



Aanvaring stuw bij Grave



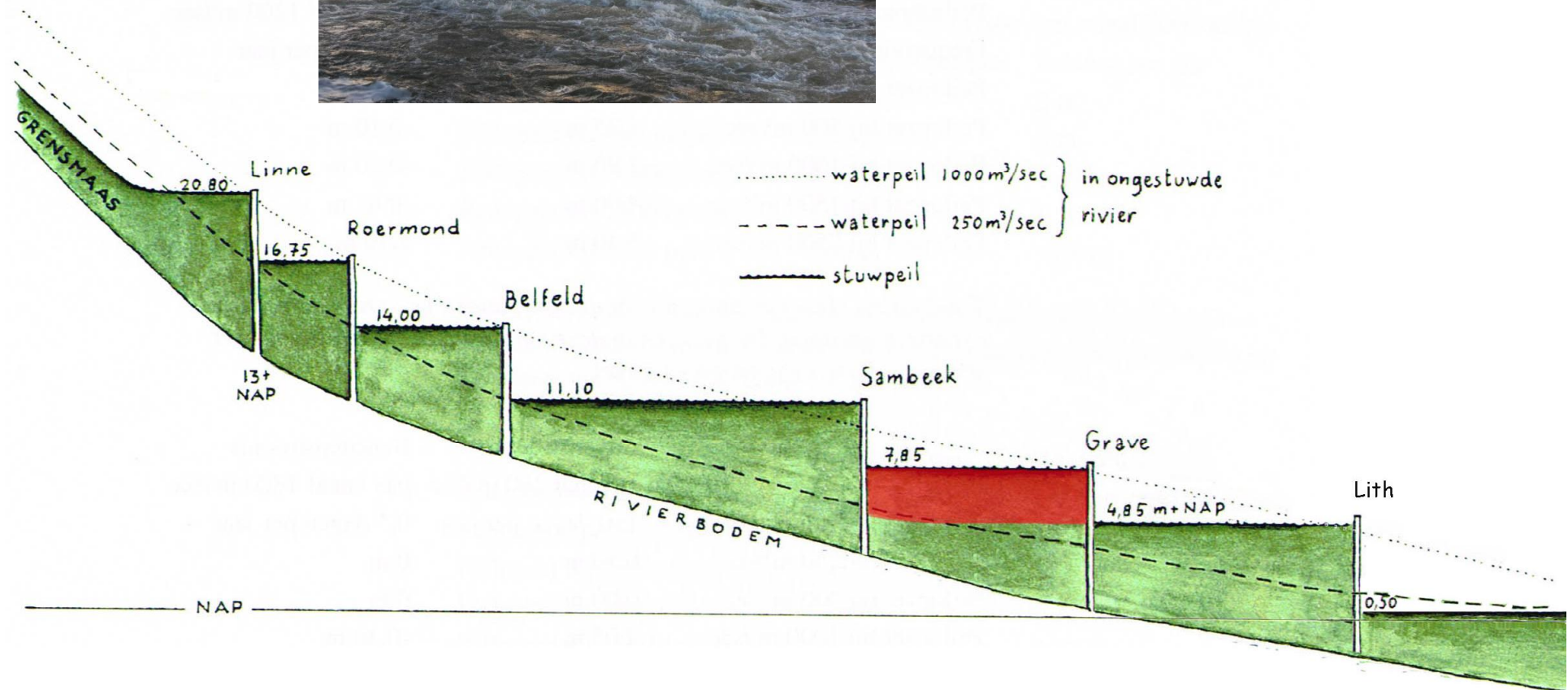
Ir. Robert de Roos Ir. Wim Kortlever

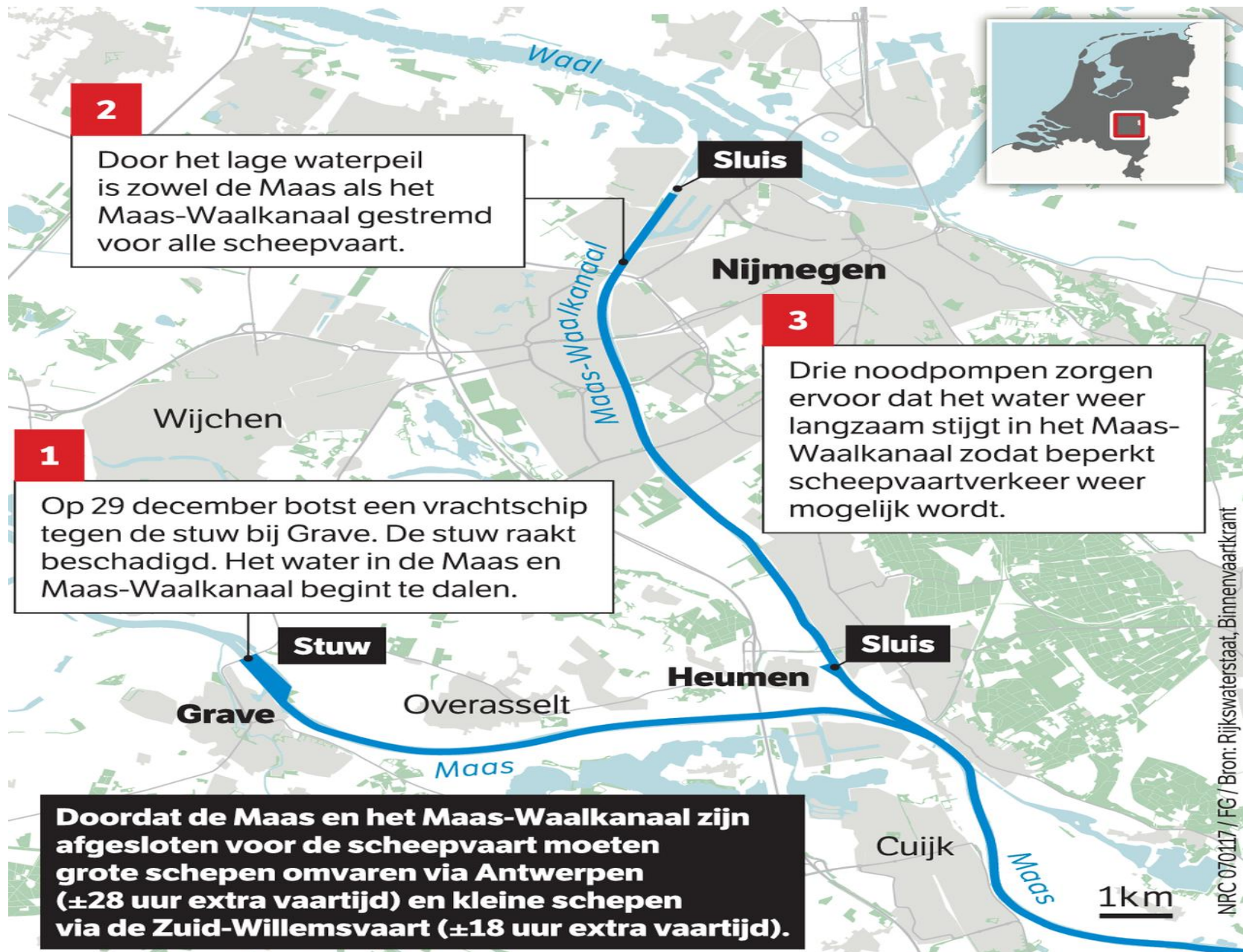
Presentatie



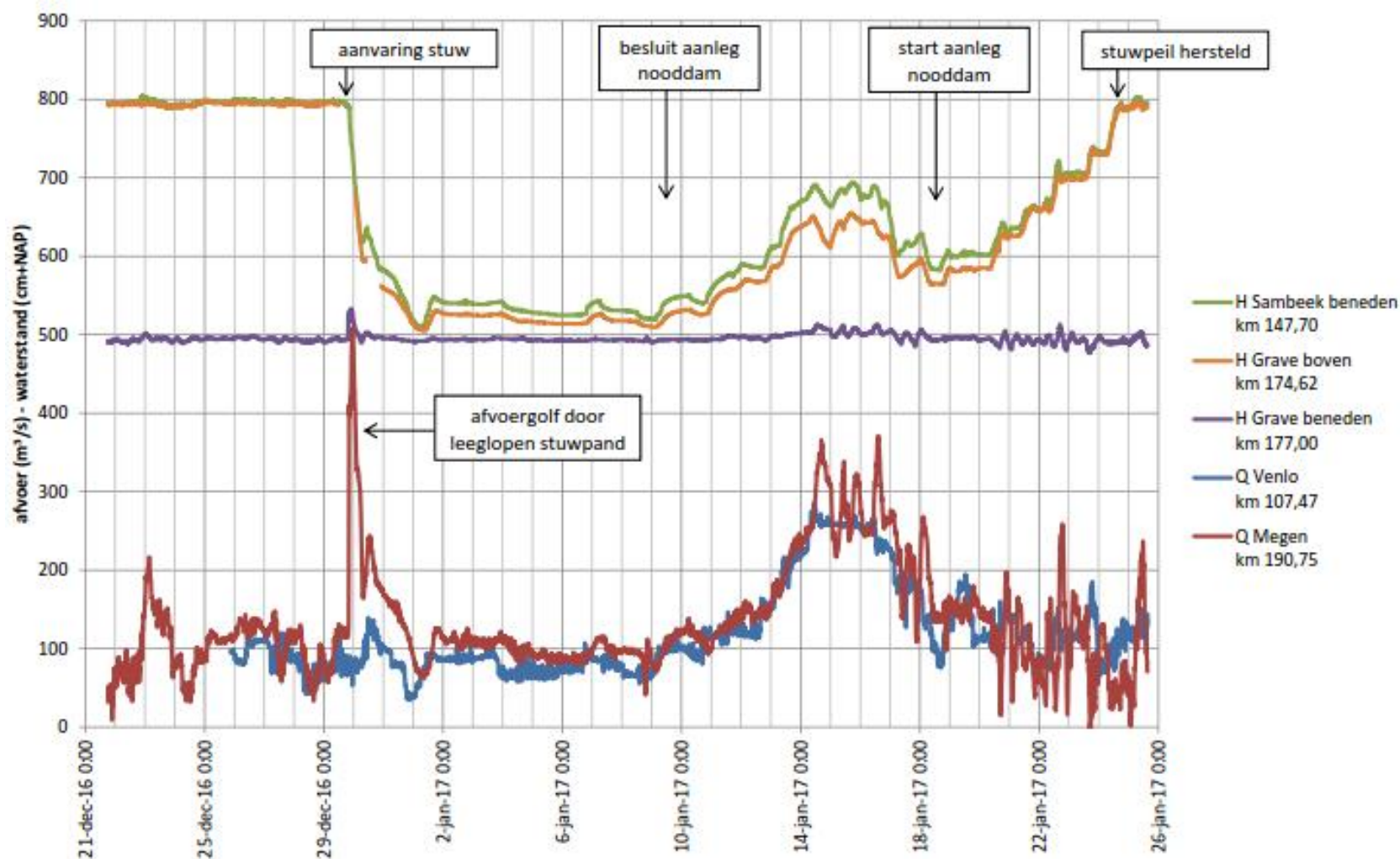
- De eerste week: Robert de Roos
RWS, de aannemer: ViVo, Volker Infra & Van Oord, Mobiele Dijk: Liebregts, Deltares, TUD en vele anderen
- De diepte in: Wim Kortlever
Stroomsnelheden en bodembescherming

