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Deltares
Enabling Delta Life

# Building towards a conceptual model for phosphorus transport in lowland catchments

## Biogeochemical and hydrological controls on P retention

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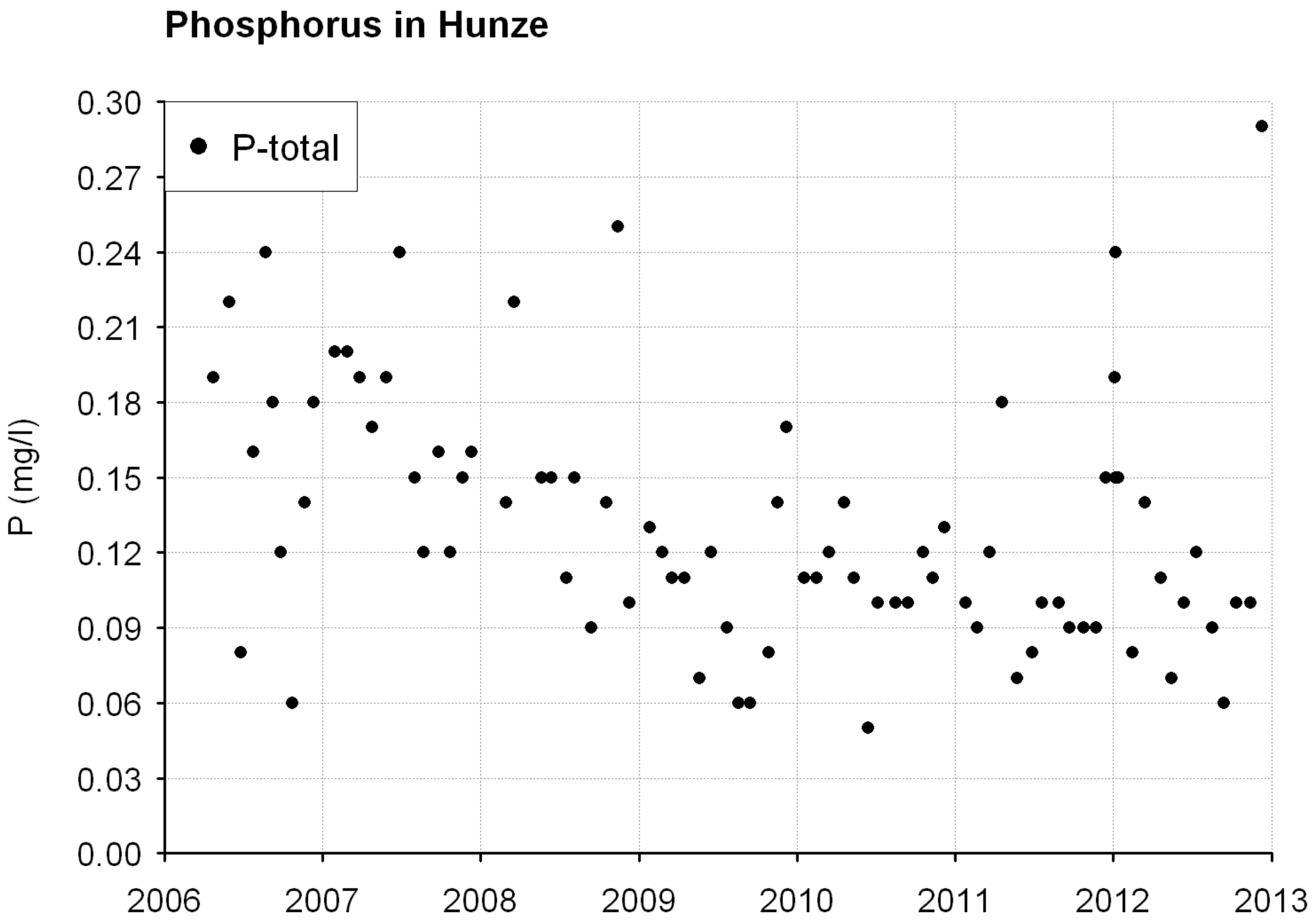
26 oktober 2015

