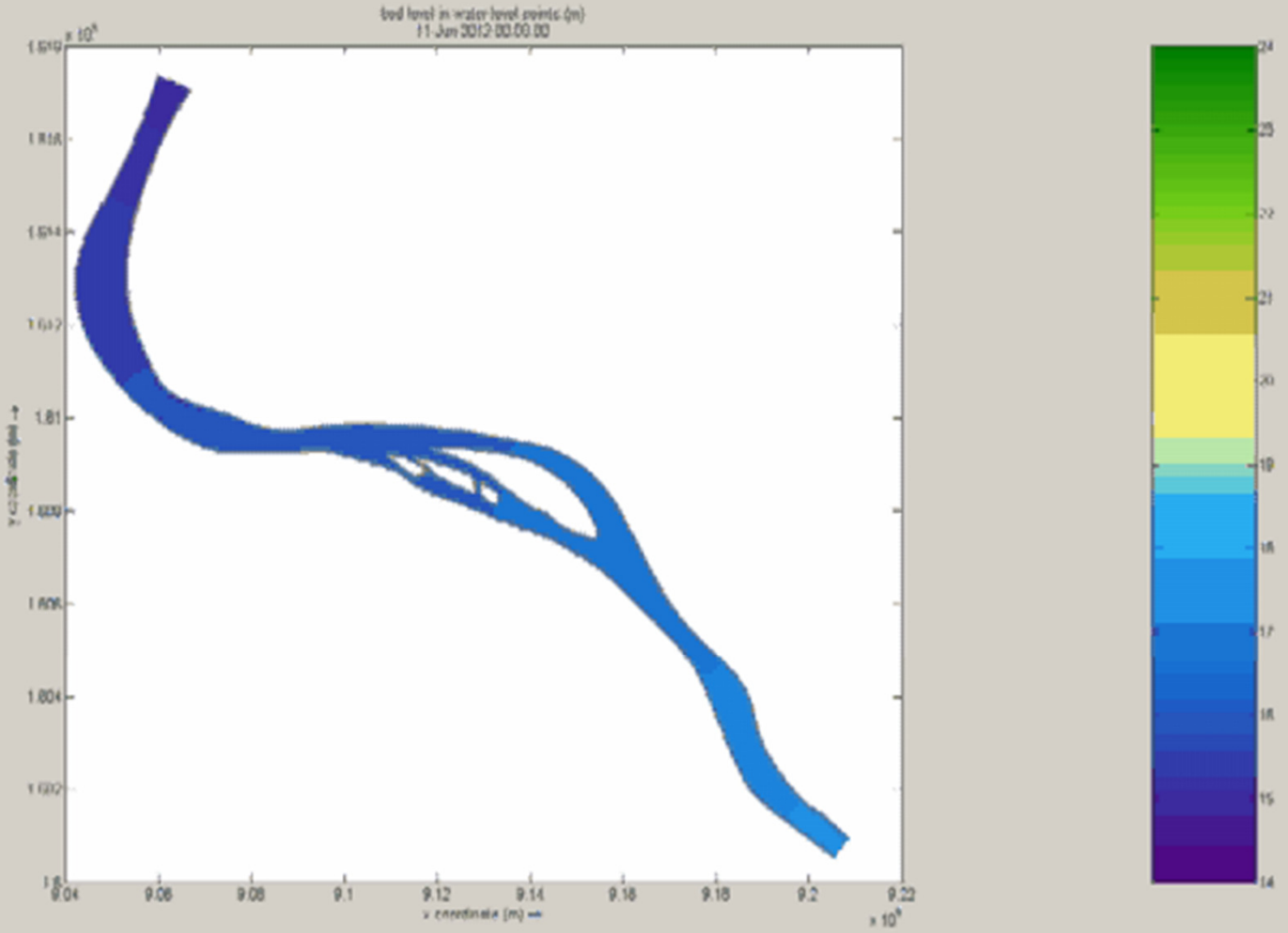
Deltares

Engineering of river bends

Engineering of river bends

Deltares

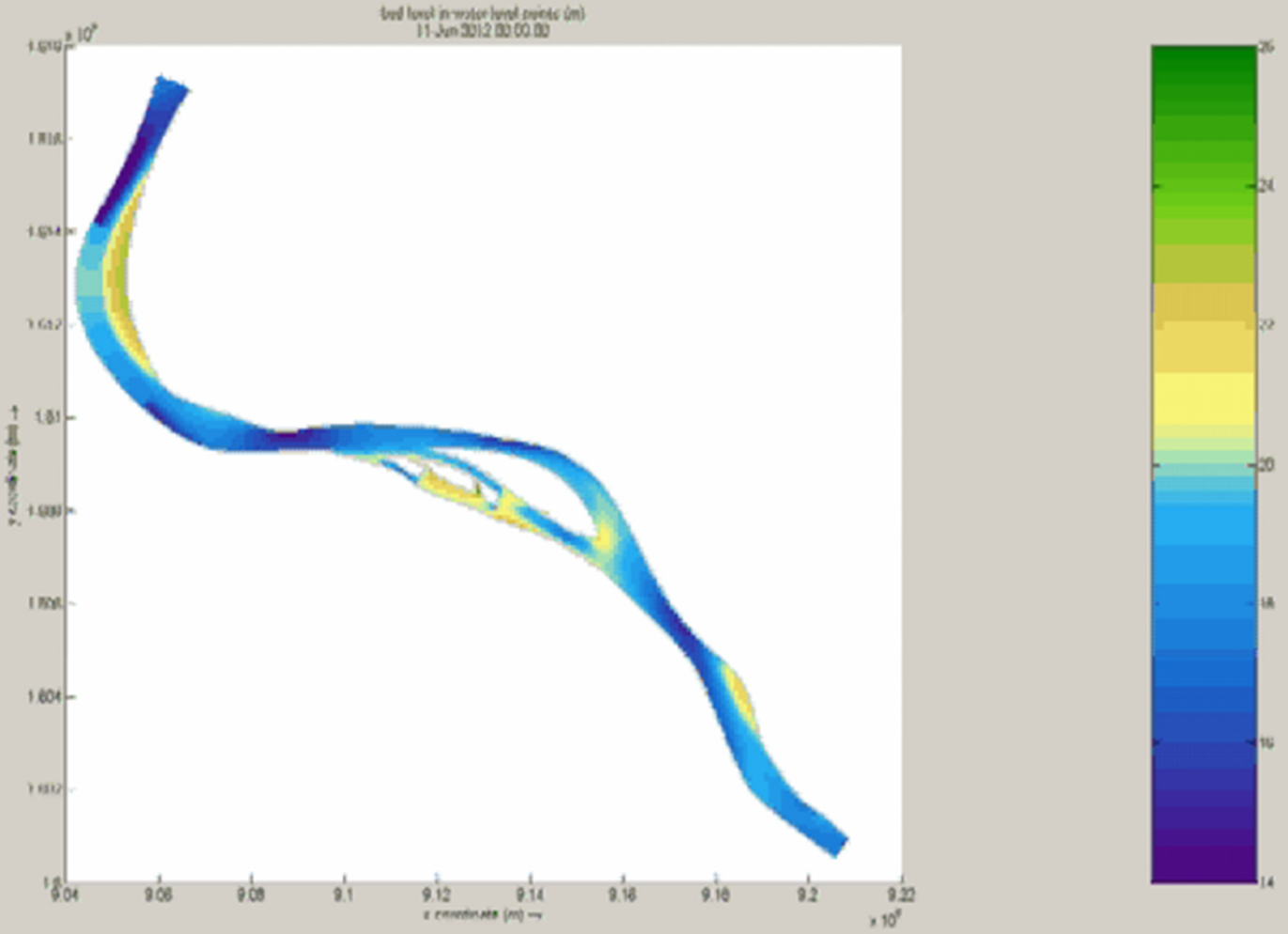
Engineering of river bends



Hypothetical application to Río Magdalena in Colombia

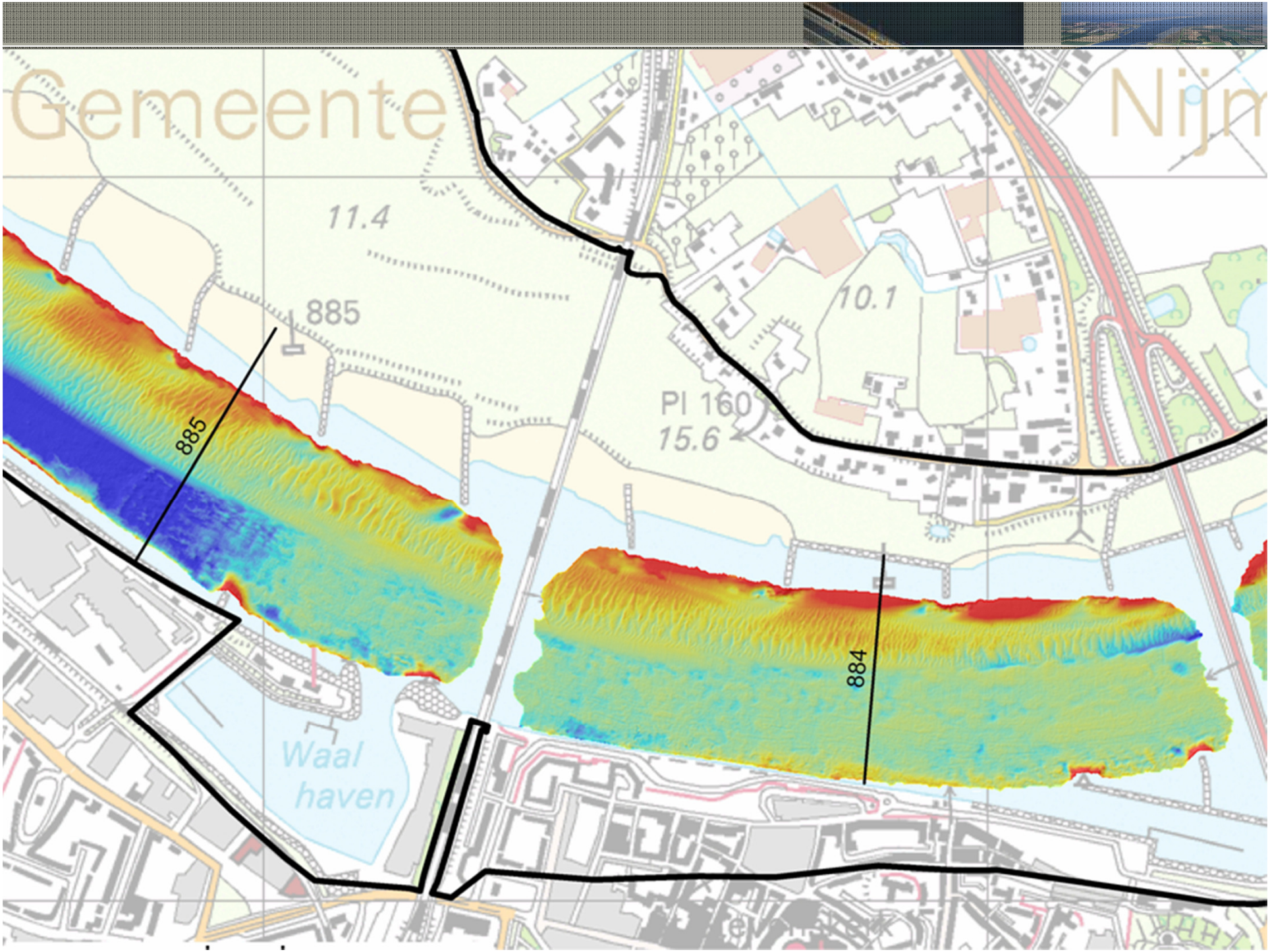
Deltares

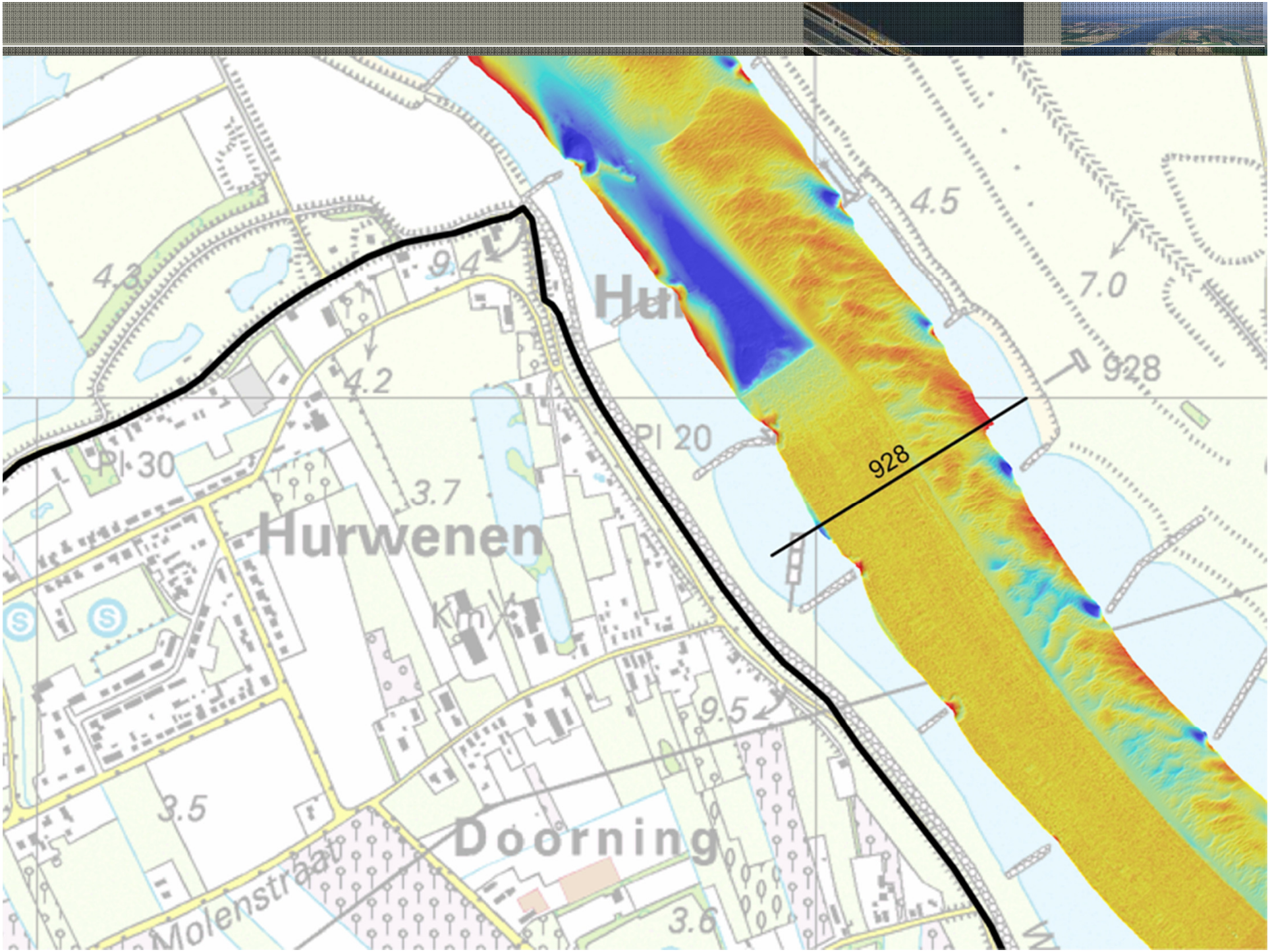
Engineering of river bends



Hypothetical application to Río Magdalena in Colombia

