# Transport and transformation of nitrate in a Danish riparian lowland

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## 1. Introduction

Prompted by the Danish Commission on Nature and Agriculture new regulation strategies are currently being developed in Denmark based on spatially differentiated N-regulation. Measures to reduce nitrate leaching can be focused in areas of low N-retention, whereas higher N-application can be allowed in areas with high natural reduction of nitrate in the groundwater and riparian zones.

The TReNDS project (Transport and Reduction of Nitrate in Danish landscapes at various Scales) aims to acquire knowledge on local-scale nitrate removal. Knowledge gaps related to the effects of drainage, the subsurface geochemistry and N-removal in riparian lowlands currently prevents meaningful regulations at the desired scale.

Riparian lowlands often function as major sinks for nitrate-N. However, since they may constitute a very small fraction of the catchment area, they have shown difficult to incorporate into current hydrological models on which N-leaching is calculated. Models incorporate N-retention functions with different complexities – some including riparian lowlands with varying level of detail. This project seeks to investigate the interaction between flow pathways (including drainage) and the subsurface biogeochemistry influencing N-removal in riparian lowlands to improve the understanding of this important landscape element with regards to N-retention.

## 3. Flow paths

Four different transects have been chosen within the wetland to represent different flow typologies. All four transects begin at the hillslope adjacent to a drain outlet, and end at the stream. The four transects cover different combinations of e.g. terrain slope, drainage input, infiltration capacity, lithology, subsurface drainage and distance to the stream.

Along each transect a number of boreholes have been made and piezometers have been installed at different depths. From the piezometer pipes the hydraulic heads have been measured every 3 weeks for from September 1st 2016 to August 31st 2017 and slug tests have been made to determine hydraulic conductivity. Flow meters have been installed at the drain outlets in the hillslope to measure incoming surface water. Darcy fluxes in and out of the transect area are calculated from hydraulic heads from the piezometers and infiltration capacities have been measured with double ring infiltrometers.

From these measurements it is possible to estimate the amount of flow along three main flow paths:

- Overland flow
- Drainage flow
- Groundwater flow

Drain water entering the transect areas at the hillslope may infiltrate into the wetland soil and travel to the stream as groundwater flow or via a separate drain system in the lowland soils. The hydraulic conductivity is highest near the surface and decreases exponentially with depth (figure 4d). Overland flow will occur when one of the following three conditions is fulfilled:

- Hydraulic loading > infiltration capacity
- Hydraulic loading > top soil storage capacity
- Hydraulic loading > groundwater (+ lowland drain) flow rate

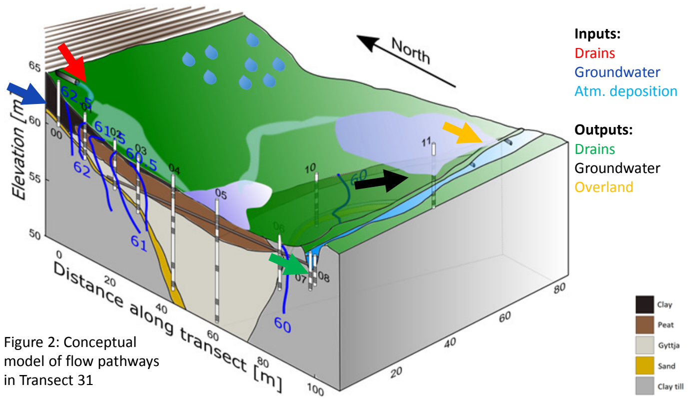



Figure 2: Conceptual model of flow pathways in Transect 31

| Table 1: Transect nitrogen balances and characteristics | Transect 31 | Transect 32 | Transect 33 | Transect 34 |
|---|---|---|---|---|
| Total into wetland (*via drains) [kg N/yr] | 84.7 (*66.5) | 304 (*301) | 602 (*601) | 191 (*190) |
| Mean TN in drain [mg/l] | 10.5 | 9.3 | 11.9 | 9.4 |
| Output to stream [kg N/yr] | 61.0 | 327 | 164 | N/A |
| Nitrogen removal [kg N/yr] | 23.7 (28 %) | -22.7 (-7.5 %) | 438 (73 %) | N/A |
| Wetland efficiency [kg N/ha/yr] | 18.9 | -136 | 346 | N/A |
| Wetland gradient [%] | 3 | 9 | 2.5 | 6.5 |
| Distance to stream [m] | 90-140 | 35 | 150 m | 80 |
| Seasonal soil water storage [m³] | 2600 | 250 | 1500 | 630 |
| Drain catchment [ha] | 3.5 | 7.64 | 13.7 | 6.87 |

## 2. Study site

The main area of investigation is the riparian lowland located in Fensholt, an area 5 km west of Odder, Denmark. The landscape is a hilly moraine landscape with a series of valley systems. The riparian lowland is located within one of these valleys along a small man-made headwater stream stretching approximately 1.5 km from WSW towards NNE.