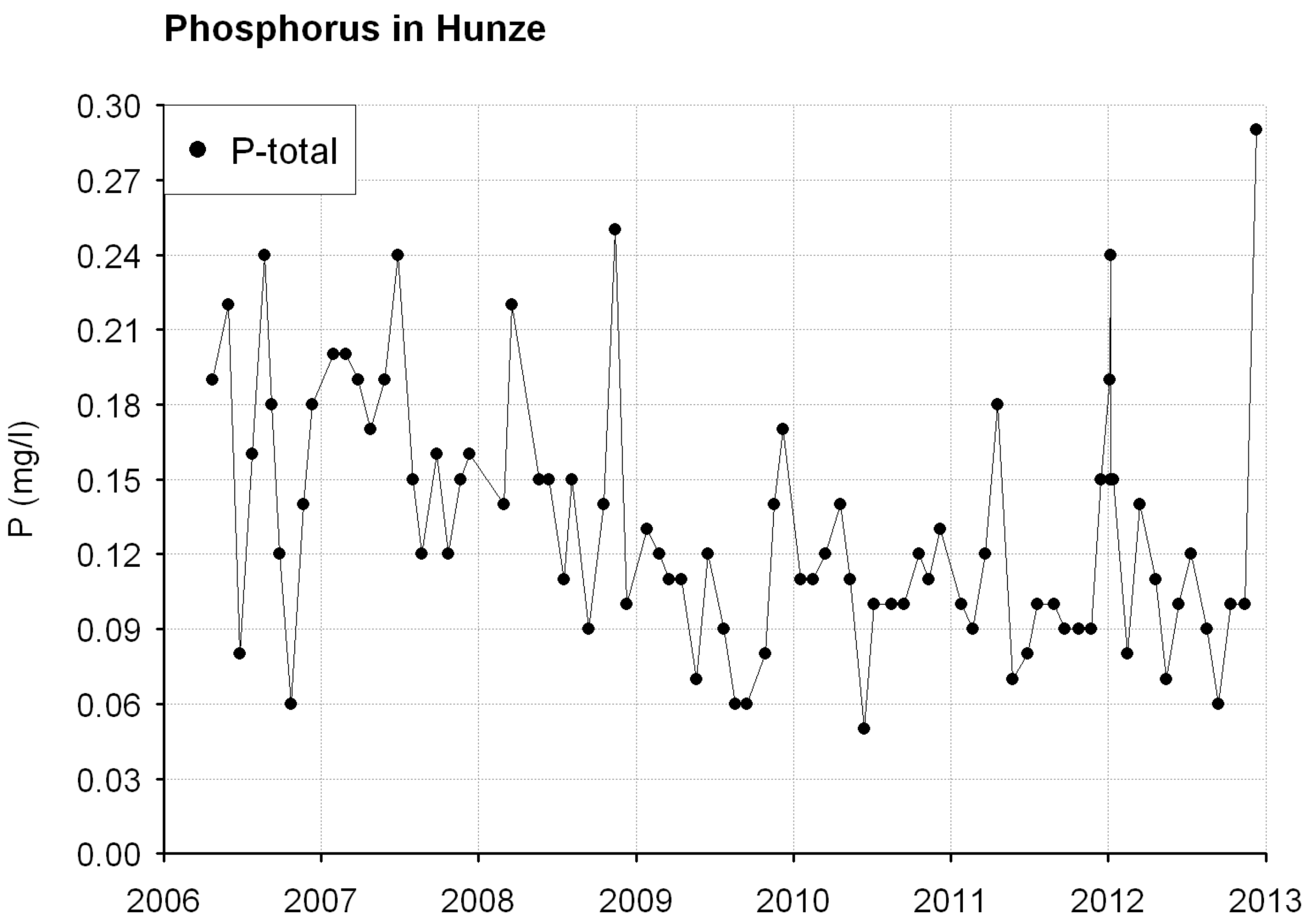
# Phosphorus in surface water


Phosphorus in Hunze

P-total in unfiltered samples:
common practice in surface water monitoring

Data WSHA

# Phosphorus in surface water

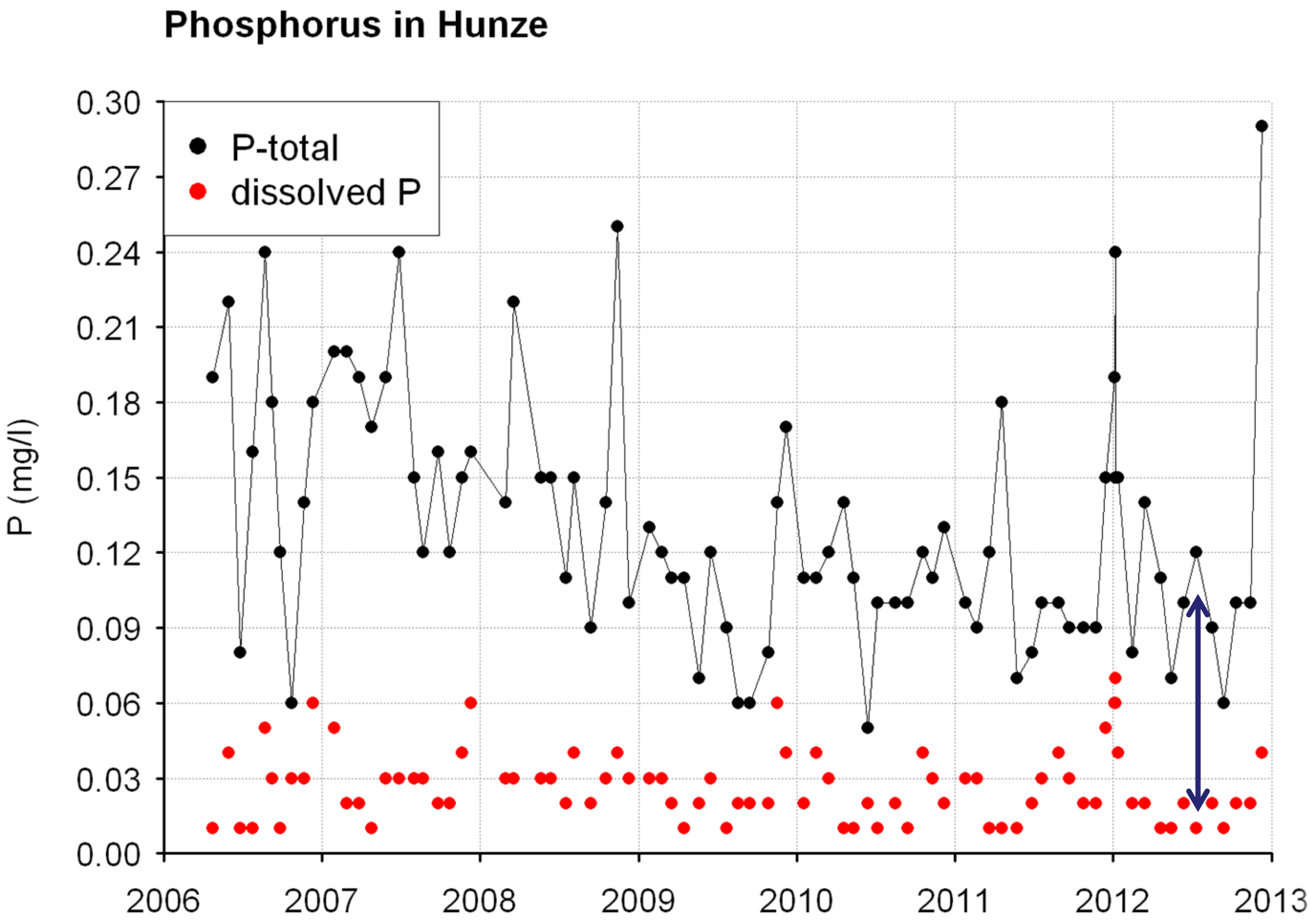


Observation 1:

variable in time

Data WSHA

# Phosphorus in surface water



Observation 2:

low dissolved concentrations

Particulate P
- inorganic P?
- organic P?

Data WSHA

Chemical and biological properties?
Transport mechanisms?

