Supplement to "Main channel width effects on overtopping-induced non-cohesive fluvial dike breaching"
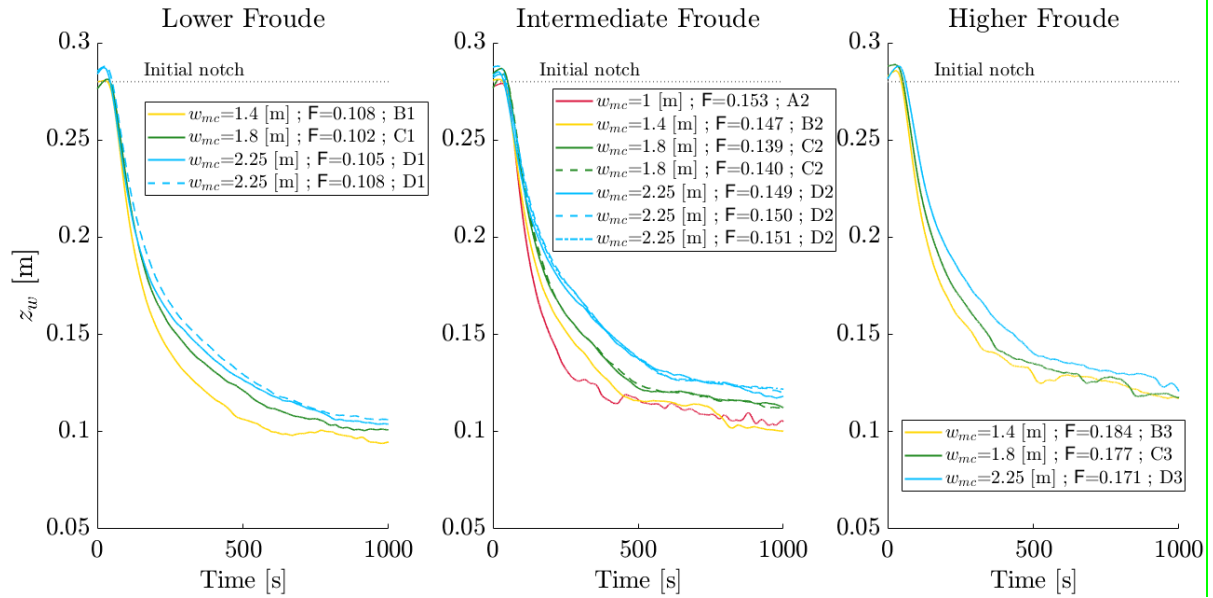

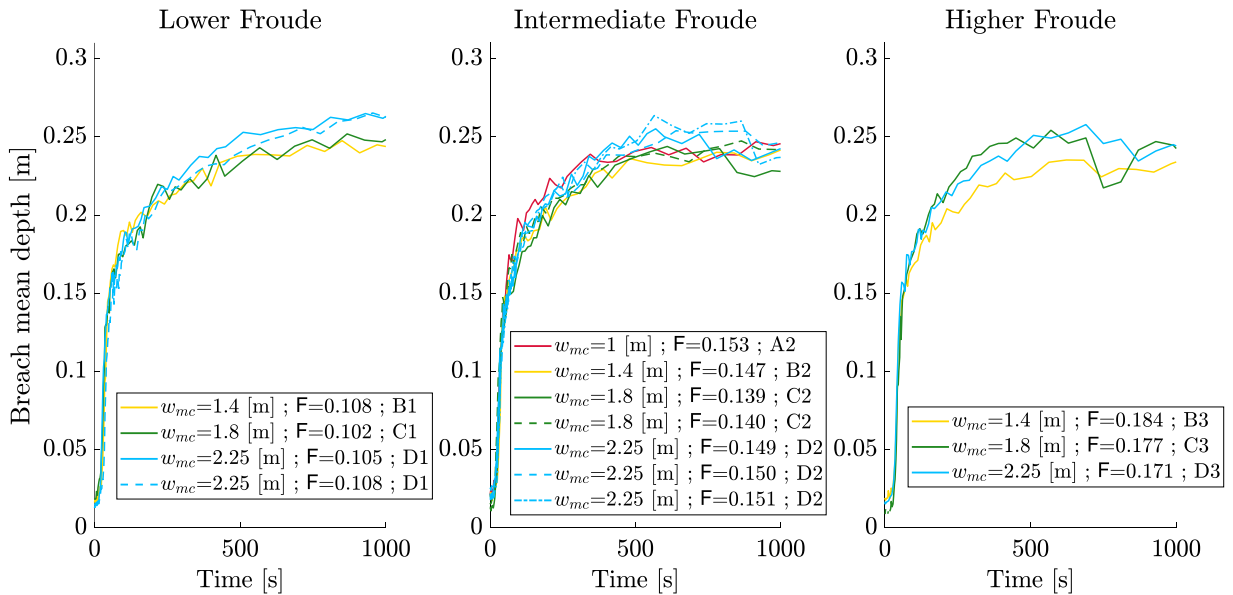Figure S1 Water level evolution in main channel. Origin of time corresponds to start of Stage 1.