Overzicht stuwen in de Maas





Waterstanden en afvoer stuwpand Grave



Eerste gevolgen

- Scheepvaart Pand Grave gestremd
- Maas-Waalkanaal onbevaarbaar



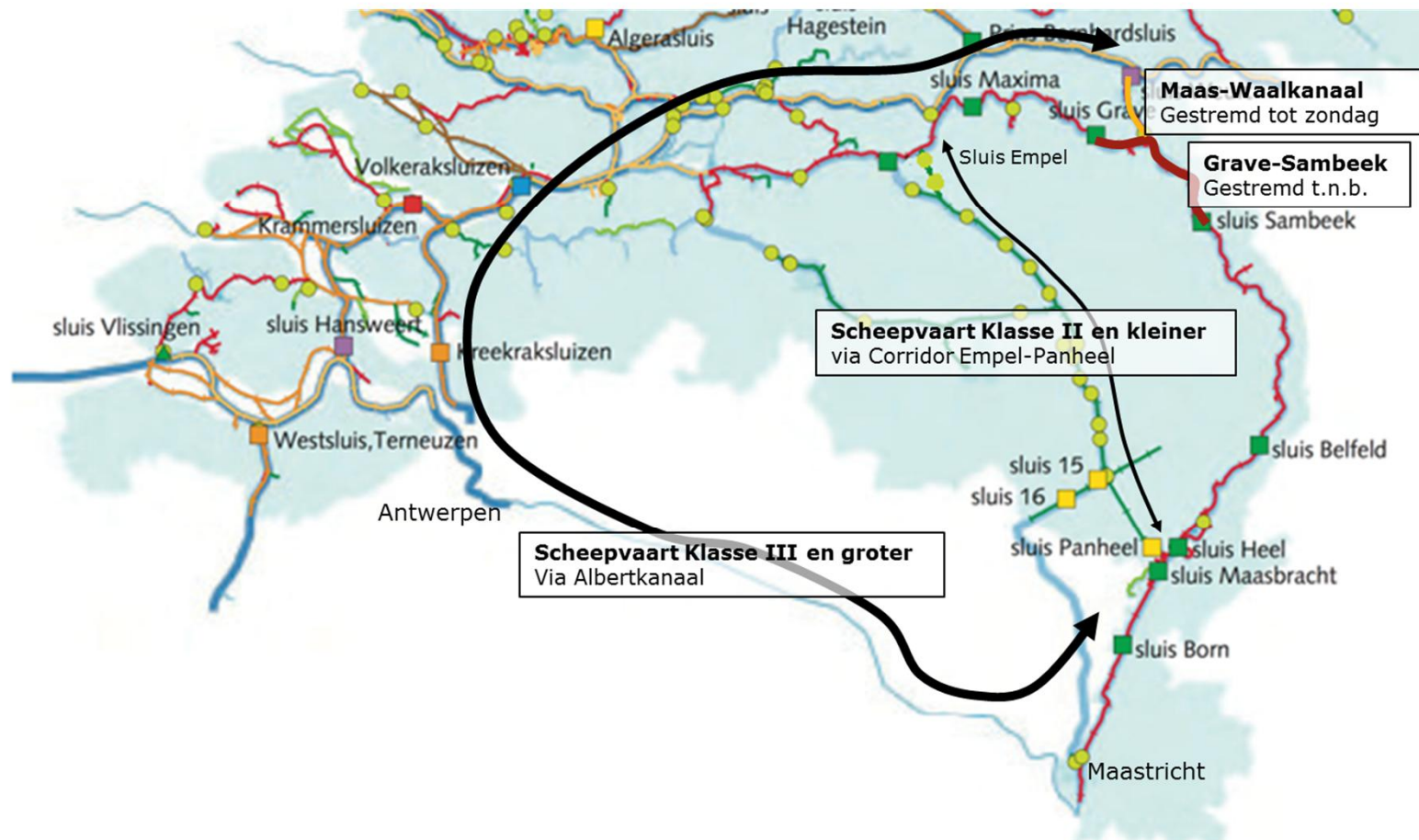
Sluiten Sluizen bij Heumen, sluisdeur overbelast?

- Stabiliteit sluiscomplex Sambeek en waterkeringen
- CTW ingeschakeld voor vermeend 'sinkhole' bij Sambeek
- Droogvallende woonboten
- Schepen vast in havens, veerboten gestremd



