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Maximova, Tatiana; Vanlede, Joris

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Analysis of the depoldering of the Hedwige-Prosperpolder with a 2D TELEMAC model (Scheldt estuary, the Netherlands and Belgium)

Maximova, T. [1], Vanlede, J.[1]

[1]Flanders Hydraulics Research
Berchemlei 115, 2140 Antwerp- Borgerhout, Belgium
Joris.Vanlede@mow.vlaanderen.be

Abstract— **This paper describes the development and calibration of a two-dimensional hydrodynamic model of the Hedwige-Prosperpolder. The model is used for the analysis of various alternatives for the depoldering.**

I. INTRODUCTION

The Hedwige-Prosperpolder is located on the border between Belgium and the Netherlands (Fig. 1). In 2006, plans were made to flood this area in the framework of nature restoration in the Natura 2000 zone “Westerschelde & Saeftinge”. The aim is to develop an extensive brackish marshes area (465 hectares) in the Hedwige-Prosperpolder with one single intervention. An initial system of gullies and creeks will be developed in the polder, and after the dikes are breached the natural dynamics of sedimentation and erosion will take over. The depoldering is considered successful if the polder further develops autonomously into an ecologically valuable intertidal area. The expected estuarine nature will consist of a mix of estuarine habitats: gullies, creeks, tidal flats and salt marshes.

In this paper a detailed 2D model is described for the Hedwige-Prosperpolder [2]. This model is developed to study the depoldering with varying creek systems in the polder, breach locations and different amounts of marsh excavation on the Scheldt side of the existing dike. The study is based on the analysis of the water depths and velocities, flow discharges in the polders, bed shear stress (to estimate an expected erosion or deposition) and flooding duration.

TELEMAC is chosen as the modelling platform to study the hydrodynamics in the different design alternatives. It is important to have a well refined grid which can represent the flow in the narrow creeks in the study zone correctly. The use of an unstructured grid in TELEMAC allows for local grid refinement and results in an accurate representation of the complex geometry of the study area.

A. *Model grid*

The model domain is discretised into an unstructured grid of triangular elements and it is locally refined in the study area.

The downstream boundary of the detailed model is located at Walsoorden in the Western Scheldt. The upstream boundary is located at Antwerp in the Lower Sea Scheldt (Fig. 2). The grid resolution of the calibrated model is 10 m at the Hedwige – Prosperpolder, with about 144.000 nodes and 284.000 elements. The model is calibrated for the current situation (an unbreached dike between the Scheldt and the polder and therefore no flow in the study area). For the scenario analysis the grid resolution of the polders is refined and the bathymetry is adapted (see III.B).

B. *Bathymetry*

The bathymetry for the Western Scheldt and Sea Scheldt is defined based on samples from 2013. TAW is used as a vertical reference. In the locations where data from 2013 are missing, samples from 2011 were used. The bathymetric data for the polders date from 2001.

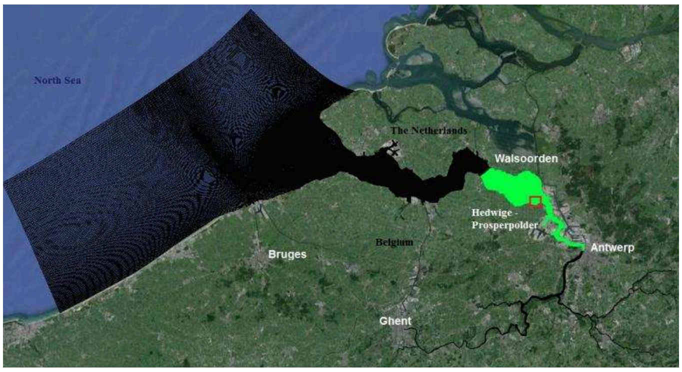

Figure 1. Grid of the overall model (black) and detailed model (green)

