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Commune
d'Yverdon-les-Bains

Direction Générale de l'Environnement (DGE)
Direction des ressources et du patrimoine naturels
DGE – EAU : Ressources en eau et économie hydraulique

HYDRAULIC SIMULATION OF THE THIELLE

EXTREME FLOOD EVENT AND CONSEQUENCES OF FAILURE DIKE

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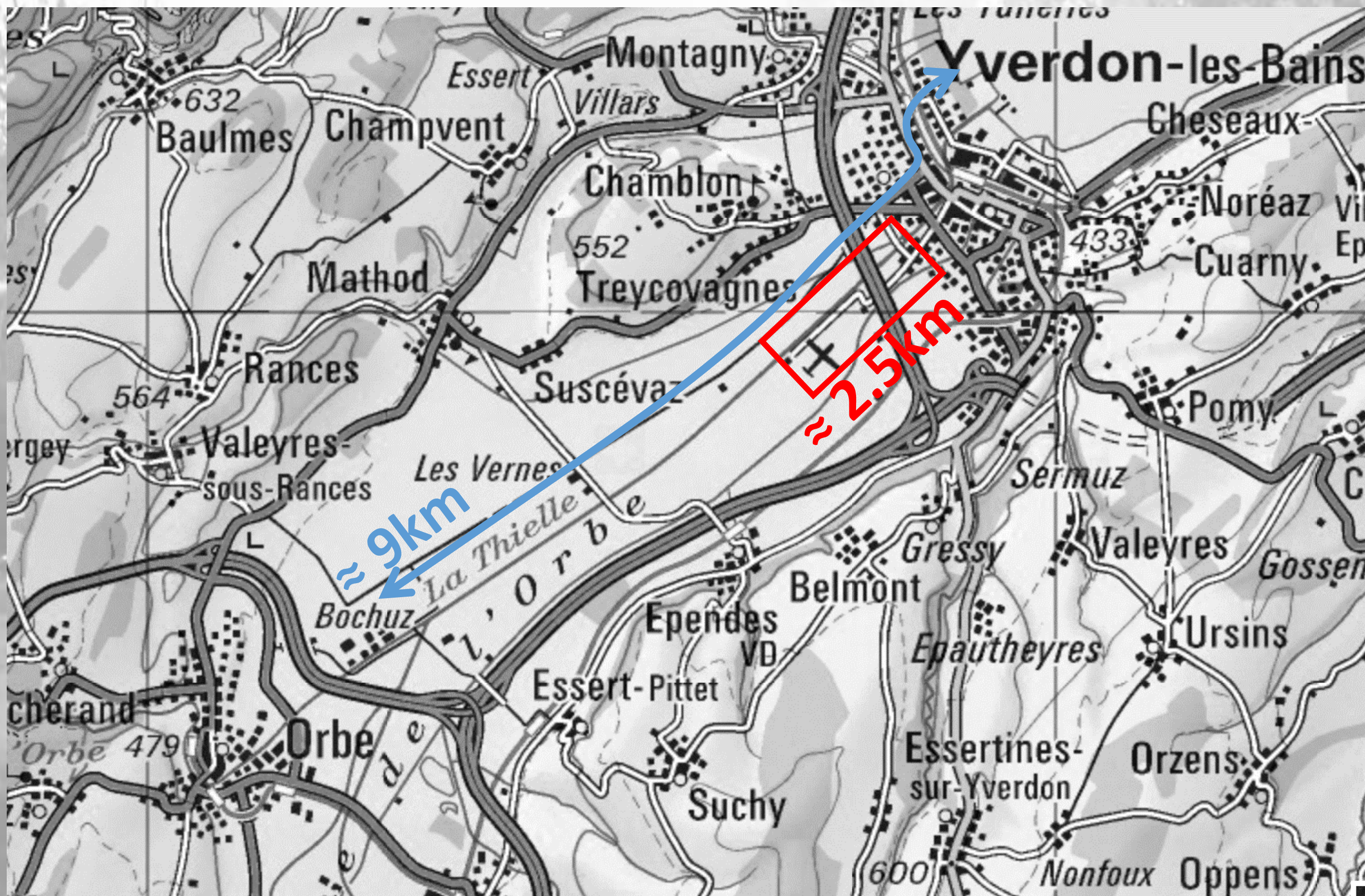
Location of the project



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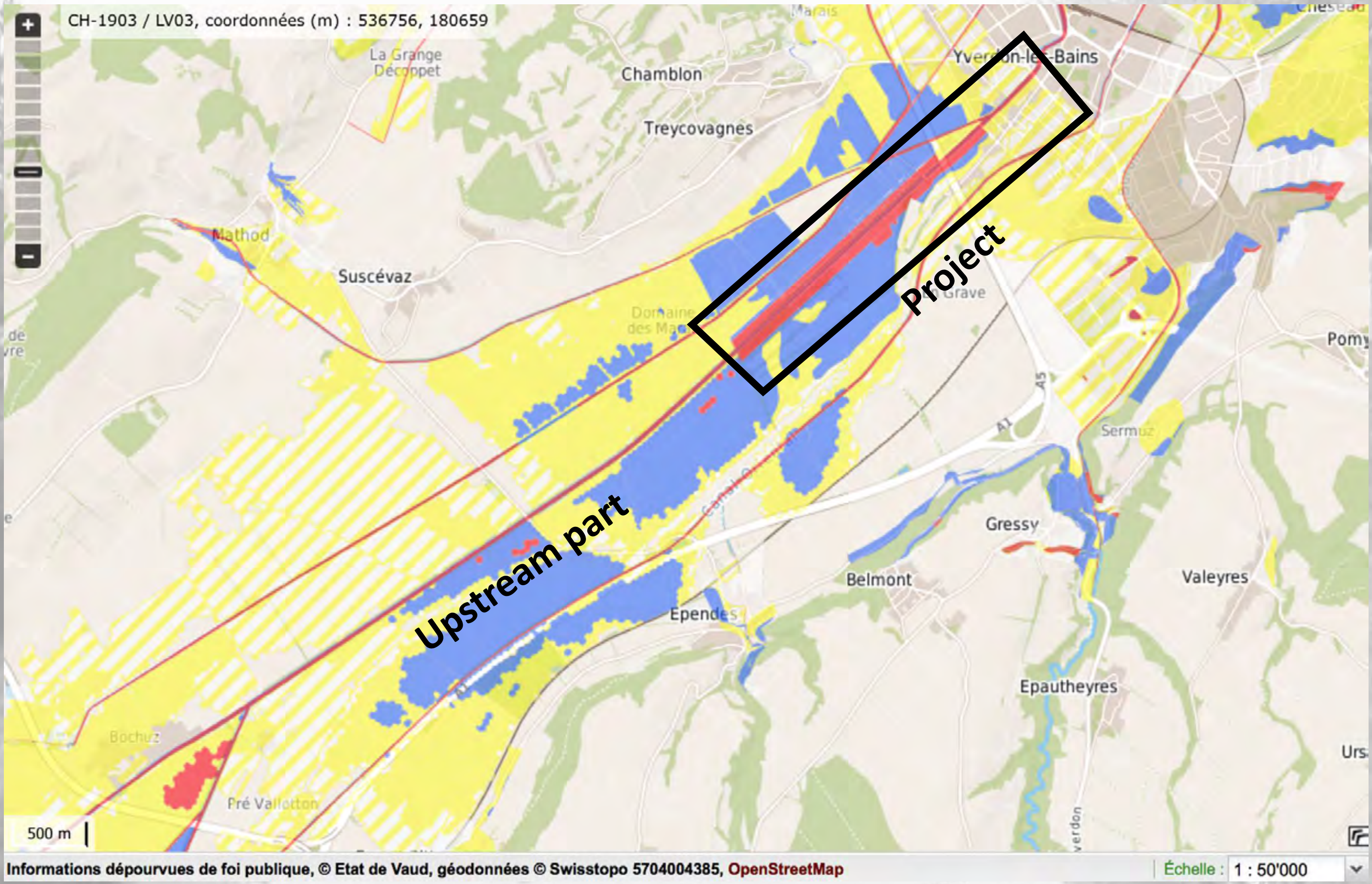
Current situation



The project

- Hazard formed by different processes:

  Flood events by overflow (insufficient capacity of the river, return period 30 years)

  Exfiltration trough the dike

  Upwelling of the water table

- This area: high biological interest
- The project:

  Revitalization of the river with ecological objectives

  Protection against flood events with a return period of 100 years

  Widening of the river along a section

  Construction of three weirs

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Aim of the modelisation

- Verify the geometry of the modelisation for Q100 (made initially on HecRas) with Basement
- Study the position, length and efficiency of the three weirs
- Analyze the upstream part for extreme events without and with a scenario of breaking dike

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Methodology

1. Data pre-processing
   - Hec Ras (export of the cross section of the project)
   - Excel (treatment of the cross section, definition of the top of the dike)
   - ArcInfo (creation od the DEM with interpolation of the cross section)
   - SMS Aquaveo (generation of the grid, material property, bouddary nodes)
2. Simulation
   - Basement
3. Data post-processing
   - Octave (export of the maximum depth and maximum intenstiy of all time steps)
   - SMS et Arcinfo (import maximum value, generation of the coutours, creation of the new intensity map)

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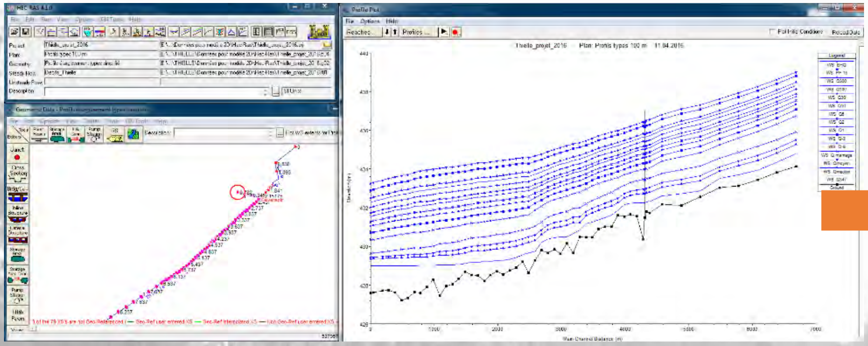
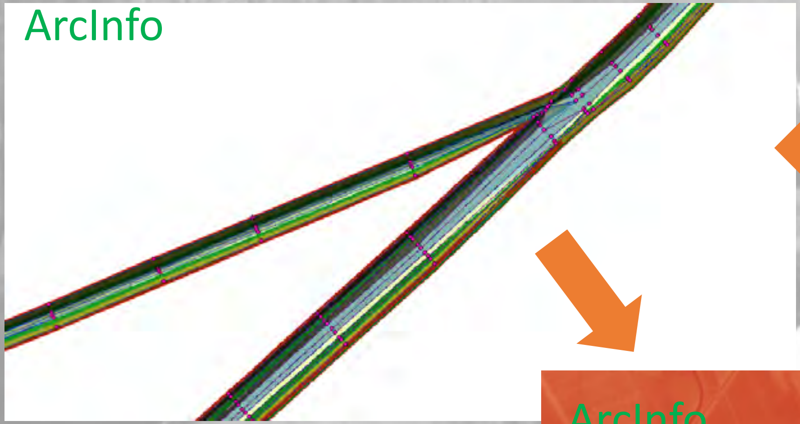
HecRas