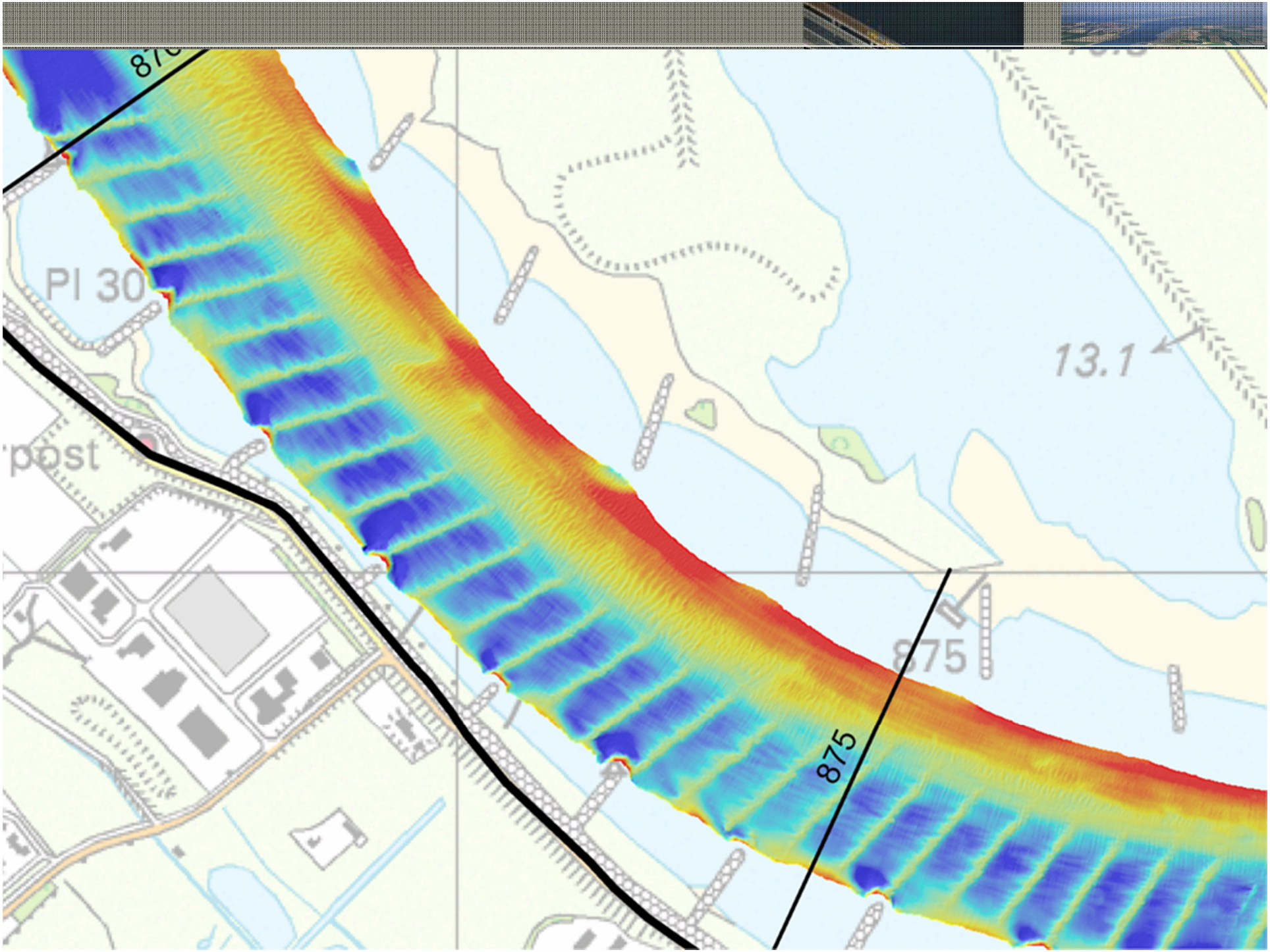
Deltares


Gemeente
Nijm
11.4
885
10.1
PI 160
15.6
885
884
Waal
haven


Hurwenen
Doorning
Molenstraat
928
928
Pl 30
Pl 20
4.5
7.0
4.2
9.4
4.2
3.7
9.5
3.5
3.6

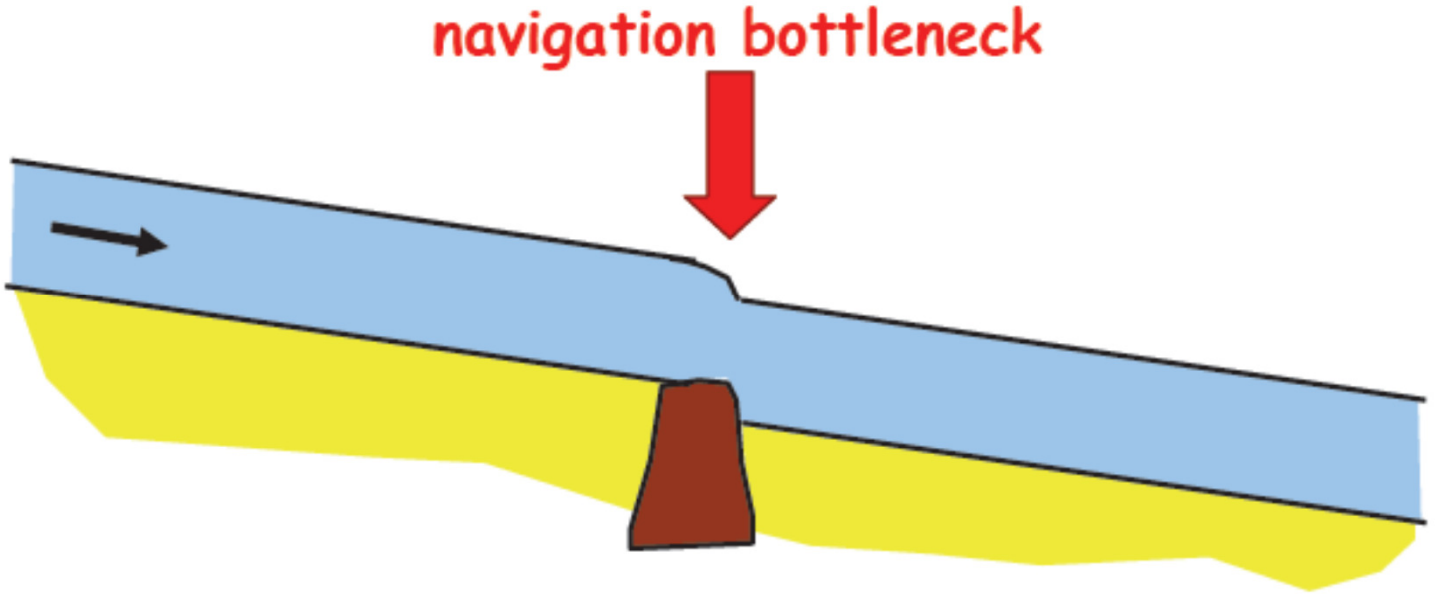
Engineering of river bends

Deltares


PI 30
13.1
875
875

Engineering of river bends

Sustainable improvement of navigability?

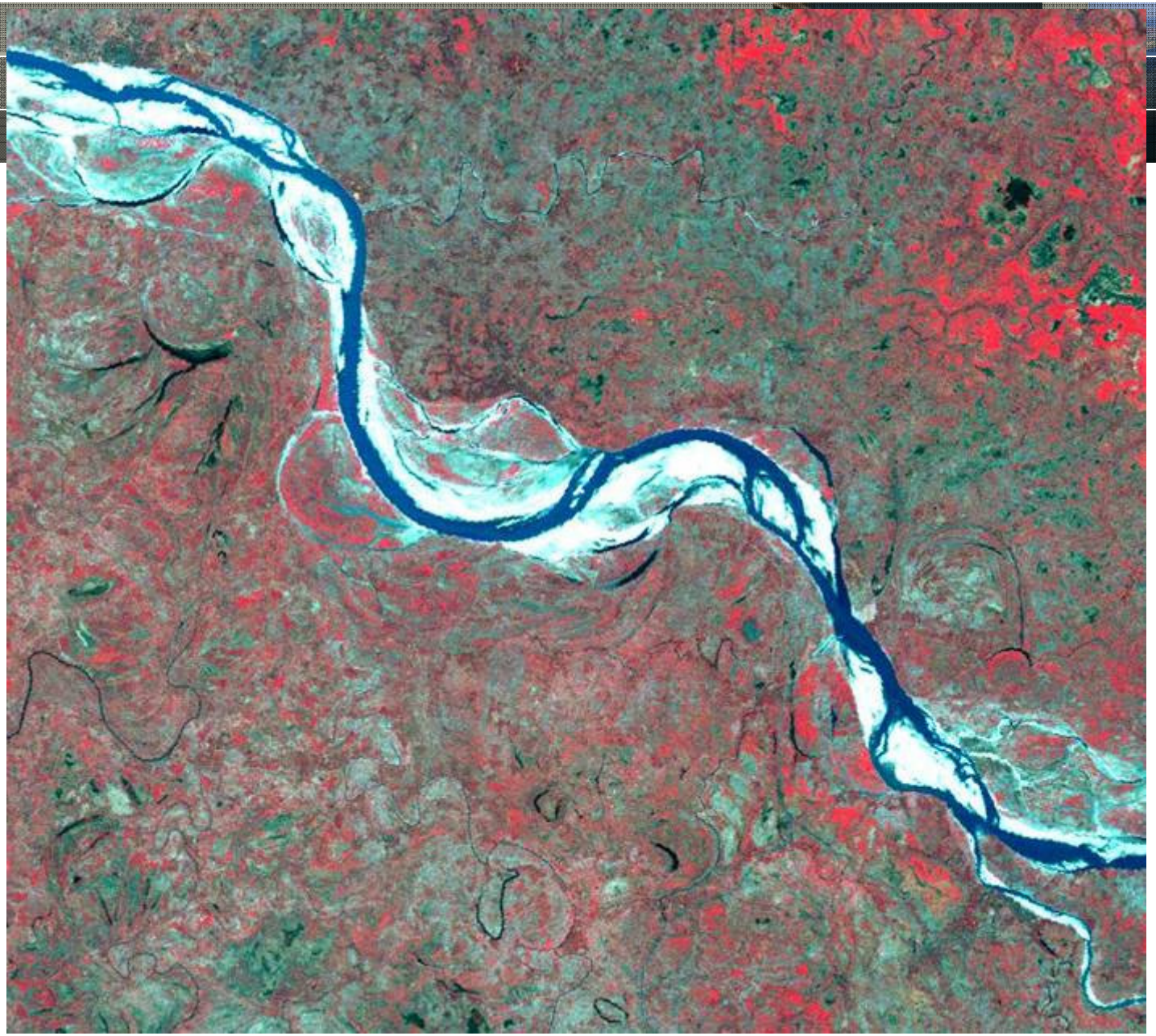


Regrets within 10 years after implementation!