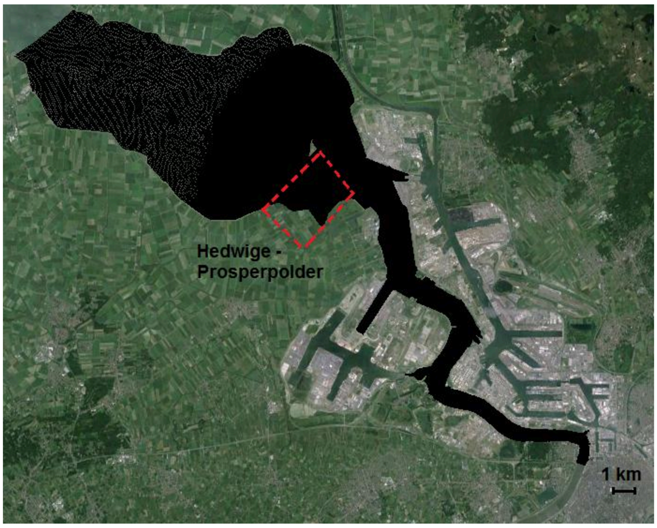

Figure 2. Model grid

C. Boundary conditions

The boundary conditions for the TELEMAC model in this study are generated by nesting in the NEVLA (a bigger model for the entire Scheldt estuary) [1], [5]. The choice of boundary conditions was optimized during the calibration procedure. A combination of the discharge at the downstream boundary and the water level at the upstream boundary produced the best results.

10 minute time series of the discharge at Walsoorden and the water level at Antwerp are presented in Fig. 3.

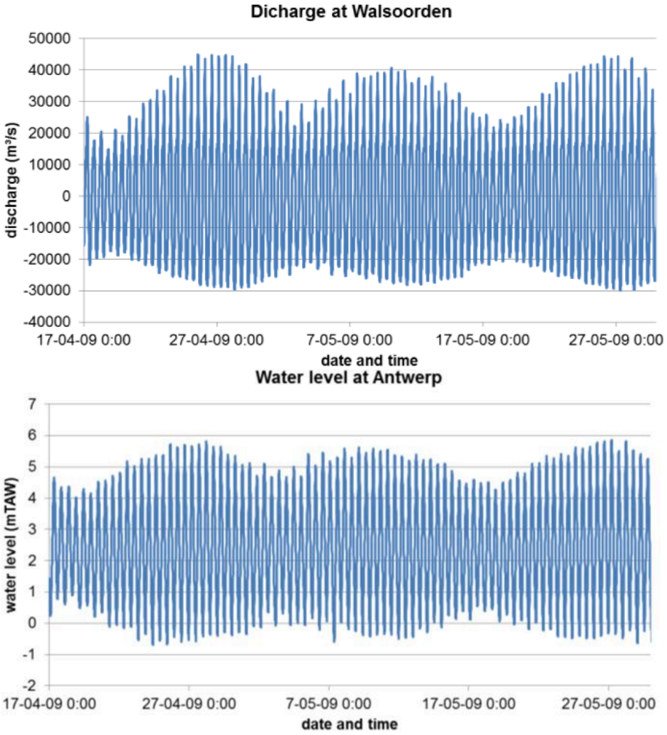

Figure 3. Discharge at the downstream boundary and water level at the upstream boundary

D. Bed roughness

Bed roughness in the model is defined using the Manning roughness.

A uniform roughness field was used in the model. A value of 0.021 $m^{-1/3}s$ was chosen during the calibration procedure.

E. Simulation period

Based on the tidal conditions during which ADCP and discharge measurements are available (see further), the model is run from 17/04/2009 00:00 to 30/05/2009 03:00.

II. MODEL CALIBRATION

A. Available measurement data

The model was calibrated based on comparison of the calculated and measured water levels, velocities and discharges. The location of the available measurements is presented in Fig. 4.

The time series of water level were retrieved from the Hydro Meteo Centrum Zeeland database (HMCZ) for the stations on the Dutch territory and from Hydrologisch Informatie Centrum (HIC) for the stations in Belgium.

Velocities were measured by the Acoustic Doppler Current Profiler (ADCP). The resulting dataset consists of velocity vectors distributed over the transect and over the water depth during one tidal cycle. Discharges are obtained by integration of ADCP data over the cross section.