Hinder voor scheepvaart

Omleidingsroutes calamiteit stuw Grave



Herstelmaatregelen



Doel

- Snel herstel peil Pand Grave
- Woonboten drijvend
- Herstel schade stuw

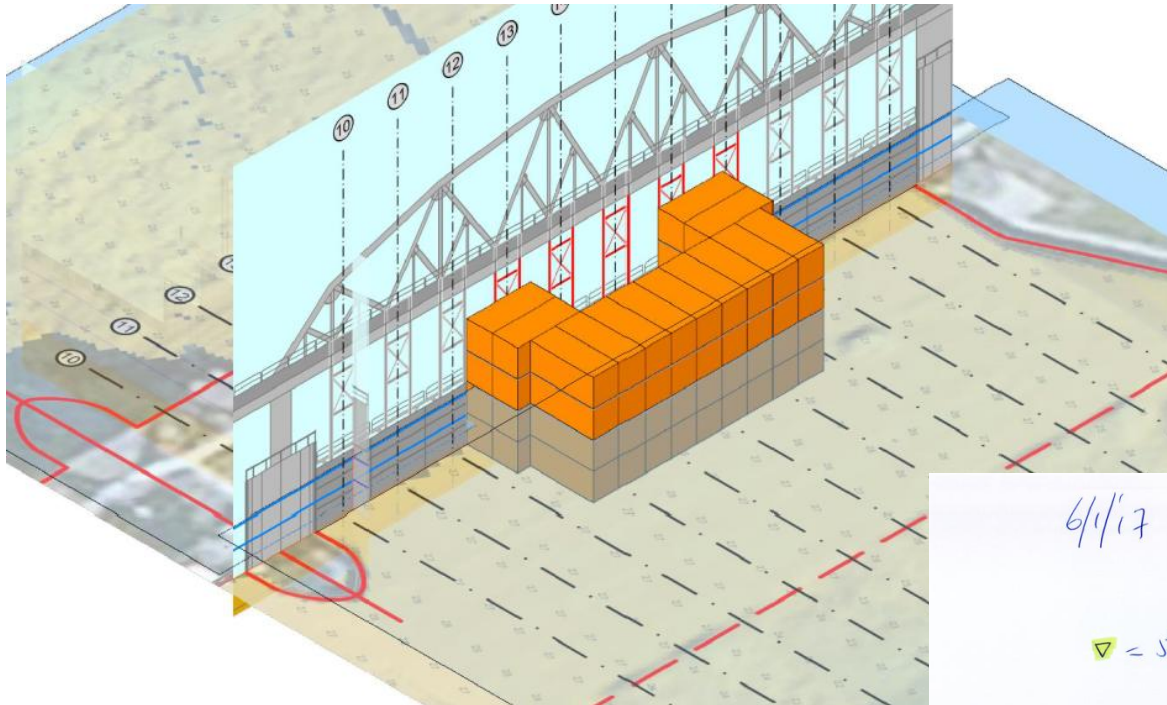
12 alternatieven voor stuw

Criteria

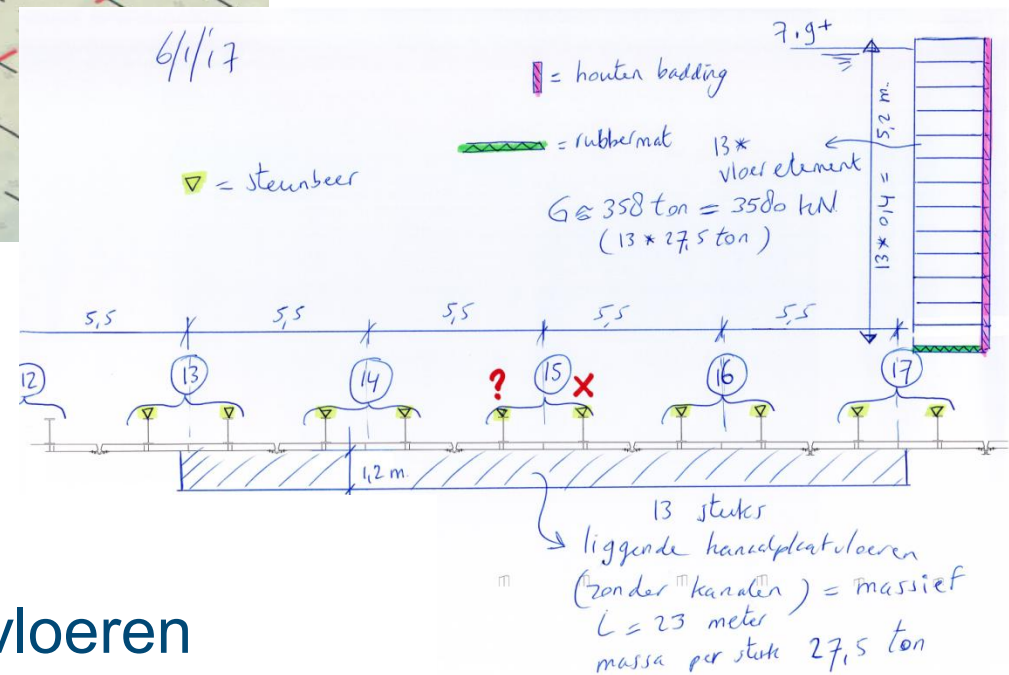
- Veiligheid
- Technische haalbaarheid
- Ruimte voor reparatie
- Doorlooptijd
- Binnen 48 uur te verwijderen i.v.m. hoogwater (opstuwing)



