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Vorgeschlagene Zitierweise/Suggested citation:
Knaapen, Michiel; Wertwijn, Cynthia (2013): Probabilistic Channel Infill Approach. In: Kopmann, Rebekka; Goll, Annalena (Hg.): XXth TELEMAC-MASCARET. User Conference 2013. Karlsruhe: Bundesanstalt für Wasserbau. S. 99-102.

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TUC 2013, 16-18/10/2013, Karlsruhe - Kopmann, Goll (eds.) - © 2013 Bundesanstalt für Wasserbau ISBN 978-3-939230-07-6

Probabilistic Channel Infill Approach

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Abstract—**The design of access channels aims to achieve a balance between the requirements for navigation and the need for both capital and maintenance dredging; these are essentially the key factors on which decisions are based, whilst considering the constraints posed by the site-specific environmental settings and legislation. Within the constraints of navigation requirements, channel and trench design can be optimized to minimize capital dredge volumes and the expected sedimentation and related costs of maintenance dredging. However, the infill of channels and trenches is highly stochastic, due to the large number of uncertainties in flow and wave forcing, sediment characteristics and the well-known limitations in sediment transport models. This paper describes an approach taking these uncertainties into account.**

I. INTRODUCTION

The infill of channels and trenches in practice is difficult to estimate. There is considerable uncertainty in the calculation of sediment transport and infill rates that are difficult to capture. As the costs of dredging in general are high, it is important to get the best infill predictions possible, taking these uncertainties into account. This is impossible using a single model. An ensemble of model simulations, however, does allow engineers to quantify the uncertainties and determine the most likely infill rates.

Bakker et al. [1] proposed a stochastic approach based on a highly simplified model for sediment transport. Such a simplified approach does account for all parameter uncertainties. However, by missing the fundamental physical processes of sediment transport, it also introduces additional uncertainties. To make the stochastic approach more accurate, it needs to be combined with a proper model to calculate sediment transport and morphological change.

Here, the stochastic approach with ensemble simulations is extended using a more advanced numerical model for channel and trench infill based on the TELEMAC modeling system [2], [3]. This model has achieved good agreement with observed channel infill over time in flume experiments.

To avoid large computation times, this model is used as a numerical flume simulating relatively small sections of a trench or channel. Further reduction in the computation time is achieved using a morphological speed-up factor. The model is then run with a large number of different settings for e.g. grain sizes, roughness, slope effects for a range of forcing conditions, using Monte Carlo techniques.

The structure of the paper is the following: Section II summarises the specific settings of the sediment transport model. Previous results are given in section III, showing the best model prediction and a sensitivity analysis into the effect of the grain size on the trench development. Section IV describes the parameter variations in the ensemble simulations. And section V then gives the results of this ensemble. Conclusions are drawn and discussed in section VI.

II. THE MODEL

TELEMAC is run in depth averaged mode, fully coupled to SISYPHE for sediment transport and uses wave results from TOMAWAC for wave stirring. The depth averaged sediment concentration is derived from the Soulsby-van Rijn formula [4]:

$$C_S = q_s (hU)^{-1}, \tag{1}$$

where q_s is the suspended load transport rate, h the water depth and U the depth average velocity. The erosion-deposition term is based on Miles [4]:

$$W_s\left(C_S - C\right)_{z=0} = W_s\left((1+2\tau^2)\mathrm{E}(\tau) - 2\tau\pi^{-\frac{1}{2}}e^{-\tau^2}\right)\left(C_S - C_0\right)_{z=0}, \tag{2}$$

with W_s the settling velocity of the sediment and C_s the saturated concentration just above the bed and C_0 the actual concentration above the bed. Finally, τ is a non-dimensional time.

The model has shown to accurately reproduce suspended sediment transport in the Thames, and the morphodynamic development trenches in flume experiments [2].

