Analyses of the fluxes of water, sediment, nutrients and metals, after restoration of the tidal regime of a former polder in the River Rhine estuarine, part of The Netherlands*.

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Location of "Mariapolder"

Problem/objective

For storm surge control estuaries in the Southwest of The Netherlands has been dammed. By that activity inland tidal fresh water tidal wetlands (FTW) has been disconnected from the typical tidal dynamics. These areas lost their specific and rare values of biodiversity. For purposes of restoration of FTW dams and dykes will be reopened allowing estuarine water flowing in and out again.

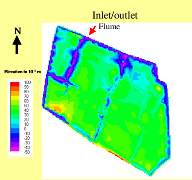
The **problems**, which go together with tide restoration, are the unknown effects of new tidal currents (erosion), of sedimentation rates and of the influx of metals adsorbed to suspended sediments, dissolved nutrients and toxic materials. These processes and fluxes may frustrate the targets of restoration of FTW.

The **objective** of this research was to quantify the rates of erosion and sedimentation and to calculate the balances of nutrients and heavy metals from flux measurements

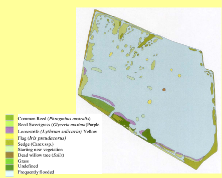
The "**Mariapolder**" (25 ha), which was managed as grassland since 1904, appeared to be an excellent **experimental site** for this purpose. By reopening in of a sluice in the dam around the Mariapolder in 1994, the fresh water tidal dynamics returned. Except for the inlet/outlet opening the Mariapolder is isolated from surrounding water by a dyke and from groundwater by a 2m thick layer of heavy clay with very low permeability. The fresh water (with sediments, pollutants) entering the Mariapolder originate from River Rhine. Following restoration, the **tidal range** within the polder has varied between 0.6 and 0.8 m at the inlet and tidal velocity as high as 4 m^3/s have been measured at the same site during incoming tides. Within the restored area, tidal water level amplitude has varied between 0.4 and 0.5 m.

Methods

Automated water level recorders have been used to estimate water fluxes into and from the Mariapolder over 48-hour study periods. From physical and chemical analyses of water collected during the 48-hour periods, balances of suspended sediments, dissolved nutrients, and metals were calculated.



Elevation map of the Mariapolder. Survey of 1998



Vegetation map of the Mariapolder (2001)

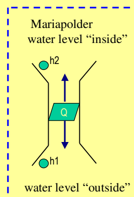
Q-h relation

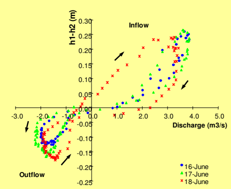
Formula of Q-h relation in hydraulic construction:

$$Q = C * \Delta h^{u} \quad (m^3 s^{-1})$$

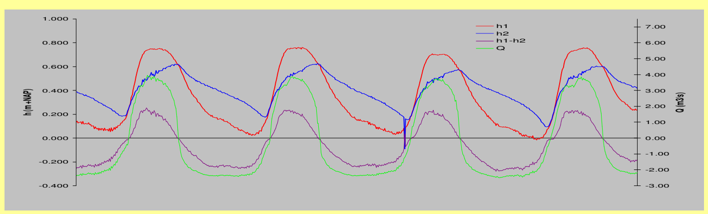
$$\log(\Delta h) = 1/u * \log(Q) - 1/u * \log(C)$$

- h1, h2 pressure sensor: logged at 5 minute intervals
- C and u are determined empirically
- Simultaneously measurement of Q and Δh (3 tide waves)
- Q calculated from measured flow rates at 10-minute intervals



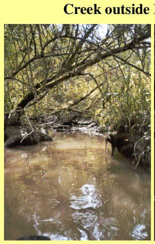


Relation between discharge and the differences between upstream and downstream water levels (dh)



Water level and discharge variation during 48 hr. in June 1998. msl: mean sea level; h1: water level outside Mariapolder; h2: water level inside Mariapolder near the flume; h in m +msl; Q: calculated discharge in m^3s^{-1}

Creek outside Mariapolder

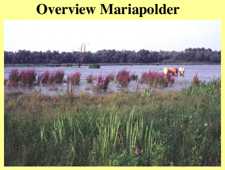


East of inlet/outlet

West of inlet/outlet

Overview Mariapolder

view from SW



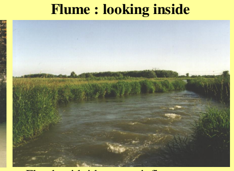
view from SE

view from NW, near inlet/outlet

Flume: looking outside

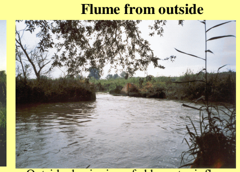
Ebb, nearly low tide: water outflow

Flume : looking inside



Flood, mid tide: water inflow

Flume from outside



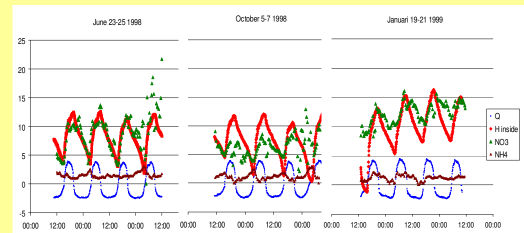
Outside: beginning of ebb; water inflow

Results

There has been a consistent net flux of suspended sediments into the Mariapolder leading to an average raise of 1 - 2 mm/y in surface elevation.

The Mariapolder appears to be a net yearly **sink for nitrate-nitrogen** and a net exporter of some dissolved metals. The mechanisms that control the sink-source dynamics are not yet fully understood and need further investigation.

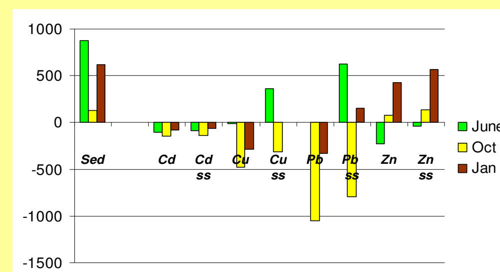
Following restoration, most of the agricultural grassland vegetation has disappeared and pioneer vegetation typical of TFW has developed within the Mariapolder.



Water level, discharge, nitrate and ammonium concentrations during field campaigns. Q: discharge in m3s-1, negative discharges: flow out of the Mariapolder, positive discharge: flow into the Mariapolder, H inside: water level inside the Mariapolder near the inlet in 20*h with h in m. above mean sea level, nitrate in mol$[NO_3^-\text{-N}]m^{-3}$, ammonium in $10*mol[NH_4^+\text{-N}]m^{-3}$, time in hrs.

	suspended sediment	nutrients		
		NH_4^+	NO_3^-	PO_4^{3-}
Jun-98	872	-2.1	66.4	0.7
Oct-98	125	-1.8	-85.9	1.9
Jan-99	619	3	163.3	2.8

Balances of suspended sediment and nutrients per tide cycle (units in kg/tide). Negative values means net flux leaving the polder is greater then the entering flux



Tidal cycle balances of suspended sediment and of four heavy metals. Sed: suspended sediment in kg (dry matter), ss: balance mass includes dissolved and absorbed species in g, mass of Zn & Zn ss in 10g