Numerical modelling of flood control areas with controlled reduced tide

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Outline

General framework

Numerical modelling

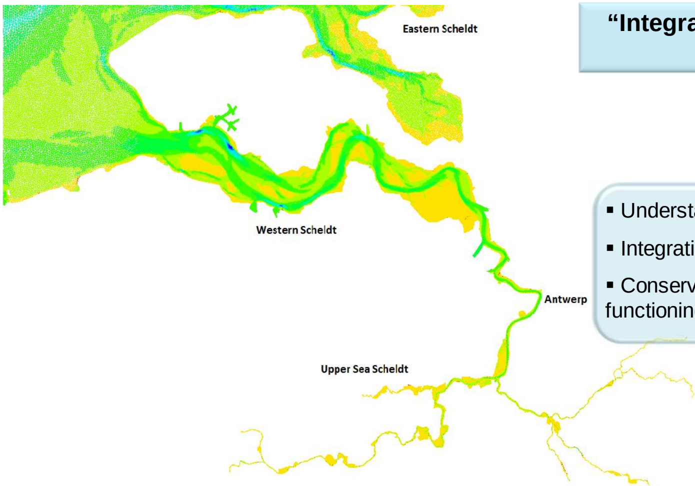
- TELEMAC 3D model
- Culvert functionality implementation

Study case

- Bergenmeersen flood control area

Concluding remarks

Motivation



"Integrated Plan Upper Sea Scheldt"

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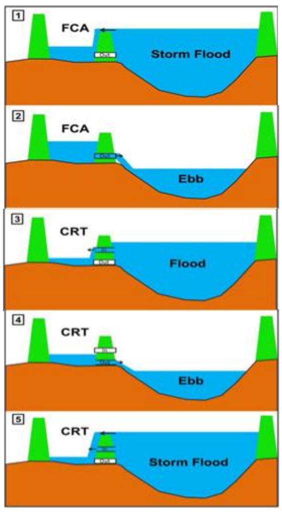
- Understanding of hydrodynamics
- Integration of future navigability
- Conservation of ecological functioning and safety

Flood control areas (FCA) with Controlled Reduced Tide (CRT) function



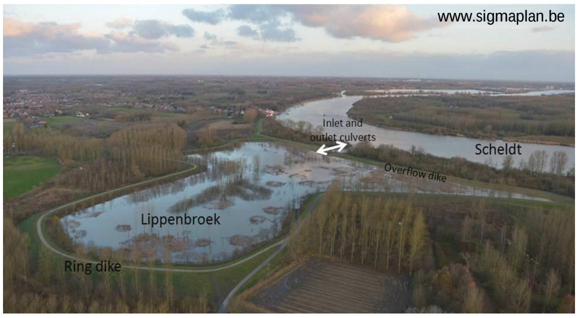
- $h_{river} > h_{FCA}$ ⇨ Water flows over the dyke
- $h_{river} < h_{FCA}$ ⇨ Water flows through the outlet

With CRT funtion:

- $h_{river} > h_{FCA}$ and $h_{river} < h_{dyke\_crest}$
  ⇨ Water flows through the inlet
- $h_{river} < h_{FCA}$
  ⇨ Water flows through the outlet
- $h_{river} > h_{FCA}$ and $h_{river} > h_{dyke\_crest}$
  ⇨ Water flows through the inlet and over the dyke

General Framework 3/3 | Numerical modelling | Study case | Concluding Remarks

Flood control areas (FCA) with Controlled Reduced Tide (CRT) function



- In **2013,** 13 areas were already activated
- In **2040** more than 40 areas will be activated

Main target

- **Implementation of a culvert functionality**
  - Model water flow through culverts;
  - Verify and validate model results during storm surge event

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General Framework | Numerical modelling 1/5 | Study case | Concluding Remarks

TELEMAC-3D (Hervouet, 2007)

- Circulation hydrodynamic model
- 3D RANS equations with a free surface
- With or without hydrostatic hypothesis
- Finite elements method
- Open source (since July 2011)

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Culvert functionality implementation – TELEMAC-3D (version v6p3)

$$\frac{\partial U}{\partial x}+\frac{\partial V}{\partial y}+\frac{\partial W}{\partial z}=0$$

$$\frac{\partial U}{\partial t}+U\frac{\partial U}{\partial x}+V\frac{\partial U}{\partial y}+W\frac{\partial U}{\partial z}=-g\frac{\partial \eta}{\partial x}+\nu\Delta(U)+F_x$$

$$\frac{\partial V}{\partial t}+U\frac{\partial V}{\partial x}+V\frac{\partial V}{\partial y}+W\frac{\partial V}{\partial z}=-g\frac{\partial \eta}{\partial y}+\nu\Delta(V)+F_y$$

$$\frac{\partial h}{\partial t}+\frac{\partial (uh)}{\partial x}+\frac{\partial (vh)}{\partial y}=0$$ **+ Source/ Sink term**

$$\frac{\partial T}{\partial t}+U\frac{\partial T}{\partial x}+V\frac{\partial T}{\partial y}+W\frac{\partial T}{\partial z}=\nu_t\Delta(T)+Q'$$