Excel

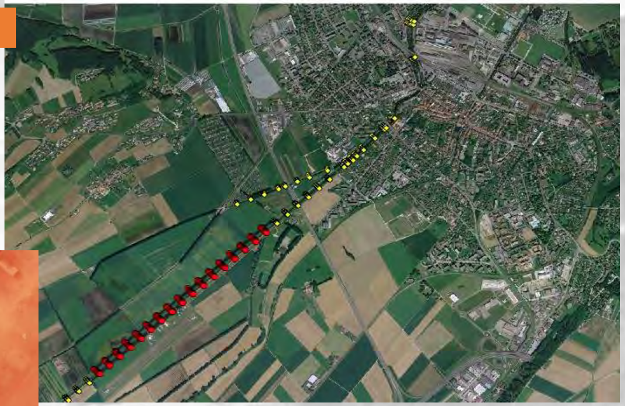
COOX	COOY	COOZ	ID_PROFIL	PROJET	ID PROFIL
533093.21	176660.83	438.96	10	0	1
533096.13	176656.45	436.73	20	0	1
533100.86	176649.38	436.07	30	0	1
533103.27	176645.77	434.48	40	0	1
533104.99	176643.19	434.34	50	0	1
533107.65	176639.22	434.13	60	0	1
533111.03	176634.16	436.84	70	0	1
533114.52	176628.93	437.1	80	0	1
533116.78	176625.54	438.85	90	0	1
533116.8	176625.52	438.85	100	0	1
33118.23	176623.38	438.84	110	0	1
533342.23	176828.13	438.42	10	0	2
533345.36	176823.45	436.18	20	0	2
533349.7	176816.95	435.59	30	0	2
533352.45	176812.84	434.06	40	0	2
533354.45	176809.84	433.94	50	0	2
533356.52	176806.74	433.81	60	0	2
533359.43	176802.39	436.01	70	0	2
533363.78	176795.88	436.54	80	0	2

ArcInfo

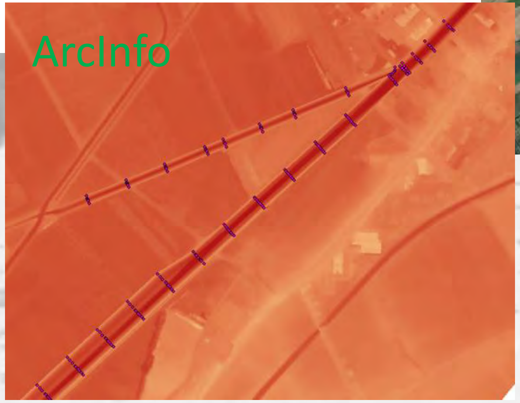


ArcInfo

Lake



ArcInfo



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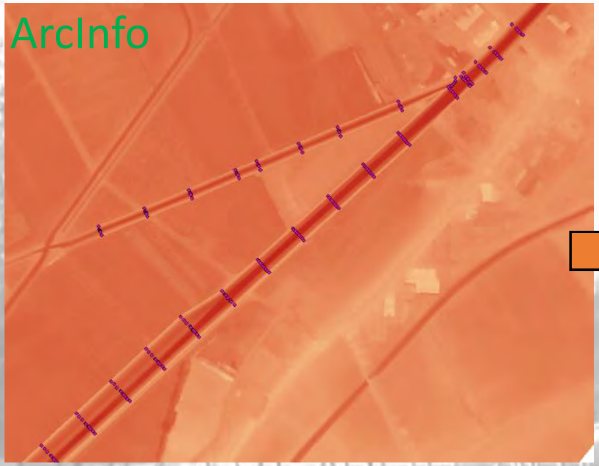
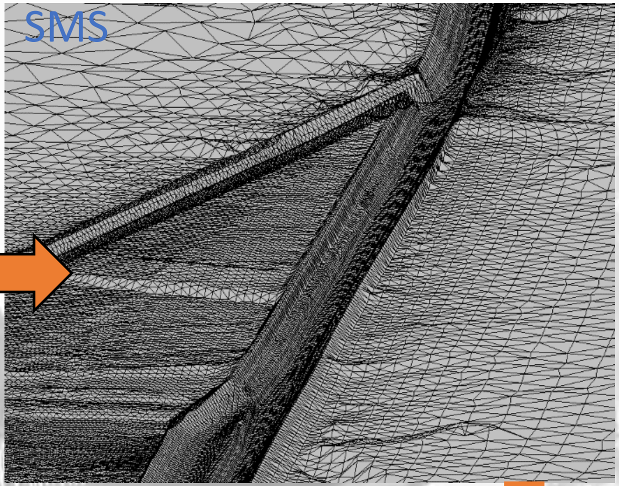
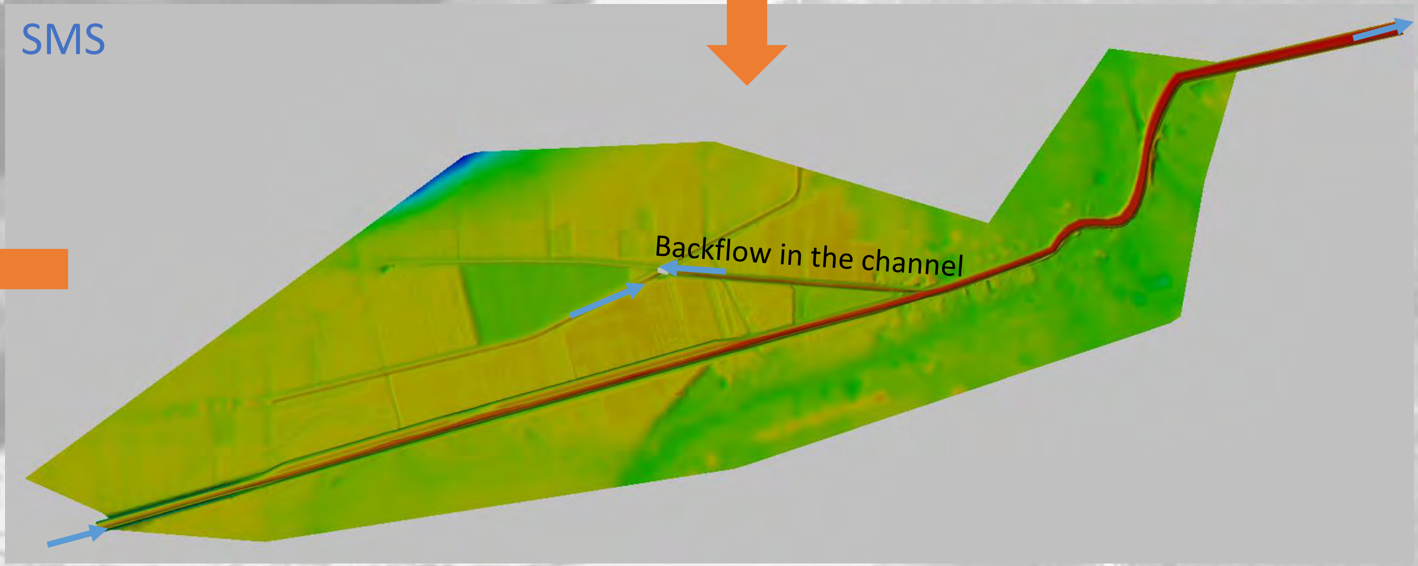
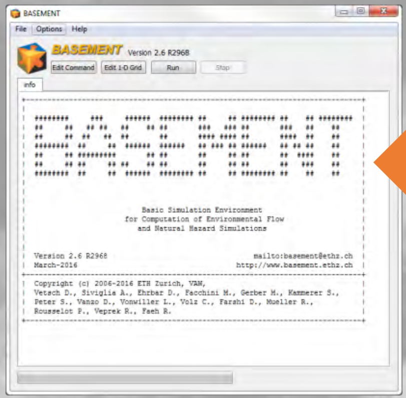




197’642 elements
3’839’489 m²
Mean Resolution: 19m²





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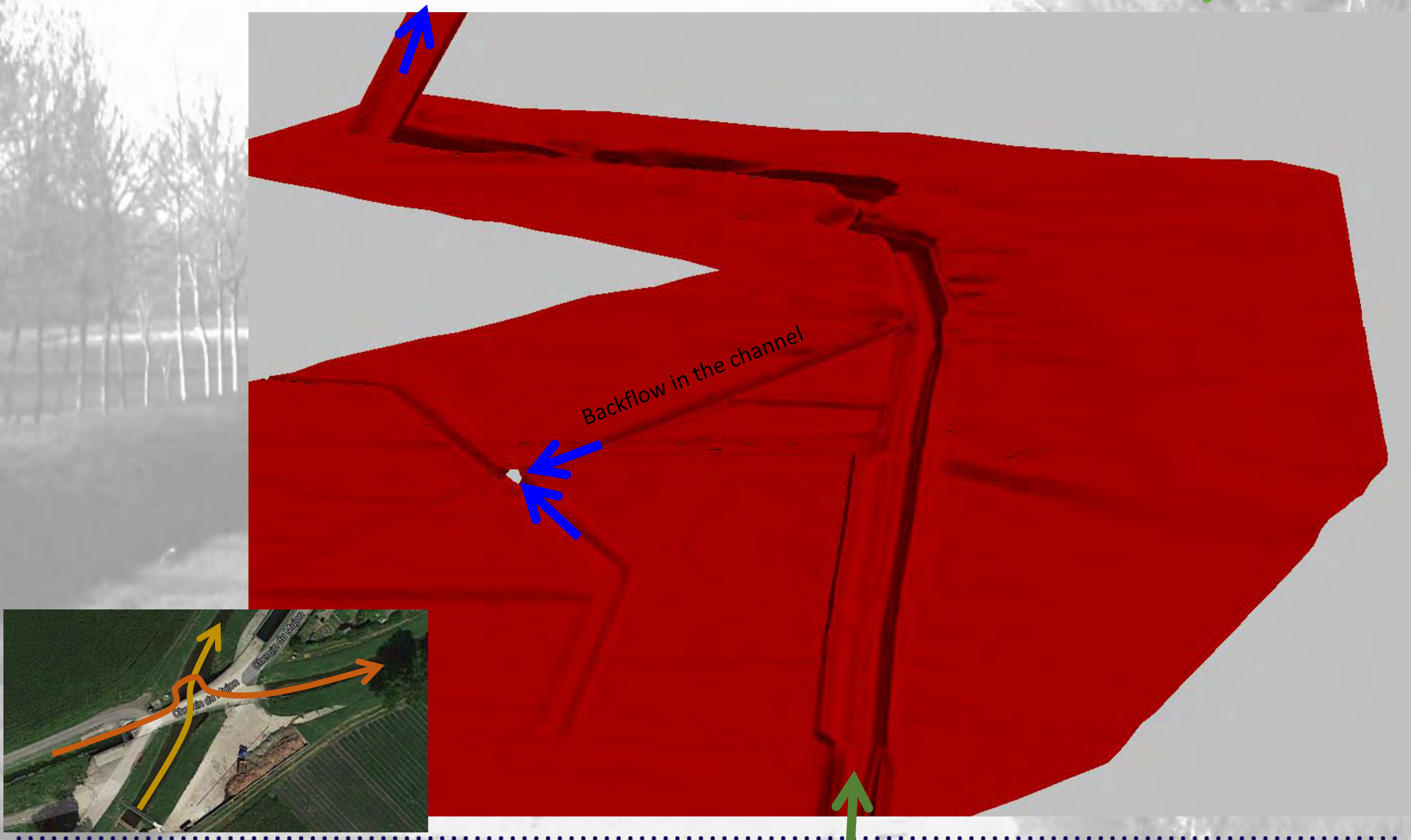
Final mesh of the project