B. Methodology

The main objective of the model calibration in this project is to improve the model accuracy for the velocities near the Hedwige-Prosperpolder. Bed roughness and velocity diffusivity are used as calibration parameters.

The measured water levels are compared with the model results for the period from 18/04/2009 to 30/05/2009.

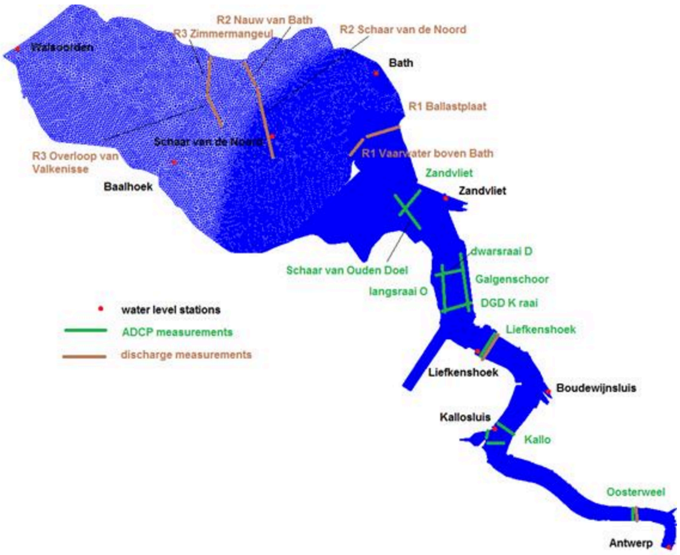

Figure 4. Available measurement data

Harmonic analysis of the tide is performed and statistical parameters (bias, RMSE, RMSE0) are calculated for high and low waters and for the time series of water levels.

The ADCP measurements and discharges are compared with the model results for the tides similar to the tides observed during the measurements. This way measured velocities and discharges can be compared to the model results on a local timescale (hours before & after high water).

C. *Results*

During the calibration procedure the amplitude and phase of two important harmonic components M2 and S2 were corrected at the boundary based on the average error in these components at all stations. Furthermore, Z0 component was corrected. The model was further calibrated by varying the roughness and diffusivity parameters.

The model run with an uniform roughness field (0.021m$^{-1/3}$s) and a default value of viscosity (10^{-4} m²/s) produced the best results. The quality assessment of the calibrated model is presented in table 1.

1) *Water levels*

The RMSE of complete water level time series is 11 to 13 cm at most stations.

The absolute value of bias of high waters is 1 to 3 cm at most stations. The bias of low waters varies between -5 and 4 cm. The RMSE of high and low waters is 9 to 11 cm everywhere except Boudewijnsluis (RMSE of high waters is 14 cm) and Zandvliet (RMSE of low waters is 13 cm). The RMSE of high and low water time is 7 to 12 min.

The M2 component is very important because it has the highest amplitude. The tidal amplitude depends to a large extent on the amplitude of M2. The difference between the calculated and measured M2 amplitude is -2 to 3 cm (Fig. 5). The difference in the M2 phase is very small (1 degree or smaller) at all stations.