due to sediment

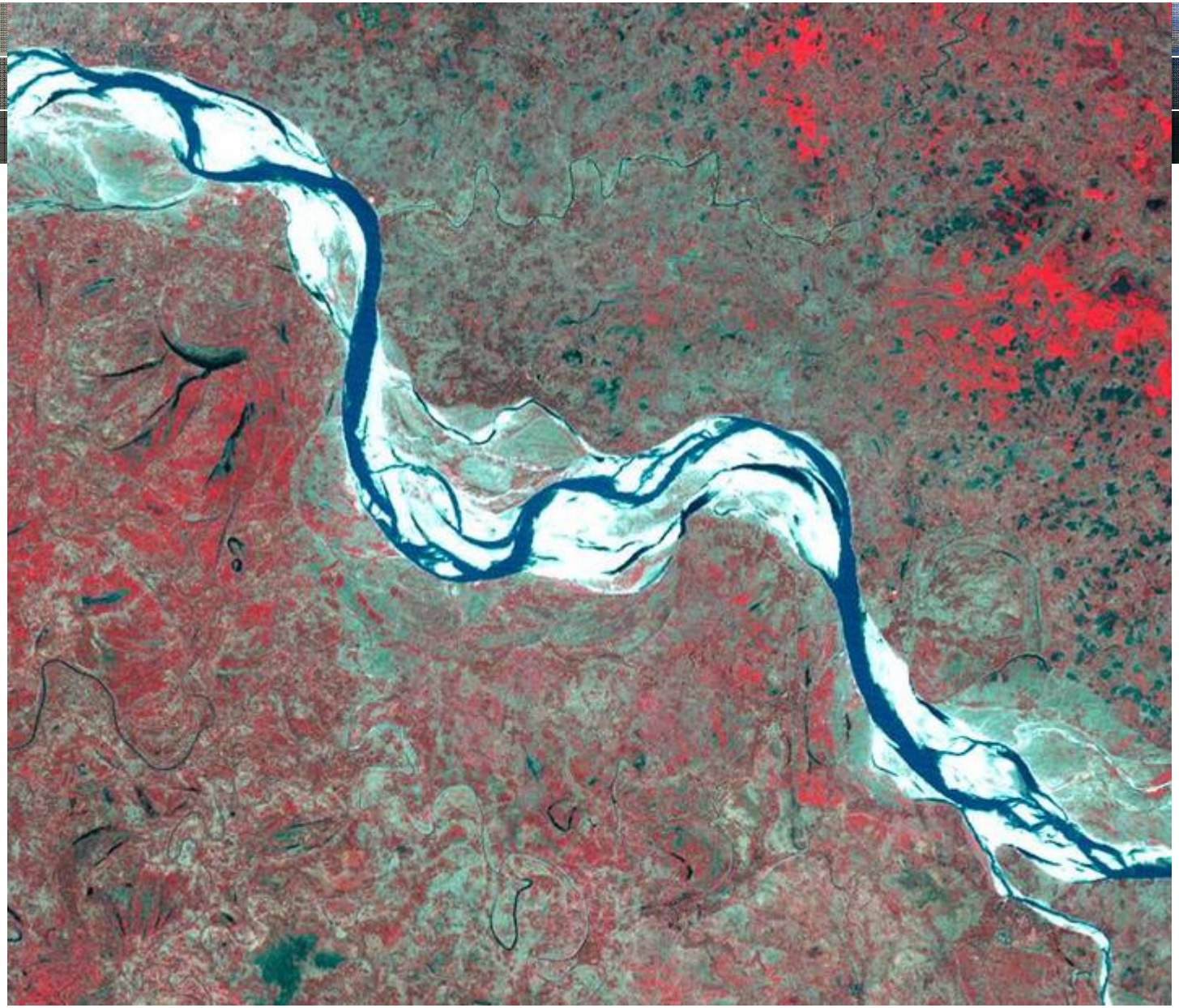
Deltares

1977



Deltares

1985

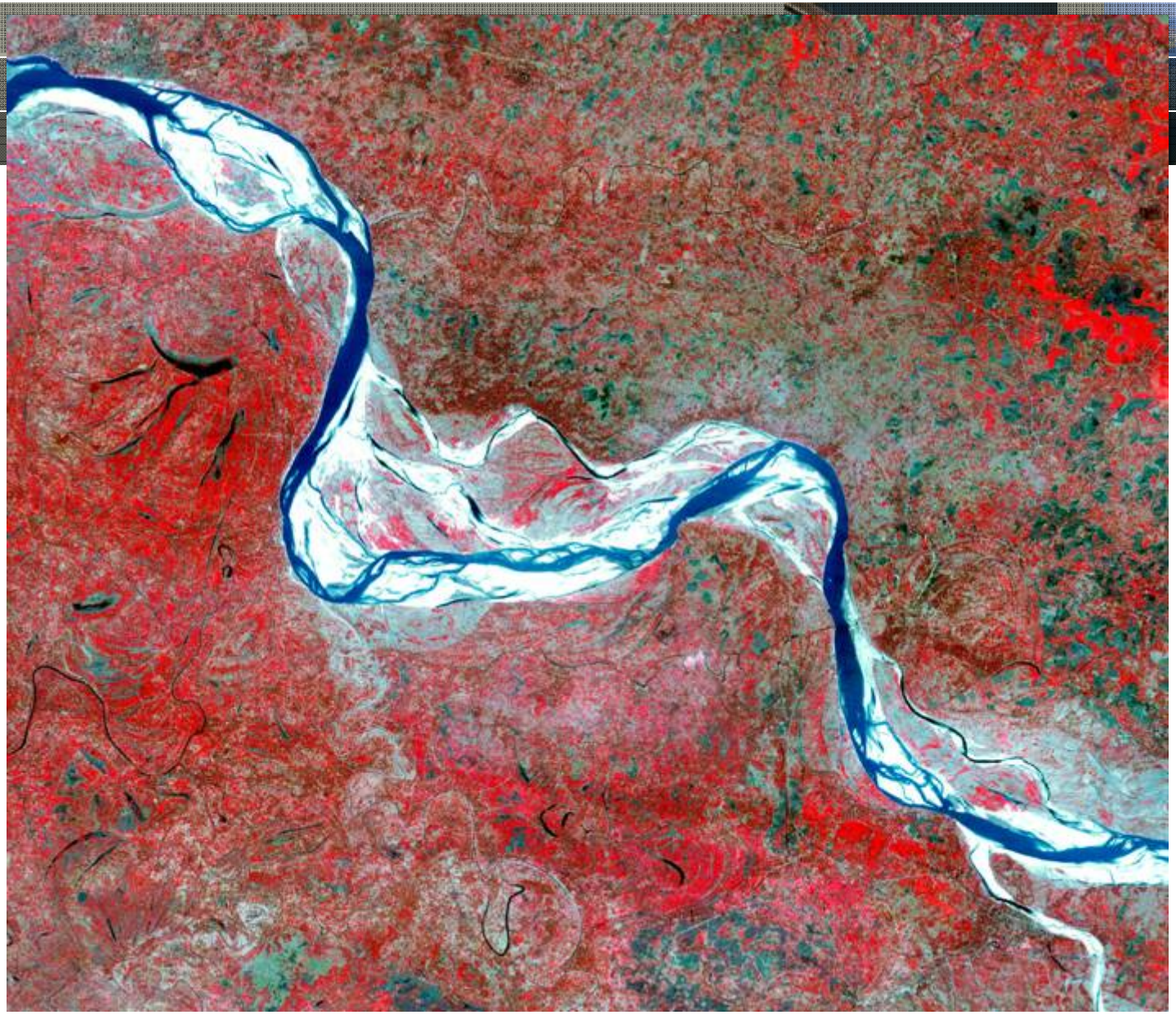


Deltares

1989

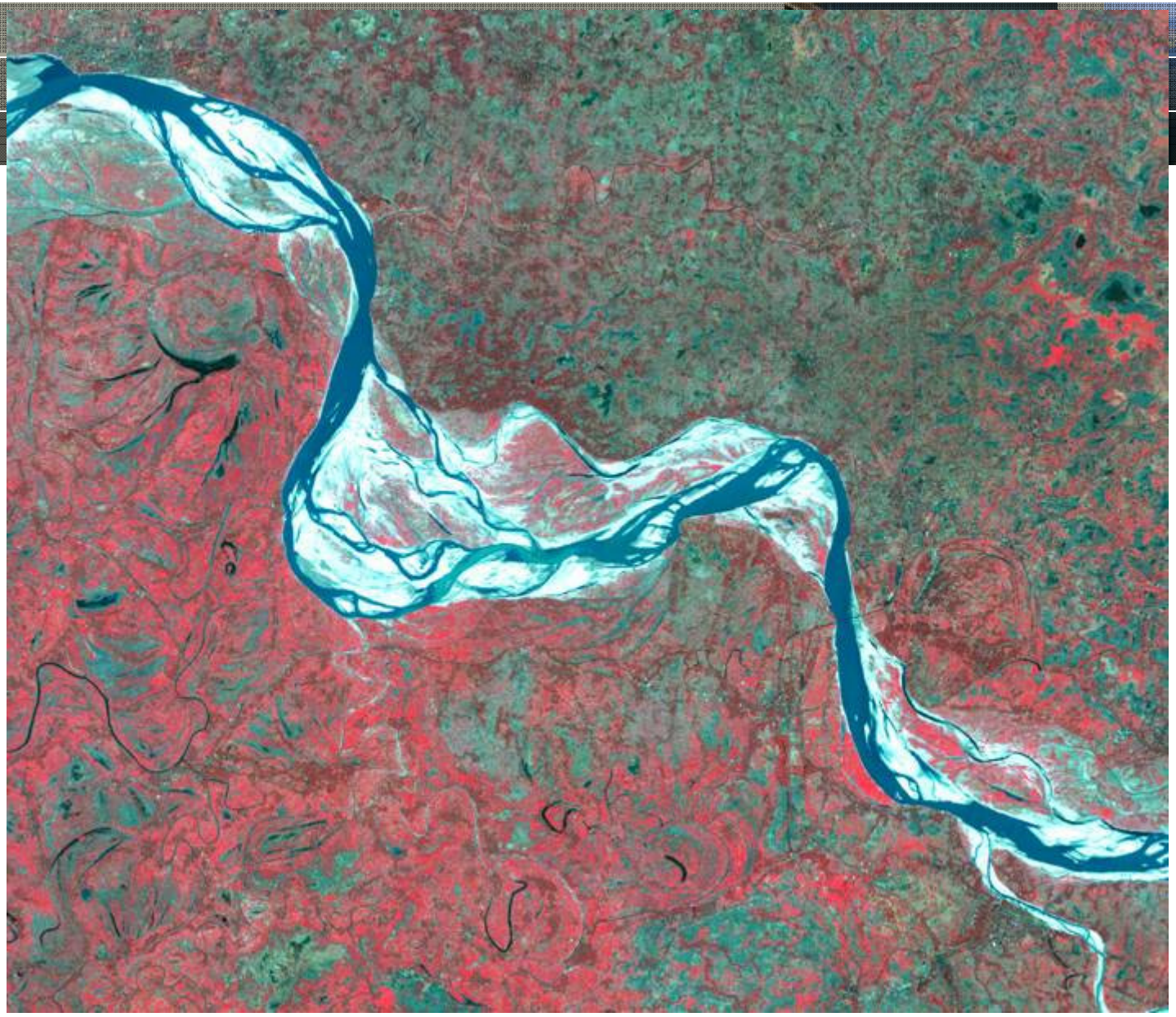
Deltares

1997



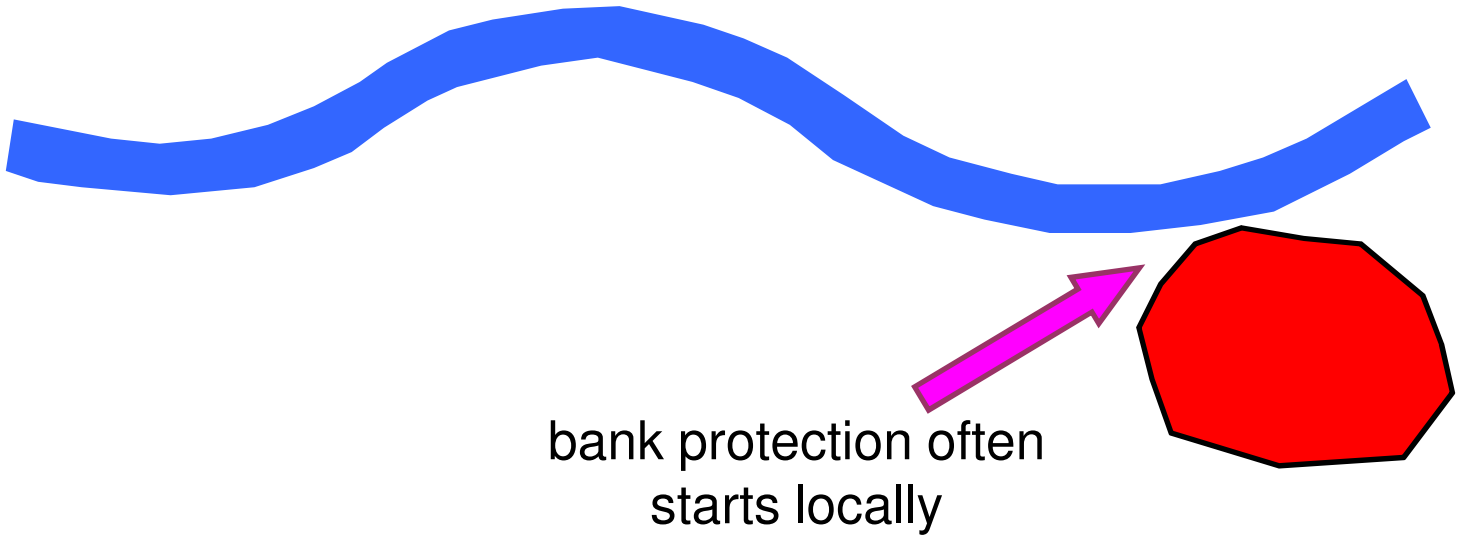
Deltares

1999

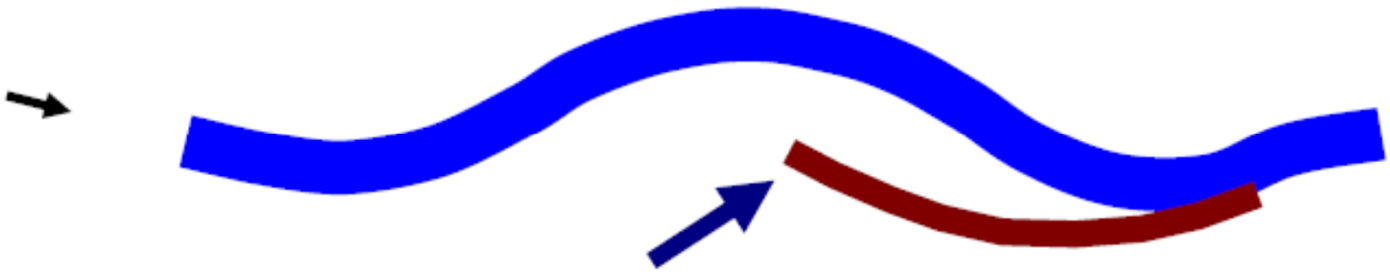


Deltares

Bank protection and river training against erosion