Alternatieven tijdelijke constructie

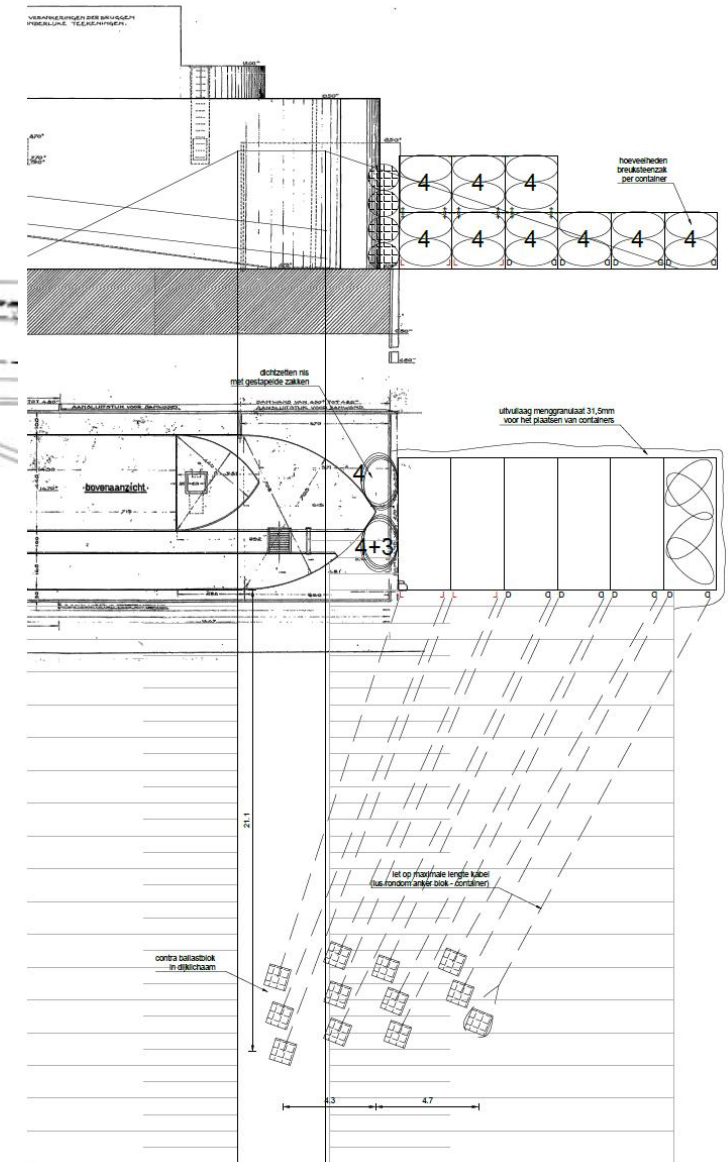


Alternatief scheepscontainers



Alternatief kanaalplaatvloeren

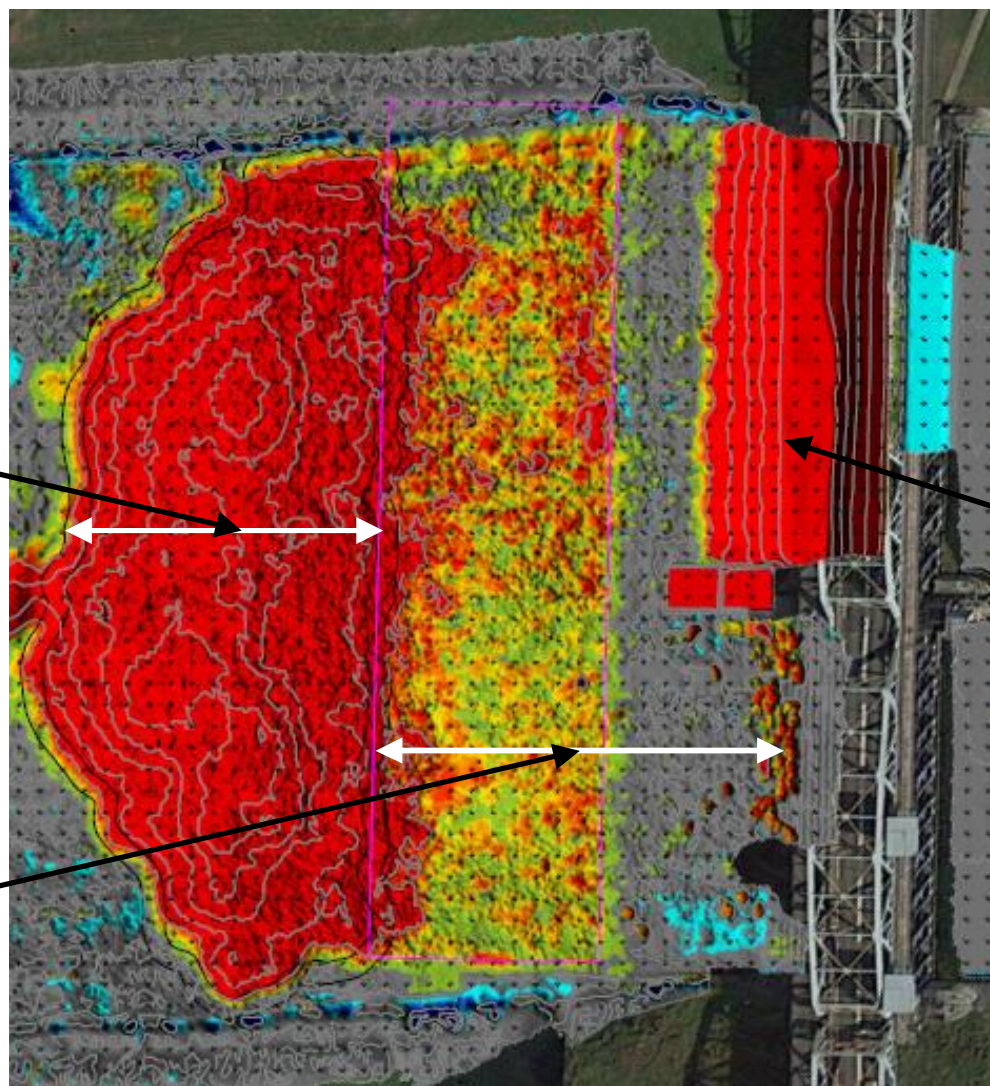




Zand en bescherming in ontgronding

40 m
0,70 m 40-200 kg
0,40 m 45/180 mm

50 m
0,70 m 40-200 kg
Ingegoten met beton



Dam

Kruin
300-1000 kg

Talud
40-200 kg



Opstuwing door gesloten dam

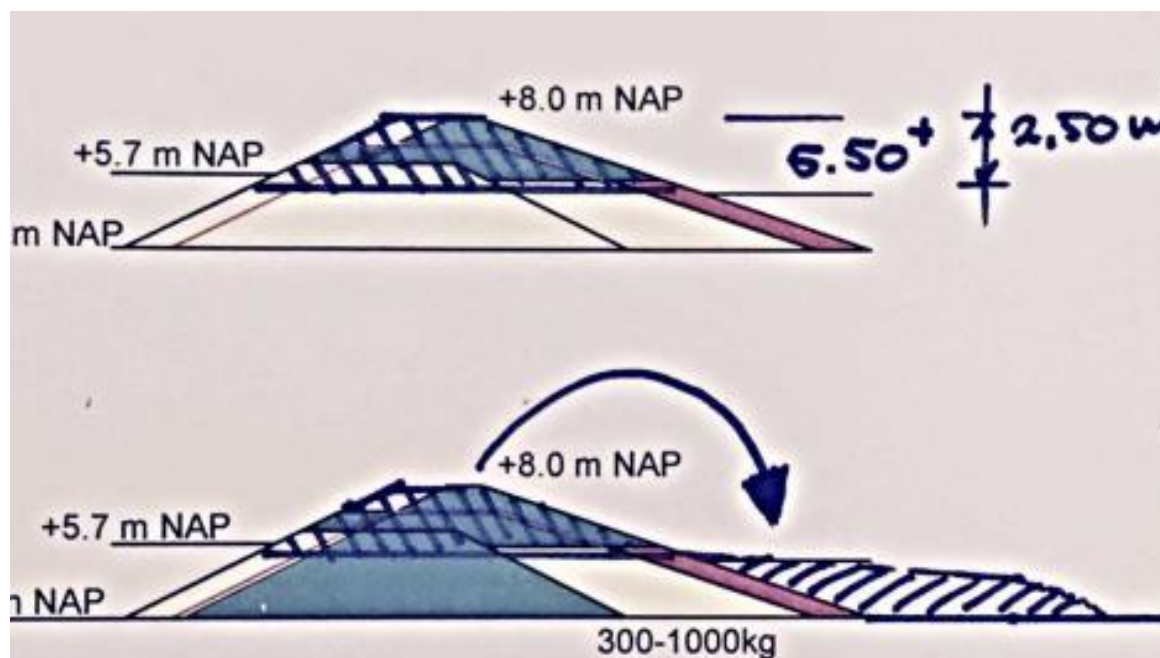


Hoogwaterafvoeren

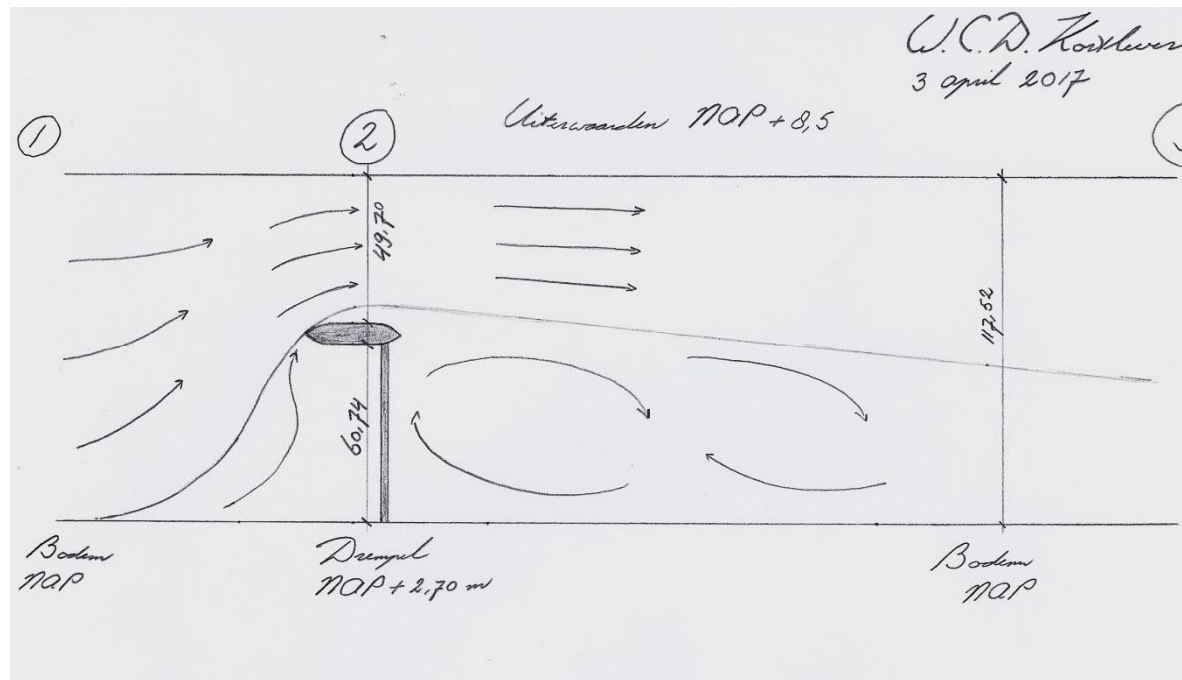
$1500 \text{ m}^3/\text{s} \Rightarrow + 43 \text{ cm}$

$3400 \text{ m}^3/\text{s} \Rightarrow + 9 \text{ cm (MHW)}$

Wanneer 2000 à 3000 m^3/s wordt verwacht $\Rightarrow$ kruinverlaging



Stroomsnelheden



$$u_{\max} = 6,84 \text{ m/s}, h = 2,94 \text{ m}$$

$$Fr = 1,27 \text{ Superkritisch!}$$

$Q = 850 \text{ m}^3/\text{s}$
 $b_2 = 117,52 \text{ m}$
 $h_2 = 6,3 - 2,7 = 3,6 \text{ m}$
 $h_{\text{ref}} = 6,3 \text{ m}$

① $u_2 = \frac{Q}{b_2 \cdot h_2} = \frac{850}{117,52 \cdot 6,3} = 1,15 \text{ m/s}$

U.C.D. Kortbeers
3 april 2017

$R_1 - R_2 -$

1. Bernoulli $h_1 + \frac{u_1^2}{2g} = h_2 + \frac{u_2^2}{2g}$

2. Continuity $Q = \mu b_2 \cdot h_2 \cdot u_2 = b_2 \cdot h_{\text{ref}} \cdot u_1$

$R_2 - R_3 -$

3. Continuity $h_2 + \frac{u_2^2}{2g} = h_3 + \frac{u_3^2}{2g} + \frac{(u_2 - u_3)^2}{2g}$

4. Continuity $Q = \mu b_2 \cdot h_2 \cdot u_2 = b_3 \cdot h_{\text{ref}} \cdot u_3$

Set $\mu = 0,85 \Rightarrow \mu b_2 = 0,85 \cdot 49,70 = 42,25 \text{ m}$

4. $h_2 \cdot u_2 = \frac{850}{42,25} \Leftrightarrow h_2 = \frac{20,12}{u_2}$

3. $\frac{20,12}{u_2} + \frac{u_2^2}{2g} = 3,6 + \frac{1,15^2}{2g} + \frac{(u_2 - 1,15)^2}{2g}$

3. $\frac{20,12}{u_2} + \frac{u_2^2}{2g} = 3,6 + \frac{1,15^2}{2g} + \frac{u_2^2}{2g} - \frac{2 \cdot u_2 \cdot 1,15}{2g} + \frac{1,15^2}{2g}$

3. $\frac{20,12}{u_2} = 3,60 + \frac{1,15^2}{g} - \frac{2,30 \cdot u_2}{g}$

3. $0,117 u_2^2 - 3,73 u_2 + 20,12 = 0$

3. $u_{2,1,2} = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a} = \frac{3,73 \pm \sqrt{3,73^2 - 4 \cdot 0,117 \cdot 20,12}}{2 \cdot 0,117}$

$\frac{3,73 \pm 2,13}{0,234} = \frac{5,86}{0,234} = 25,0$ and $\frac{1,60}{0,234} = 6,84 \text{ m/s}$

4. $h_{2,2} = \frac{20,12}{6,84} = 2,94 \text{ m}$

2. $h_{\text{ref}} \cdot \frac{Q}{b_2 \cdot u_1} = \frac{850}{117,52 \cdot u_1} = \frac{7,23}{u_1}$