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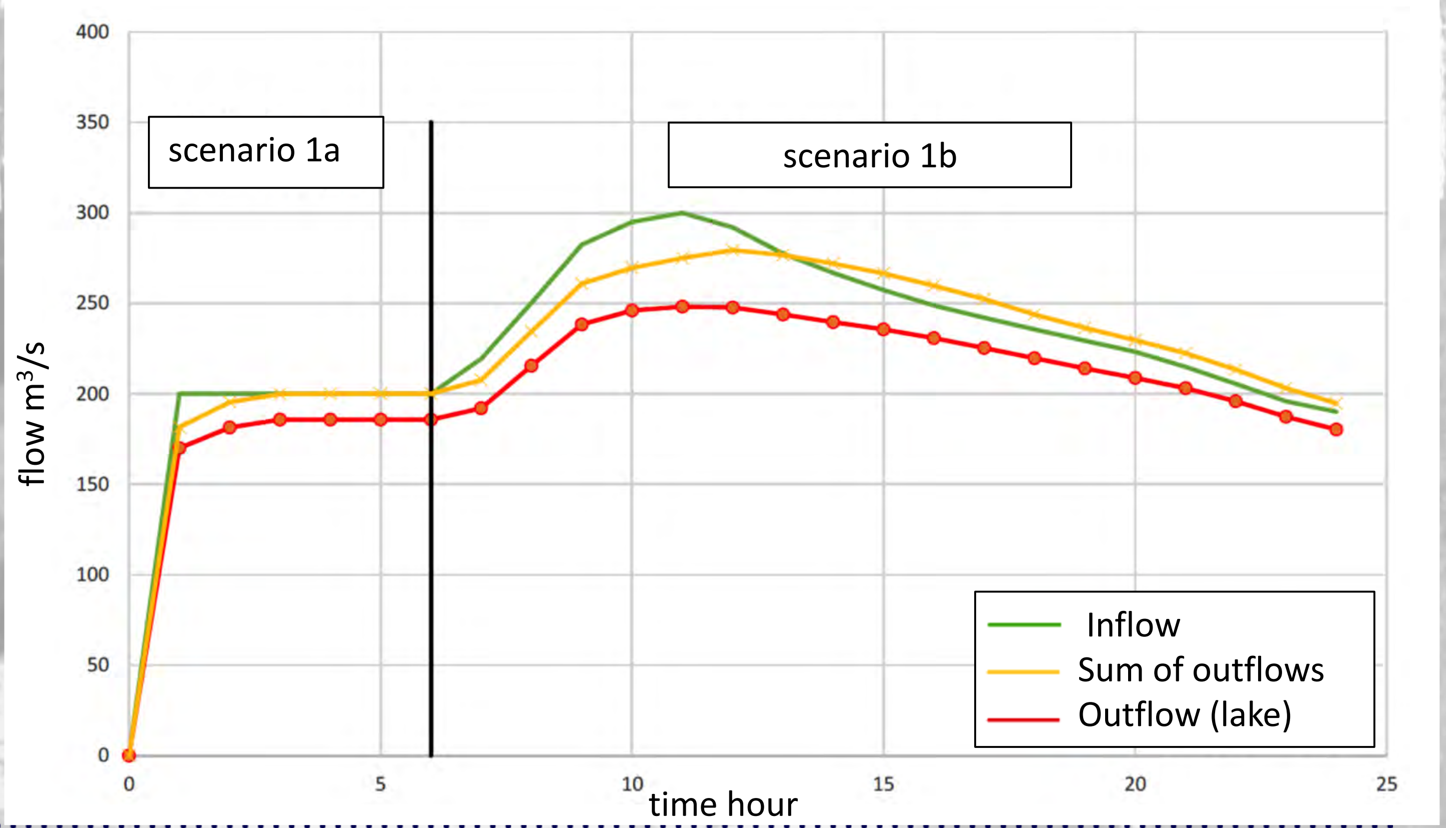
Simulation with Basement (flood occurring in the lake)

- Stationary case for Q100 = 200 m³/s (scenario 1a)
- Extreme flood Qextrem = 300 m³/s with three weirs on service (scenario 1b)
- Extreme event upstream of the revitalization, without and with dike breaking (scenario 2)

Inflow: hydrograph

Outflow: zhydrograph (flood occurring in the lake)



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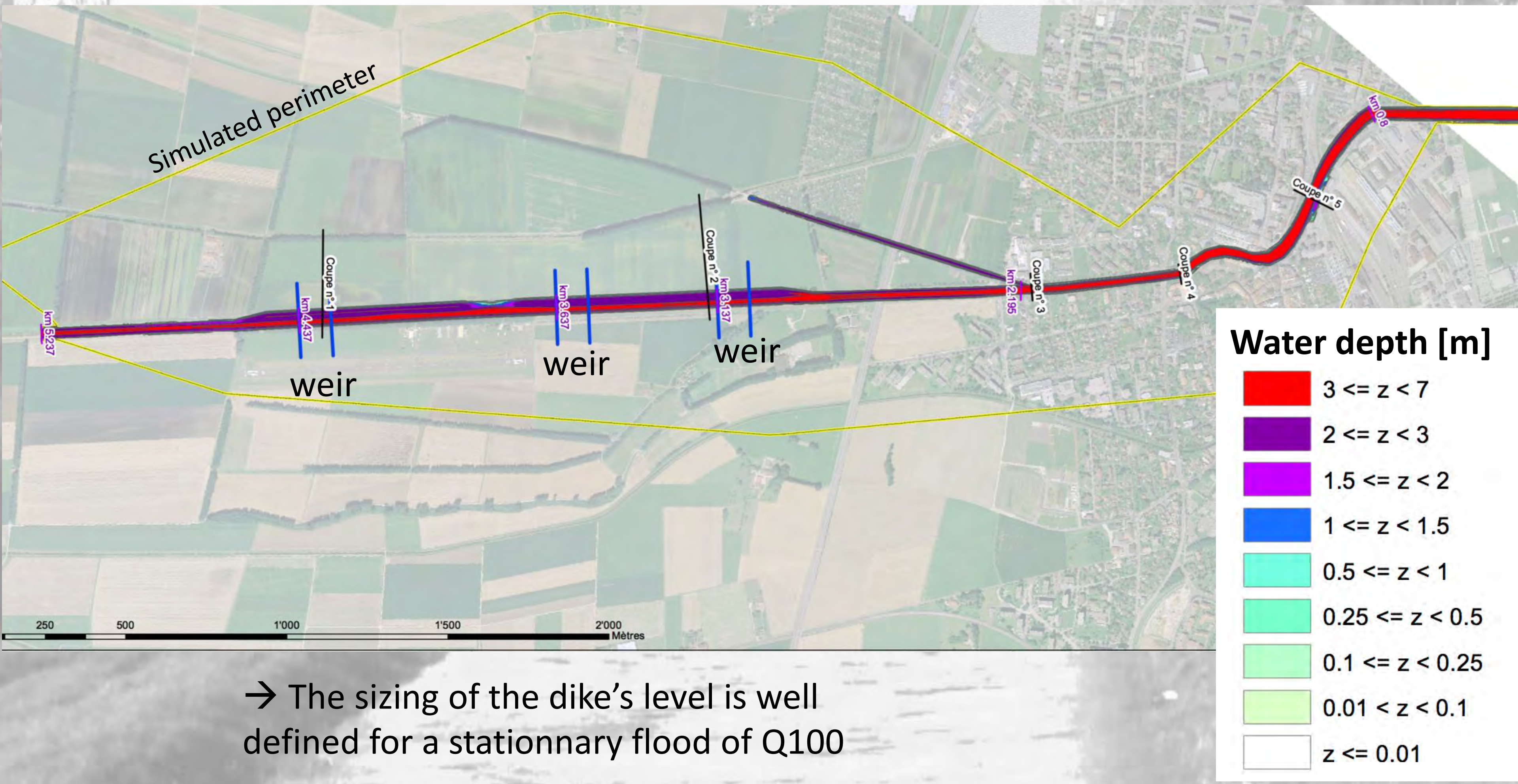
Scenario 1a: stationary case, t=6 hours