Figure S2 Breach mean depth evolution. The breach mean depth is defined as the ratio between the breach area and the maximum breach width, both computed along the dike crest centre line.
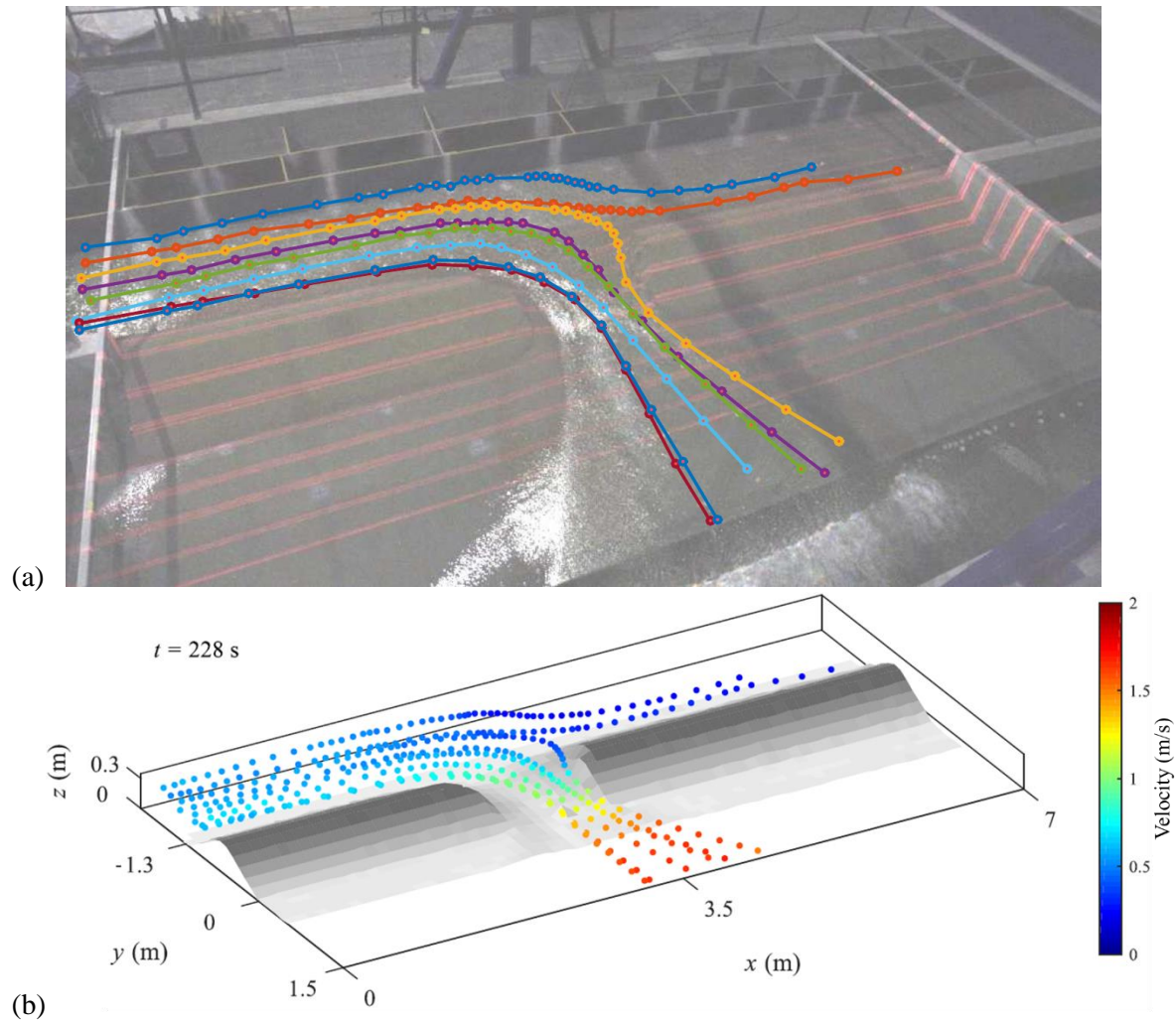
(a)

(b)

Figure S3 Laboratory Test B2. (a) Float positions and (b) associated velocity 228 s after beginning of breaching obtained using LPT.