1. $2,7 + \frac{7,23^2}{u_1^2} + \frac{u_1^2}{2g} = 2,94 + \frac{6,84^2}{2g}$

$2,94 + 2,70 = \text{NAP} + 5,64 \text{ m}$

$Fr = \frac{6,84}{\sqrt{9,81 \cdot 2,94}} = 1,27$

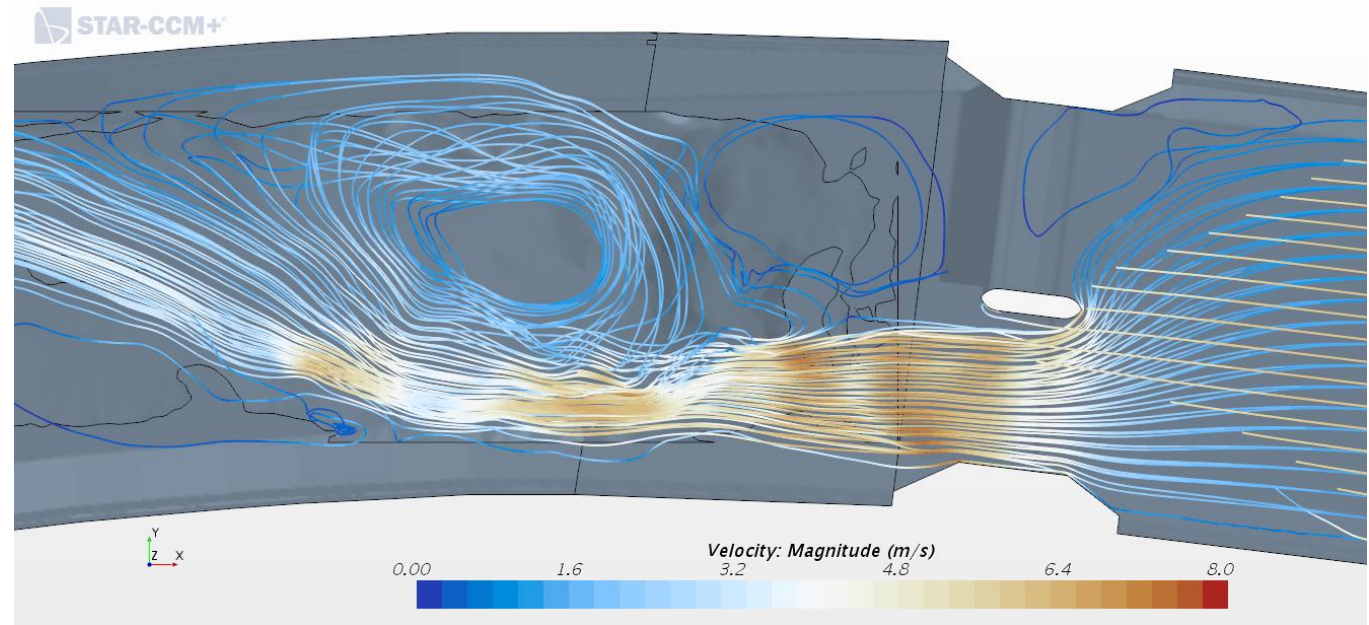
Stroomsnelheden met CFD

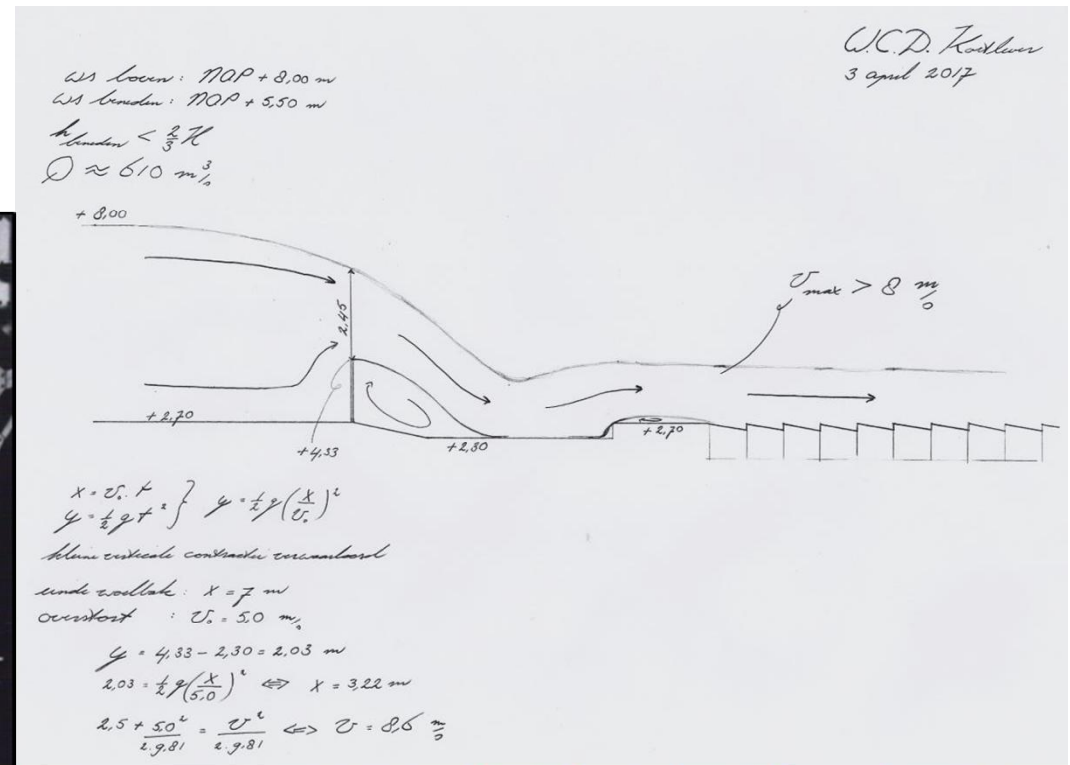