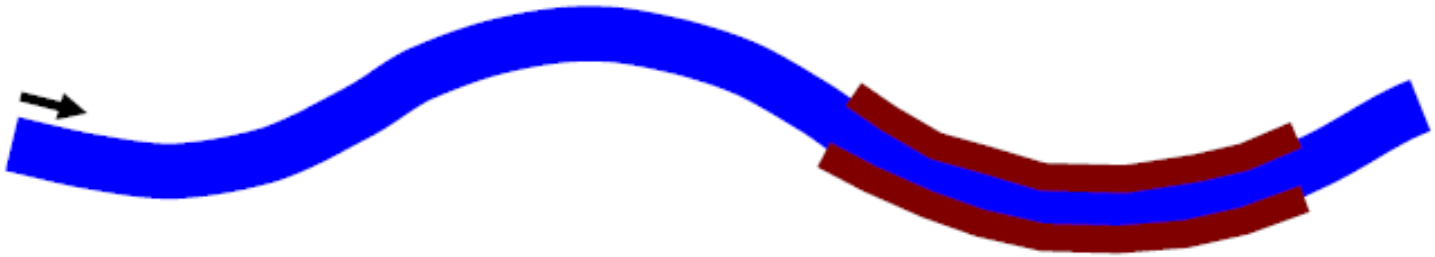


Bank protection and river training against erosion



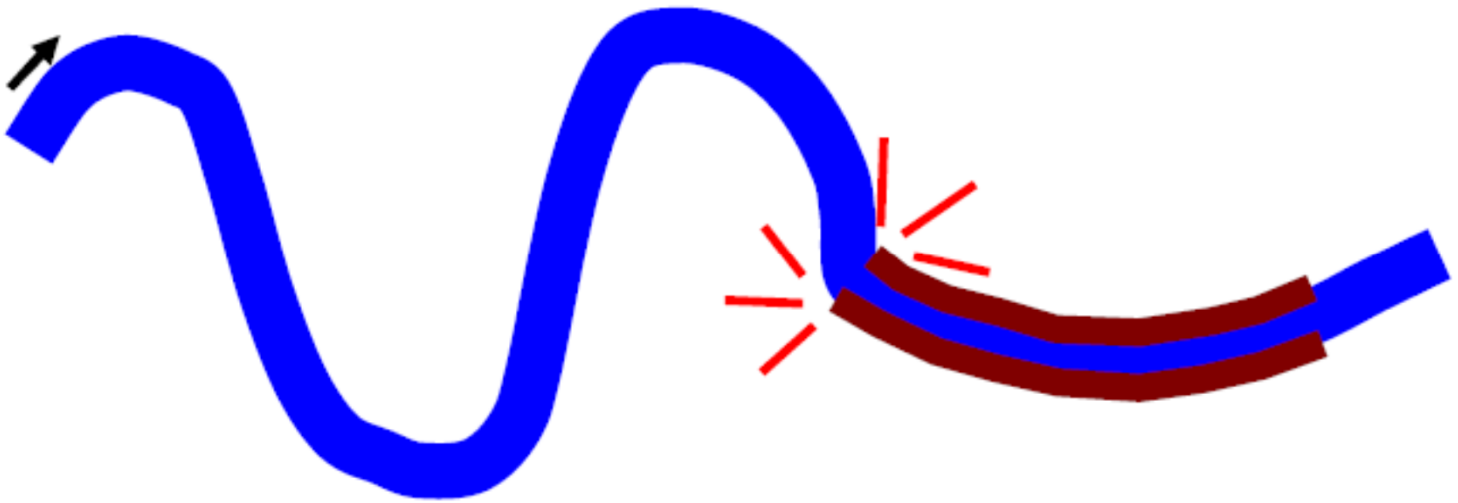
Deltares

Bank protection and river training against erosion



Deltares

Bank protection and river training against erosion

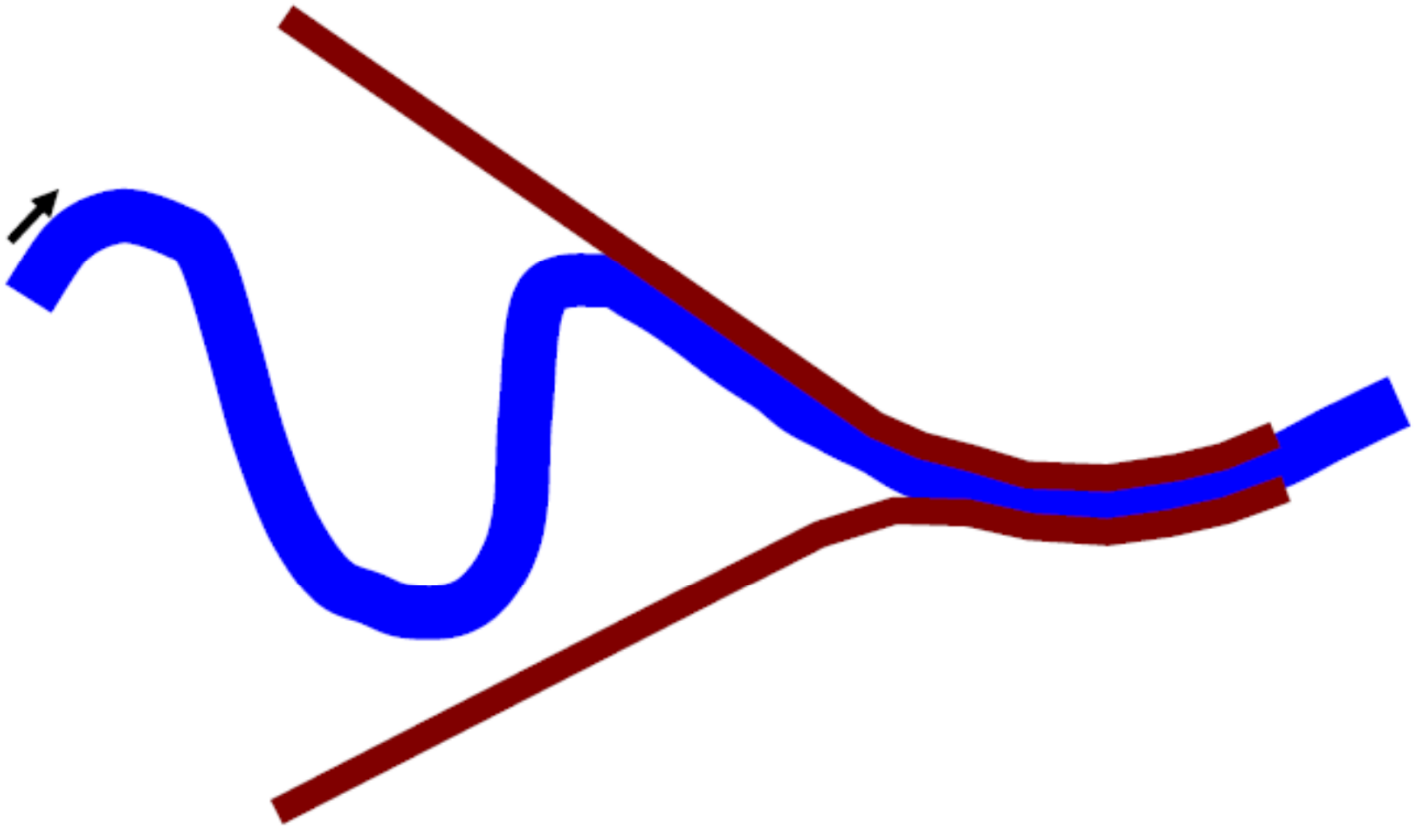


Problem at terminations … hence training of a longer reach

Once started, you are obliged to continue?