Flow chart

Decision: $z_s > z_b$ — Yes / No

$$\frac{dz_s}{dt} = \left[Q_{in} - Q_b - Q_{out}(z_s)\right]\frac{1}{A_r}$$

Q_b

$$Q_{out} = f(z_s)$$

Breach discharge

$$Q_b = 0$$

$$m = \frac{1}{\tan\varphi_r}$$

$$Q_b = c_1\, b_{\text{top}}\, (z_s - z_b)^{3/2} + c_2\, m\, (z_s - z_b)^{5/2}$$

Water level above each reach

Flat top reach

$$h_{\text{top}} = \frac{2}{3}(z_s - z_b)$$

Downstream (D/S) reach

$$Q_b = \frac{1}{n} A_h R_h^{2/3} S_d^{1/2}$$

$Q_b, h_{\text{top}}, h_{\text{D/S}}, n$
A_h, R_h

$$\tau_b = \frac{\rho g n^2 Q_b^2}{A_h^2 R_h^{1/3}}$$

Q_b

A_h, R_h

if $z_b > 0$: $A_h = f_1(b_{\text{D/S}})$ and $R_h = f_2(b_{\text{D/S}})$
else : $A_h = f_1(b_{\text{eff\%}} b_{\text{D/S}})$ and $R_h = f_2(b_{\text{eff\%}} b_{\text{D/S}})$

Legend

State variables
Input variables
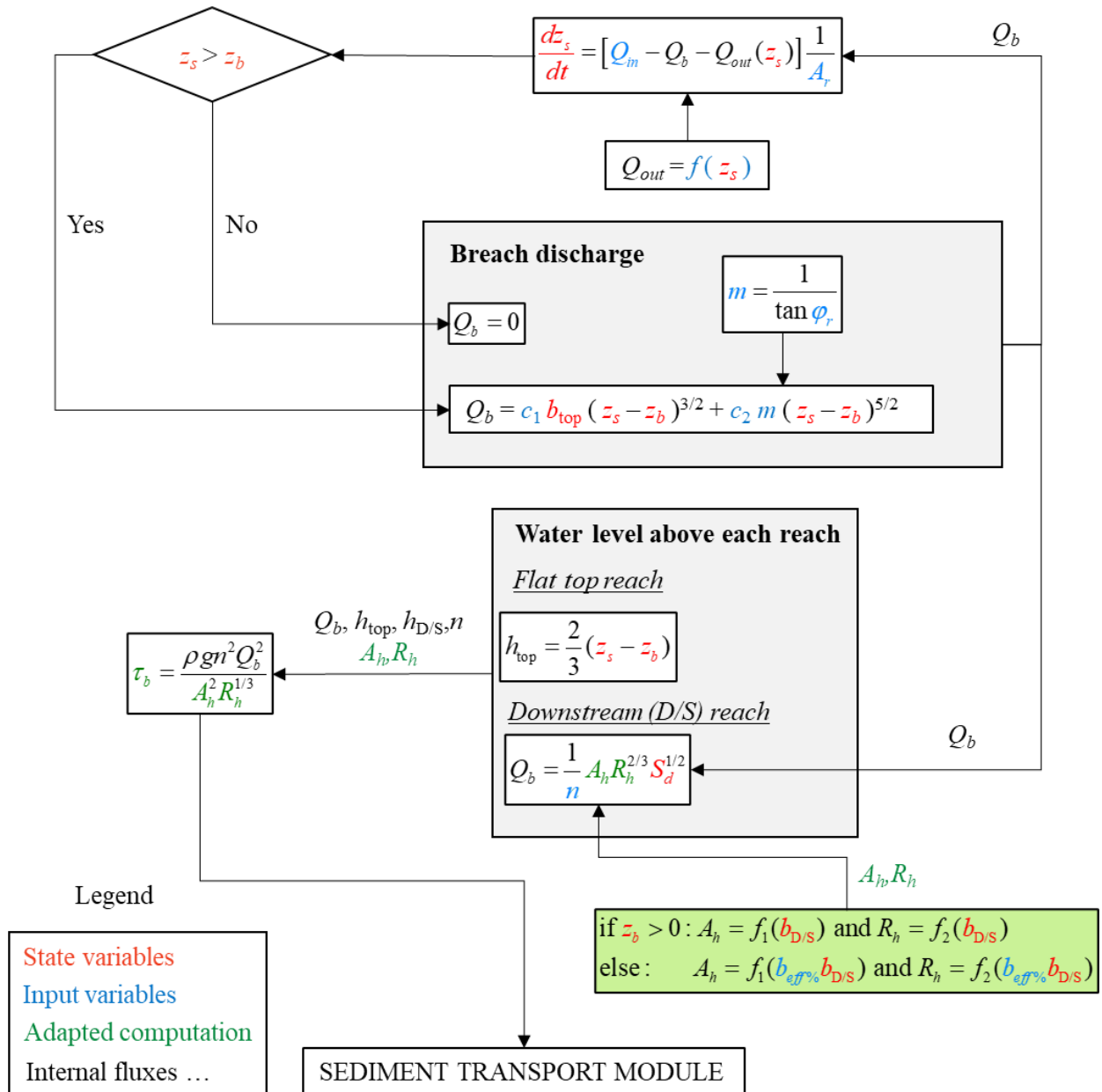Adapted computation
Internal fluxes …