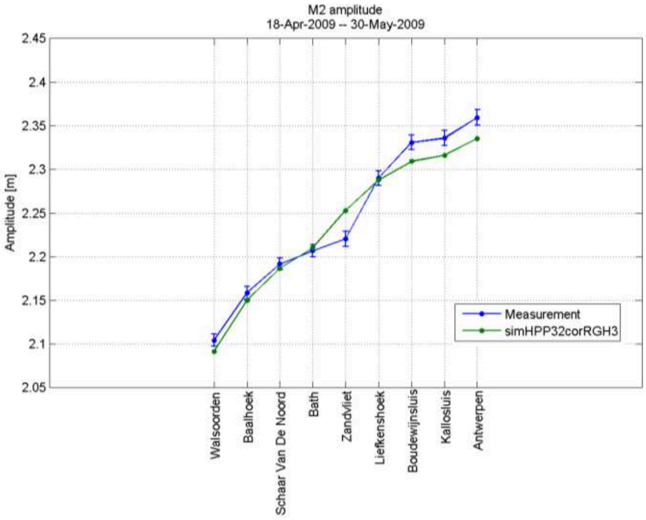

Figure 5. M2 amplitude

TABLE I. QUANTIFIED MODEL QUALITY ASSESSMENT

Parameter		Unit	Value
RMSE WL time series		cm	13
RMSE high water			11
RMSE low water			11
Bias WL time series			1
Bias high water			-2
Bias low water			0
RMSE high water phase		min	9
RMSE low water phase			10
RMSE velocity magnitude	Schaar van Ouden Doel	cm/s	15
	Zandvliet		14
	Galgenschoor		18
	langsraai O		17
	dwarsraai D		23
	DGD K raai 27/09		16
	DGD K raai 11/03		18
	Liefkenshoek		15
	Kallo		13
	Oosterweel		18

2) *ADCP velocities*

The results of comparison of the measured and calculated velocities are presented in table 1. The location of the transects is shown in Fig. 4. Fig. 6presents a vector plot of the modeled and measured velocities for one of the transects at Liefkenshoek.

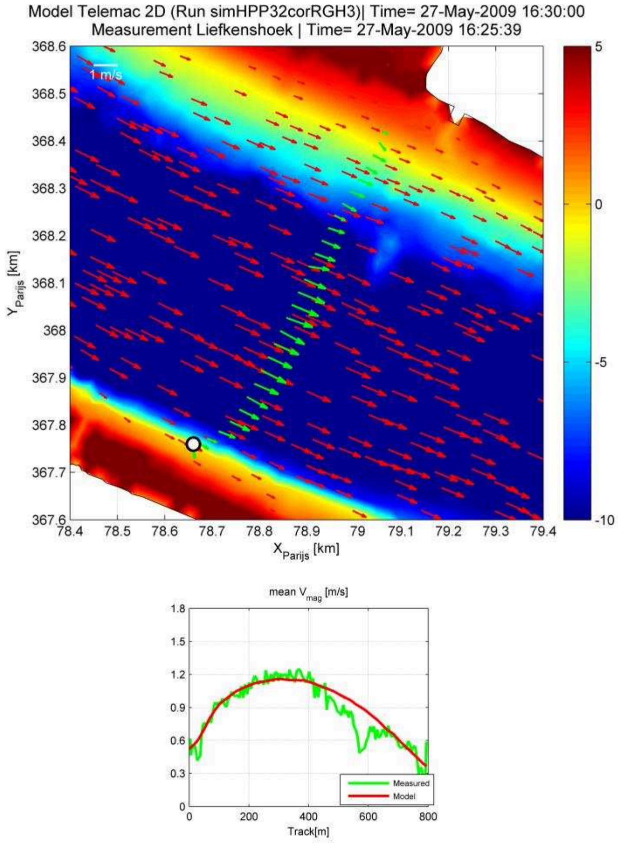

Figure 6. Vector plot of the modeled and measured velocities at Liefkenshoek (white circle on the figure shows the location of the first measurement (0 m))

The model accuracy is good at all the analyzed locations. The RMSE of the velocity magnitude varies between 0.13 m/s at Kallo and 0.23 m/s at dwarsraai D.

The velocity direction is represented accurately in the model for most transects. Big differences are observed around slack and in the locations where flow velocities are very low and flow directions are badly defined (for example, near the entrance to the Kallo lock). These differences affect the total RMSE values.

3) Discharges

Discharges are well represented in the model at most locations. They have the same shape as the measurements. The RMSE of the discharge time series is 5 to 10% of the maximum discharge at a certain location (e.g. Fig. 7). The model results and measurements are analyzed for the comparable tides. Differences between the calculations and measurements are expected when the agreement between the measured and modeled tides is not sufficient.