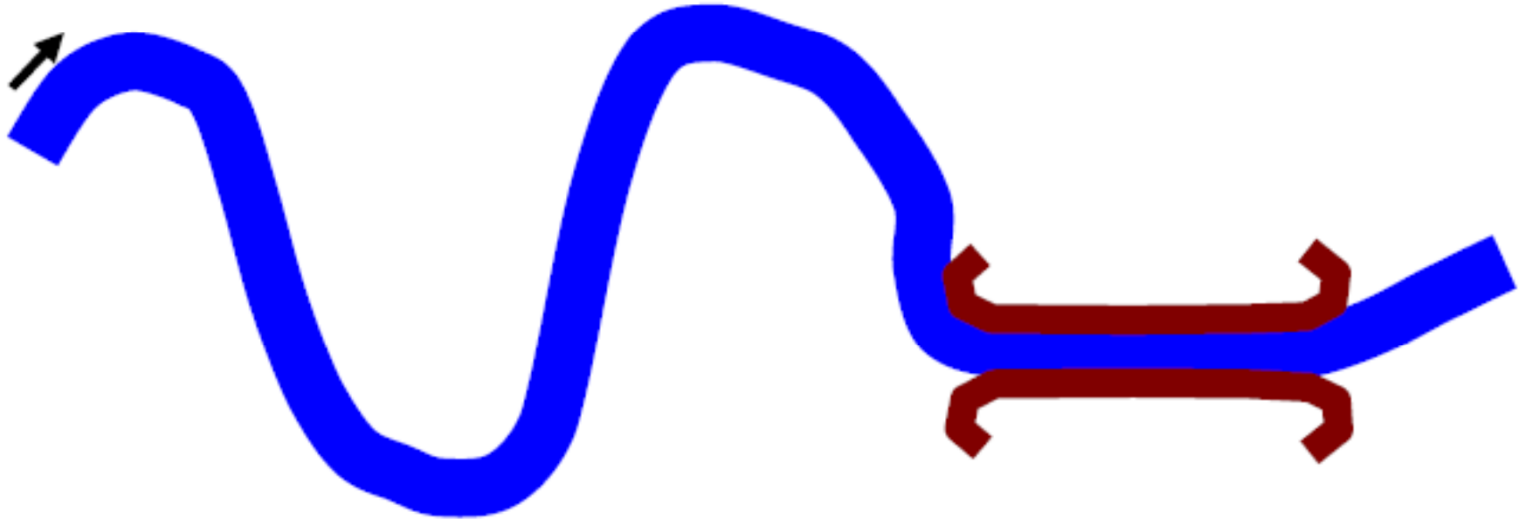
Deltares

Bank protection and river training against erosion



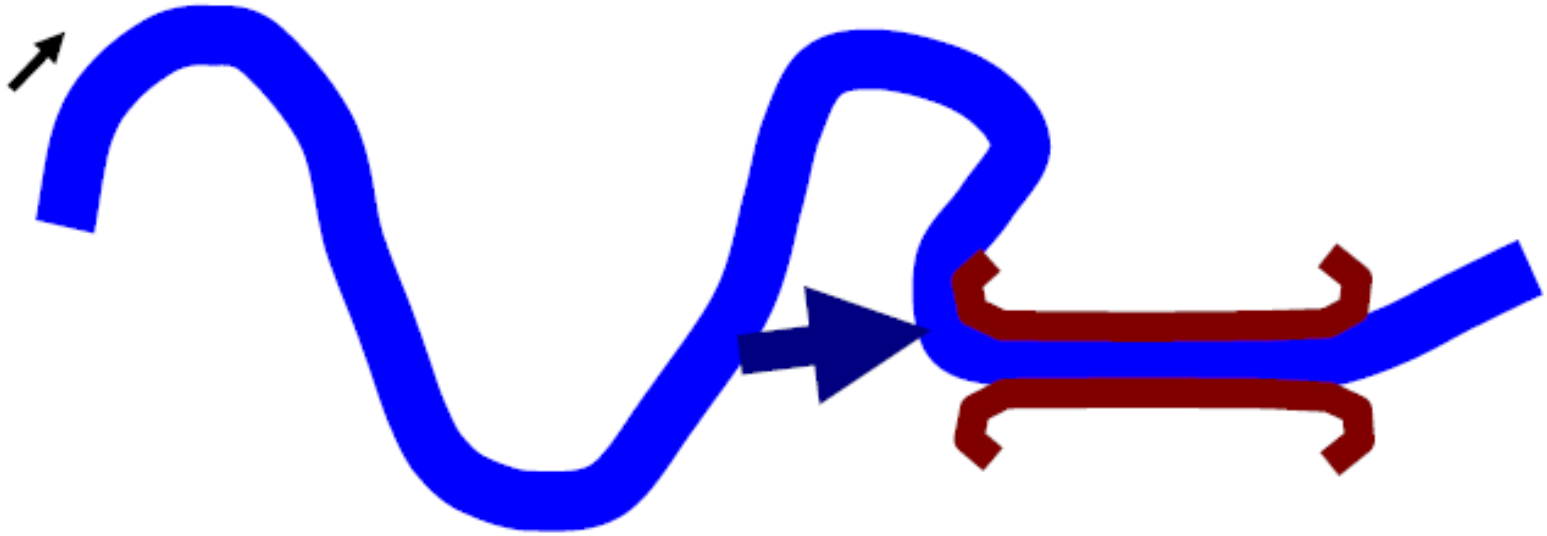
Deltares

Bank protection and river training against erosion



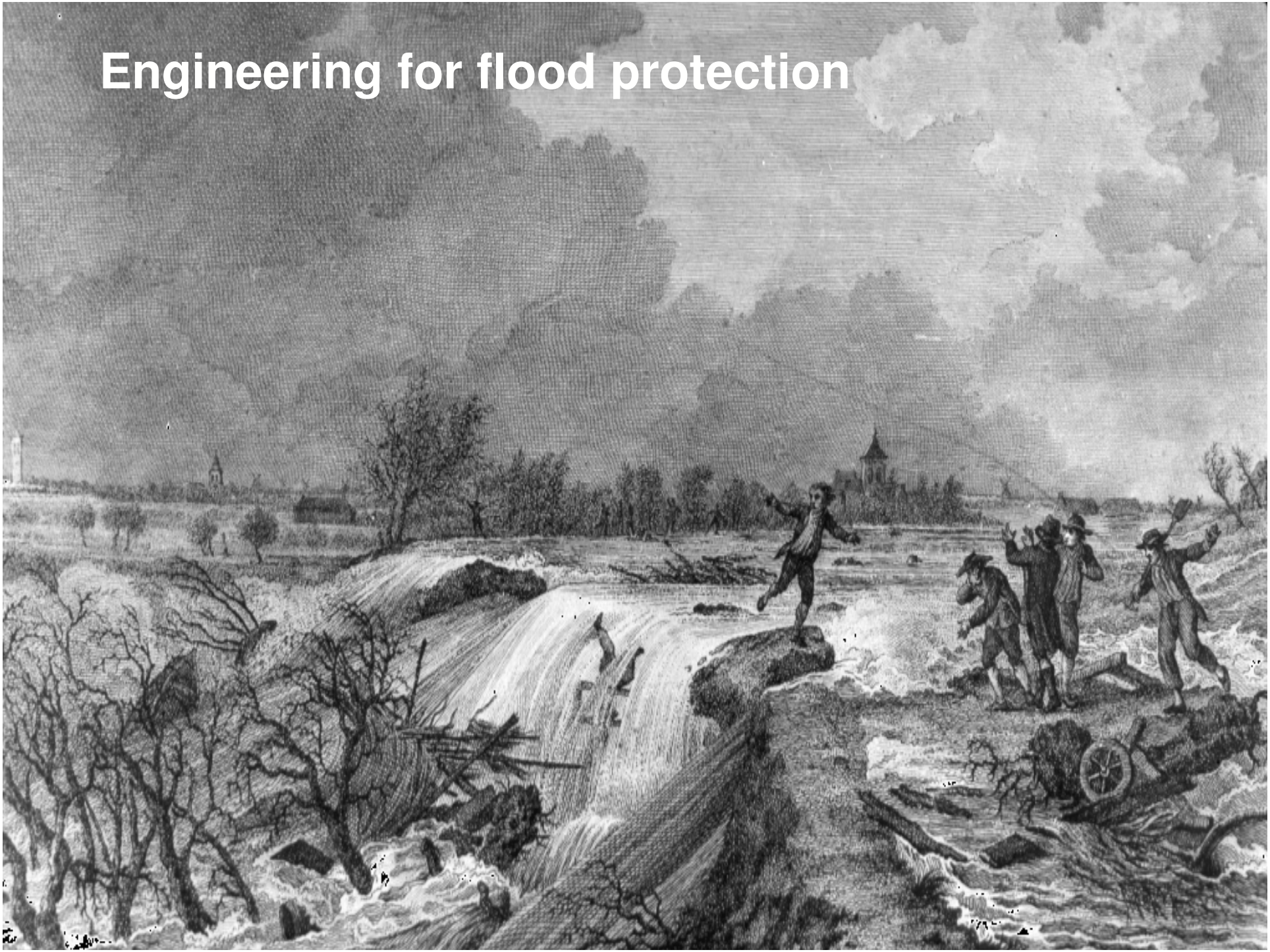
Deltares

Bank protection and river training against erosion



Deltares

Engineering for flood protection



Engineering for flood protection

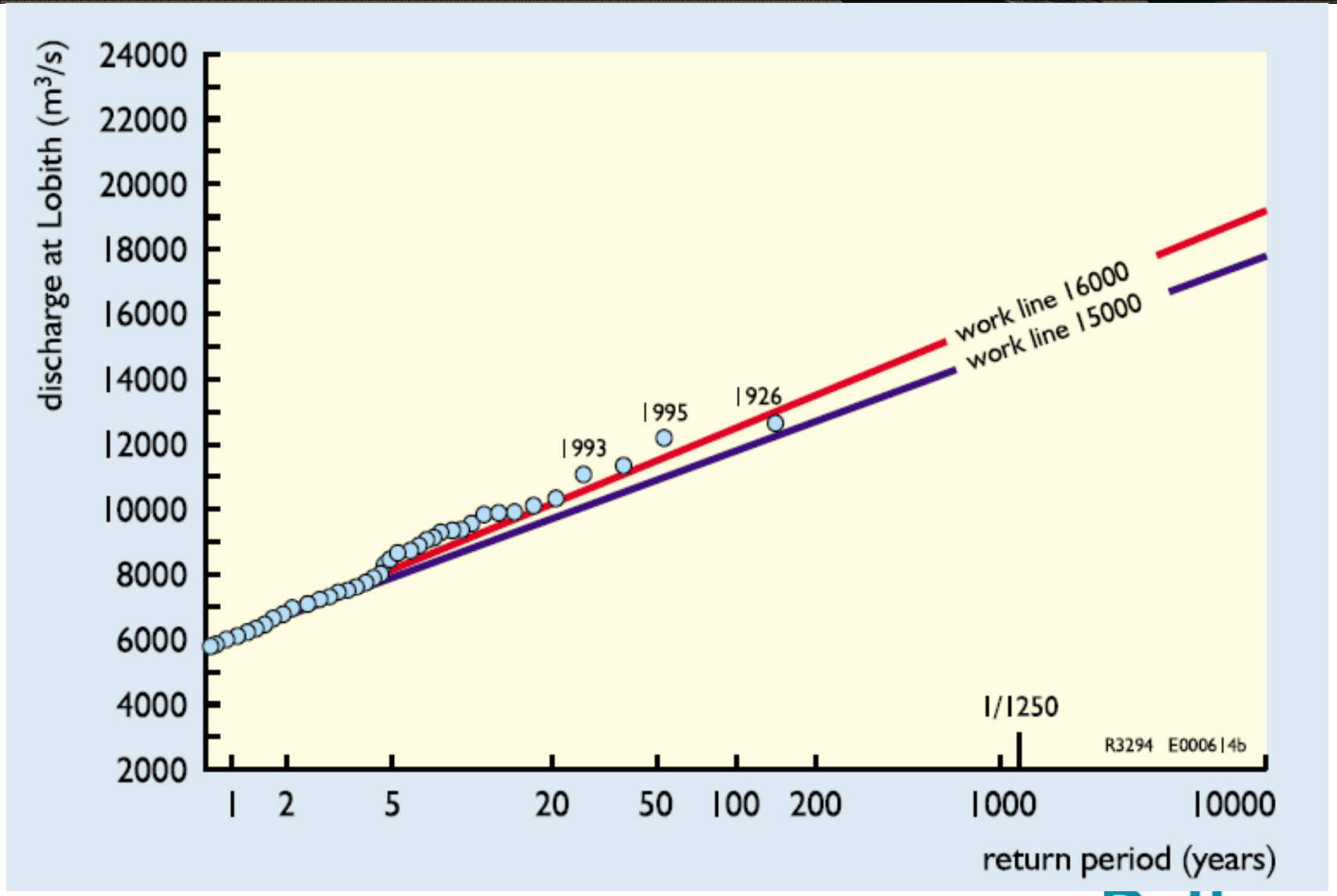
Flood disaster 1953

Rhine and Meuse floods in 1993 and 1995

Rhine flood in 1995: 250.000 evacuated

Deltares

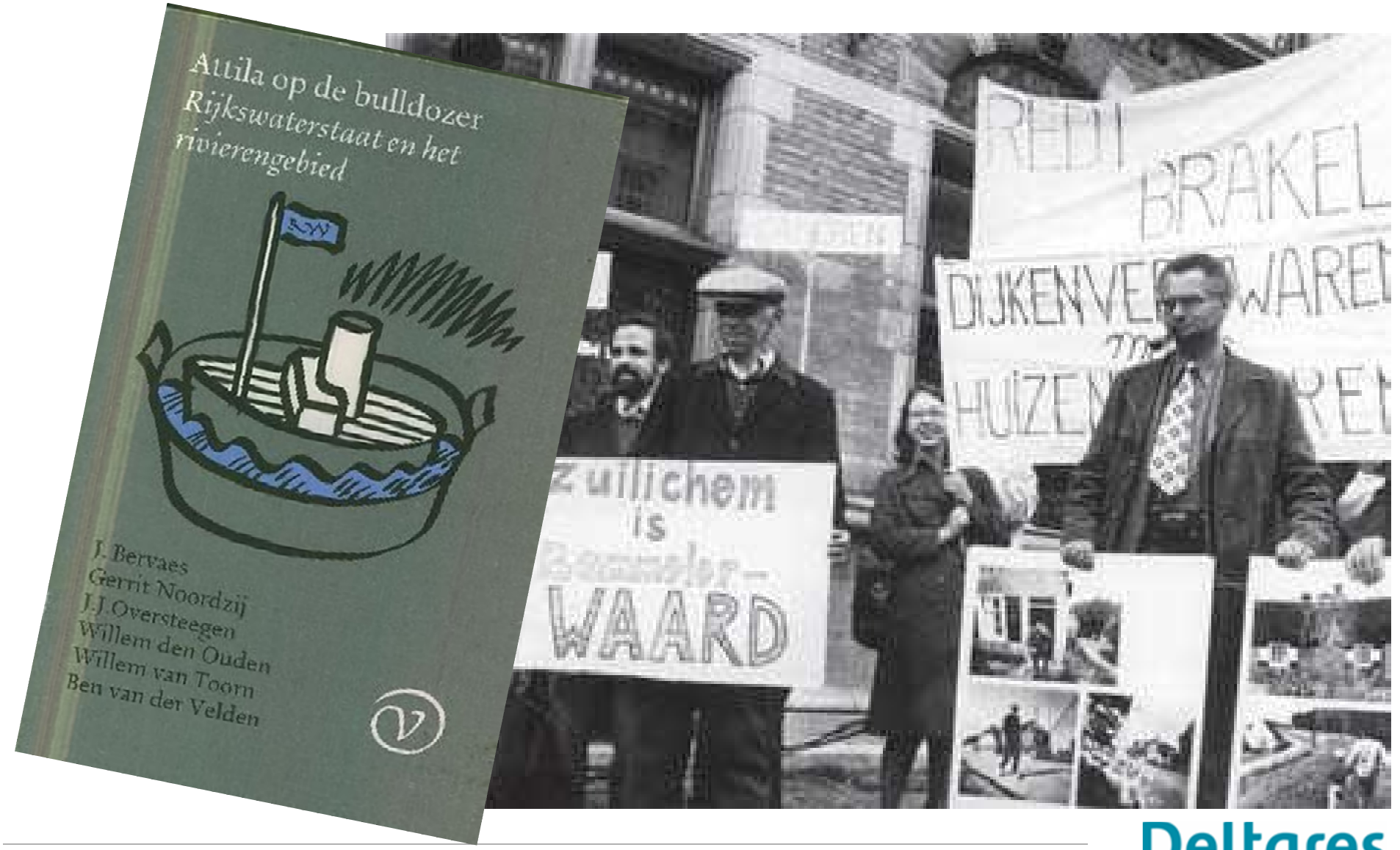
Rhine and Meuse floods in 1993 and 1995



Deltares

Engineering for flood protection

Engineering for flood protection



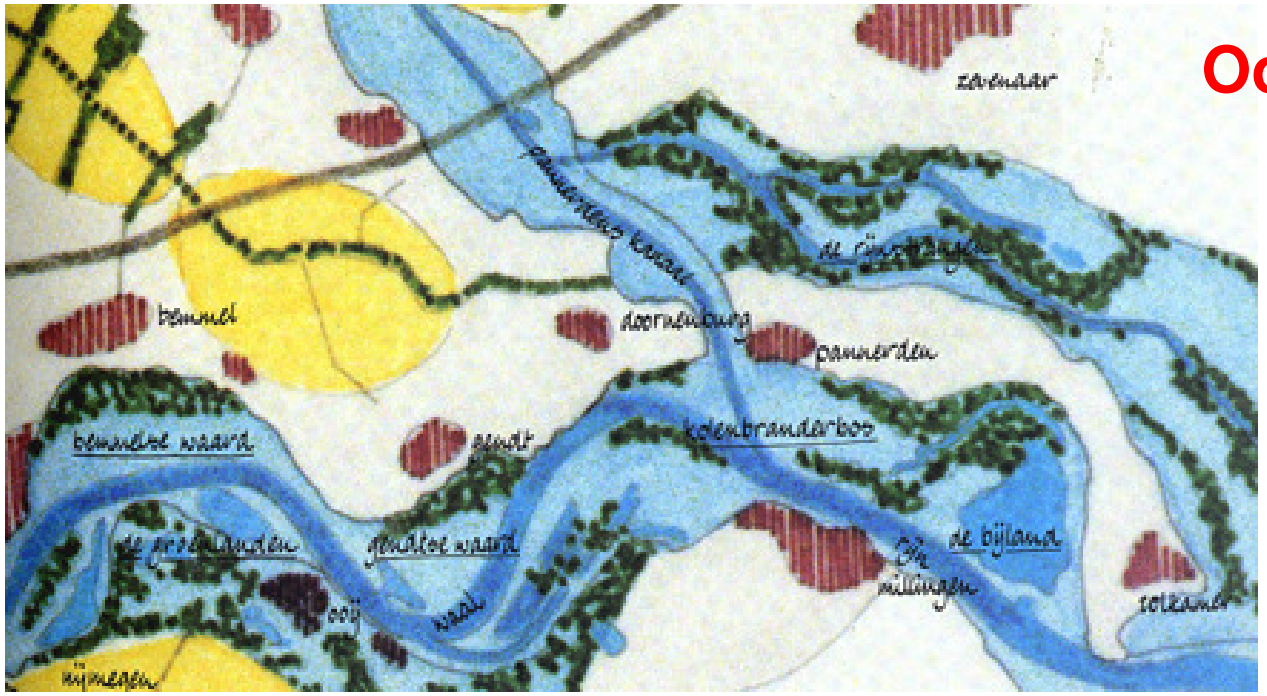
Deltares


Alternative solutions:
1. Raising the bridge
2. Creating space by releasing air from tyres