Gesloten dam

Gestreken stuw

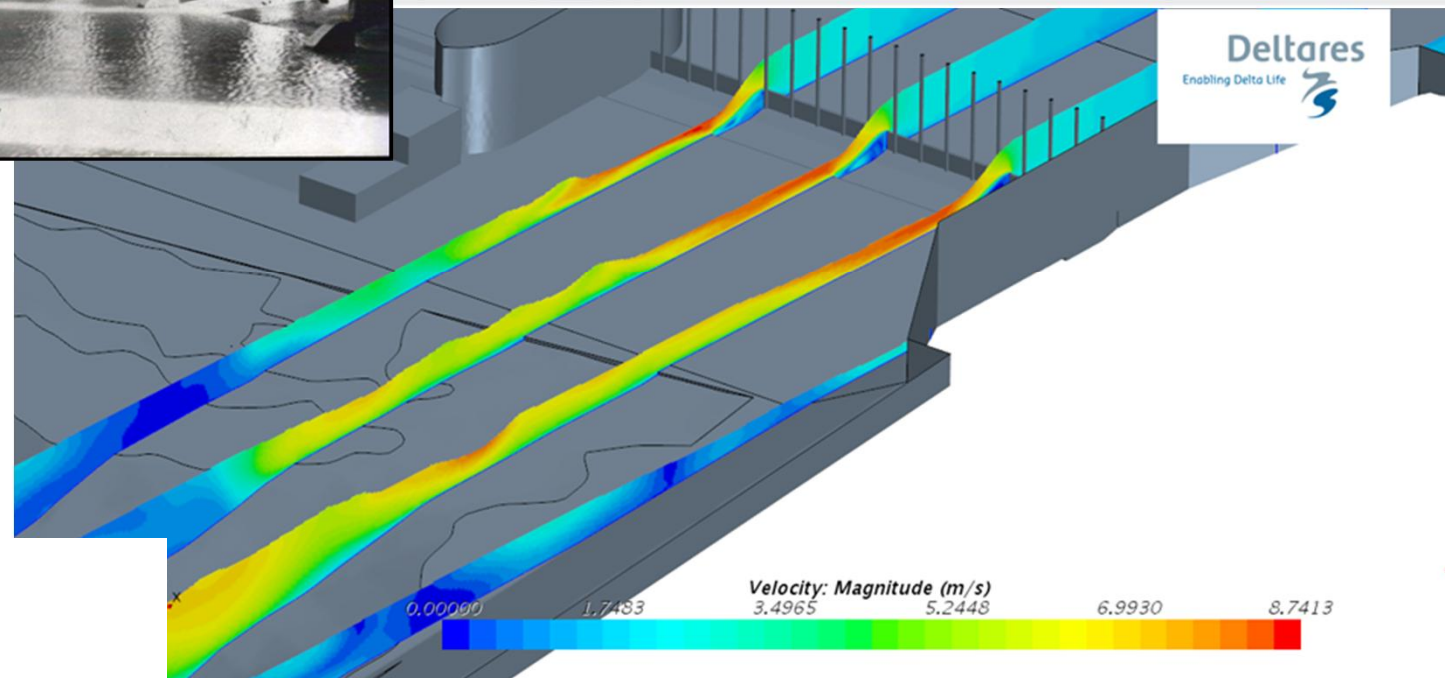
Schotten en jukken verwijderd

Afvoer
840 m³/s





Stuw in bedrijf
Jukken en
onderschotten

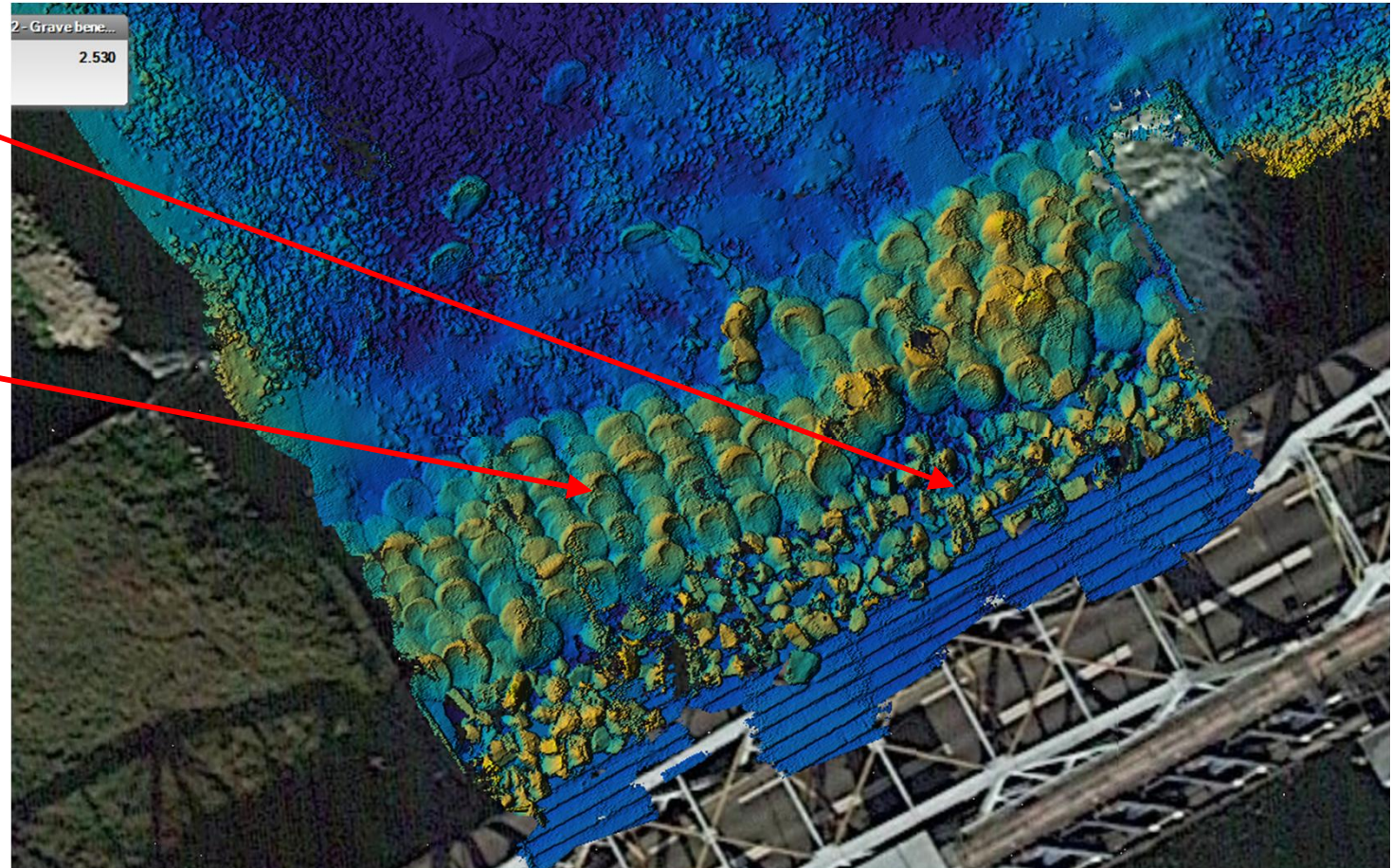


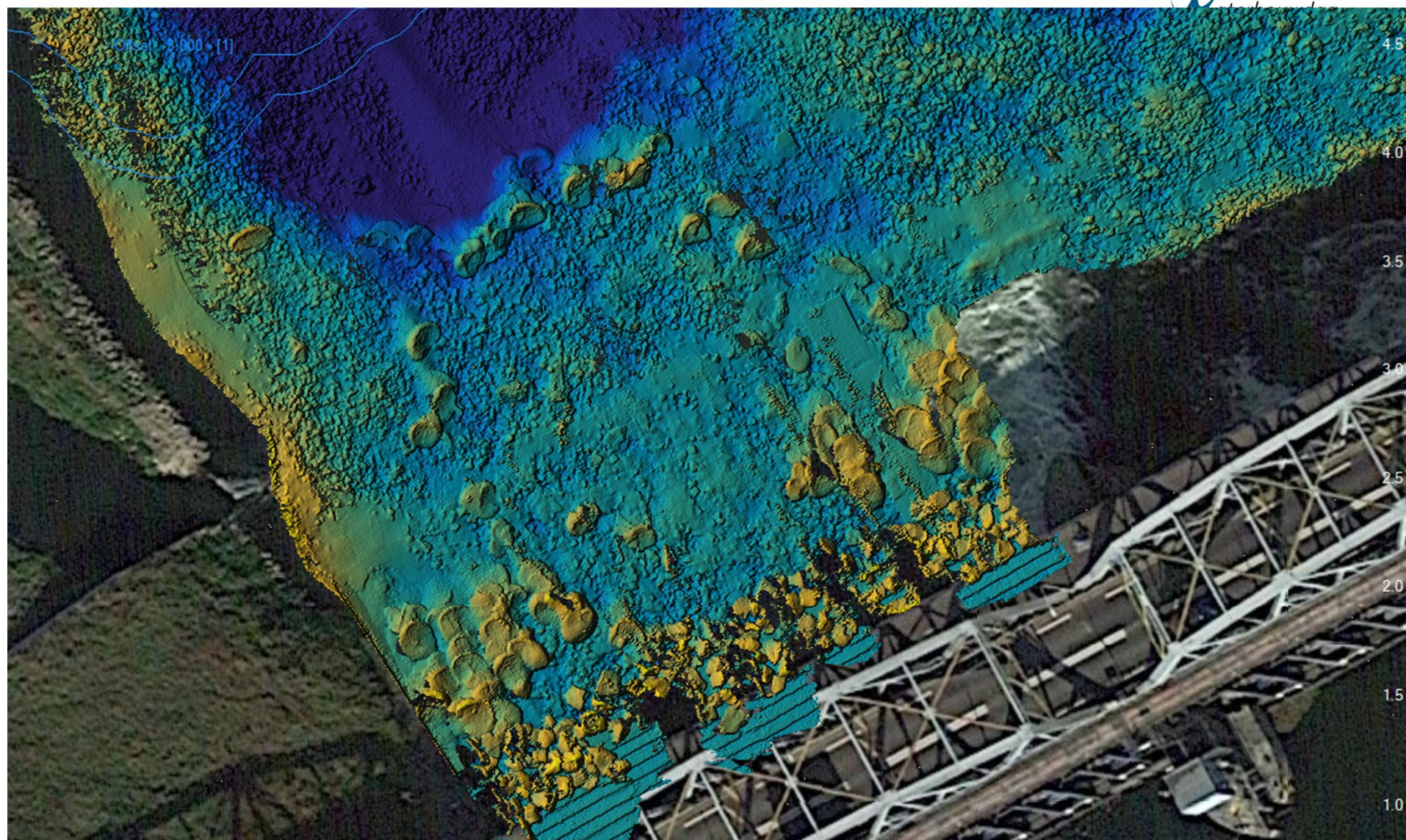
Extra maatregel

Stenen 3-6 ton in