→ The sizing of the dike's level is well defined for a stationnary flood of Q100

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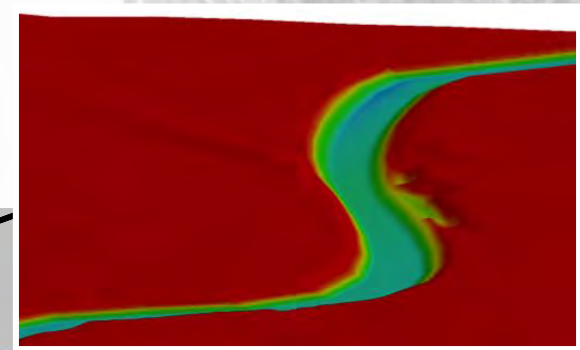
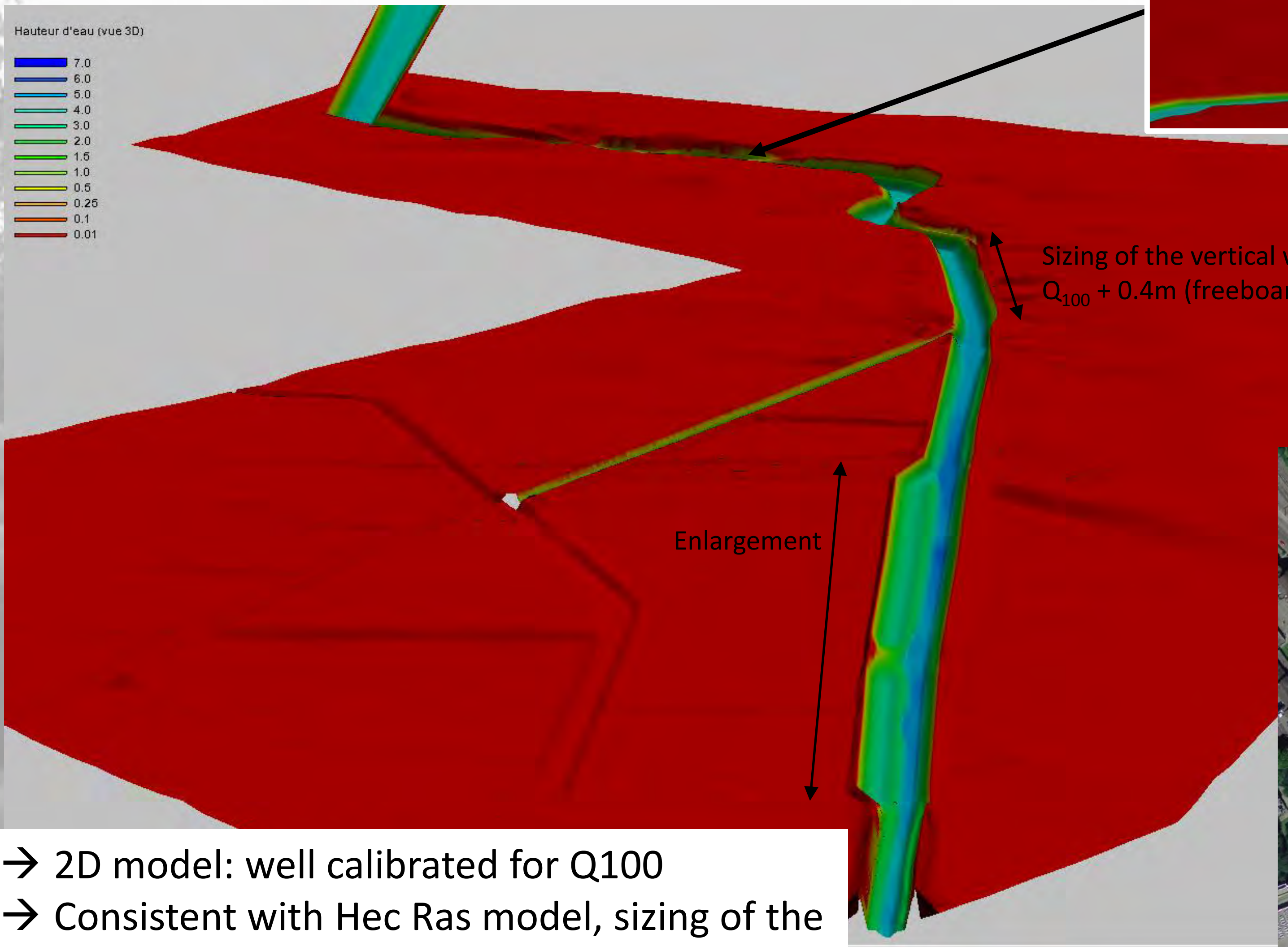
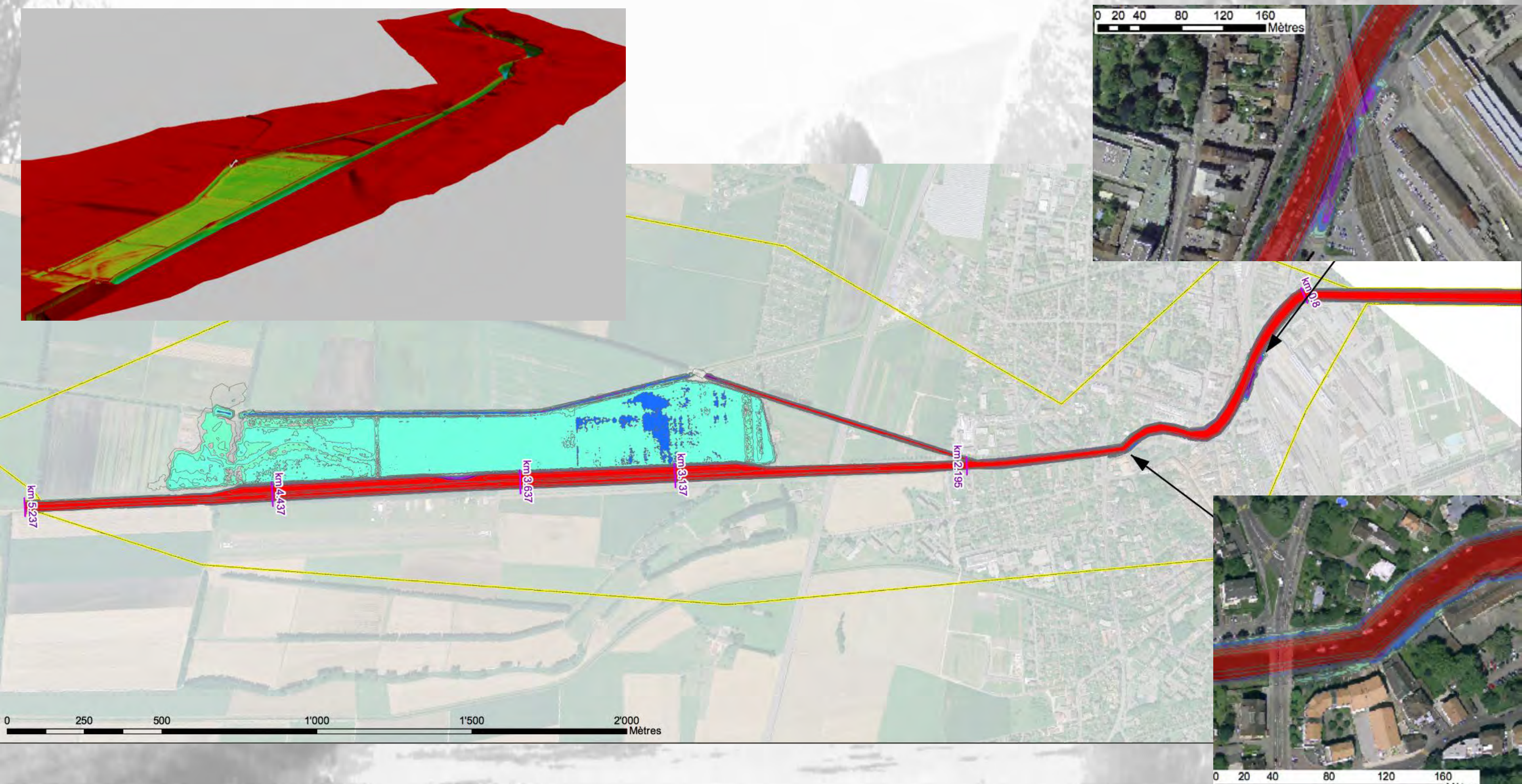