# P speciation in surface water: samping in three areas:

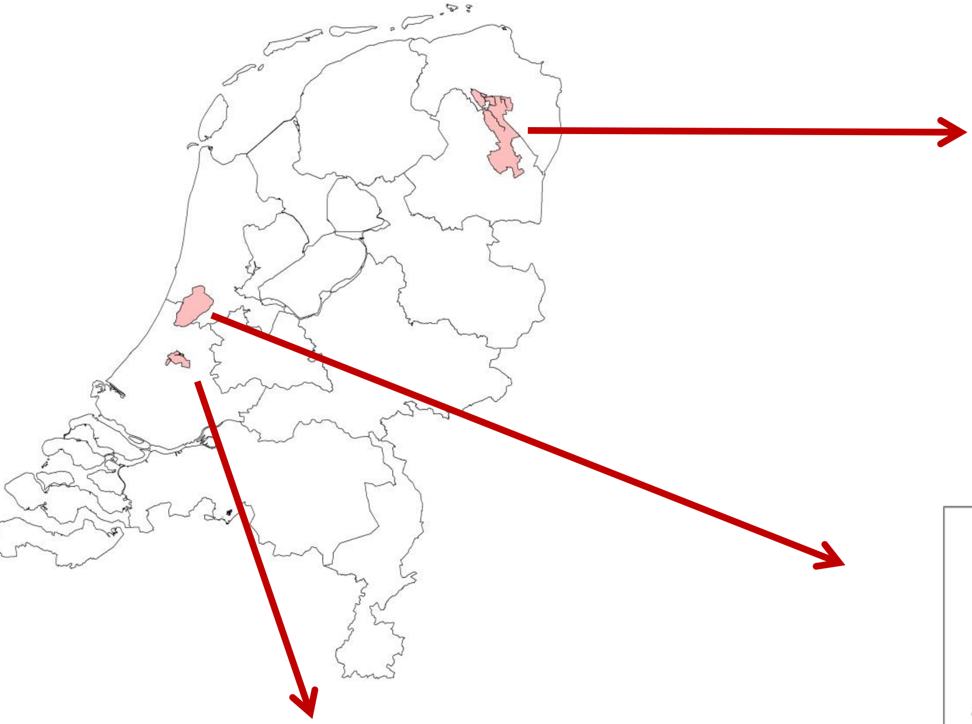
Hunze catchment

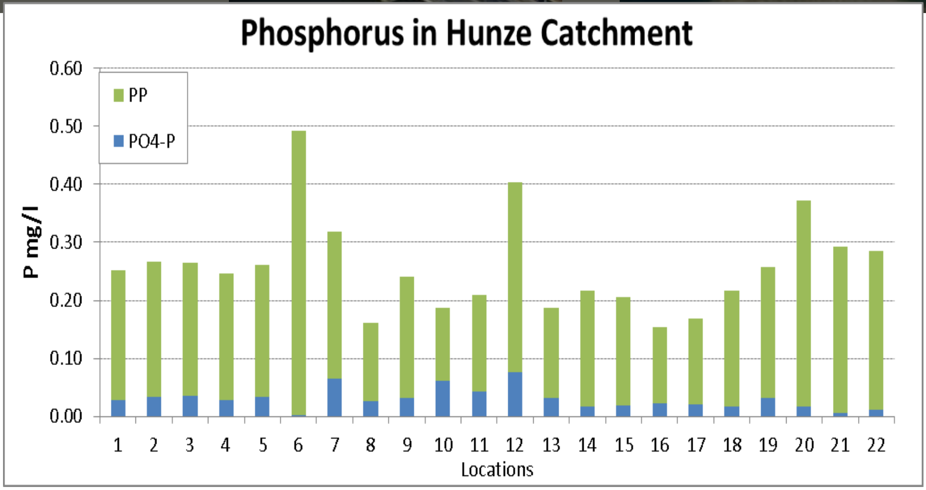
Haarlemmermeer polder

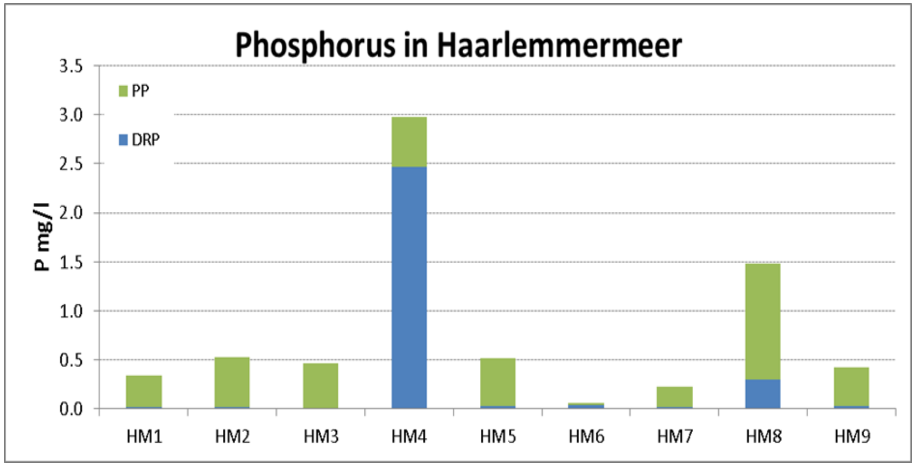
Noordplas polder

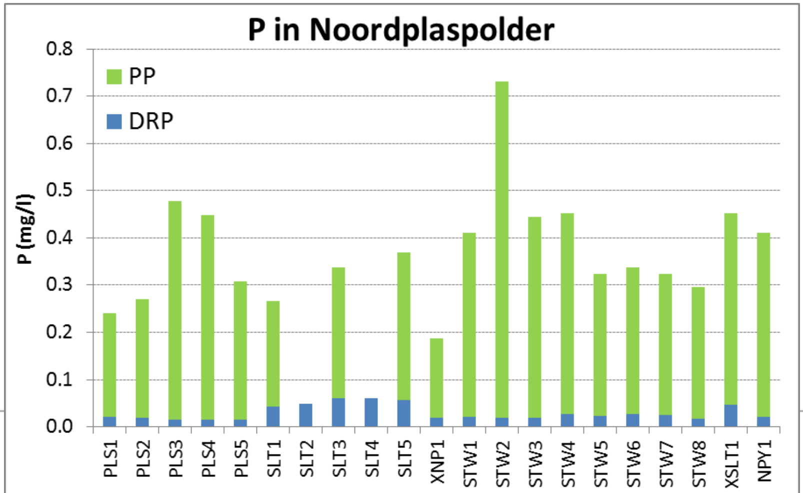
Van der Grift et al., 2015; in prep.