rijen, 7 m

Netten gevuld met
steen, 4 ton, 15 m

Netten gekoppeld
⇒ 8 ton
Dakpansgewijs

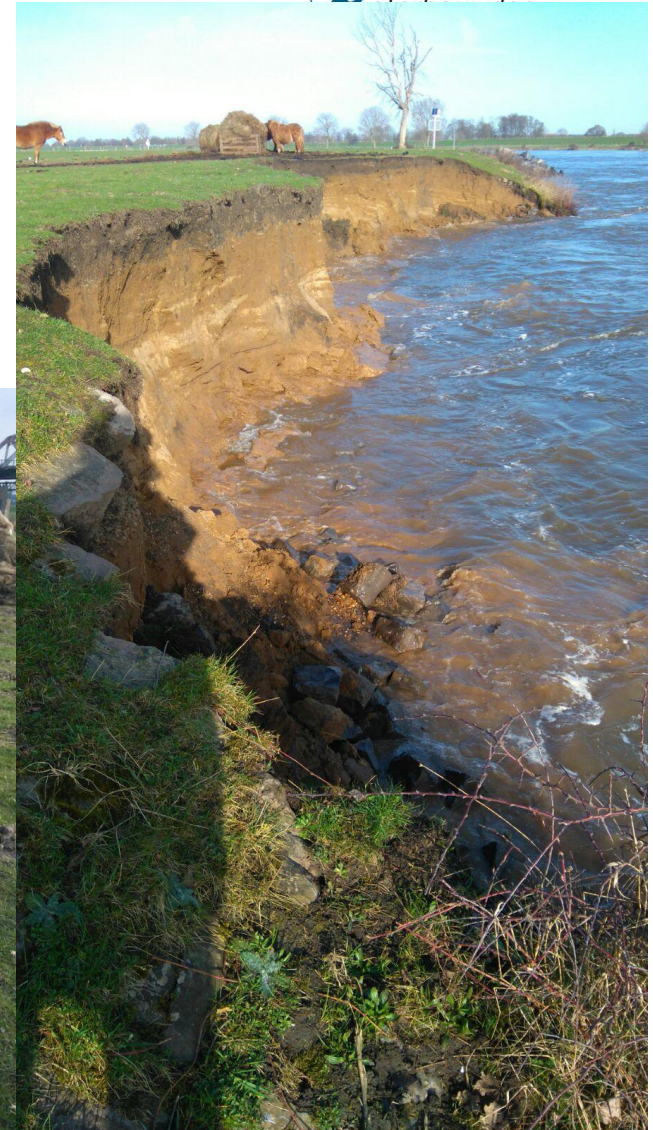


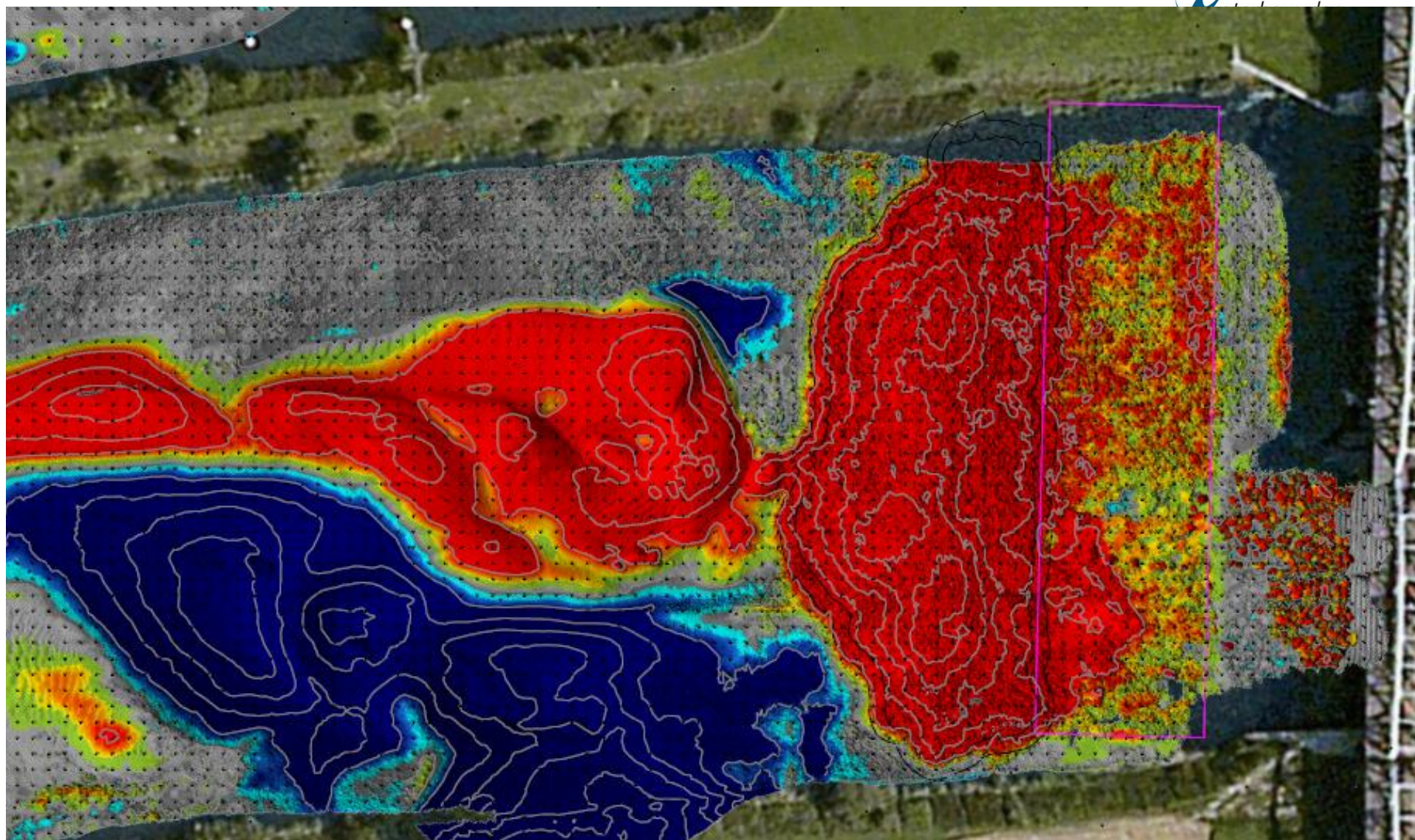


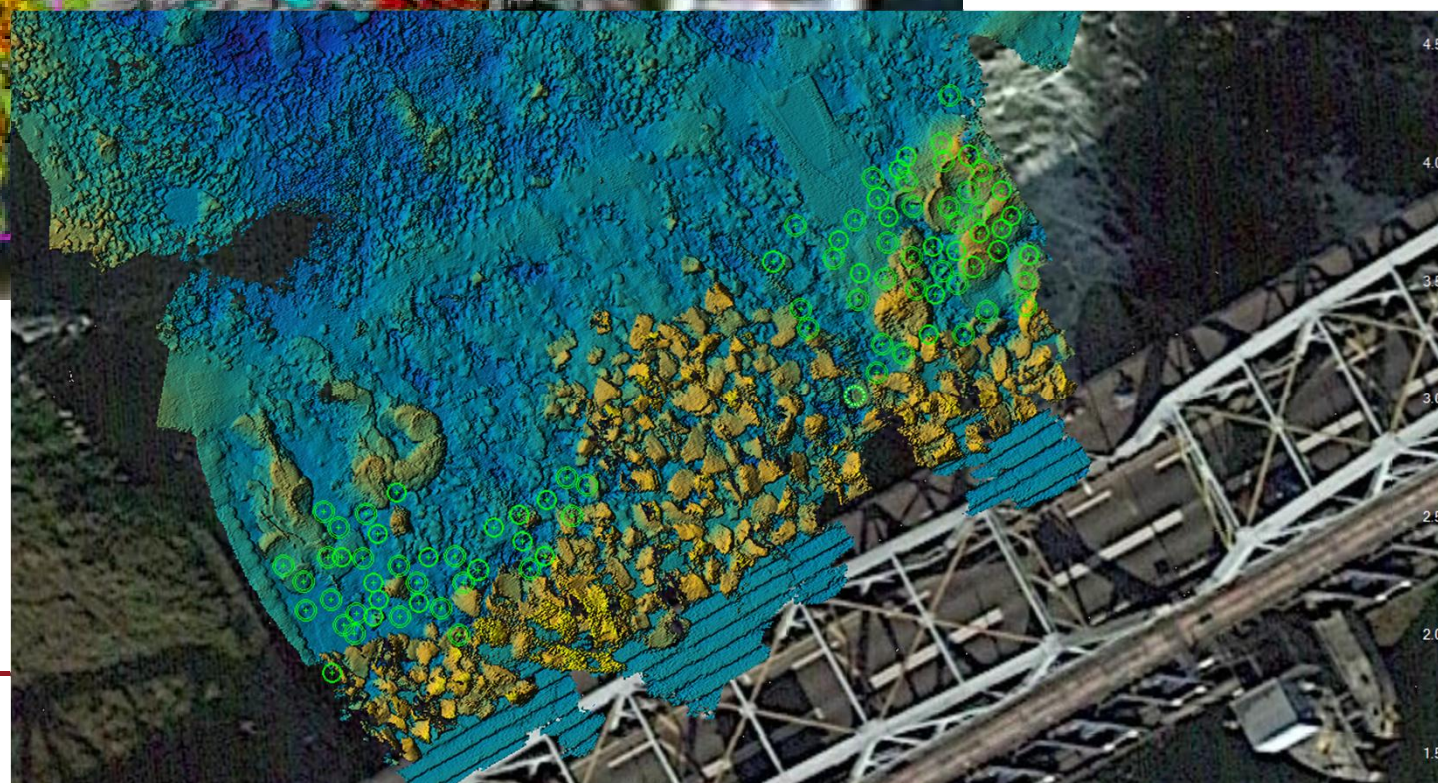
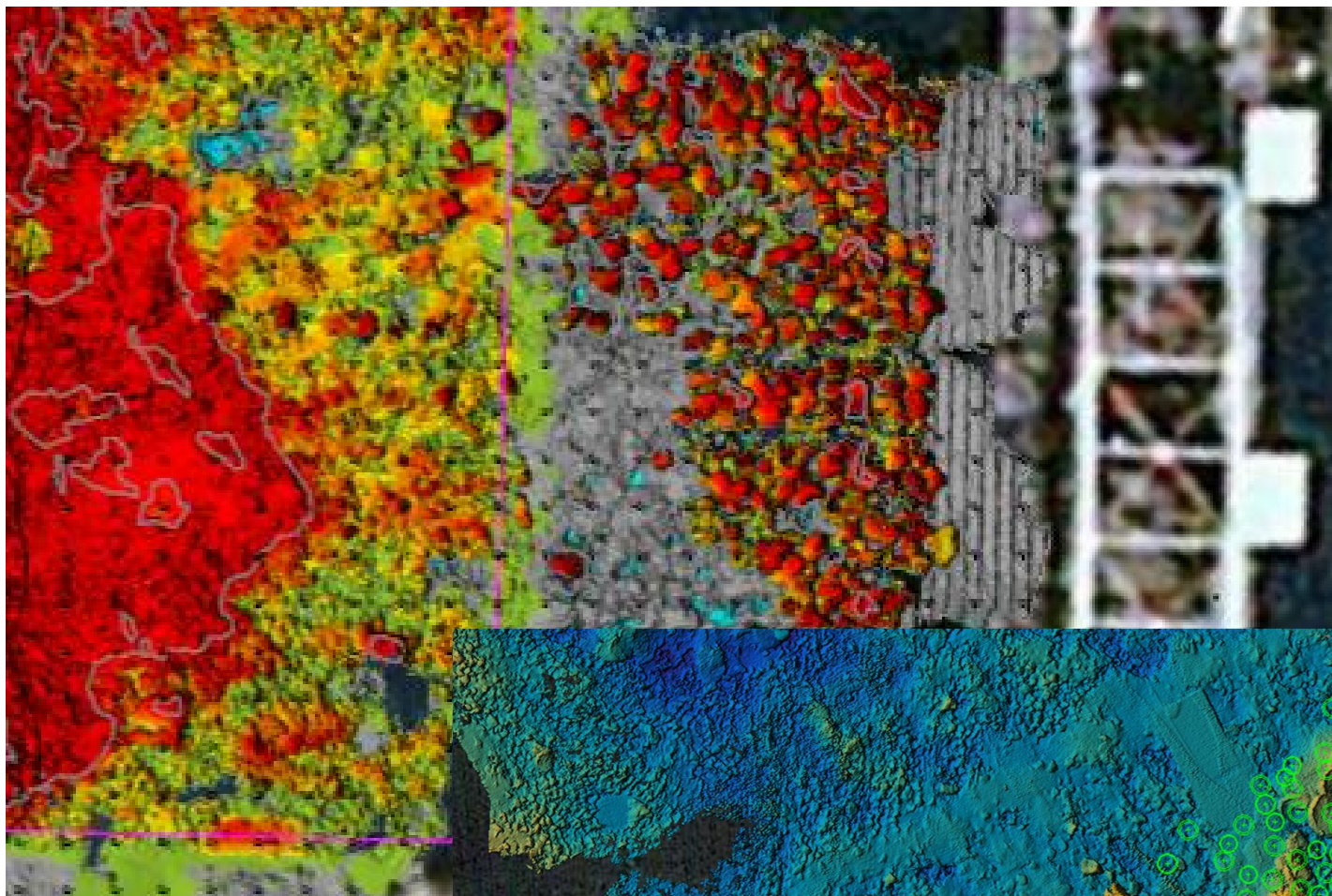
Hoogwatergolf in maart

