Investigating summer flow paths in a Dutch agricultural field using high frequency direct measurements

Joost Delsman$^{1,2}$, Maarten Waterloo$^2$, Michel Groen$^2$, Koos Groen$^{2,3}$, Pieter Stuyfzand$^{2,4}$

$^1$Deltares, $^2$VU University Amsterdam, $^3$Acacia Water, $^4$KWR

Background and research questions

- Netherlands: low-lying delta
- Shallow saline groundwater in coastal region (< 2 m)
- Saline exfiltration mitigated by diverted freshwater
- Global change: sustainable?

→ What controls dynamics of surface water salinity?
→ Implications for water management?
Schematic overview

- tile drain
- ditch
- fresh groundwater
- saline groundwater
- agricultural field
- sprinkling
- extraneous water supply

Measurement setup

- instream reservoirs: measurement of Q and EC of drains, ditch and intake
- 7 tile drains connected to instream reservoir
- pezometers (1, 2 m BGS) at and between tile drains
- floating evaporation pan
- array of temperature sensors perpendicular to ditch - field interface
Measurement results

**P-ET**

- Precipitation
- Evapotranspiration

**levels**

- Drain level
- Culvert damages
- Groundwater level
- Ditch water level

**Q**

- Drain discharge
- Ditch discharge
- Intake flux

'wet' year
'dry' year
Drainage theory

- Tile drains: non-linear response to groundwater level rise
- Ditch: linear response to groundwater level rise
- Ditch: no difference resistance in-/exfiltration
- Hooghoudt drainage theory fits well

Flow path separation

- Separate measurement of tile drain and ditch discharge
- Ditch discharge =/= groundwater exfiltration to ditch
- Solved Q, TDS, H balance (+ uncertainty)
- Separated shallow and deep flow paths to ditch based on salinity and temperature
- Used TDS shallow (0.5 g/L) / TDS deep groundwater (15 g/L) to separate deep and shallow groundwater contribution tile drains
Precipitation event

P-ET

drain

response
depth flow path

ditch

fraction
depth

Flow paths and exfiltration salinity

a

Before rainfall
Flow and salinity distribution in dynamic equilibrium

b

Shortly after rainfall
Groundwater levels rise:
flow responds quickly, discharge increases
Salinity distribution response lags:
'shallow' flowpaths discharge 'deep' groundwater,
exemplified by flowpath intersecting concentration boundary, denoted by red circle

c

After some time
Salinity distribution again in equilibrium with flow distribution:
'shallow' groundwater exfiltrates
Ditch salinity and flushing requirement

- Calculated surface water salinity if flows not separated
- Calculated flushing needed to keep ditch salinity below 1.5 g/L TDS (local salinity norm for growing potatoes) assuming complete mixing
Conclusions

- Non-linear / linear response drains and ditch
- Exfiltration salinity controlled by pressure wave celerity versus water velocity
- Salinity surface water also result of changing fractions drain / ditch
- Tile drains transport majority of salinity

- Water required to enable sprinkling far outweighs sprinkling demand (6x in dry year)
- Less water required in dry than wet periods for flushing: operational control could significantly decrease water demand

Questions?