# Samping in three areas: particulate P and dissolved P

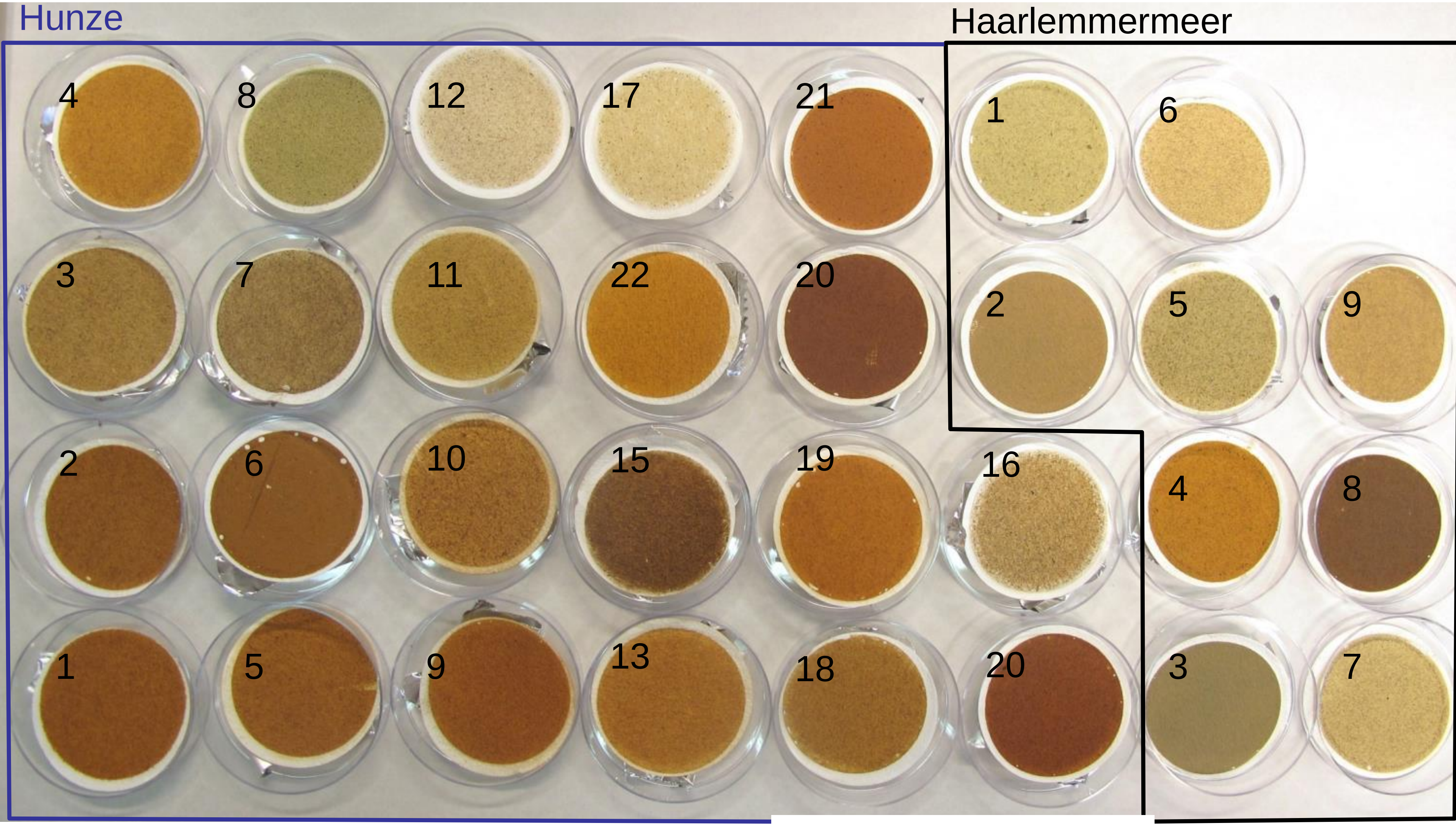




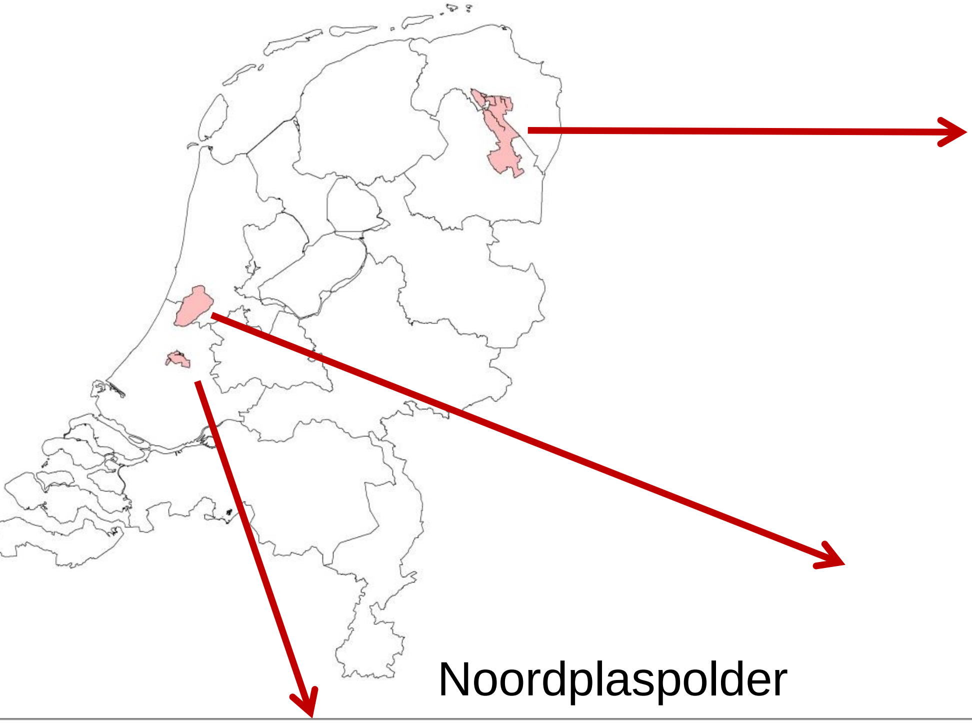




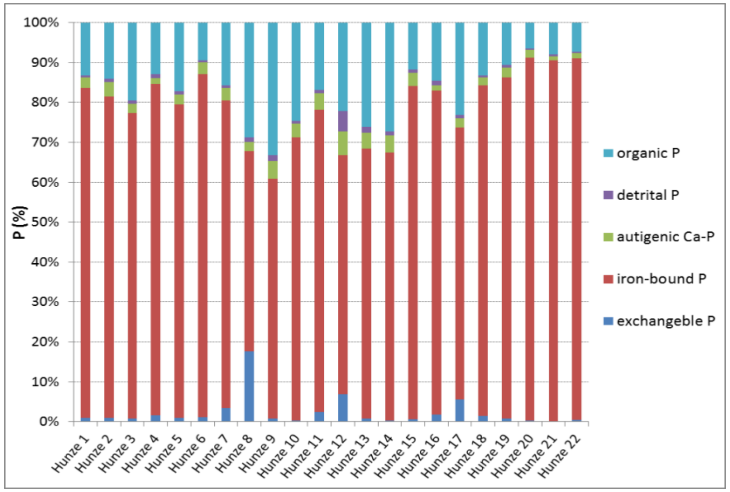
# Suspended sediment samples



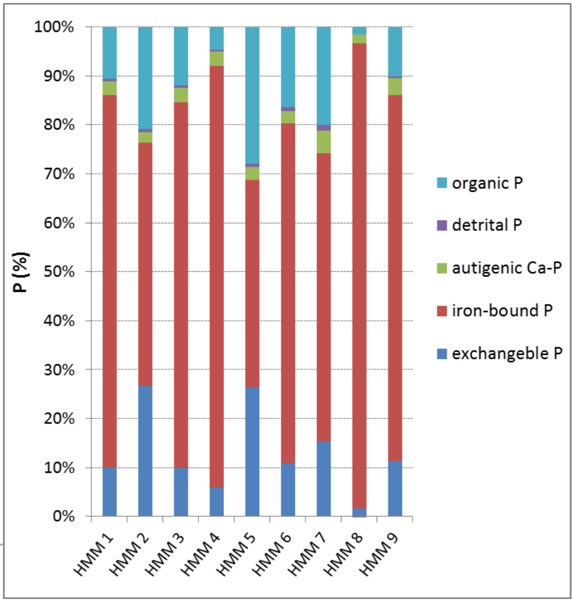
# Sequential extraction: P fractionation in suspended sediment