- If water flows from the river to the floodplain:

$Q_{floodplain} = - Q_{river}$

Source ↓ Sink ↓

- If water flows from the floodplain to the river:

$Q_{river} = - Q_{floodplain}$

Source ↓ Sink ↓

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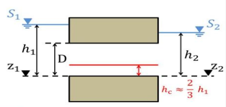
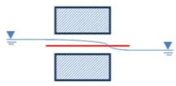
Culvert functionality – theoretical framework

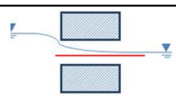


Bodhaine (1968) :

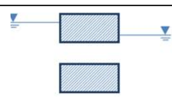
Type 2 – Critical depth at outlet: $Q=\mu h_c W\sqrt{2g*(S_1-(z_2+h_c))}$



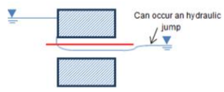
Type 3 – Tranquil flow: $Q=\mu(S_2-z_2)W\sqrt{2g(S_1-S_2)}$



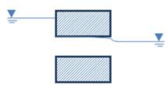
Type 4 – Submerged outlet: $Q=\mu DW\sqrt{2g(S_1-S_2)}$



Type 5 – Rapid flow at inlet: $Q=\mu DW\sqrt{2gh_1}$



Type 6 – Full flow with free outfall: $Q=\mu DW\sqrt{2g(S_1-(z_2+D))}$



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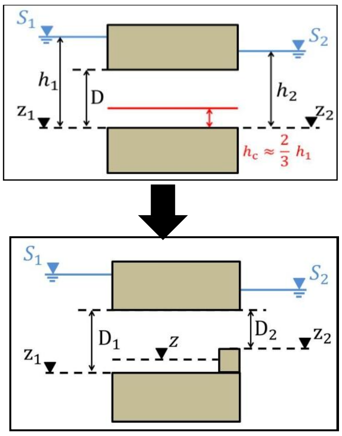
Culvert functionality – theoretical framework

Bodhaine (1968) :



Culvert functionality – theoretical framework

$$\Delta H = C\frac{U^2}{2g} \qquad C = C_1 + C_2 + C_3 + C_v + C_T + C_p$$

Head losses due:

- entrance, contraction of the flow (C_1)
- friction (C_2)
- outlet, expansion of the flow (C_3)
- valve (C_v)
- trash screens (C_T)
- entrance pilars (C_P)

Bergenmeersen area

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Two periods: - 10th to 12th September 2014 (13h campaign)

- 5th to 7th December 2013 (Storm surge)

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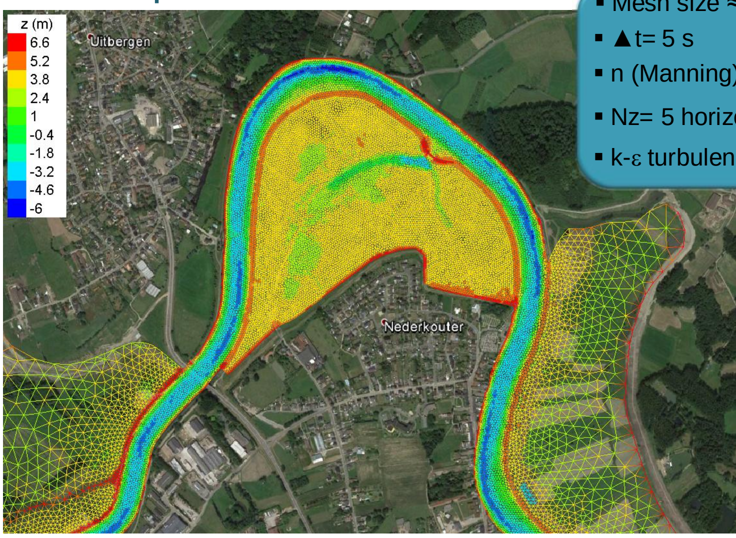
Model setup



- Mesh size ≈ 5 - 20 m
- ▲t= 5 s
- n (Manning)=0.016
- Nz= 5 horizontal plans
- k-ε turbulence model

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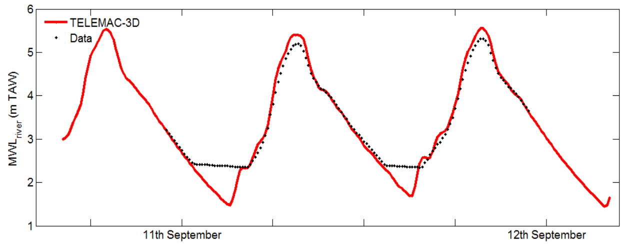
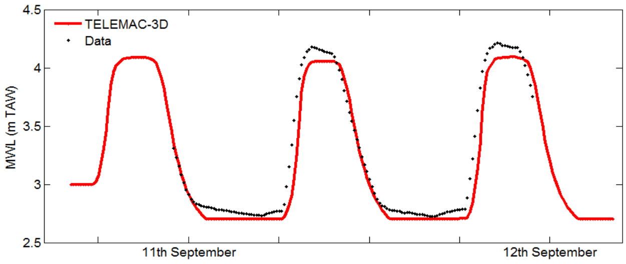
General Framework | Numerical modelling | **Study case** 3/6 | Concluding Remarks