SEDIMENT TRANSPORT MODULE

Figure S4 Flow chart of the hydrodynamic module of the numerical model. Green variables are computed using a different approach as the one used in DLBreach (Wu, 2013).
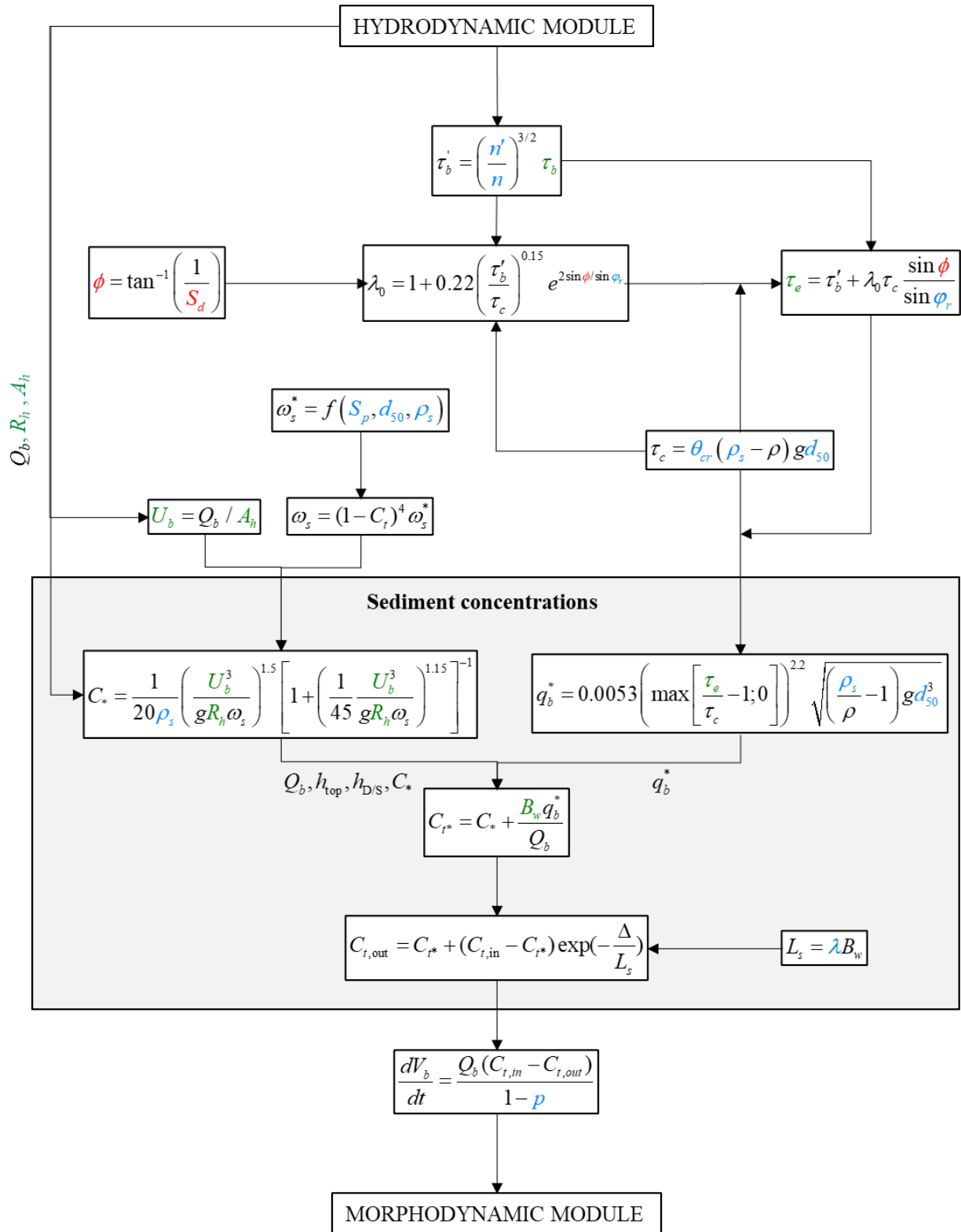
HYDRODYNAMIC MODULE