III. PREVIOUS RESULTS

A. *Best fit model*

Previous work showed that the coupled TELEMAC-SISYPHE model using default settings reproduces the infill measured during flume experiments by van Rijn [6] very well (Fig. 1).

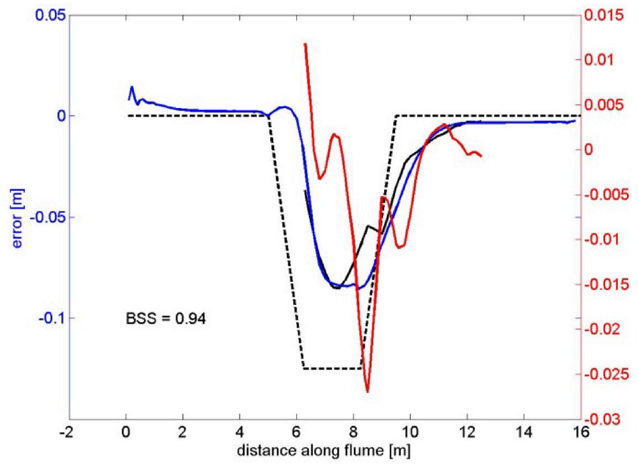

Figure 1. The morphodynamic model has an almost perfect fit with the flume experiments of van Rijn [5]. The black lines denote the initial (dashed) and final bathymetry measured in the experiments. The Blue line denotes the predicted bathymetry, while the red line (right axis) shows the difference between the measured and modelled levels.

The experiments were performed at Delft Hydraulics in a small flume with a length of 17 m, a width of 0.3 m and a depth of 0.5 m (Fig. 2). The channel had side slopes of 1 to 10 and a depth of 0.125 m. Sediment was used with D50 = 0.1 mm and D90 = 0.13 mm. To maintain equilibrium bed conditions away from the channel, 0.0167 kg/s/m sediment was fed into the flume at the inflow boundary. Regular waves with a period of 1.5 s and height of 0.08 m were generated and a steady current following the waves was imposed. The water depth was 0.255 m and the current velocity was 0.18 m/s.

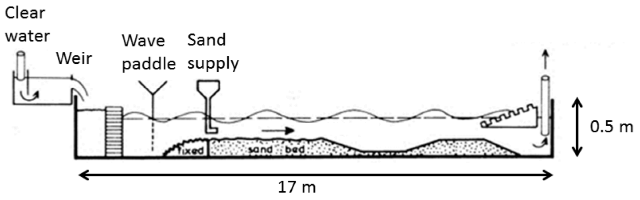

Figure 2. Cross profile of the measurement section of the flume (after [6]).

The difference between modelled and measured profiles is small. The maximum bed level error is still large, i.e. less than 25 mm on an observed bed change up to 50 mm, but this happens very locally. The Brier Skill score [7] is 0.94, where 1.0 denotes a perfect fit. The maximum error in the prediction is located at the upstream end of the trench, where some sediment appears to have slumped in the flume experiments. See [2] or [3] for more details.

B. Sensitivities to grain size

A sensitivity analysis showed that the dynamics of the trench change when varying the grains size. The analysis shows that the grain size has an influence on the infill rates. With a grain size of 0.3 mm, which would be the modelling grain size if the sediment scaled to best reproduce suspended load transport, the channel migrates a bit further, while the reduction in channel depth slightly increases as well (Fig. 3). However, with an even larger grain size (1 mm), the reduction in channel depth reduces compared to the best model (Fig. 4). The migration is about the same as with the 0.1 mm sediment, but the width of the channel is massively increased.