Water levels

10th to 12th September 2014 (13h campaign)



Scheldt river



Inside the FCA

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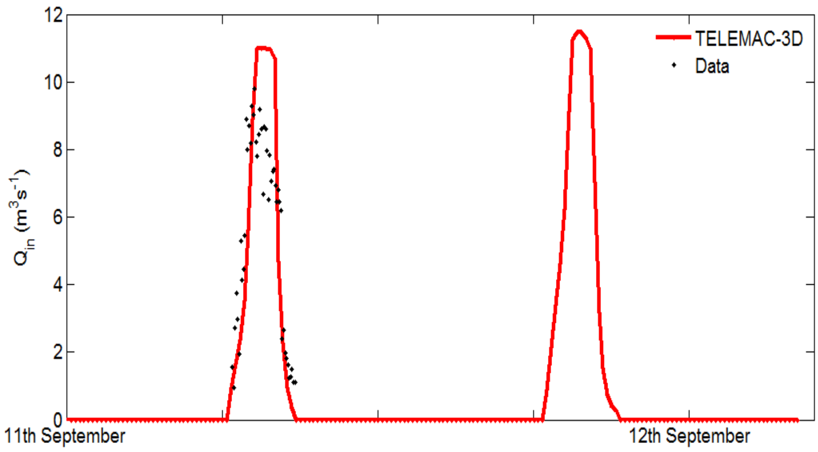
Inlet discharge

10th to 12th September 2014 (13h campaign)



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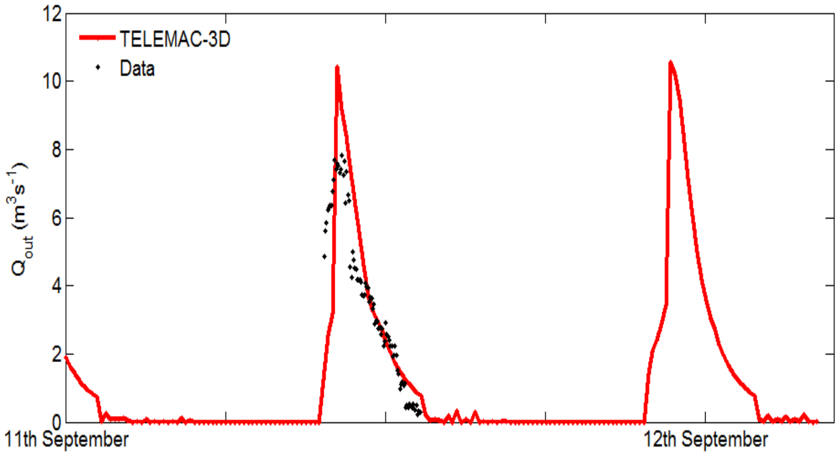
General Framework | Numerical modelling | **Study case** 5/6 | Concluding Remarks

Outlet discharge

10th to 12th September 2014 (13h campaign)



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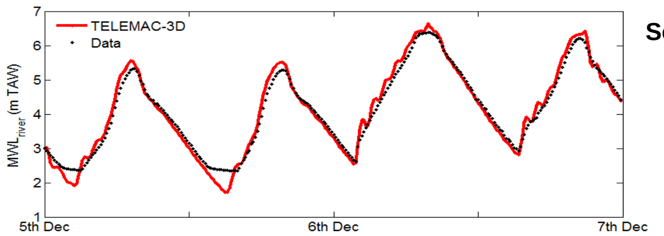
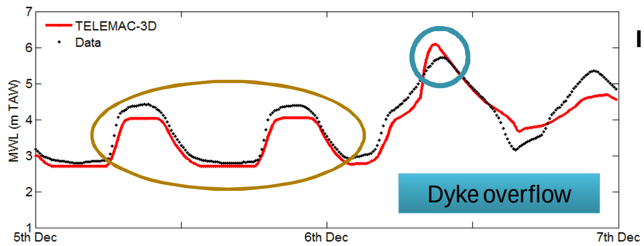
Water levels

5th to 7th December 2013 (Storm surge)



Scheldt river



Inside the FCA

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Concluding remarks

- TELEMAC-3D is able to model flows through culverts;
- TELEMAC-3D can now take into account flood control areas with controlled reduced tide;
- Model results were verified against data measurements;
- Numerical results agree fairly well with measurements when storm surges are modelled.

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Thank you

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