$$\tau_b' = \left(\frac{n'}{n}\right)^{3/2} \tau_b$$

$$\phi = \tan^{-1}\left(\frac{1}{S_d}\right)$$

$$\lambda_0 = 1 + 0.22\left(\frac{\tau_b'}{\tau_c}\right)^{0.15} e^{2\sin\phi/\sin\varphi_r}$$

$$\tau_e = \tau_b' + \lambda_0 \tau_c \frac{\sin\phi}{\sin\varphi_r}$$

$$\omega_s^* = f\left(S_p, d_{50}, \rho_s\right)$$

$$\tau_c = \theta_{cr}\left(\rho_s - \rho\right) g d_{50}$$

Q_b, R_h, A_h

$$U_b = Q_b / A_h$$

$$\omega_s = (1 - C_t)^4 \omega_s^*$$

Sediment concentrations

$$C_* = \frac{1}{20\rho_s}\left(\frac{U_b^3}{gR_h\omega_s}\right)^{1.5}\left[1 + \left(\frac{1}{45}\frac{U_b^3}{gR_h\omega_s}\right)^{1.15}\right]^{-1}$$

$$q_b^* = 0.0053\left(\max\left[\frac{\tau_e}{\tau_c} - 1; 0\right]\right)^{2.2}\sqrt{\left(\frac{\rho_s}{\rho} - 1\right)gd_{50}^3}$$

$Q_b, h_{\text{top}}, h_{\text{D/S}}, C_*$

q_b^*

$$C_{t*} = C_* + \frac{B_w q_b^*}{Q_b}$$

$$C_{t,\text{out}} = C_{t*} + (C_{t,\text{in}} - C_{t*})\exp(-\frac{\Delta}{L_s})$$

$$L_s = \lambda B_w$$

$$\frac{dV_b}{dt} = \frac{Q_b(C_{t,in} - C_{t,out})}{1 - p}$$

MORPHODYNAMIC MODULE

Figure S5 Flow chart of the sediment transport module.

SEDIMENT TRANSPORT MODULE

$$c_b = \min\left[1, \max\left(0, 1.8\frac{b_{top}}{b_{D/S}} - 0.8\right)\right]$$

$$\frac{dz_b}{dt} = \frac{1}{A_{e,tot}}\frac{dV_b}{dt}$$

$$A_{e,tot} = A_{bottom} + 2A_{side}$$

Breach width variation

Flat top reach

$$\frac{db_{top}}{dt} = 2\frac{dz_b}{dt}\left(\frac{1}{\sin\varphi_r} - \frac{1}{\tan\varphi_r}\right)$$

$$\frac{dB_{top}}{dt} = \frac{2}{\sin\varphi_r}\frac{dz_b}{dt}$$

D/S reach

$$\frac{db_{D/S}}{dt} = 2\frac{dz_b}{dt}\left(\frac{\max(c_b, \cos\varphi_r)}{\sin\varphi_r} - \frac{1}{\tan\varphi_r}\right)$$