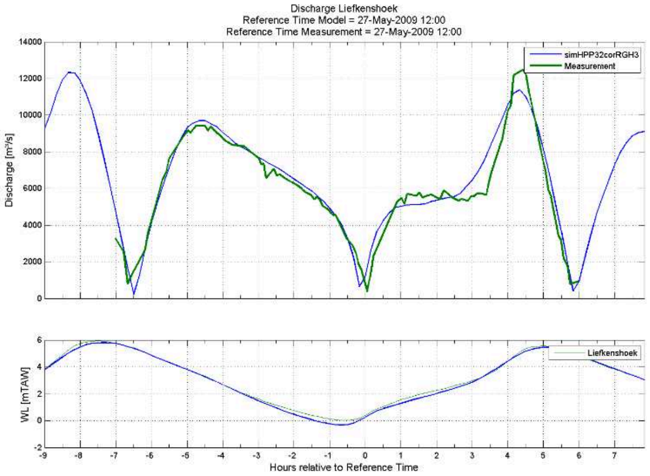

Figure 7. Discharge time series at Liefkenshoek

III. SCENARIO ANALYSIS

A. Introduction

The proposal for the development of the Hedwige-Prosperpolder is currently publicly available in a procedure of public consultation [3] (Rijksinpassingsplan, Fig. 8).

In the Rijksinpassingsplan a system of gullies and creeks is developed in the Hedwigepolder. This system is connected with the Scheldt estuary via two channels that should be excavated. Special attention is paid to the design of the creeks because they are important for a good drainage of the area. The hydrodynamics in the polder is studied based on the analysis of the water levels, water depth, velocities, discharges, bed shear stress and flood duration.

B. Implementation in the model

Simulation period used for the scenario analysis is shorter than the one used for calibration. Therefore, a finer grid resolution can be used in the study area (5 m). This is important for an accurate representation of the channels located in the polders. The total number of nodes in the grid used for the scenario analysis is about 378.000. The total number of the grid cells is about 752.000.

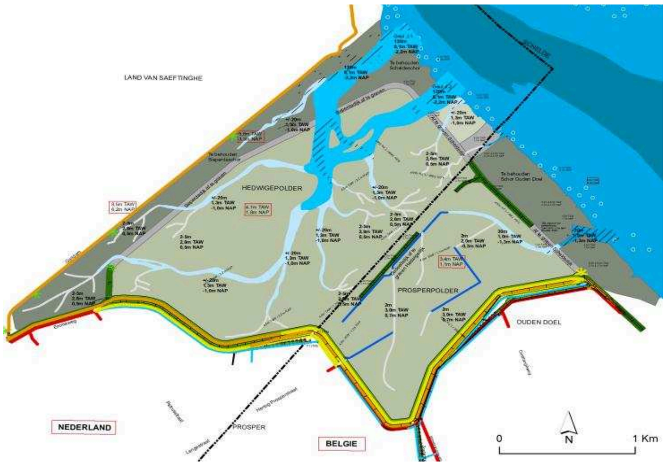

Figure 8. Rijksinpassingsplan

1) Bathymetry

First, a basis bathymetry is made (without channels and the excavation of the tidal marsh). This bathymetry is based on the most recent measurements of the Hedwige-Prosperpolder and the adjacent intertidal and subtidal areas and includes the dikes. Afterwards, a channel system is implemented according to the development plan by the linear interpolation between the elevation of the channel edges and the depth of the thalweg. This results in a channel network with triangular cross sections. The thalweg is located in the middle of the channels and the thalweg depths are given in the Rijksinpassingsplan. The elevation of the channel edges is based on the basis bathymetry [4].

The smallest creeks on the development plan (2 to 5 m) are not implemented in the bathymetry because they are smaller than the grid resolution of the model (5 m).

2) Bed roughness

A higher bed roughness (0.06 $m^{-1/3}s$) is defined for the tidal marshes located in the Hedwige and Prosperpolder. This value is chosen based on the estimation of vegetation in the area. The roughness of the river channel and of a deeper part of the polders is 0.021 $m^{-1/3}s$ (chosen during the calibration procedure).

3) Simulation period

The simulation period is chosen from 17/05/2009 00:00 to 27/05/2009 12:00. Three different tides are analysed: spring, average and neap.