→ 2D model: well calibrated for Q100

→ Consistent with Hec Ras model, sizing of the dikes well defined

Scenario 1b:maximum flood, Qextreme, t=14 hours



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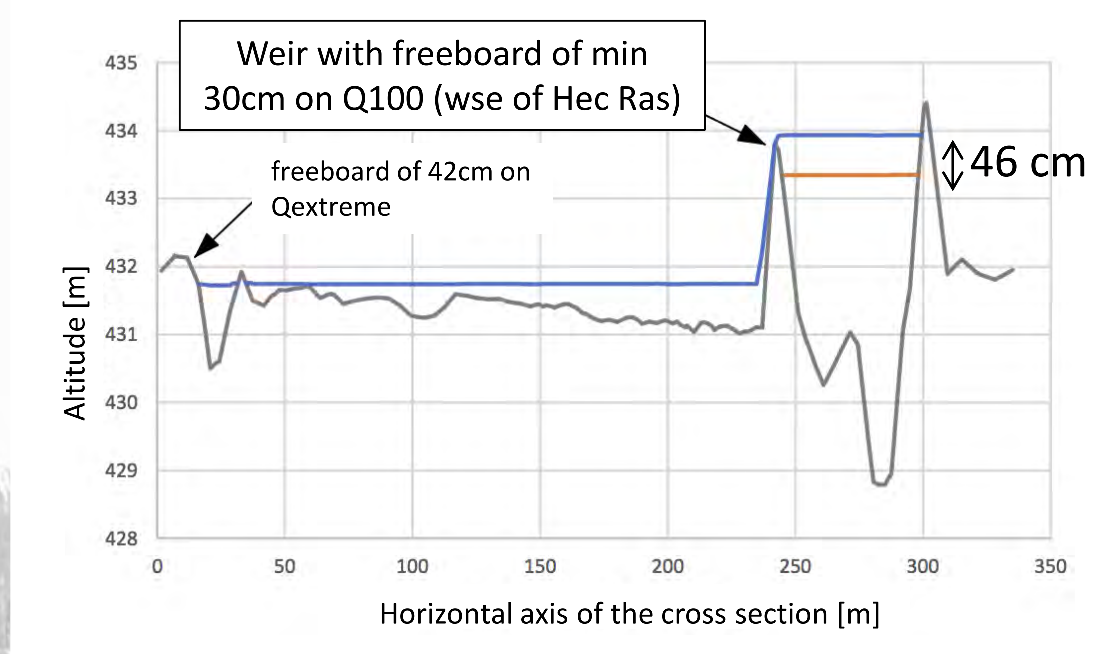
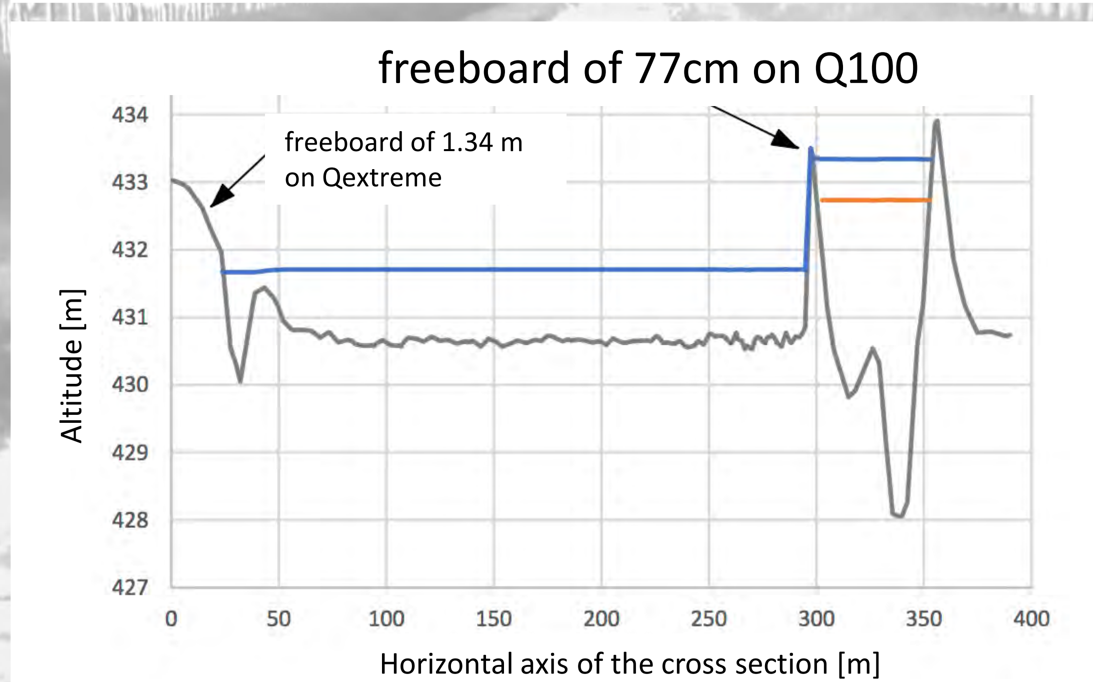
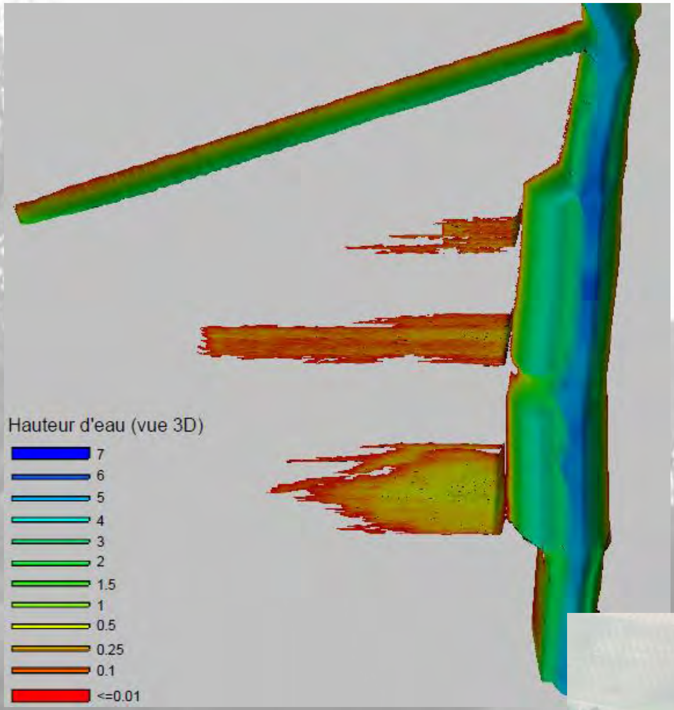
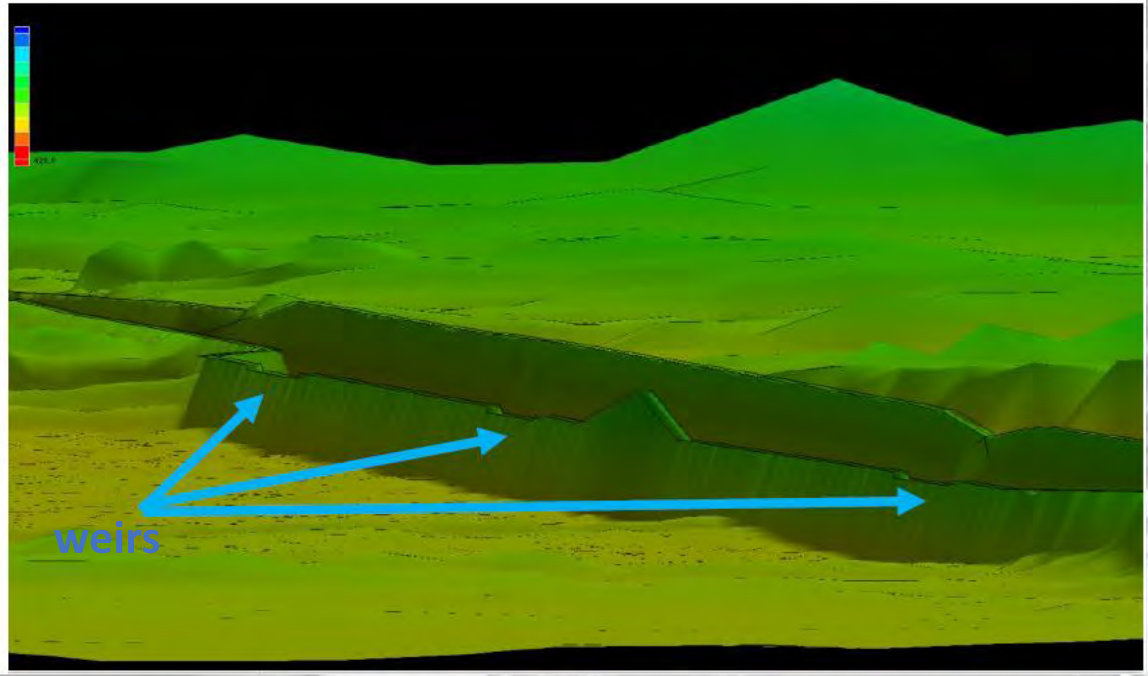
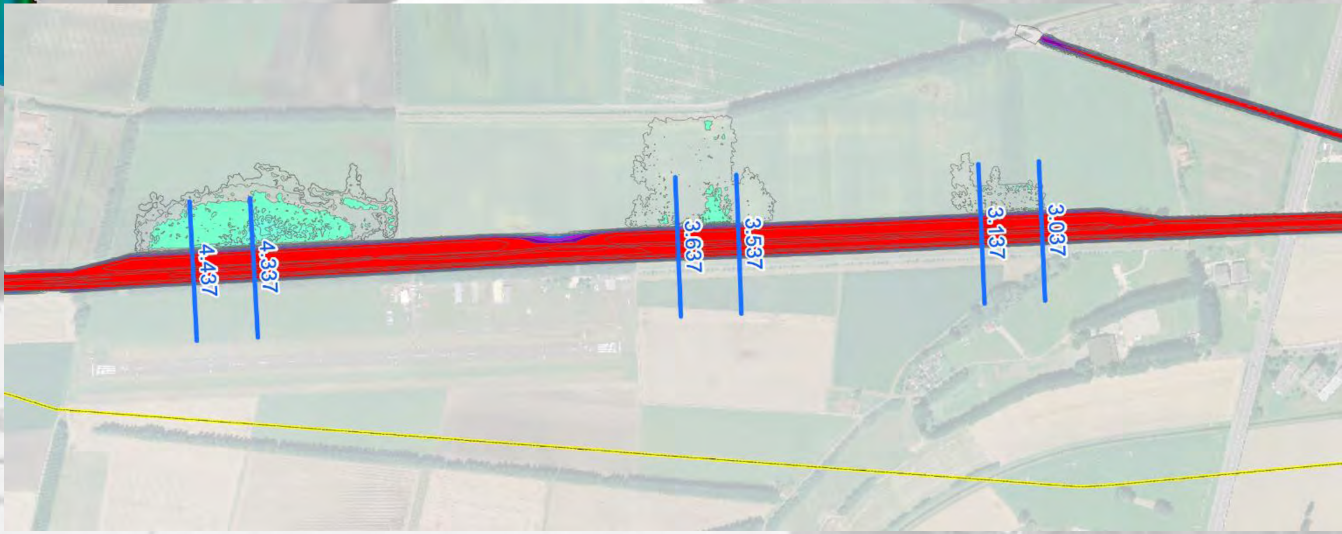


Q100
Qextreme







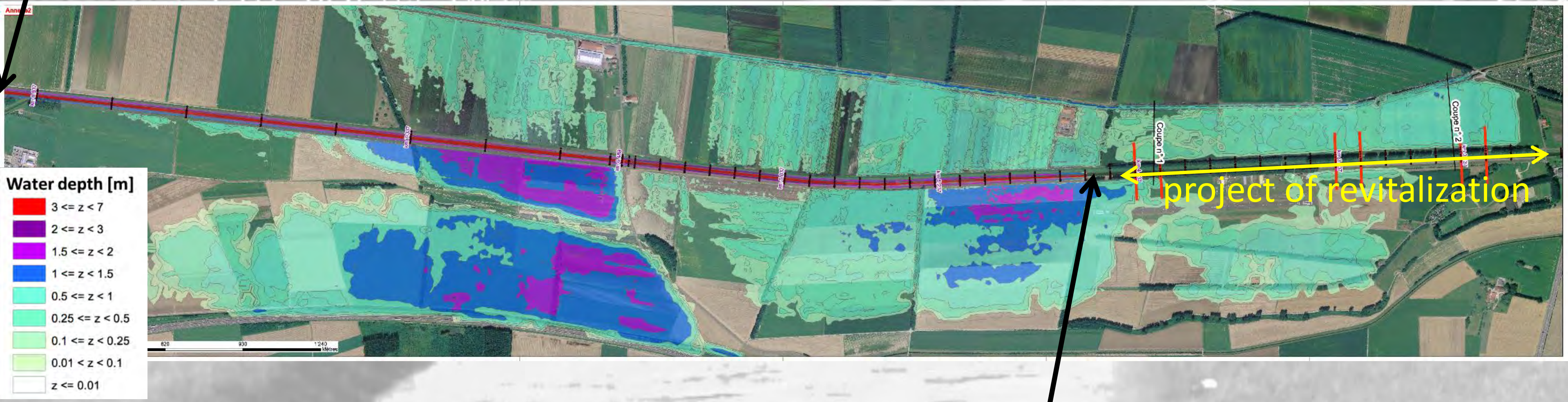


- Begining of the overflow: t= 9 hours, Qinflow: 260 m^3/s
- The weirs will be reinforced with non-erodible coating

Scenario 2: extreme flood upstream of the revitalization

Inflow: hydrograph

- **zero_gradient**: This boundary condition is used for outflow out of the computational area. Basically, the flux entering the boundary element leaves the computational area with the flux over the boundary. Mathematically speaking, all gradients of the main variables waterdepth and velocities are zero in the boundary cell. No further variables have to be defined using this boundary condition.