$$\frac{dB_{D/S}}{dt} = \frac{2c_b}{\sin\varphi_r}\frac{dz_b}{dt}$$

Update of geometrical variables
$$\left(z_b, S_d, b_{top}, b_{D/S}\right)$$

HYDRODYNAMIC MODULE
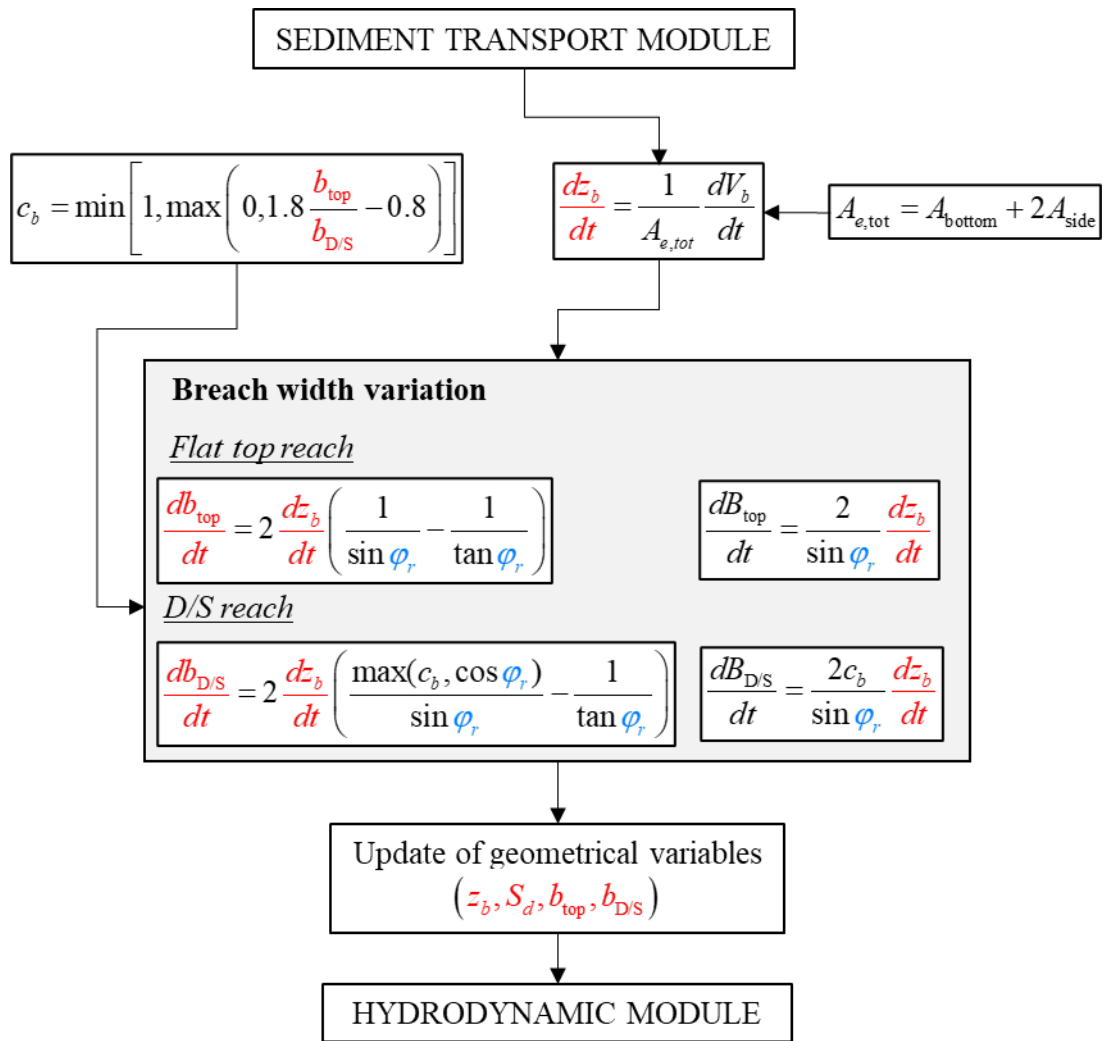
Figure S6 Flow chart of the morphodynamic module.

Table S1 Summary of parameters involved in the numerical model.