Room for the River programme

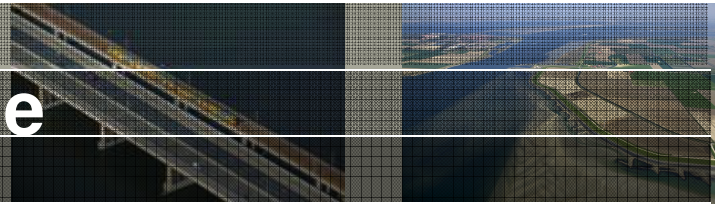
Alternative solutions:

1. Raising the dikes
2. Creating space by floodplain excavation and dike set-back



Ooievaar Plan (1985)

Room for the River programme



The “Planning Kit”, an instrument for democratic decision making:

- Total of 693 proposals for giving more room to the river
- Proposed by central government, provinces, municipalities, individual citizens, environmentalists, sand miners, etc.
- Evaluation of effects on flood water levels, costs, number of houses to be demolished, and spatial quality (nature, landscape, cultural heritage)
- Results summarized in the Planning Kit, easy-to-use
- Even popular among people without any affinity with technology and computers

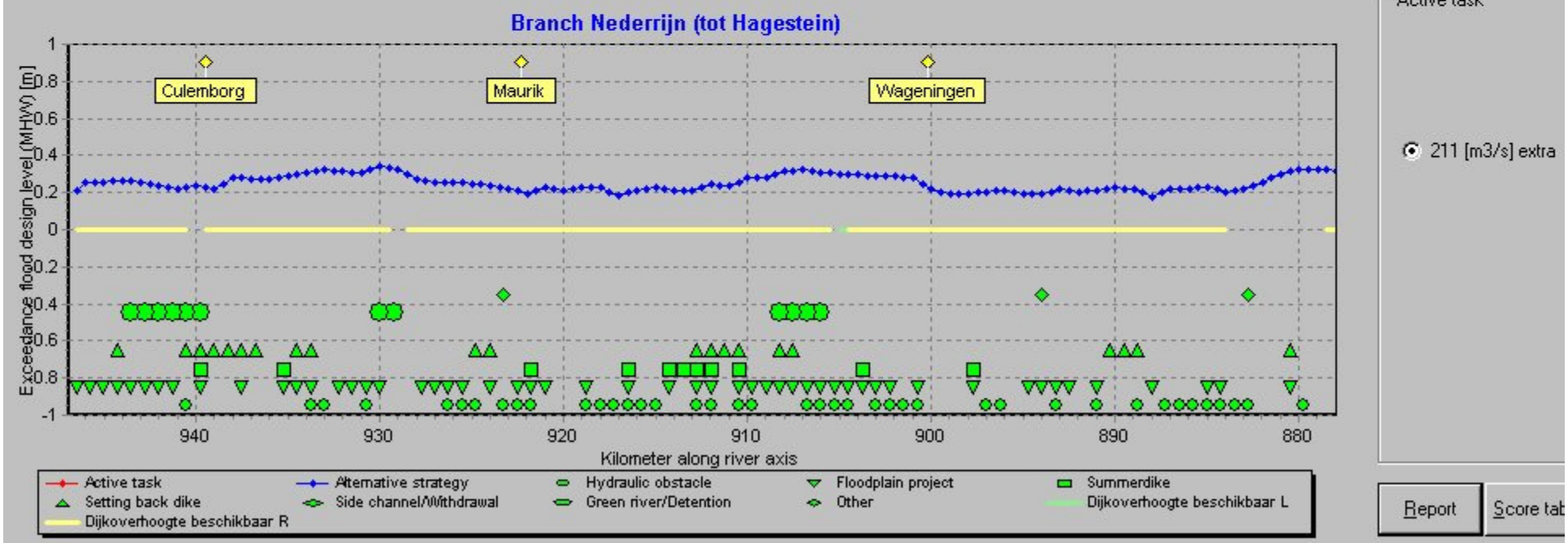
Information accessible in the same way for all parties