Outflow: zero_gradient

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Scenario 2: three possibilities

- Aim: protection of the aerodrome

- Three possibilities

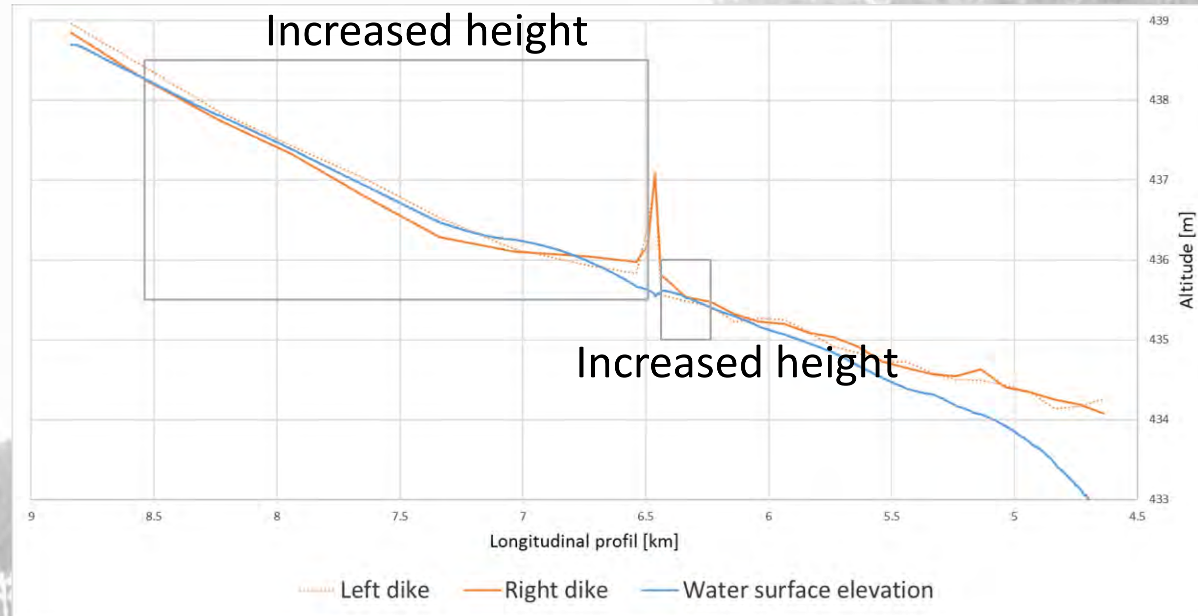
  P1: raise the dike locally

  P2: construct a dike to protect the aerodrome

  P3: raise the road to avoid the connection between the upstream and downstream compartment

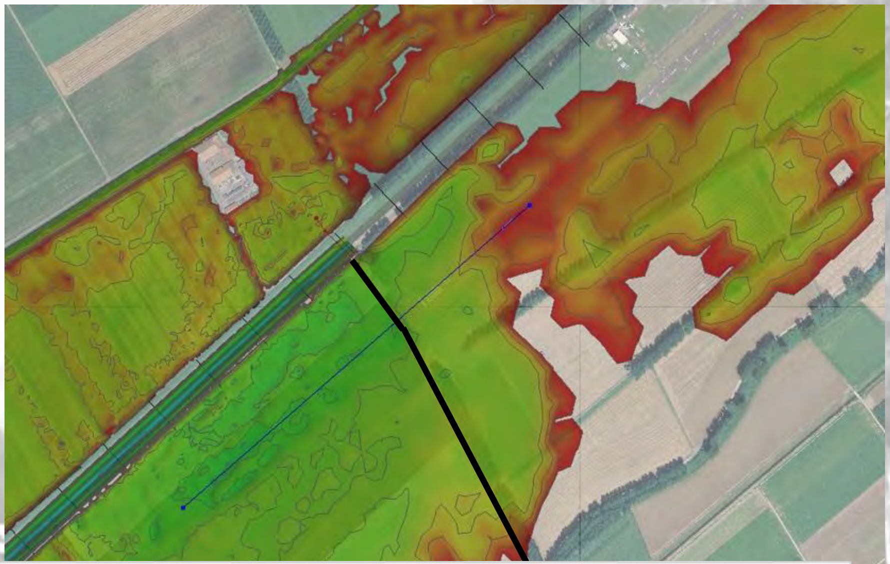
1. Raise the dike locally

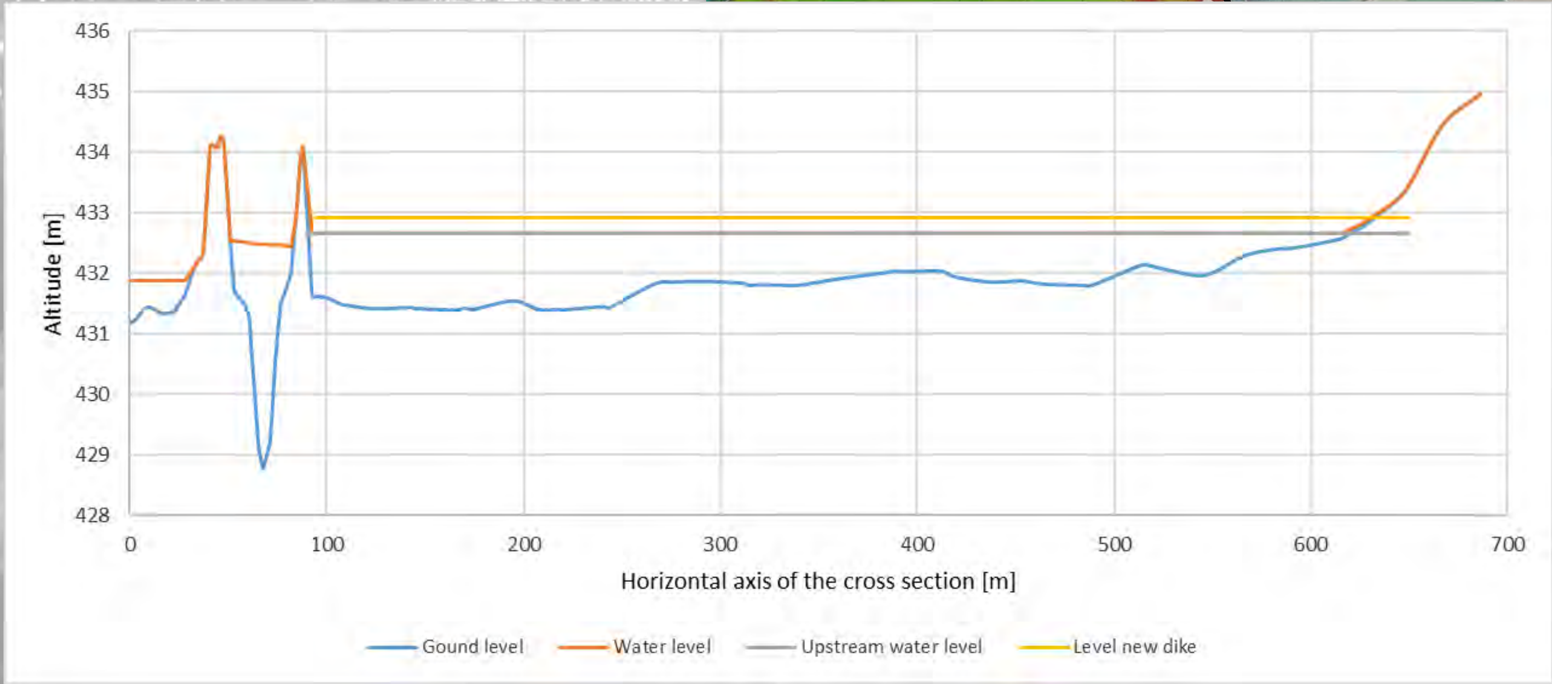
- Km 8.537 to km 6.489: 2’048m
→ Increased height of the dike ≈ 30 cm
- Km 6.437 to km 6.237: 200m
→ Increased height of the dike ≈ 15 cm



2. Construct a dike to protect the aerodrome

- 55m → mean extra height ≈110cm (with a freeboard of 25cm on the water surface elevation / low speed)