C. Results

1) Flow velocities

The maximum velocities reach 1.2 to 1.4 m/s above the tidal marsh and more than 1.8 m/s in the channels and openings between the polders (**Erreur ! Source du renvoi introuvable.**). This flow can result in erosion, depending on the presence of hard soil layers which are insensitive or less sensitive to erosion.

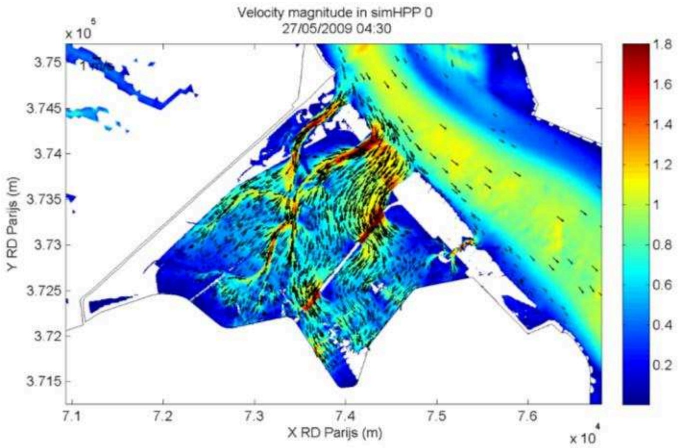

Figure 9. Flow velocities at max flood during spring tide (m/s)

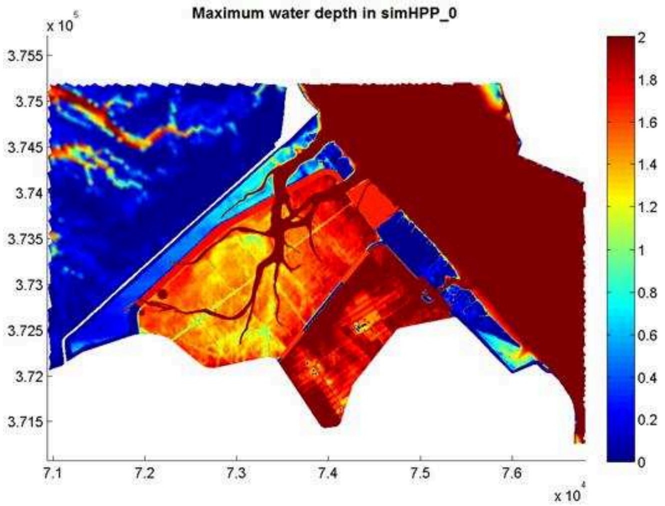

Figure 10. Maximum water depth during spring tide (m)

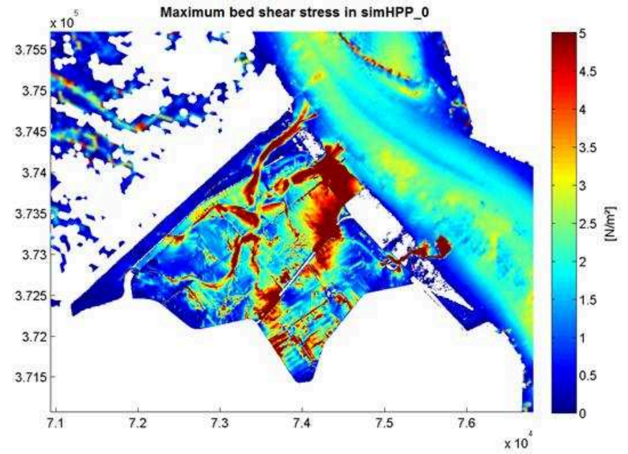

Figure 11. Maximum bed shear stress during spring tide (Pa)