Deltares

Options Language Help

Code	Photo(s) present	Aerial photo present	Visualisation present	Landscape present	Description	River	Reach
1_R22_1_L	-		-	-	Uiterwaardvergraving Manuswaard-De Spees natuur	Nederrijn (tot Hagestein)	Gestuwde Neder-Rijn en Lek (kmr. 900,22 - 946,74)
2_1	-				Uiterwaardvergraving Middelwaard natuur en obstakelv	Nederrijn (tot Hagestein)	Gestuwde Neder-Rijn en Lek (kmr. 900,22 - 946,74)
2_1a	-		-		Uiterwaardvergraving Middelwaard natuur	Nederrijn (tot Hagestein)	Gestuwde Neder-Rijn en Lek (kmr. 900,22 - 946,74)
2_2	-				Uiterwaardvergraving Middelwaard natuur	Nederrijn (tot Hagestein)	Gestuwde Neder-Rijn en Lek (kmr. 900,22 - 946,74)
3_1	-				Rhenen	Nederrijn (tot Hagestein)	Gestuwde Neder-Rijn en Lek (kmr. 900,22 - 946,74)
3_2	-				Rhenen	Nederrijn (tot Hagestein)	Gestuwde Neder-Rijn en Lek (kmr. 900,22 - 946,74)
4_1	-				Uiterwaardvergraving De Tollewaard natuur 1	Nederrijn (tot Hagestein)	Gestuwde Neder-Rijn en Lek (kmr. 900,22 - 946,74)

er: Nederrijn (tot Hagestein) Map Show only selected projects Deselect projects



Active task

211 [m3/s] extra

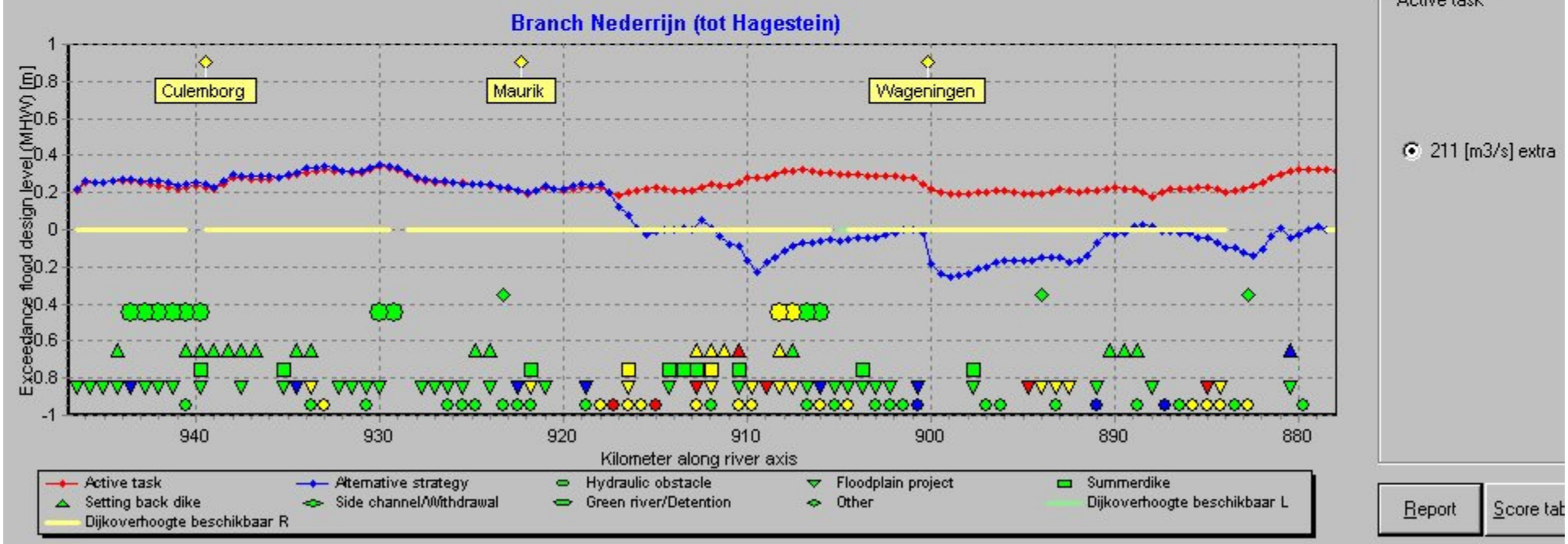
Report Score tab

ining MHW area 100.0 % TotCostEx. 0.0 M€ PKBCostEx. 0.0 M€ 23:13 23/05/200

Options Language Help

Code	Photo(s) present	Aerial photo present	Visualisation present	Landscape present	Description	River	Reach
1_R22_1_L	-		-	-	Uiterwaardvergraving Manuswaard-De Spees natuur	Nederrijn (tot Hagestein)	Gestuwde Neder-Rijn en Lek (kmr. 900,22 - 946,74)
2_1	-				Uiterwaardvergraving Middelwaard natuur en obstakelv	Nederrijn (tot Hagestein)	Gestuwde Neder-Rijn en Lek (kmr. 900,22 - 946,74)
2_1a	-		-		Uiterwaardvergraving Middelwaard natuur	Nederrijn (tot Hagestein)	Gestuwde Neder-Rijn en Lek (kmr. 900,22 - 946,74)
2_2	-				Uiterwaardvergraving Middelwaard natuur	Nederrijn (tot Hagestein)	Gestuwde Neder-Rijn en Lek (kmr. 900,22 - 946,74)
3_1	-				Rhenen	Nederrijn (tot Hagestein)	Gestuwde Neder-Rijn en Lek (kmr. 900,22 - 946,74)
3_2	-				Rhenen	Nederrijn (tot Hagestein)	Gestuwde Neder-Rijn en Lek (kmr. 900,22 - 946,74)
4_1	-				Uiterwaardvergraving De Tollewaard natuur 1	Nederrijn (tot Hagestein)	Gestuwde Neder-Rijn en Lek (kmr. 900,22 - 946,74)

er: Nederrijn (tot Hagestein) Map Show only selected projects Deselect projects



Active task

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Report Score tab

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Watermanager - PKB - []

Begin opnieuw Kies andere tak Extra Help

Maatregelen

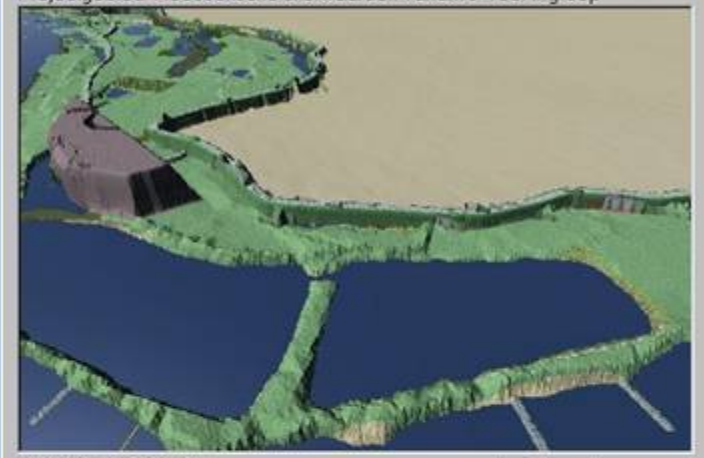
Uitleg | Lijst | Kaart

Aan	Type	Omschrijving	Km
◇	Krib	Kribverlaging op traject Waal omgeving St. Andries (km	914.8-934.2 (B)
◇	Grootschalige dijkverlegging	Heeselt, variant jan 2004	923.6-924.8 (R)
◇	Uiterwaardplan	Heesseltsche uiterwaarden variant 4	922.9-930.5 (R)
◇	Knelpunt	voormalige steenfabriek in bocht (Heesselt)	926.8-927.4 (R)
◇	**Uiterwaardplan**	**Heesseltsche uiterwaarden variant 5**	**922.9-930.5 (R)**
◇	Knelpunt	steenfabriek (Hurwenen)	928.5-929.0 (L)
◇	Uiterwaardplan	Hurwenensche uiterwaarden (model landschap)	928.6-932.9 (L)
◇	Uiterwaardplan	Hurwenensche uiterwaarden (model rivierkunde)	928.6-932.9 (L)
◇	Uiterwaardplan	Rijswaard en Kerkenwaard	931.0-937.0 (R)
◇	Uiterwaardplan	Watertoren Zaltbommel	933.6-933.9 (L)
◇	Uiterwaardplan	Zaltbommel	934.8-935.6 (L)
◇	Uiterwaardplan	Gamerensche waarden	935.5-937.3 (L)
◇	Uiterwaardplan	Gamerensche waard	936.5-939.0 (L)
◇	Uiterwaardplan	Grobsche waard	937.3-940.3 (R)
◇	Uiterwaardplan	Breemwaard	939.4-942.6 (L)
◇	Uiterwaardplan	Herwijnensche boverwaard	941.2-943.5 (R)
◇	Krib	Kribverlaging op traject Beneden-Waal (km. 934,22 - 9	934.2-953.0 (B)
◇	Zomerbed	Zomerbedverlaging WL: W4	934.2-953.0 (B)
◇	Uiterwaardplan	Ruyterwaard	942.6-946.7 (L)

Heesseltsche uiterwaarden variant 5

Informatie | Foto's | Luchtfoto's | Visualisatie

Projectgebied 'Heesseltsche uiterwaarden variant 5' vóór ingreep

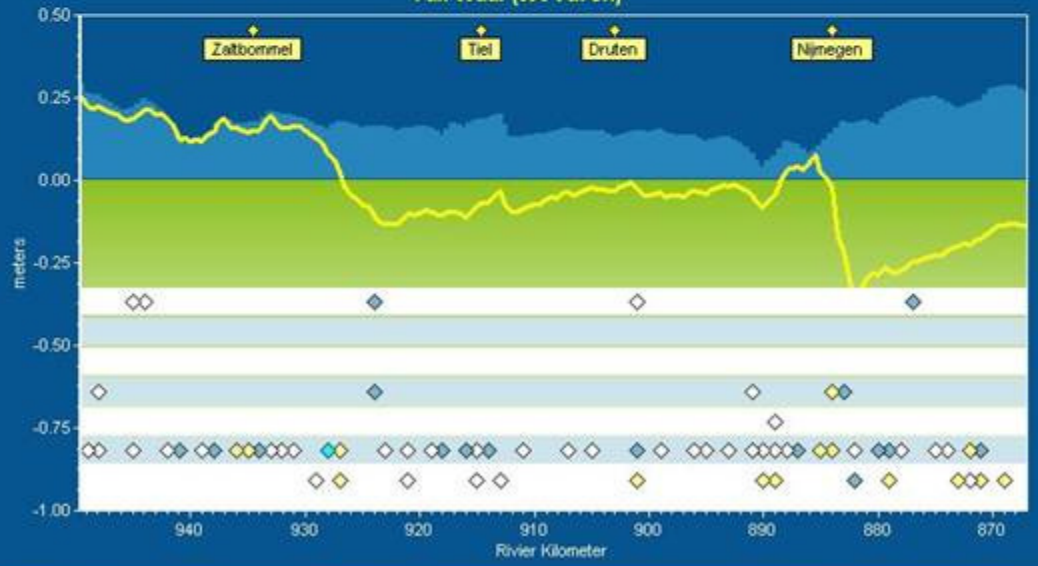


Kijkrichting: stroomafwaarts
Oever: R

Zie na ingreep

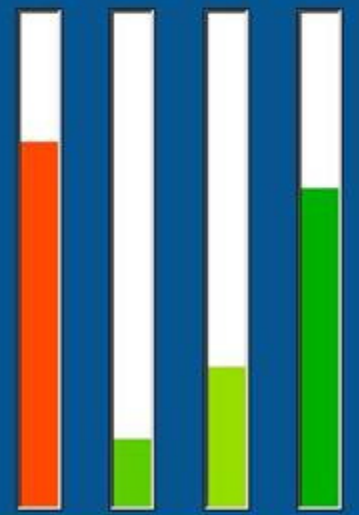
Tak Waal (tot Vuren)

Andere tak



Effecten

?



