Upscaling riparian lowland buffer zone flow dynamics in the Danish nitrogen model

Saskia Noorduijn

Anker Højberg

GEUS

EGU 2020

Online Discussion Forum

FutureCropping

Tuesday 5 May 2020

GEUS

Overall Objectives

- Determine the optimal method to **identify** and include **spatial variability** in ***riparian lowland denitrification*** in the **Danish nitrogen model**
  - **GIS analysis**
    - Drainage area and slope
  - **Geological/Hydrogeological assessments**
    - Aquifer geometry
    - Groundwater inflow (hydraulic pressure)
    - Soil types

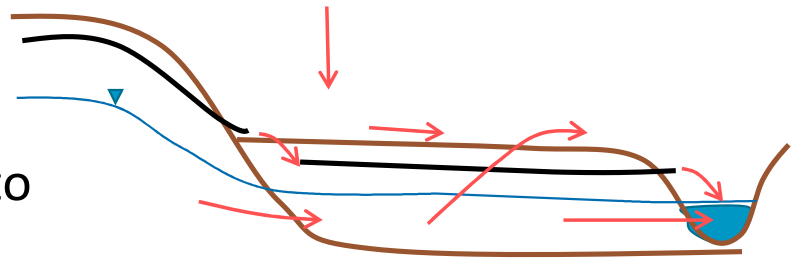
➢ **Needs to be consistent** and **transparent** at the national scale!

Starting at the small scale

- Can we **simulate** the observed flow partitioning and water balance for a selected riparian lowland area?
  - In particular, **surface flow pathways:**
    - Surface runoff, exfiltration, Tile drain flow

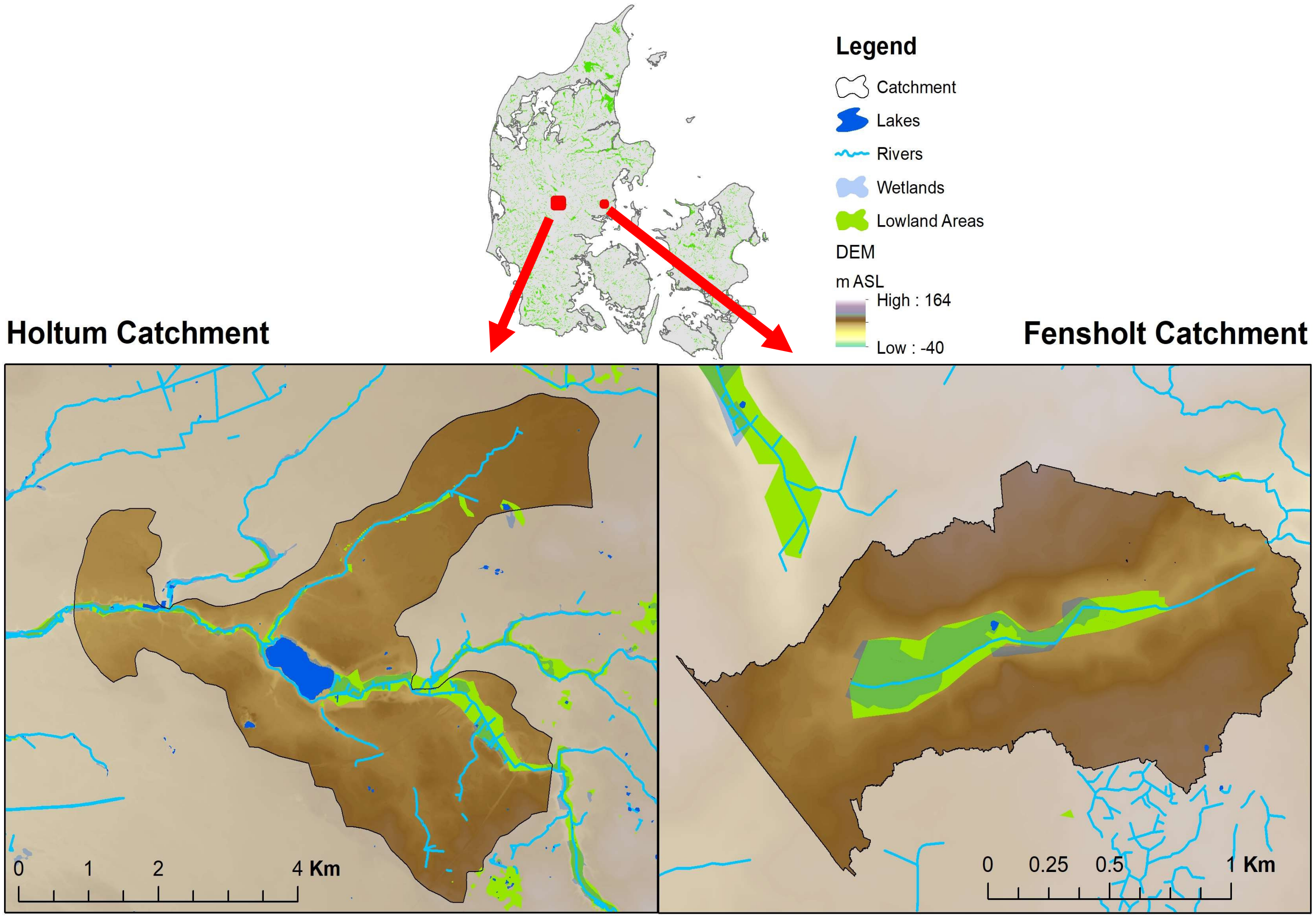
  … which provide **bypass** pathways for potential nitrate to enter surface water systems.