|	Symbol	Description
State variables	z_s, z_b	Level of the main channel free surface and breach bottom, respectively
	S_d	Downstream slopes of the dam
	$b_{top}, b_{D/S}$	Breach bottom width on the flat top reach and downstream reach, respectively
Input variables	Q_{in}, A_r	Inflow discharge and free surface area of the main channel
	$\rho_s, d_{50}, \varphi_r$	Sediment density, median grain size and repose angle
	c_1, c_2	Weir efficiency coefficients
	n, n'	n and n' total and effective Manning's coefficients, respectively
	$b_{eff\%}$	Effective fraction of the total breach width
	S_p	Corey shape factor
	θ_{cr}	Critical Shields parameter
	λ	Empirical coefficient involved in mixing length computation
	p	Dam material porosity
Output variables	Q_b, Q_{out}	Breach and outflow discharges, respectively
	A_h, R_h	Breach wetted area and hydraulic radius, respectively
	τ_b, τ_e, τ_c	Breach shear stress, effective breach shear stress and critical shear stress
	U_b, ω_s^*	Water velocity through the breach and sediment settling velocity
	C_*, q_b^*	Suspended load and bed load sediment transport capacities
	B_w	Width of the water free surface over the effective breach section
	$C_{t*}, C_{t,in}, C_{t,out}$	Sediment concentration at equilibrium, at the reach inlet and at the reach outlet
	Δ, L_s	Reach length and mixing length
	$V_b, A_{e,tot}$	Eroded sediment volume and erodible area of the breach
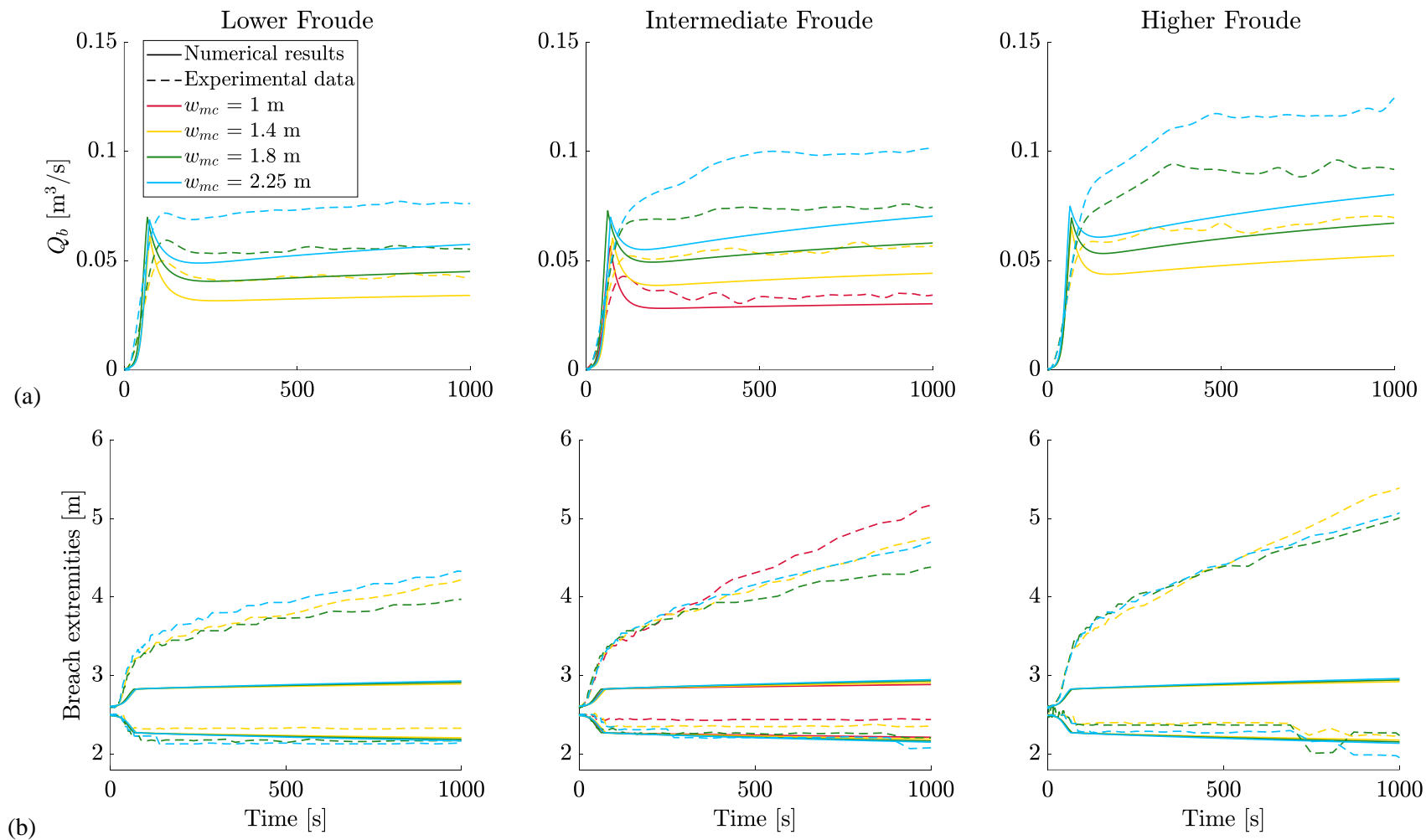
Figure S7 Comparison between results obtained experimentally and numerically with the dam breaching model (Wu, 2013), i.e., original model: (a) breach hydrographs; (b) position of the breach extremities.
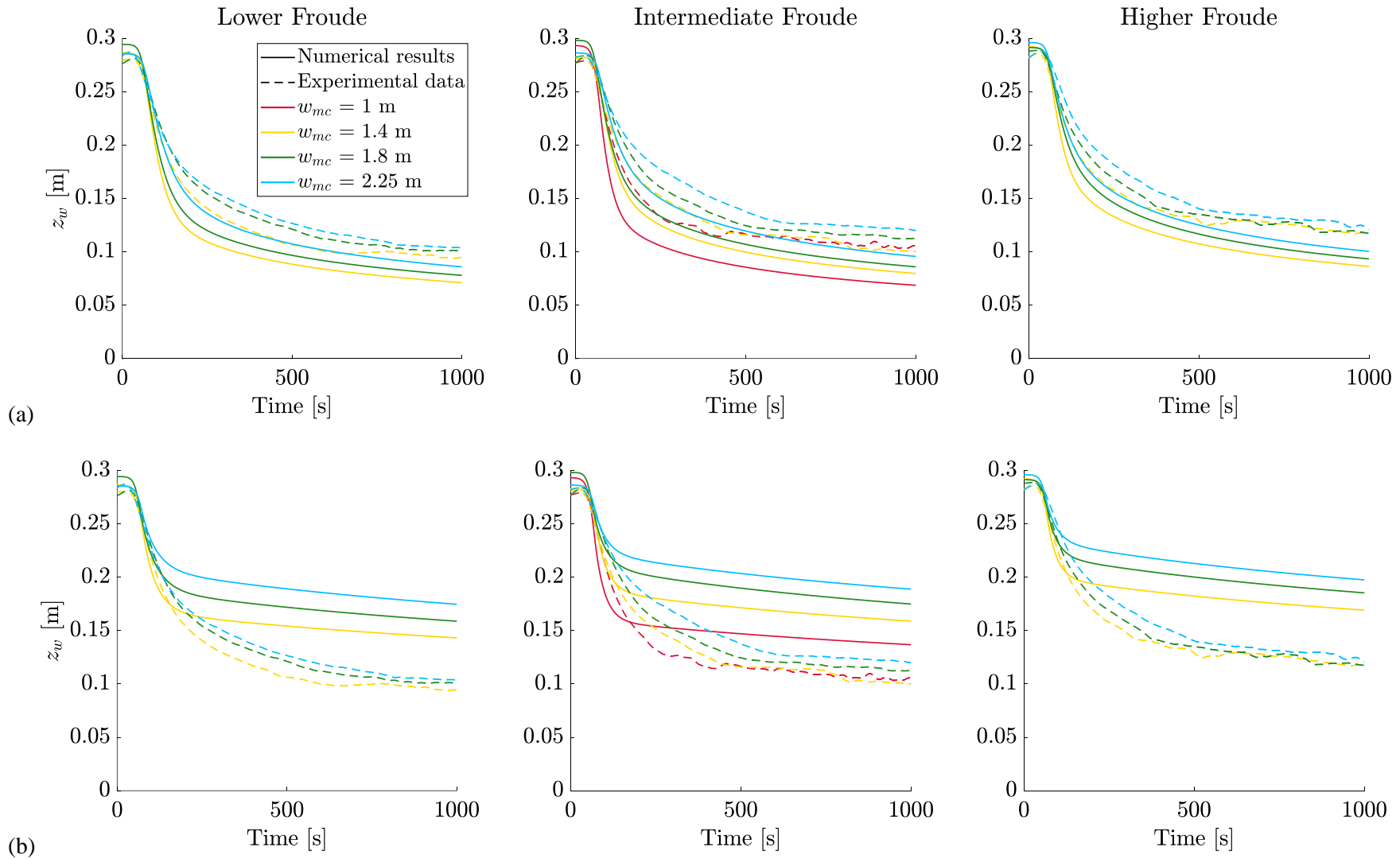
Figure S8 Evolution of the mean water level in the main channel obtained experimentally and numerically: (a) with the dike model; (b) with the dam model.