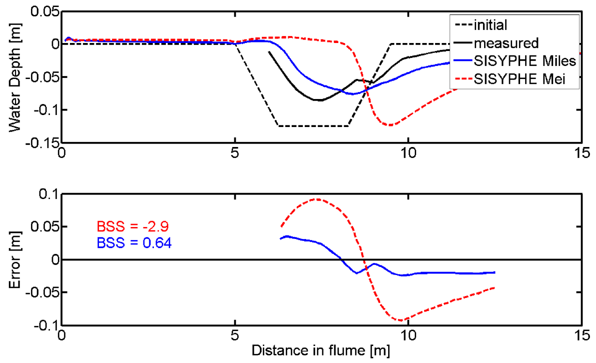

Figure 3. Prediction using 0.3mm sediment

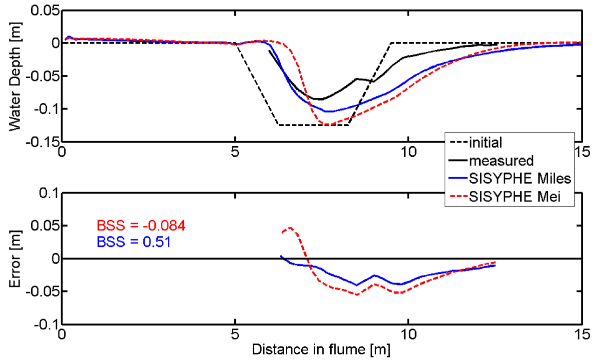

Figure 4. Prediction using 1mm sediment

IV. ENSEMBLE RUN

The findings of the sensitivity analysis show some non-linear behaviour as a function of the grain size used. To investigate further, an ensemble of simulations is derived. In principle, the same model is used as described above. However, as we are interested in practical applications, the model results are not scaled back to the flume scale. This results in a situation of a dredged trench with a depth of 1.25 m in a bottom below 2.5 m of water that flows at 0.56 m/s. Wave stirring is caused by 5 s waves 0.8 m high. The grain diameter is 0.1 mm.

The ensemble simulations introduce uncertainty around the default settings. The same model was run repeatedly with slightly different parameter setting. Assuming perfect hydrodynamics, sediment and bed characteristics are varied around the non-default parameters:

- Grain sizes (D50 and D90)
- Bed roughness
- Turbulent viscosity

All these parameter are varied assuming log normal distributions (see Fig. 5 to Fig. 8), a sensible choice for parameters with values close to zero. As a result, the right hand tails are larger than the left hand tails of the distribution. The peaks of the distributions coincide with the default settings used in the original model.