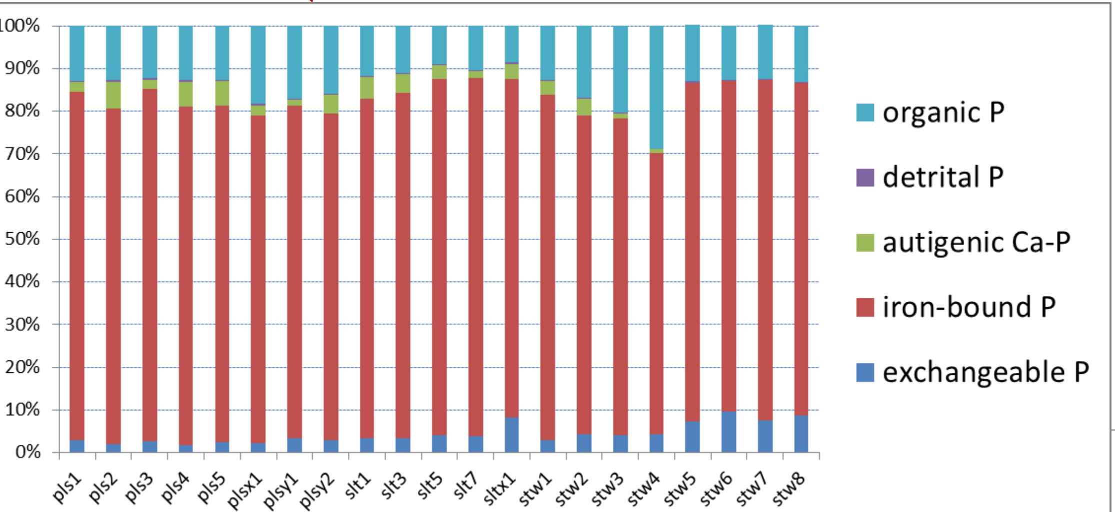
## Hunze catchment



## Haarlemmermeer



## Noordplaspolder

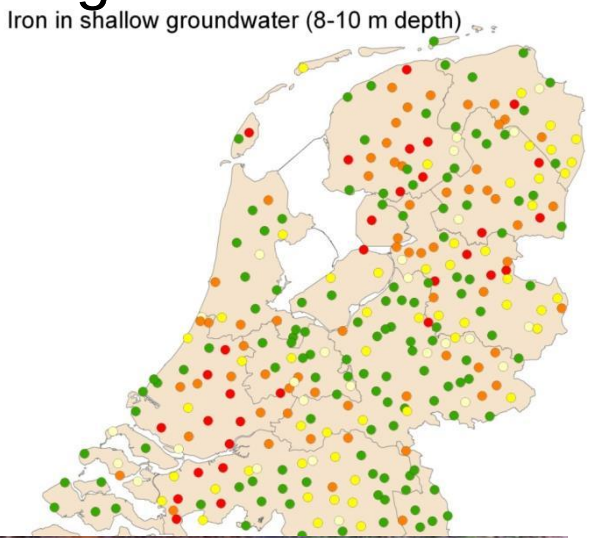


# Why dominance of Fe bound P?

Lowland area: reactive subsurface with high organic matter content

- anaerobic groundwater
- high iron(II) concentration
- contributes to surface water

So, high load of iron(II) to surface water system



Iron in shallow groundwater (8-10 m depth)

1: Oxidation iron(II) with oxygen to Fe hydroxides

$Fe^{2+} + 0.25\ O_2 + 2.5\ H_2O \rightarrow Fe(OH)_3 + 2H^+$

2: Phosphate: strong affinity with Fe hydroxides:

Surface adsorption on Fe-hydroxides surfaces

$\equiv XOH_2^+ + HPO_4^{2-} \rightarrow \equiv XOH_2\,HPO_3^- + H_2O$

Precipitation Fe phosphate phases

$Fe(OH)_3 + PO_4^{3-} \rightarrow FePO_4 + 3OH$

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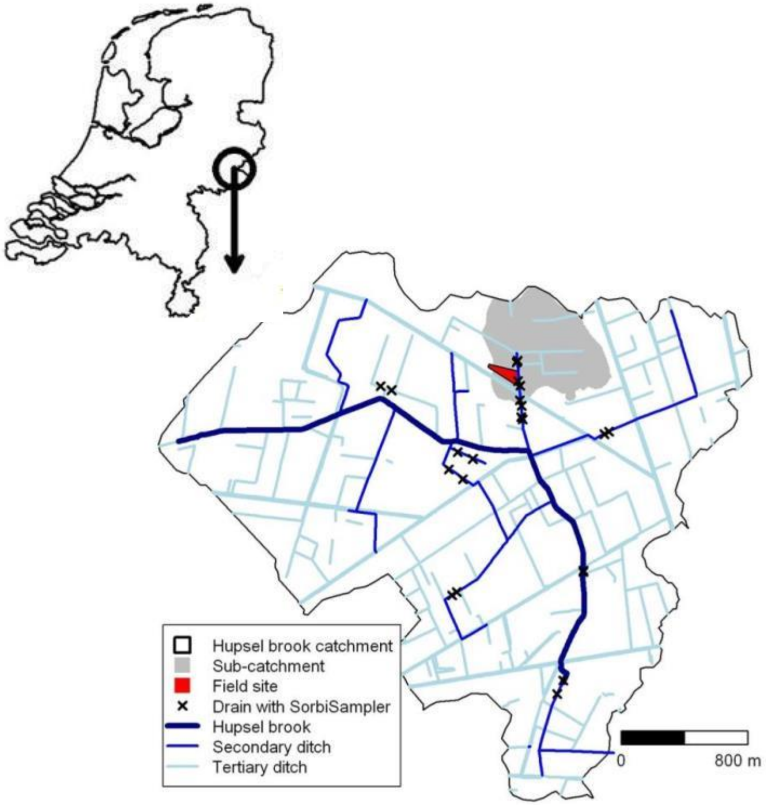
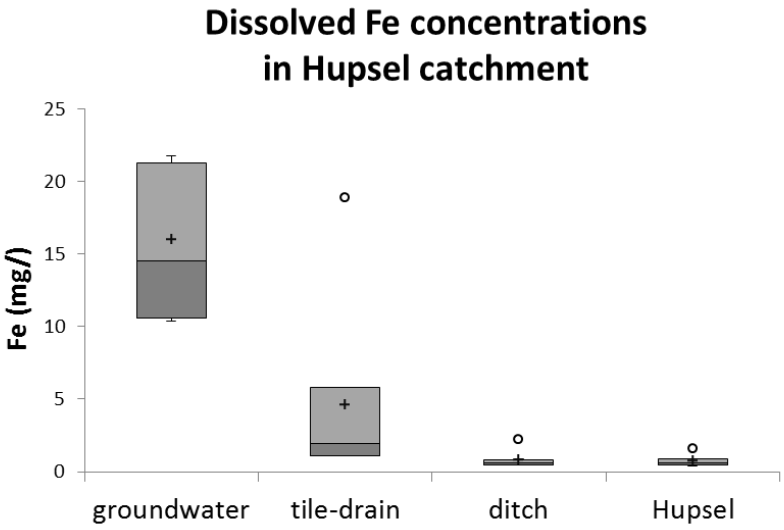
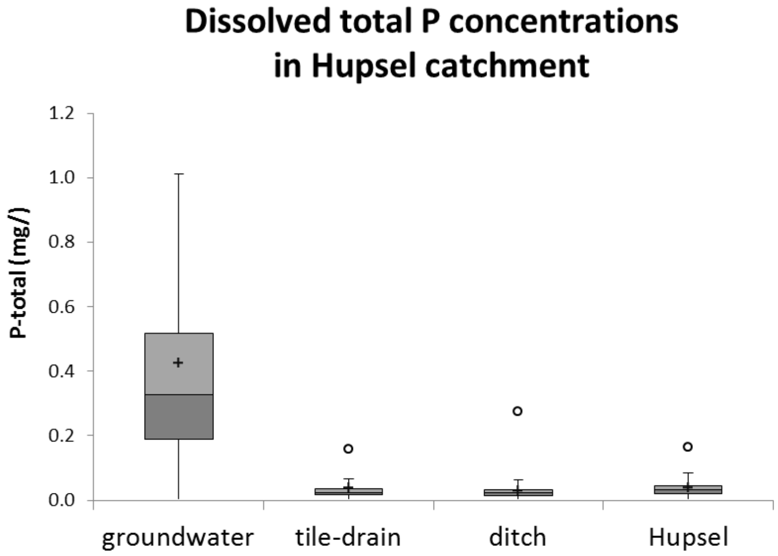
# Fe and P dynamics in at the groundwater – surface water interface

## Hupsel brook field experiment




Dissolved Fe concentrations in Hupsel catchment


Dissolved total P concentrations in Hupsel catchment

Van der Grift et al., 2014; HESS.