Room for the River programme

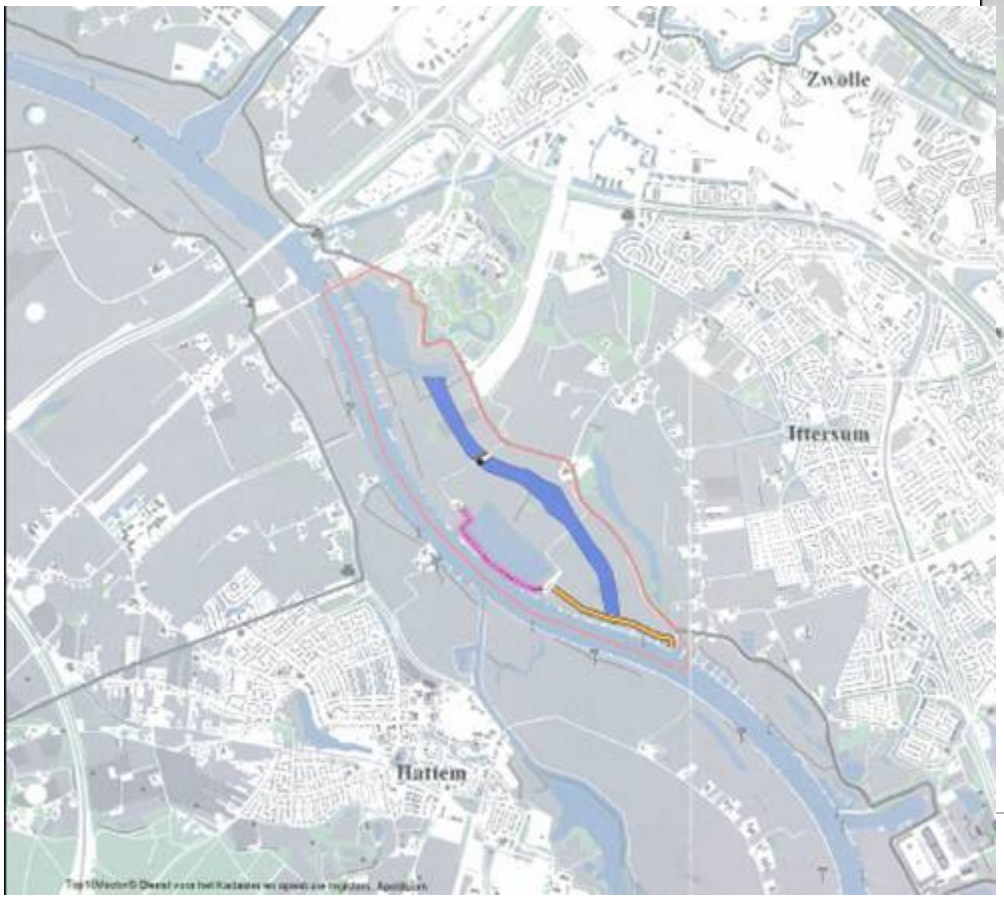
Room for the River programme

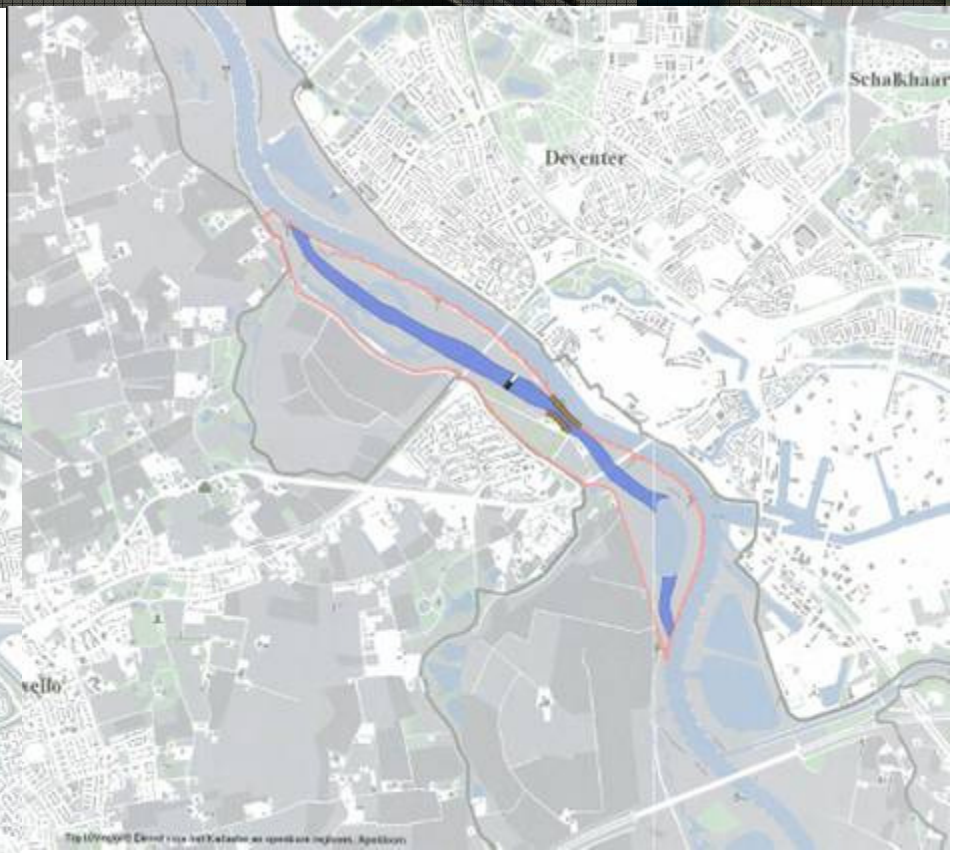
Lowering of 750 groynes

Deltares

Room for the River programme

Secondary channels





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Room for the River programme

€ 300 million

Flood channels into Noordwaard wetlands

Deltares

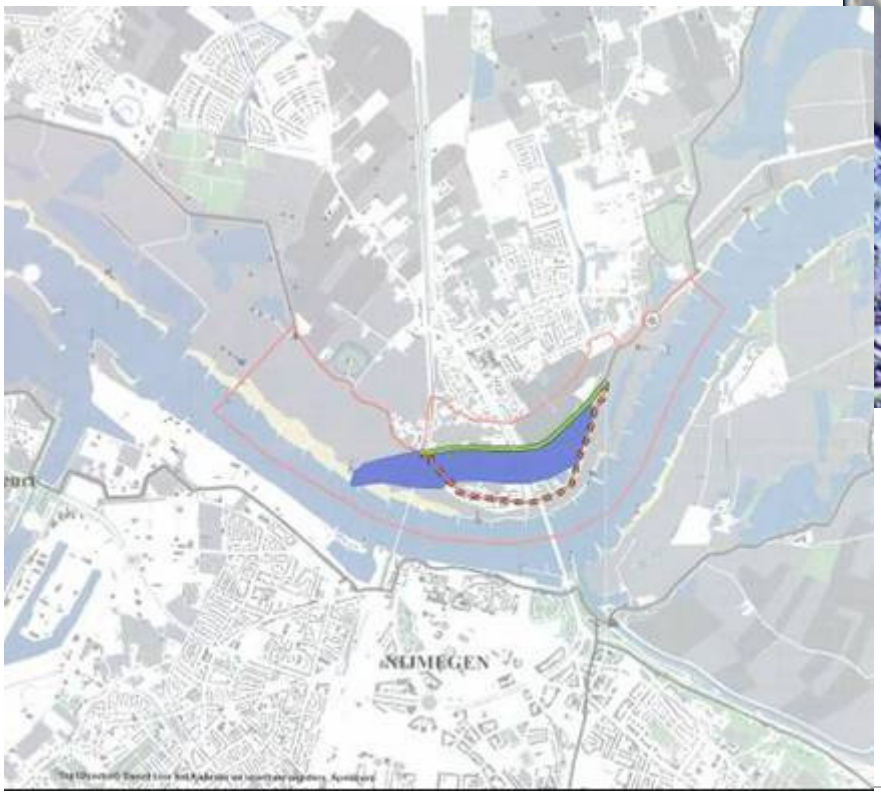
Room for the River programme

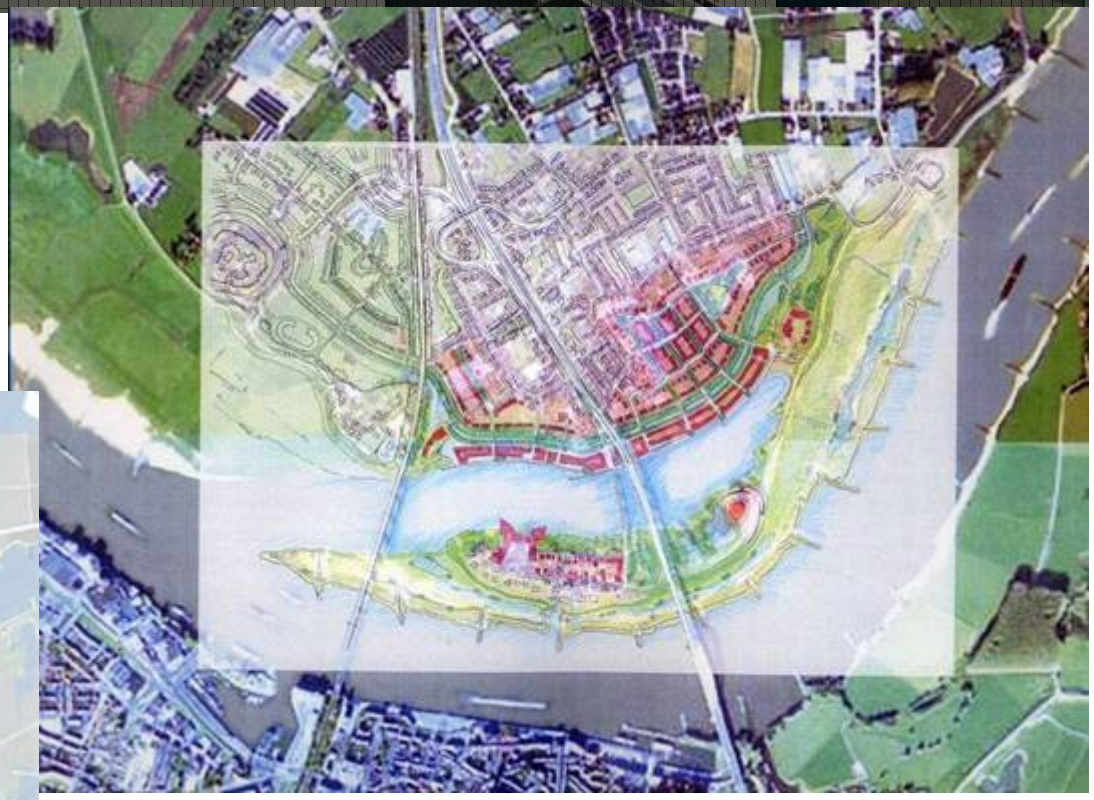
Dike relocation

Deltares

Room for the River programme

Floodway at Nijmegen





€ 300 million

Deltares

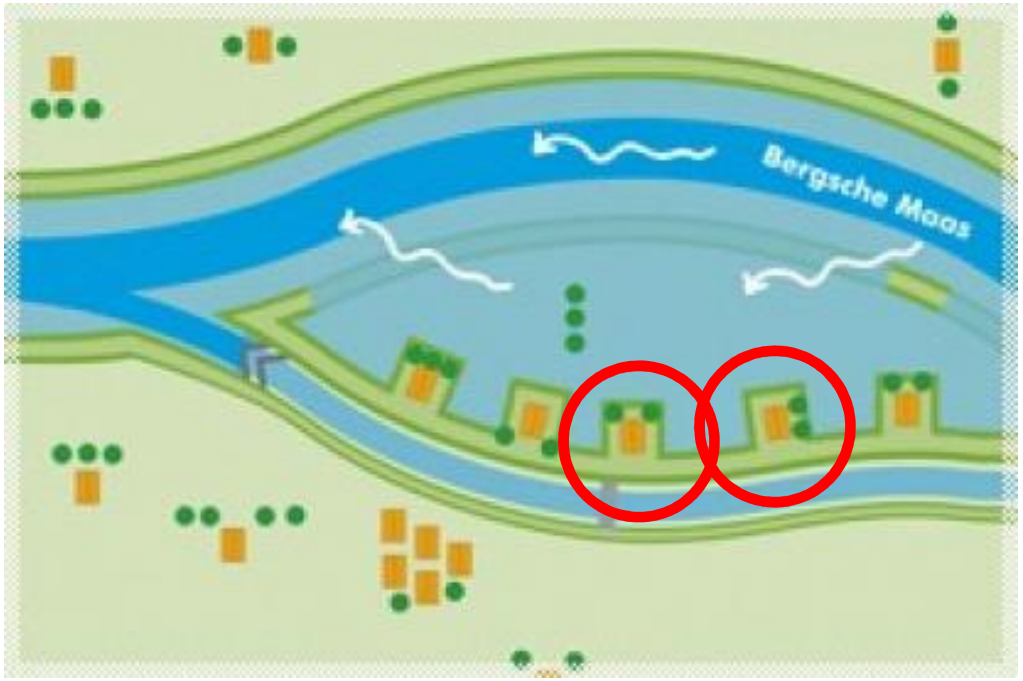
Room for the River programme

Floodway at Nijmegen

second road bridge for city paid by central government

Room for the River programme

De-poldering at Overdiep



cattle farms on mounds with financial aid from government

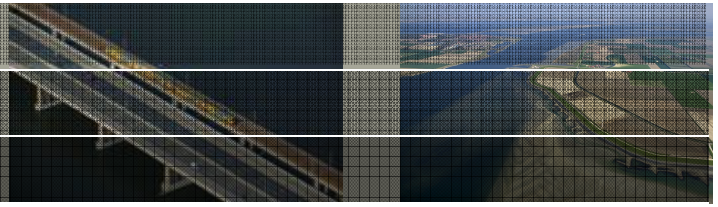
Deltares

Room for the River programme

De-poldering at Overdiep

Deltares

Engineered river systems



- Short-term improvements vs long-term sustainability:
  - > morphological impact assessment in feasibility and design phases
- Decisions to be taken when negative effects develop:
  - > invest in mitigating measures to maintain the system?
  - > create a new system?
  - > restore (parts of) the original system?
- Smart engineering to meet multiple objectives

Deltares


Hvala!
Хвала!