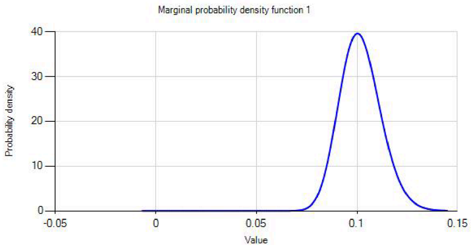

Figure 5. PDF of D_{50} in mm

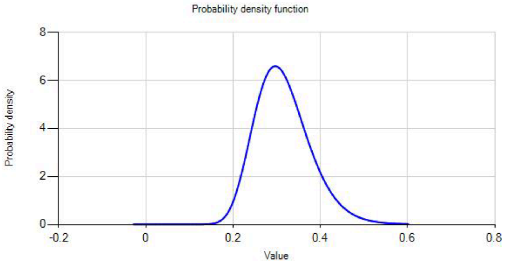

Figure 6. PDF of D_{90} in mm

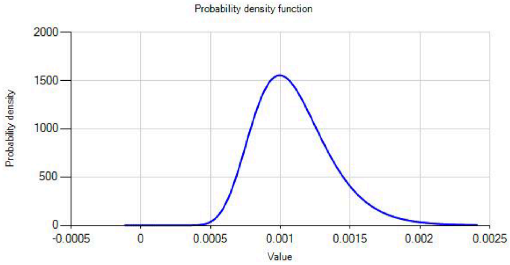

Figure 7. PDF of viscosity

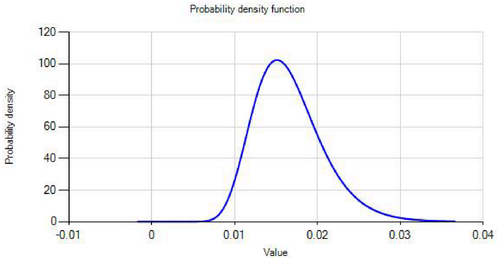

Figure 8. PDF of bed roughness length in m

An ensemble of 100 runs is created from these settings. These runs are compared to the reference run with the original model, with the default settings. To save time all runs were performed with a slightly larger time step, introducing additional model error, as the channel migrates further downstream. To compare the results, from the profiles the deepest point (referred to as depth) and the width of the area that is deeper than 0.75 m (referred to as width) are determined.

V. RESULTS

The results of the ensemble simulations are shown in Fig. 9. All simulations were stable and showed consistent dynamics of the bed. All predicted profiles are in a narrow margin around the profiles predicted using the default settings.

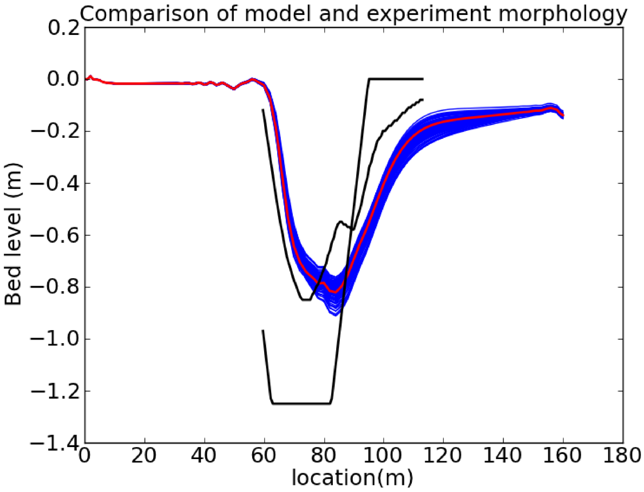

Figure 9. The ensemble of the resulting bed level profiles (blue) compared with the measured profile (initial and final) and the default prediction (red).

However, when looking at specific information the results are not all what they appear at first sight. In the case of a trench, the key elements in the channel profile are the maximum depth after a specific time and the width over which a specific depth is achieved. Fig. 10 and Fig. 11 show the histograms of the maximum depth and width with at least 0.75 m below the bed level.

The mean maximum depth in the trench is 0.82 m (Fig. 10), which is equal to the maximum depth below the surrounding bed predicted by the model with the default settings. The peak of the distribution is at 0.8 m, while the median value is 0.81 m.

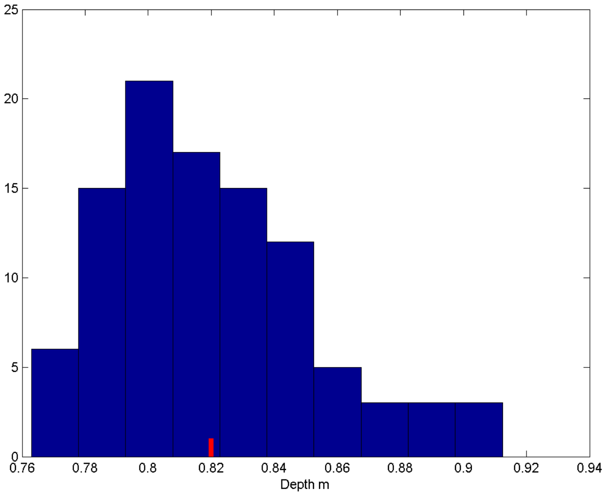

Figure 10. The histogram of the 100 resulting depth estimates at the end of the run shows that the most likely value does not coincide with the result of the default setting (red bar).

The distribution of the width over which a 0.75 m depth is achieved is given in Fig. 10. It shows a bimodal distribution, with peaks as 10 m and 12 m. Both the median and the mean are approximately 10m, which is also the peak of the distribution. All these values are 3 m less than the 13 m predicted by the model with the default settings.