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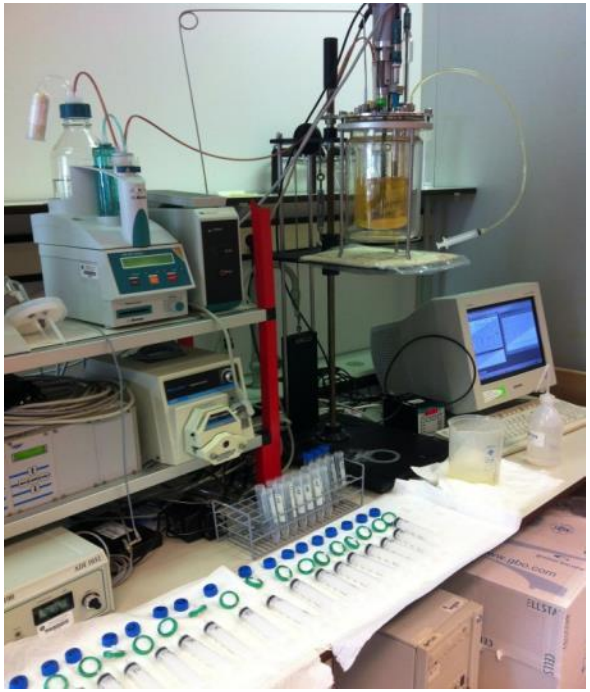
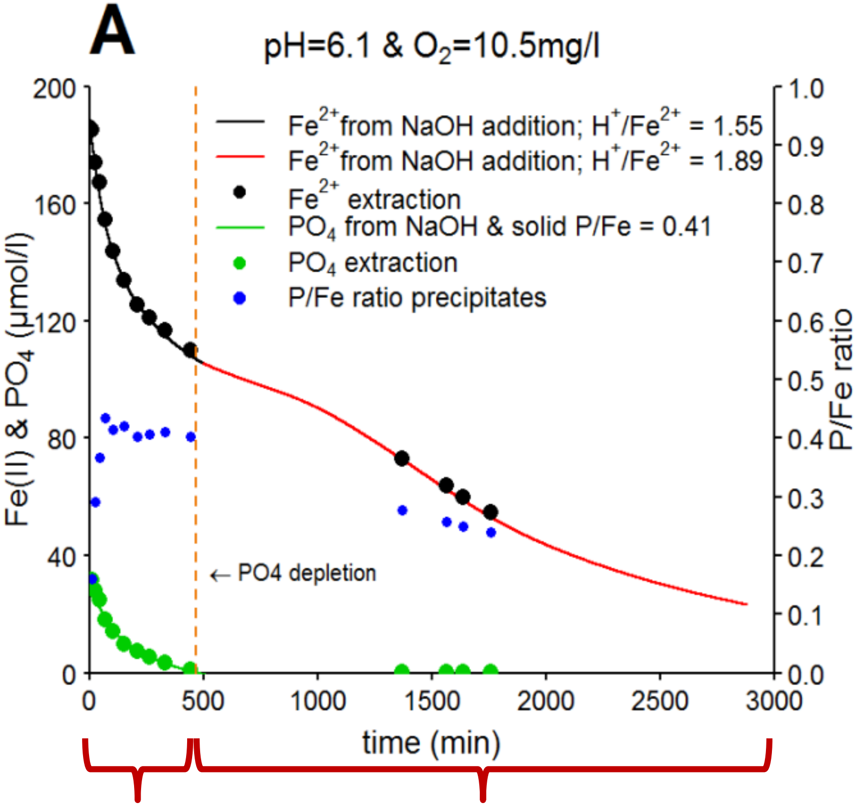
# $Fe^{2+}$ oxidation experiments in presence of $PO_4$



Reactor to oxidize $Fe^{2+}$ under controlled conditions:

- Fixed pH
- Fixed $O_2$ concentrations

P/Fe initial ratio = 0.18



$PO_4$ present:

$PO_4$ depleted:

- Fast binding of $PO_4$ during oxidation of $Fe^{2+}$:
  - No time for dissolved P transport

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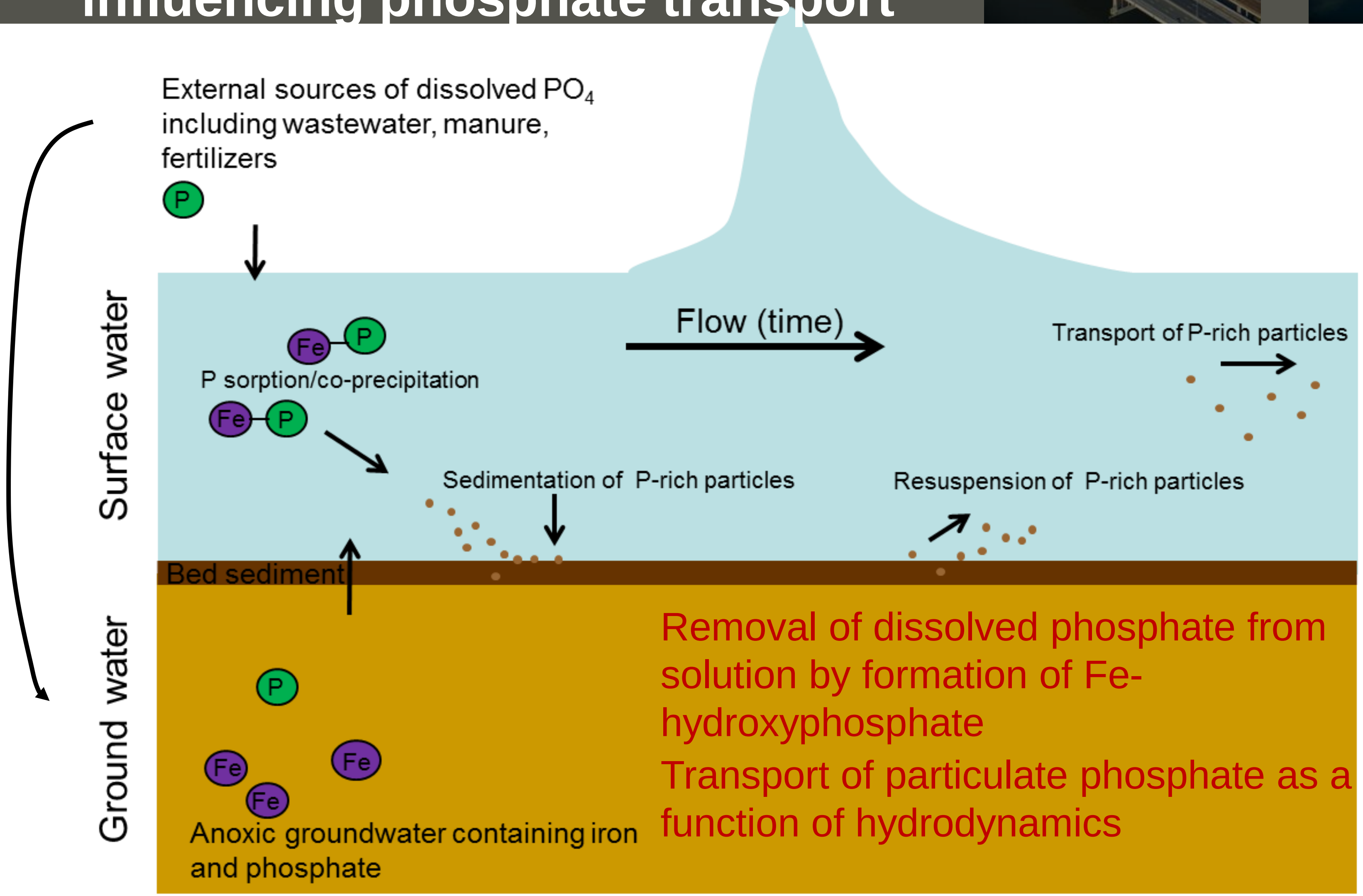
# Conceptual model of abiotic in-stream processes influencing phosphate transport