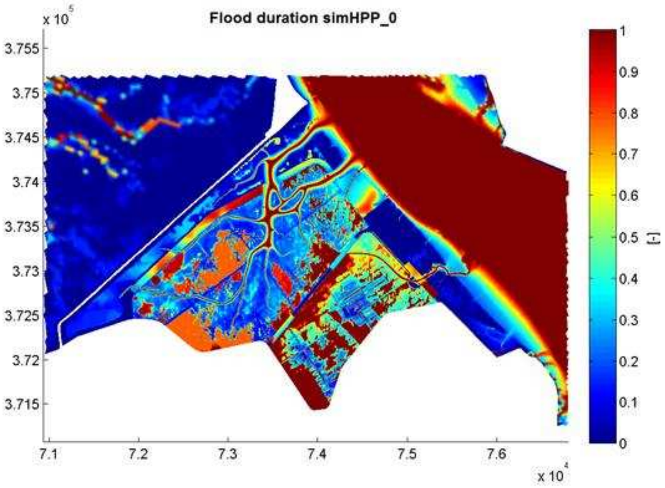

Figure 12. Flood duration (% of time wet)

2) Maximum water depth

The analysis of the maximum water depth shows that both polders get completely flooded (**Erreur ! Source du renvoi introuvable.**).

3) Bed shear stress

Maximum bed shear stress is higher than 5 N/m² in the channels and in the connections between the polders (**Erreur ! Source du renvoi introuvable.**). This can result in erosion in these zones. However, it is not possible to make conclusions about the morphodynamics based only on the analysis of the bed shear stress. Erosion and deposition will depend on the present sediment and velocity gradient.

4) Flood duration

Some zones in the Prosperpolder always stay inundated (40 to 60 cm minimum water depth), which indicates that the dewatering is insufficient there (**Erreur ! Source du renvoi introuvable.**).

Flood duration is an important parameter for the growth of vegetation in the area and for the development of the estuarine habitats. There is no fixed ecological criteria for the flood duration or height. Therefore, there is no straightforward solution for the optimization of the depoldering. Expert judgement is needed in an analysis of the model results in order to make any conclusions considering the estuarine habitats.

IV. CONCLUSIONS

A 2D TELEMAC model was developed for the Hedwige-Prosperpolder to study the hydrodynamics after depoldering. The use of an unstructured grid in TELEMAC allows for local grid refinement and results in an accurate representation of the gullies and creeks.

The model is calibrated based on the comparison of the calculated and measured water levels, velocities and discharges. The hydrodynamics in the polder is studied based on the analysis of the water levels, water depth, velocities, discharges, bed shear stress and flood duration. The model results can be analyzed with expert judgement to translate to possible vegetation growth and the development of estuarine habitats.

The calibrated TELEMAC model will be used by the University of Antwerp and NIOZ for further studies of the Hedwige-Prosperpolder.

REFERENCES

[1] T. Maximova, S. Ides, T. De Mulder, and F. Mostaert, (2009). Verbetering 2D randvoorwaardenmodel. Deelrapport 4: Extra aanpassingen Zeeschelde. WL Rapporten, 753_09. Flanders Hydraulics Research, Antwerp, Belgium

[2] T. Maximova, J. Vanlede, T. Verwaest, and F. Mostaert, (2014, in preparation). Inrichtingplan Hedwige-Prosperpolder: Subreport 1 – Numerical 2D model. WL Rapporten, 13_166. Flanders Hydraulics Research: Antwerp, Belgium

[3] Ministerie Economische Zaken en Ministerie Infrastructuur & Milieu (2013). Ontwerp-Inpassingsplan Hertogin Hedwigepolder

[4] W. Vandenbruwaene, S. Temmerman, J. Vanlede, T. Verwaest, and F. Mostaert, (2013). Ontwikkeling intergetijdengebied Hedwige- en Prosperpolder : Voorstel tot nadere dimensionering van het bressen- en krekenstelsel ten behoeve van definitieve inrichting, modellering, monitoring en uitvoering van het project. WL_Rapporten, 13_058. Waterbouwkundig Laboratorium & Universiteit Antwerpen: Antwerpen, België

[5] J. Vanlede, B. Primo, K. Delecluyse, B. Verheyen, G. Leyssen, Y. Plancke, T. Verwaest, and F. Mostaert, (2014, in preparation). Verbetering randvoorwaardenmodel: Deelrapport 7: Afregeling van het 3D Scheldemodel. WL Rapporten, 00_018. Flanders Hydraulics Research & IMDC: Antwerp, Belgium