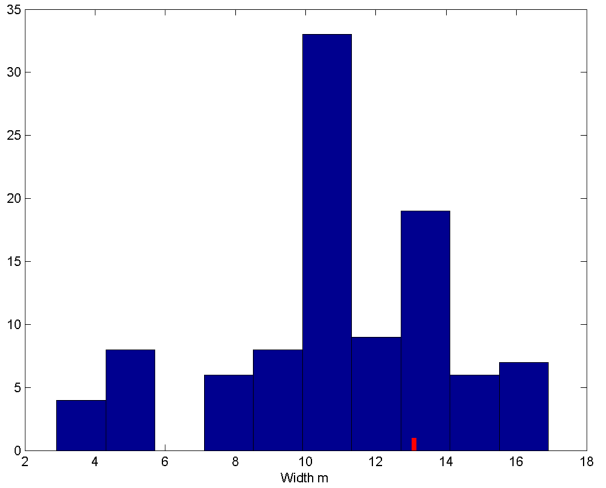

Figure 11. The histogram of the 100 resulting channel widths (defined as the width of the part that is deeper than 0.75 m). Again, this figure shows that the most likely value does not coincide with the result of the model with the default setting (red bar).

VI. CONCLUSIONS

A Monte Carlo approach is applied to quantify the uncertainties of infill in channels and trenches. The result is a statistical distribution that allows decision makers to take all natural uncertainties into account. The results using the most likely setting, which is using the default parameters for TELEMAC-SISYPHE, do neither match the mean expected change nor the most likely outcome. This is caused by the non-linearity of the distribution for the parameters and the nonlinearity of the equations. Therefore, the information regarding the uncertainties is likely to change the decisions regarding the dredging strategies.

In most practical applications there is less precise information on the sediment and bottom characteristics. In such a situation, the best settings will not necessarily produce the most likely result. Therefore, ensemble simulations will be necessary.

In this study, the focus has been on the impact of uncertainty in the sediment composition and bed structure. The uncertainty in flow, water levels and wave conditions has been ignored. However, in many cases these are the main uncertainties in the channel or trench infill. In the next phase of this research, the ensemble will be extended to include these factors.

Increasing the modelling time step to safe computation time, caused the channel to migrate further downstream, whereas the flow and initial sediment transport do not show any significant change with the larger time step.

VII. FUNDING

This work has been funded through HR Wallingford's Strategic Research Program.

REFERENCES

[1] Bakker, S.A., Winterwerp, J.C., Zuidgeest, M. (2010). "Uncertainty analysis of the mud infill of the Olokola LNG approach channel". PIANC MMX Congress Liverpool UK, 2010, p. 286.

[2] Knaapen, M.A.F., Kelly, D.M.." Modelling sediment transport with hysteresis effects". Proceedings TELEMAC & MASCARET User Club. La Rochelle. Proc. XVIIIth TELEMAC & MASCARET User Club, EDF Corporate University, Chatou France, 2011, pp. 22-27.

[3] Knaapen, M.A.F., Kelly, D.M.. "Lag effects in morphodynamic modelling of engineering impacts", Proceedings ICCE, Santander, 2012.

[4] Soulsby, R. "Dynamics of Marine Sands," Thomas Telford. London, 1997.

[5] Miles, G. V. "Sediment transport models for estuaries", Hydraulics Research Station Wallingford, Wallingford, 1981.

[6] Van Rijn L. C. "Sedimentation of dredged channels by currents and waves", Journal of Waterway, Port, Coastal and Ocean Engineering, ASCE. Vol. 112, 5, 1986.

[7] J. Sutherland, D.J.R. Walstra, T.J. Chesher, L.C. van Rijn, and H.N. Southgate (2001). "Evaluation of coastal area modelling systems at an estuary mouth", Coastal Engineering", 2004, pp.119-142.