Removal of dissolved phosphate from solution by formation of Fe-hydroxyphosphate

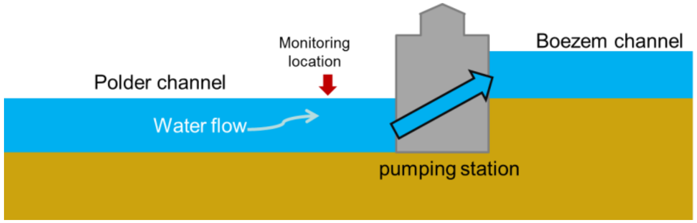
Transport of particulate phosphate as a function of hydrodynamics

Inspiration from continuous water quality / sediment measurements

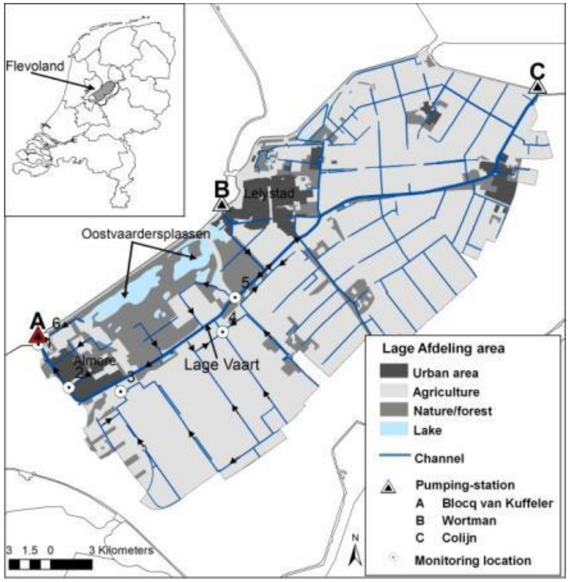
# Effect of flow velocities on re-suspension bed sediments and particulate P in polder catchment

10 minute interval measurements

- Suspended sediment (Turbidity)
- Total-P and total reactive P
- $NO_3$
- conductivity

