## 3. Fluid mud(2-layer approach) (Wang Z.B. and Winterwerp, 1992)

This feature (beta functionality) concerns the simulation of a fluid mud layer together with an overlying suspension layer using the 3D sediment transport.

Fluid mud layers may be formed from deposition of sediment from the water column. Once formed, the fluid mud layer may be forced to flow by gravity or shear stresses induced by the overlying water. If shear stresses are high enough, material from the mud layer may be entrained into the water column. When the flow in the mud layer is sufficiently high, the mud layer may erode the consolidated bed. Material thus eroded contributes to the fluid mud layer. When the fluid mud layer is at rest, the fluid mud layer is subjected to consolidation. The processes described above, are depicted in Figure B.12.



Winterwerp, J. C., Z. B. Wang, J. A. T. M. van Kester and F. J. Verweij, 1999. “On the far-field impact of Water Injection Dredging.” J. Waterway, Port, Coastal and Ocean Engineering

### 3.1 Two-layer system

The system of a suspension layer and a fluid mud layer is considered as a two layer system. A suspension layer is driven by tidal forces and possibly by wind shear stresses. Sediment may be transferred from the bottom to the fluid mud layer by erosion and the other way around by consolidation and sediment may be transferred from the fluid mud layer to the suspension layer by means of entrainment and the other way around by deposition.

### 3.2 Suspension layer

It is assumed that the velocities in the suspension layer are much larger than the velocities in the fluid mud layer. In addition it is assumed that the thickness of the fluid mud layer is negligible compared to the thickness of the water layer. Consequently, the fluid mud layer is therefore assumed not to influence the suspension layer hydrodynamically. For the present system, the bed roughness is also independent of the presence of the fluid mud layer. The fluid mud layer acts as a sediment source or sink for the suspension layer.

### 3.3 Fluid mud layer

The fluid mud flow is assumed to be driven by the shear stresses acting in the interface of suspension layer and fluid mud. The non-Newtonian rheological properties of the fluid mud layer are accounted for by the formulation of the shear stresses in the interfaces of suspension and fluid mud layer, and of fluid mud layer and the consolidated bed, if the fluid mud layer is modeled as 2DH problem.

The shear stresses in the fluid mud-water interface depend on the velocity difference between the two layers using a material specific friction coefficient. The shear stresses in the bed-fluid mud layer depend on the speed of the fluid mud flow, again using a material specific friction coefficient and a Bingham yield stress. Sediment is transported from the bed to the fluid mud layer, to the suspension layer and vice versa. The density of the fluid mud layer is assumed to be constant, as is the density of the consolidated bed. In the present formulations, the thickness of the consolidated bed is assumed not to change with time. Furthermore, the mud bed is assumed to be an infinite source of mud.

### 3.4 Mathematical modeling of fluid mud layer

The mathematical model for the fluid mud layer is given by Wang and Winterwerp (1992). Herein only a concise description is provided. The mass balance reads:



Where *t* is time, *x* and *y* are spatial coordinates, *dm* is the thickness of the fluid mud layer, *um* and *vm* are the speed of fluid mud layer in *x*-direction and *y*-direction, respectively. *cm* the (constant) sediment concentration in the mud layer(kg/m3), the right-hand term in Eq. B14 represents the source term in the mass balance.

The equations of motion for both directions read:





The shear stresses are given by:





The sediment exchange rate between the suspension layer and the fluid mud layer includes:

* Settling
* entrainment

and between the fluid mud layer and the (consolidated) bed:

* erosion
* consolidation, when the fluid mud layer is at rest (um = vm = 0).

The source term in the mass balance equation B.14 is given by:



The settling term is given by:



The entrainment term is given by Winterwerp et al. (1999)



The erosion term is given by:



The dewatering term is given by:



浮泥层为平面2D求解。

### 3.5 Applying fluid mud

The same code can be applied to both the suspension layer (possibly in 3D) and the fluid mud layer (only 2DH).

A simulation of a fluid mud problem requires the execution of two modules, one for the suspension layer and one for the fluid mud layer.



**Figure B.13:** A schematic representation of two Delft3D-FLOW modules running simultaneously simulating a fluid mud problem