The upland area is dominated by agriculture on sandy till, which is heavily drained. Drain pipes from the fields are cut off at the hillslope along the edge of the riparian lowland. The riparian lowland is dominated by organic sediments (peat and gyttja) filling up the underlying hilly topography of the immediate postglacial till surface

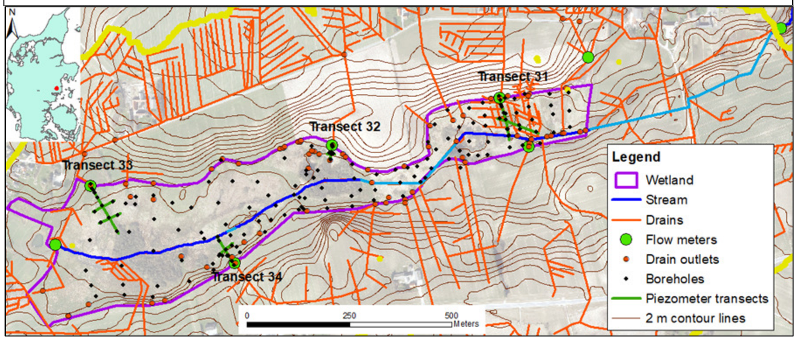



Figure 1: The Fensholt study site

## 4. Biogeochemistry

The flow paths determine the amount of contact with the wetland biogeochemical reactor. The riparian lowland sediments contains an abundance of organic matter which may function as the electron donor in denitrification of nitrate (figure 4c). Denitrification enzyme activities (DEA) were measured using the acetylene blockage method on soil samples incubated with nitrate. Results showed high DEA close to the surface and a quick exponential decrease with depth going towards zero at 25 cm depth. However, incubation experiments measuring the rates of change in nitrate and ammonium indicate nitrate removal rates of the same magnitudes taking place at 75 cm depth as in the top 25 cm. This corresponds to the depth of the center of the nitrate plume, which is disappearing downstream (figure 3) and also to the depth of increased concentrations of amorphous iron oxides in soil samples. This indicates that nitrate may be removed by dissimilatory nitrate reduction to ammonium (DNRA) coupled to Fe(II) oxidation.

Denitrification is efficient in the Fensholt riparian lowland, as long as infiltration takes place. The infiltration capacity combined with the terrain slope, the distance to the stream, and magnitude of the input flux will thus control the amount of nitrate reaching the stream.

Figure 3: Development of a nitrate plume in transect 31

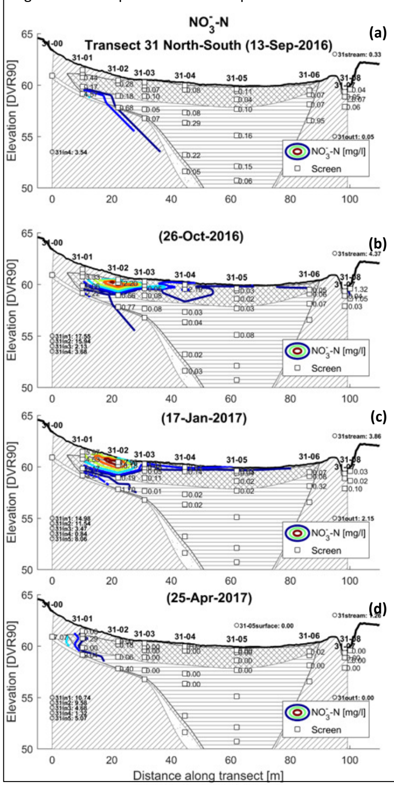
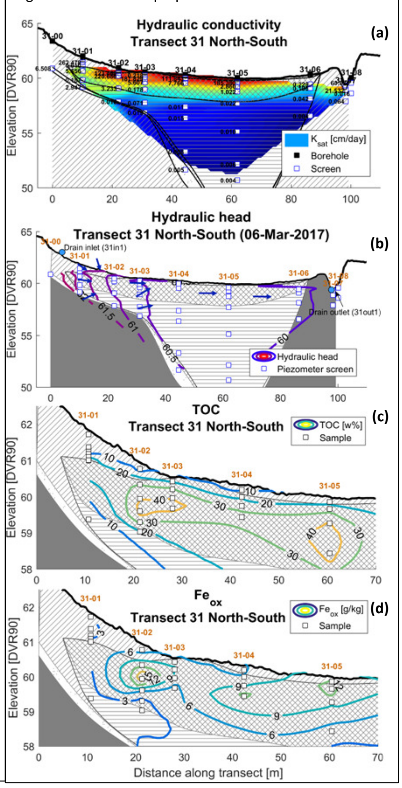



Figure 4: Transect 31 properties

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