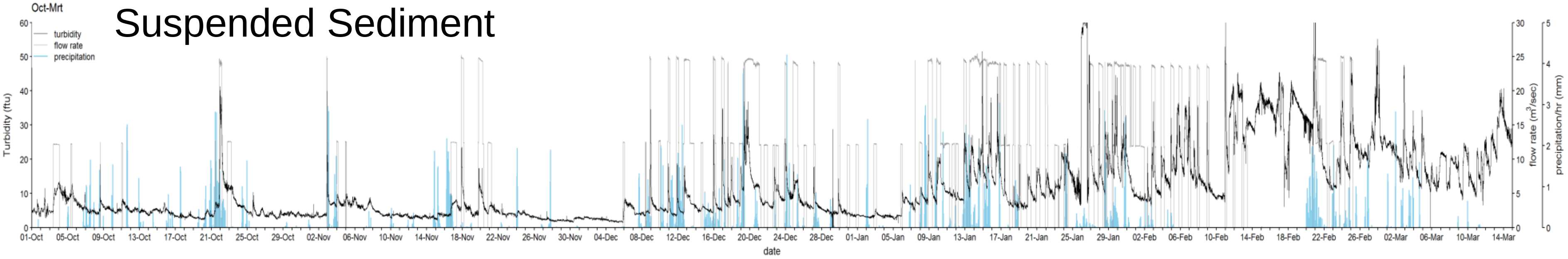


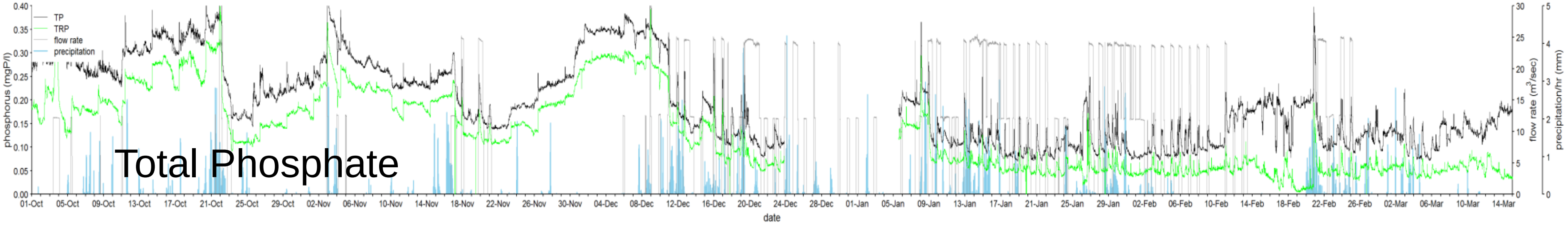
Blocq van Kuffeler pumping station



# High-Frequent monitoring at pumping-station in Flevoland

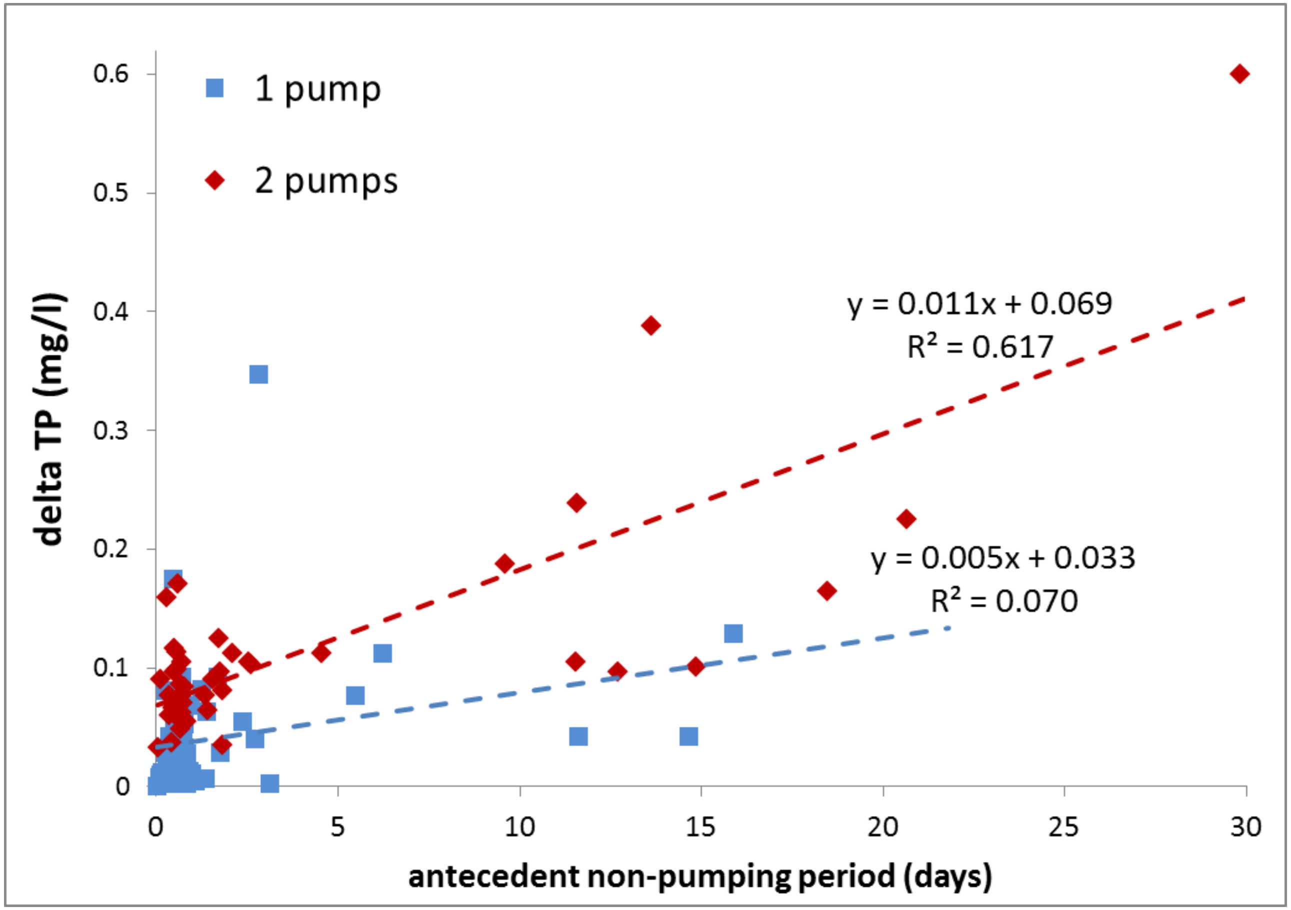
October 2014 – April 2015


Suspended Sediment


Total Phosphate

# Response on pumping: increase of TP

Total-P



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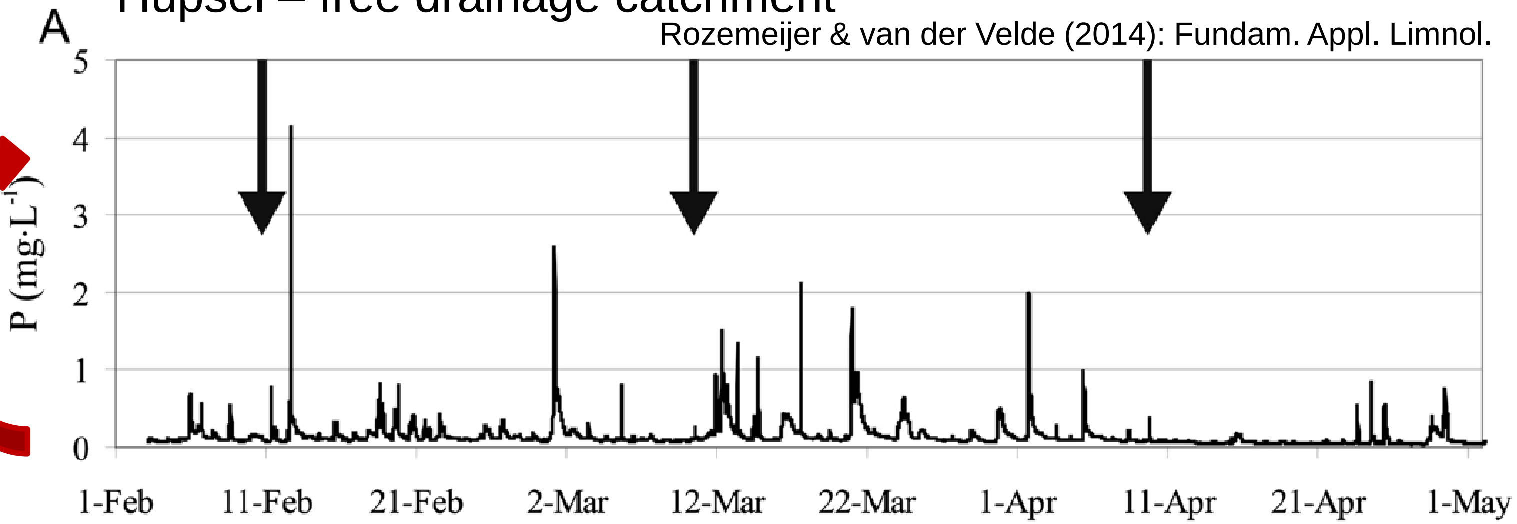
# Total P remoblisation: natural catchment vs polder

Hupsel – free drainage catchment

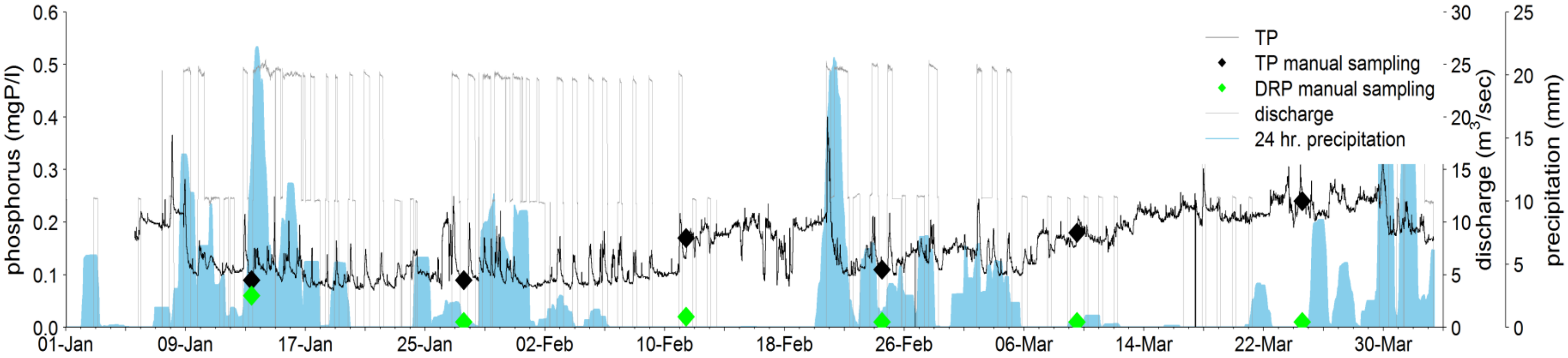
Rozemeijer & van der Velde (2014): Fundam. Appl. Limnol.

x 100



Flevoland - polder

x 2



Total P export loads from polders are less incidental and less peak flow controlled than from natural catchments

# Conclusions & questions left

- Fe-bound P is dominant P species in surface water in agricultural lowland areas
- Seepage of anaerobic groundwater controls P speciation in surface water
- Fast immobilization of P during oxidation process of Fe(II)
  - Precipitation of Fe hydroxyphosphate phase
  - How stable are these mineral phases?
  - Bioavailability?
- Flow induced resuspension of streambed sediment is main transport mechanism for P
  - Are natural catchments much more vulnerable for incidental losses than polder??