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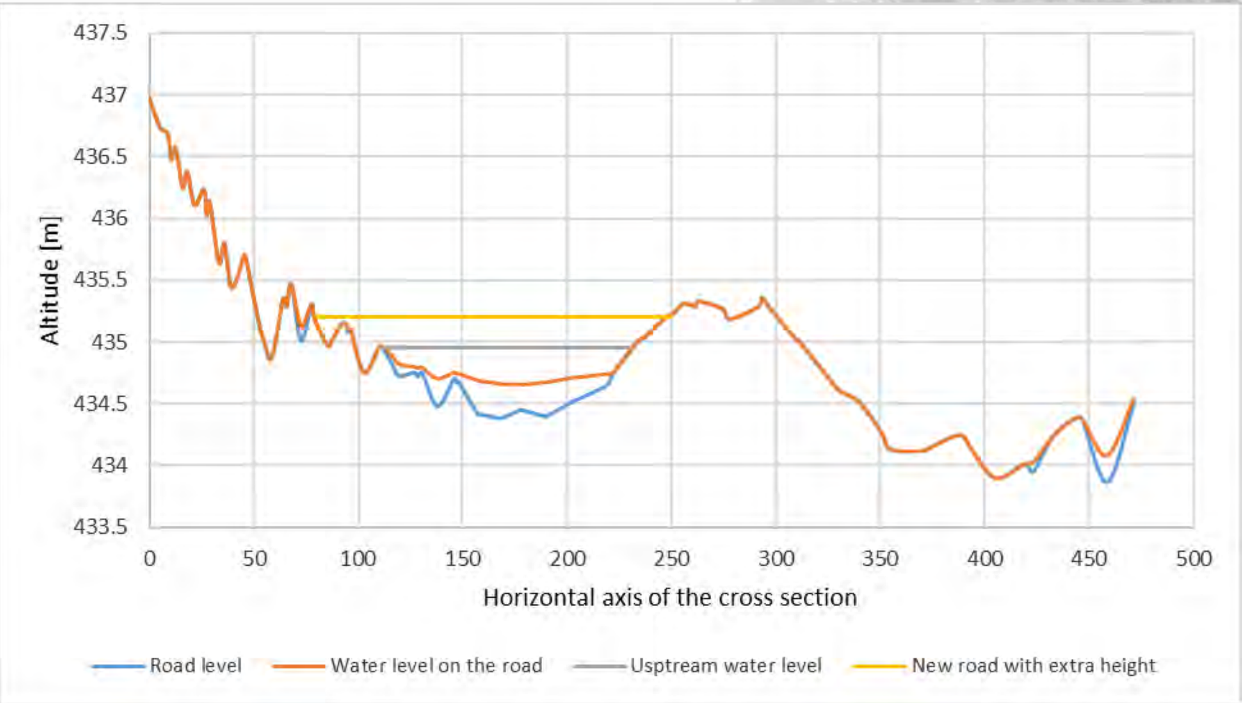
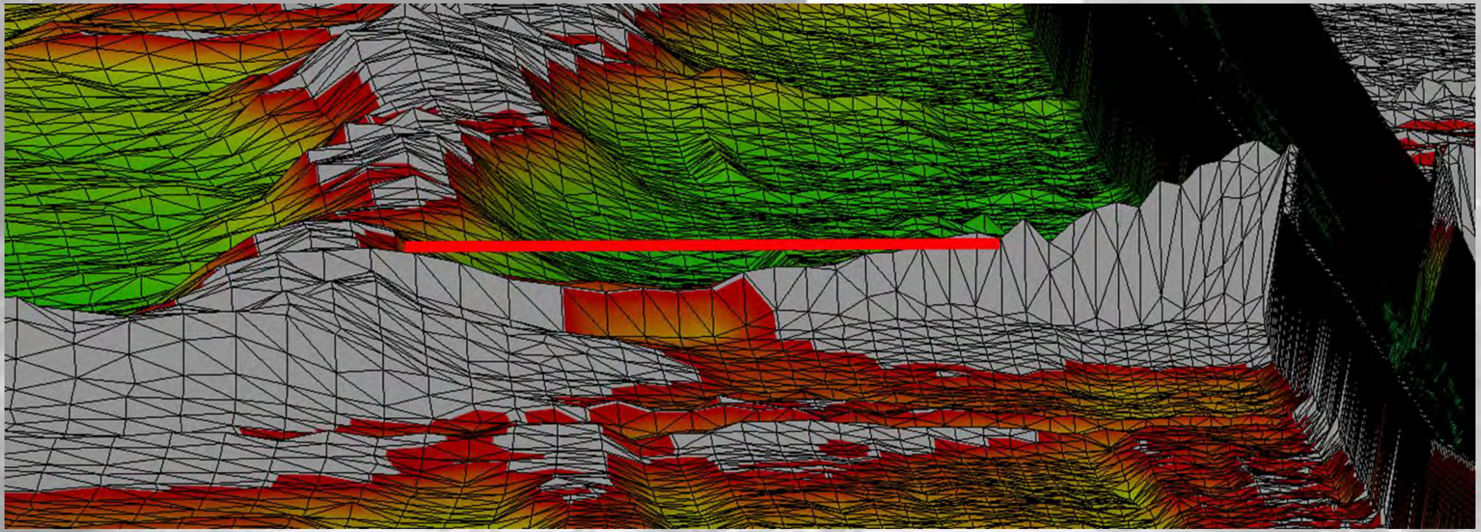
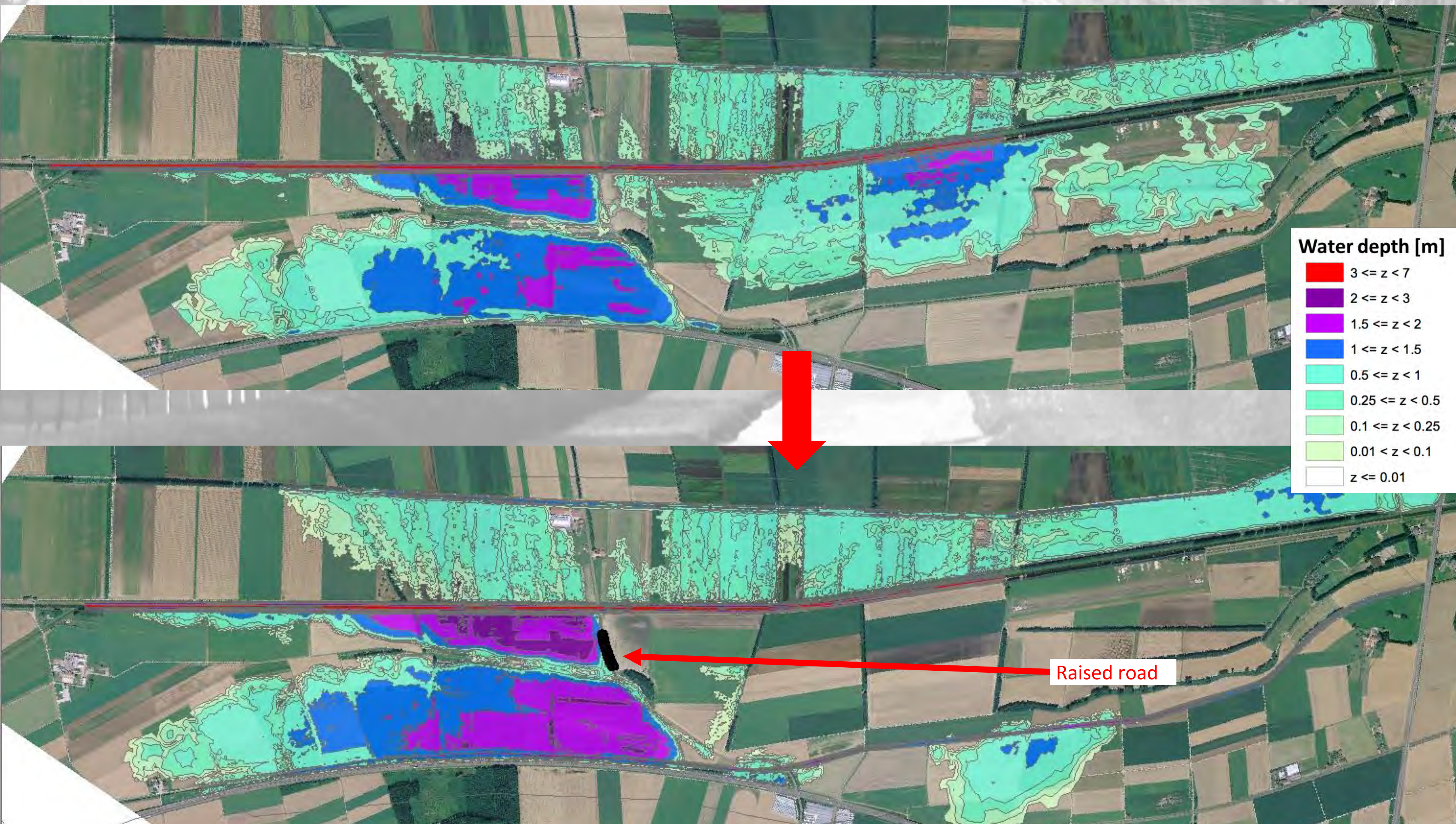
3. raise the road to avoid the connection between the upstream and downstream compartment

- 170m → mean extra height ≈50 cm (with a freeboard of 25cm on the water surface elevation / low speed)





P3: results of the simulation for Qext



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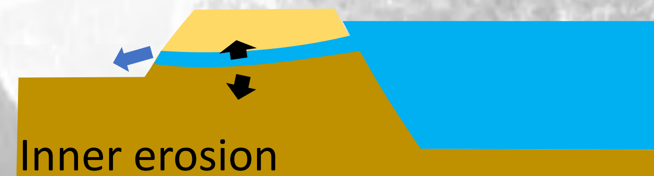
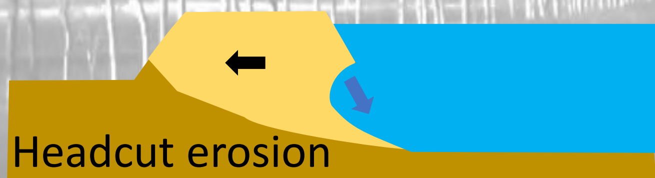
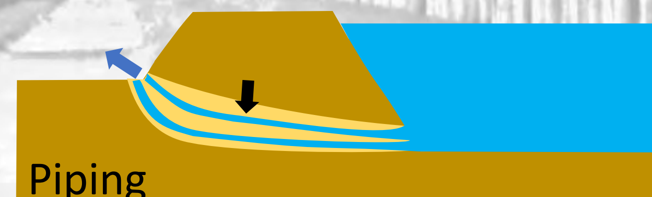
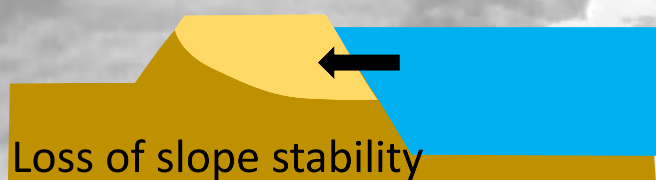
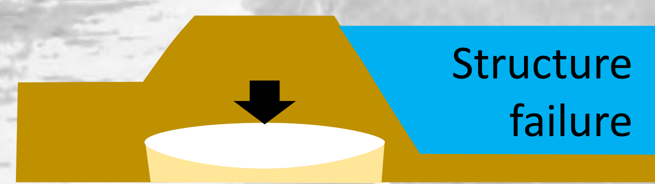
Failure mechanisms for dike











Failure mechanisms for dike

- Weak point is known → field surveys have permitted to define the places where a failure mechanism may be possible
- Geotechnical quality is not known (or bad everywhere) → the breach will be formed at the overtopping place

Rhône breach at Chamoson

Breach at Meiringen

- Breach length (cf. Rhône and Rhin) → 1.5 x width of the river (minor river bed length).
- Beginning of the breach: time when the dikes are overflowing and overtopping and/or when destabilizing geotechnical processes happen.
- Speed of erosion of the dike: we admit that the breach is completely open 1 hour after the beginning of the erosion. In reality, it’s possible that this phenomenon is quicker or slower. We admit an aperture of ¼ during 30 minutes followed of an aperture of ½ during 30 minutes and finally a complete aperture.
- The elevation of the weir after the breach is defined according to the cross section of the dike according to an erosion slope of 0-3%.

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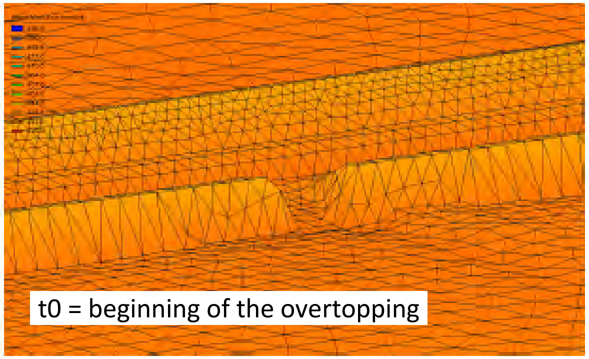
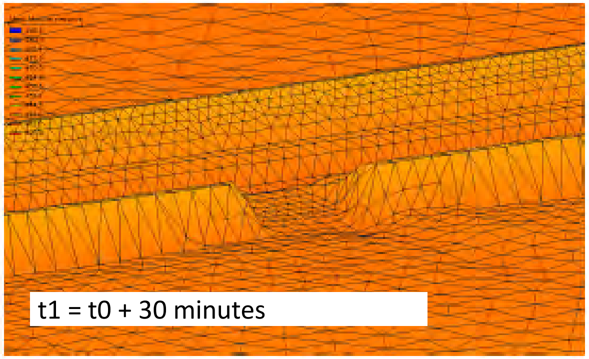
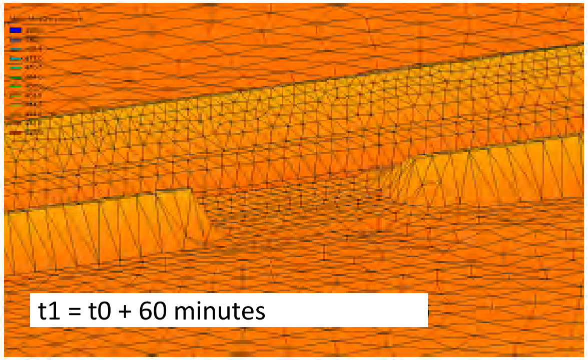
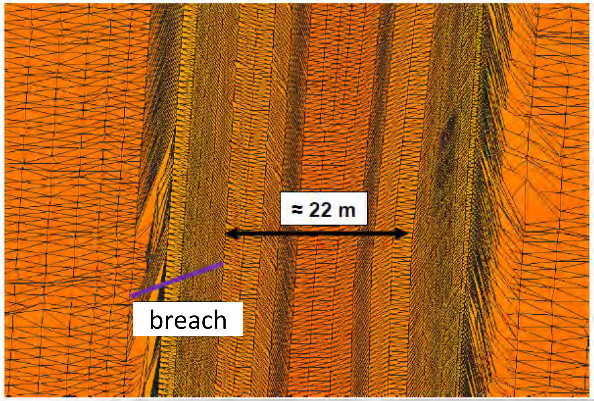
3 identical mesh (same nodes) with different elevation