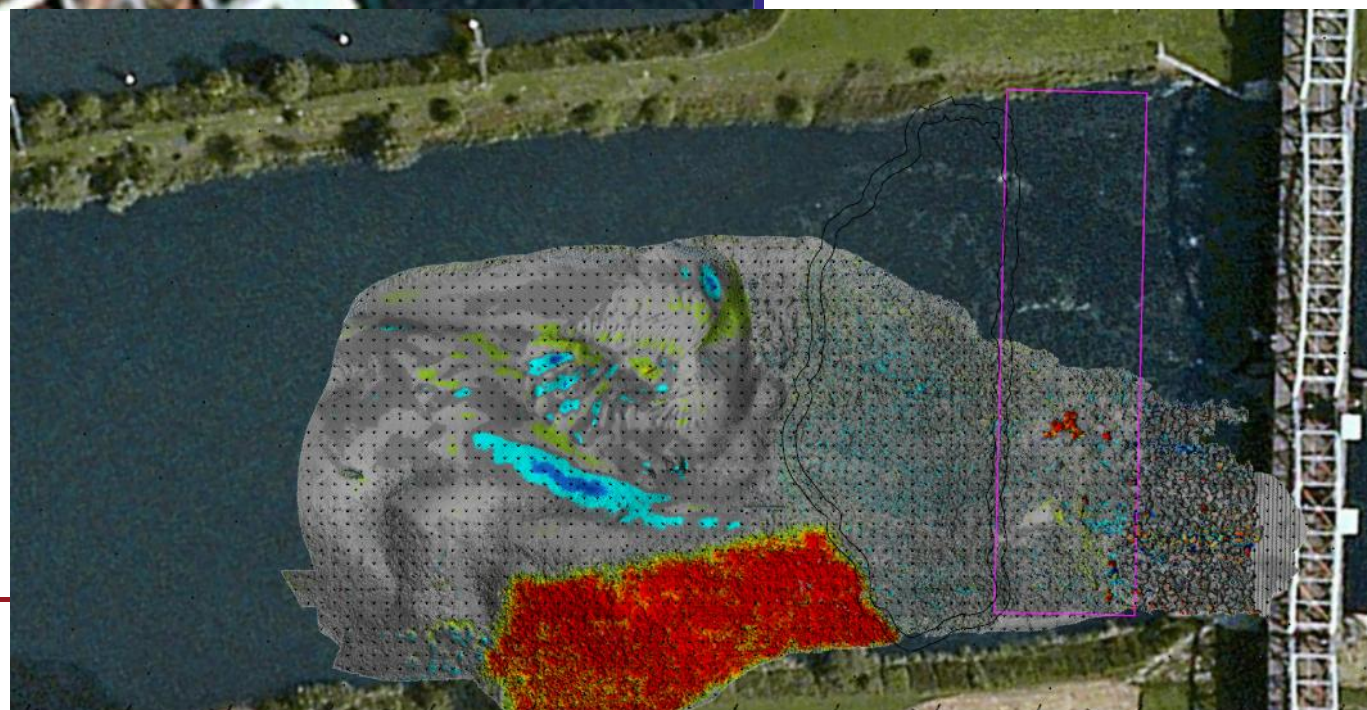
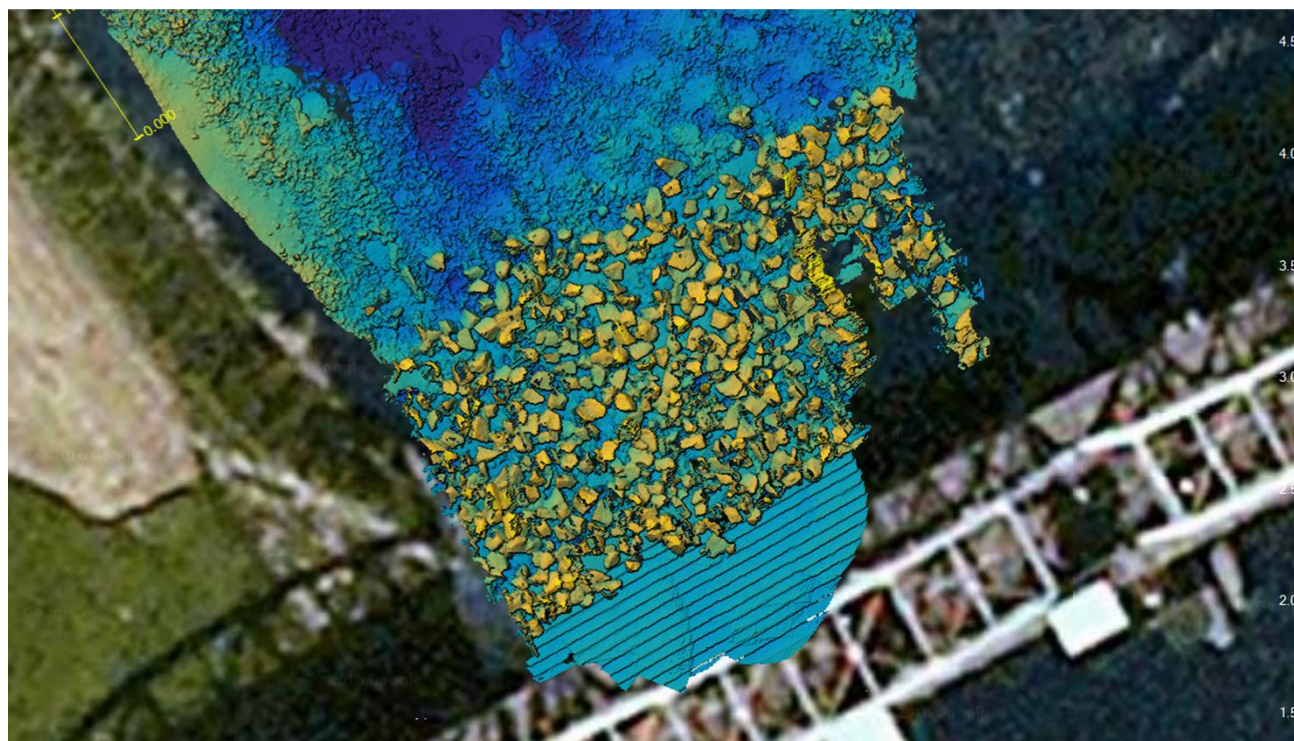


Taludafschuiving op eind van bescherming

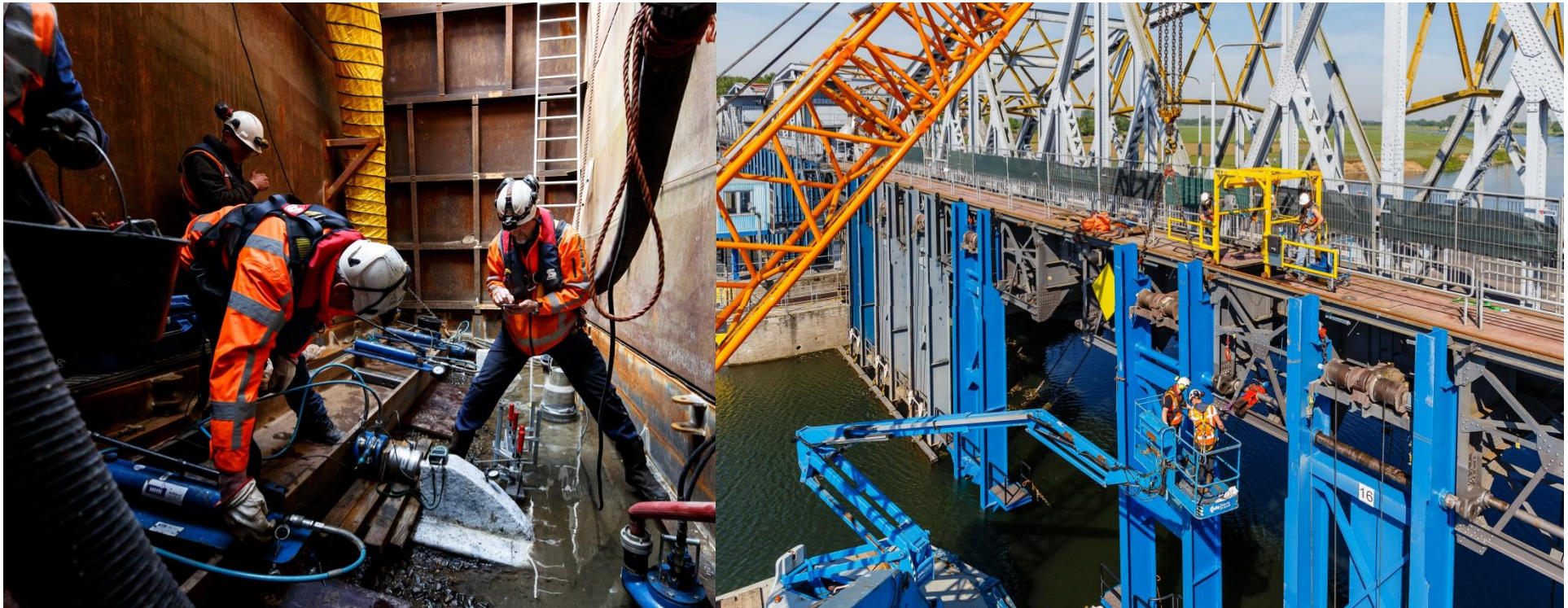








Steunberen en nieuwe jukken



Herstel stuw gereed medio juli 2017



Verwijderen dam en bodemverzwaring

Lessen geleerd!

Vervanging en renovatie natte kunstwerken

STOWBRUG GRA
OVERSPANNING 6