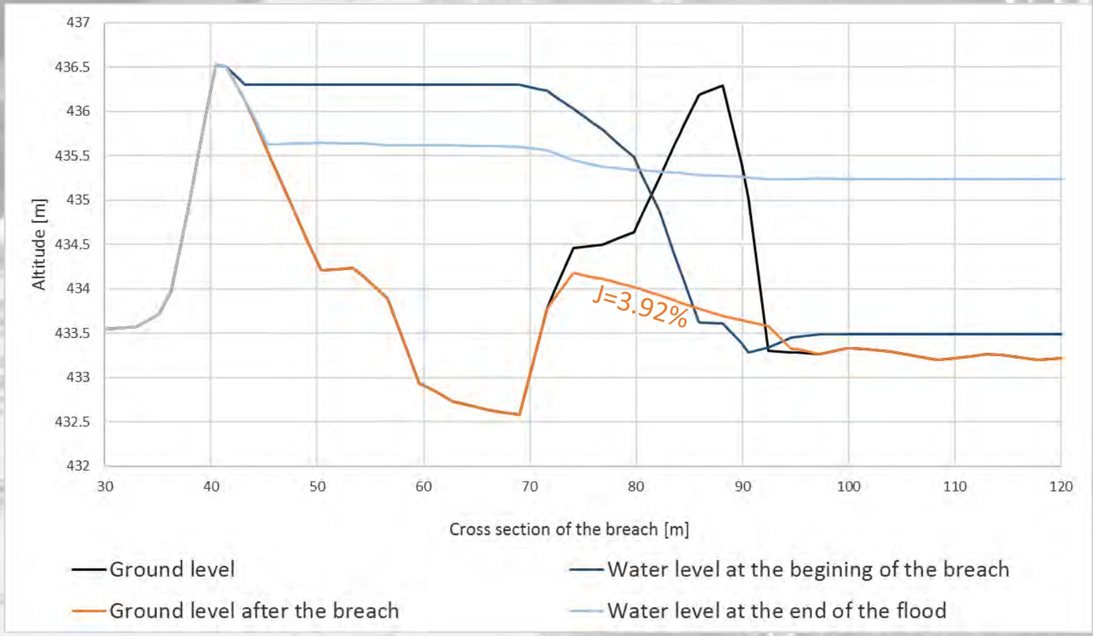






Breach length = 1.5 x minor river bed length
= 1.5*22 ≈ 35 m





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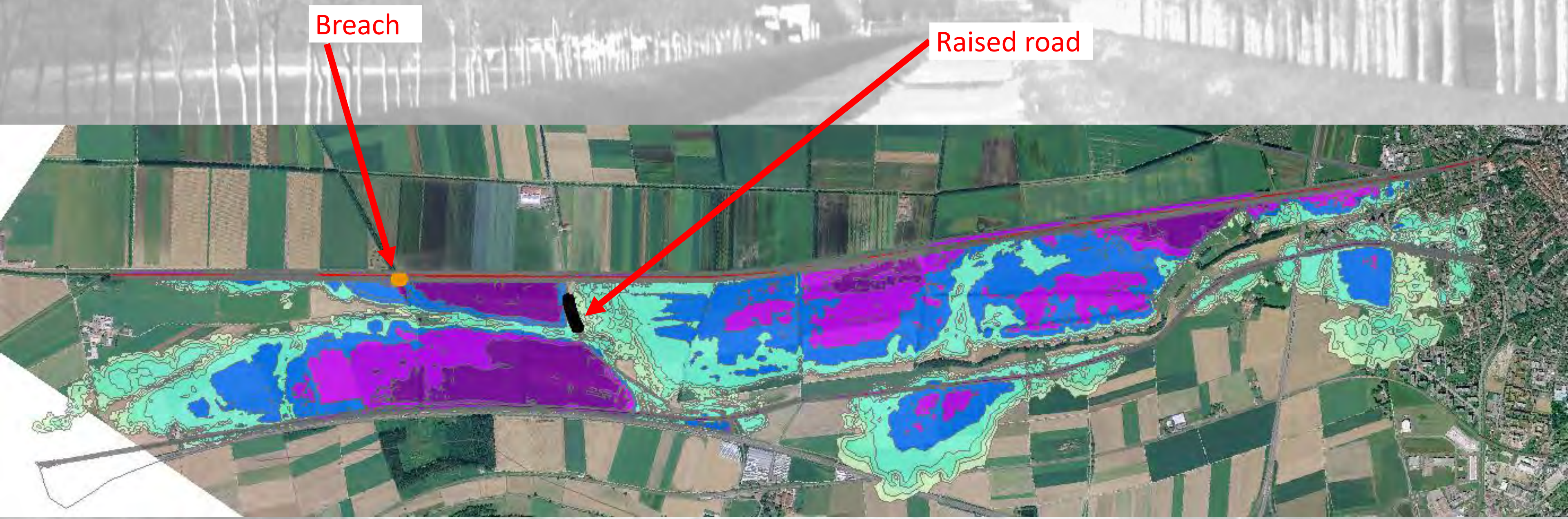
Simulation with breach

- Hydrograph: Qext = 300m³/s
- Level of the raised road: 435.2
- Beginning of the overflow: ≈ 200 m³/s
- Breach: 9m (t0) → 18m (t0 + 30 min) → 35m (t0 + 60 min)



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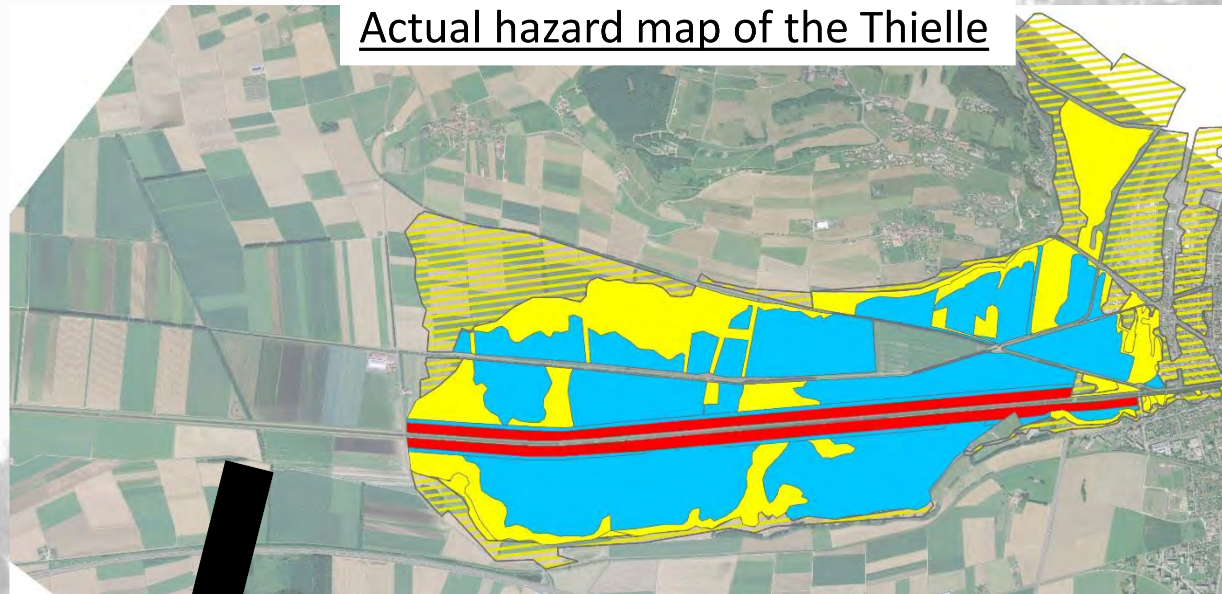
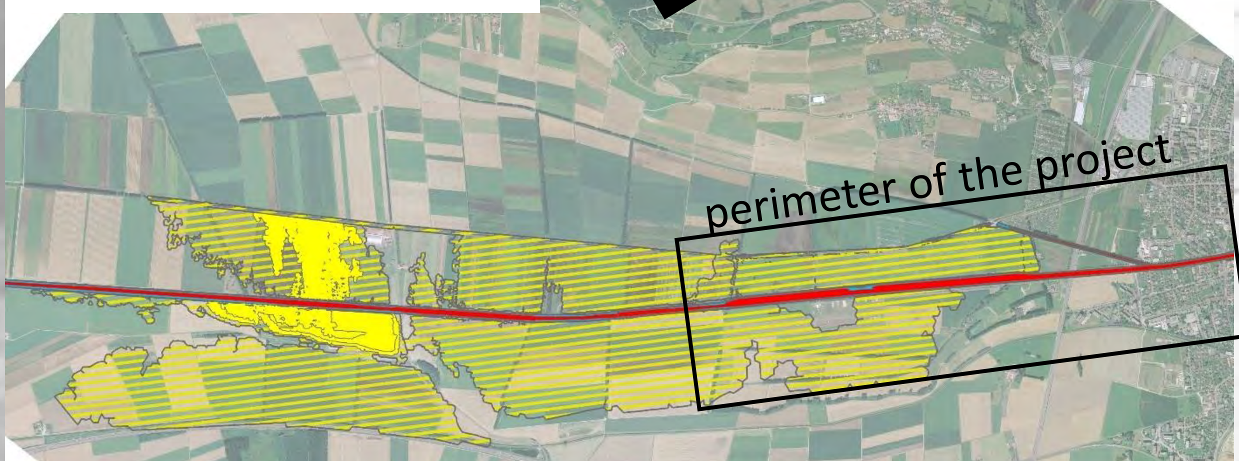
Conclusion

Actual hazard map of the Thielle



Future hazard map of the Thielle after the project



- In the perimeter of the project:

- Q100 (sizing outflow)
- Q300
- Qextreme

- Upstream of the project :

- No raised road
- Q100
- Q300
- Qextreme without breach