Transect showing the different flow pathways for water to reach the aquatic system

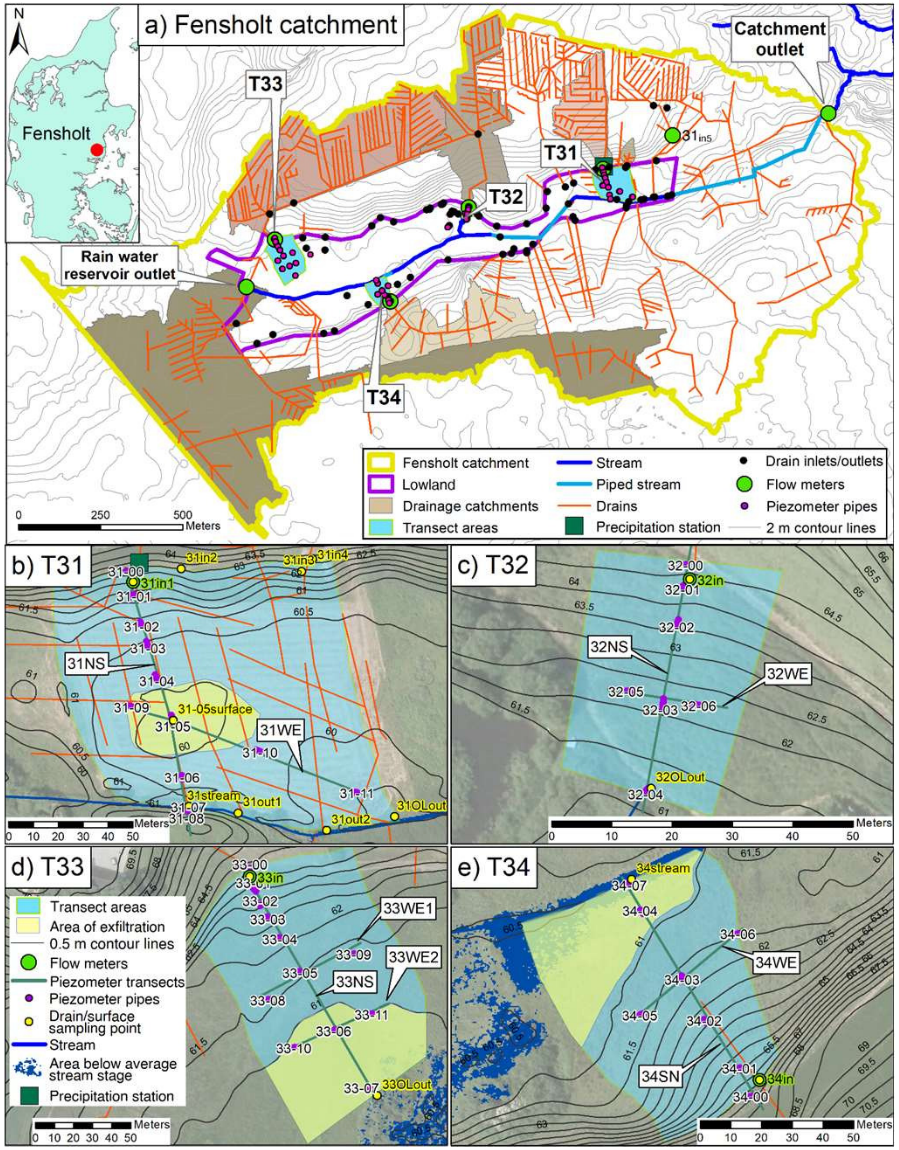


- What modifications to the current simulations are required to reproduce the observed responses?
  - e.g., model refinement, improved soil date and/or representation vegetation…

Small scale…



- Detailed data are available for 2 small riparian lowlands within Denmark.
- The Holtum and Fensholts catchments have been instrumented to help quantify their water and nitrate balances.
- This data can be used to verify whether it is possible to simulate the water balance behaviour observed at sites.



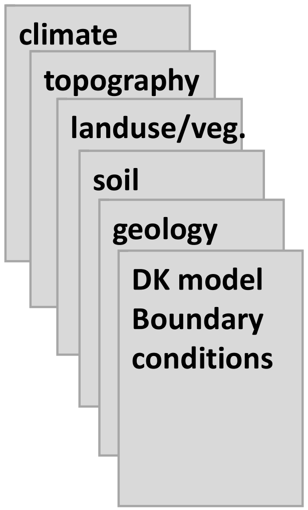
Fensholt Catchment

- The Fensholt catchment research focused on **4 transects** within the riparian lowland.
- The geomorphology and hydrology for each transect (and associated upland area) is different. (see table below)
- Different water balance partitioning was measured within the transects.

Characteristic	T31	T32	T33	T34
Riparian lowland slope (%)	3.0	9.0	2.5	6.5
Distance from hillslope drain outlet to stream (m)	90-140	35	150	80
Upland drain catchment area (AC) (ha)	3.9	7.6	13.7	6.9
Area of riparian lowland transect (AT) (ha)	1.15	0.113	1.17	0.477
Ratio of upland drain catchment area to riparian lowland transect area (R = AC/AT)	3.4	67	12	14
Tile drains present within riparian lowland	+	-	-	-

Small scale and the water balance

National scale data



Can we simulate similar variability in the observed transect water balance, using:

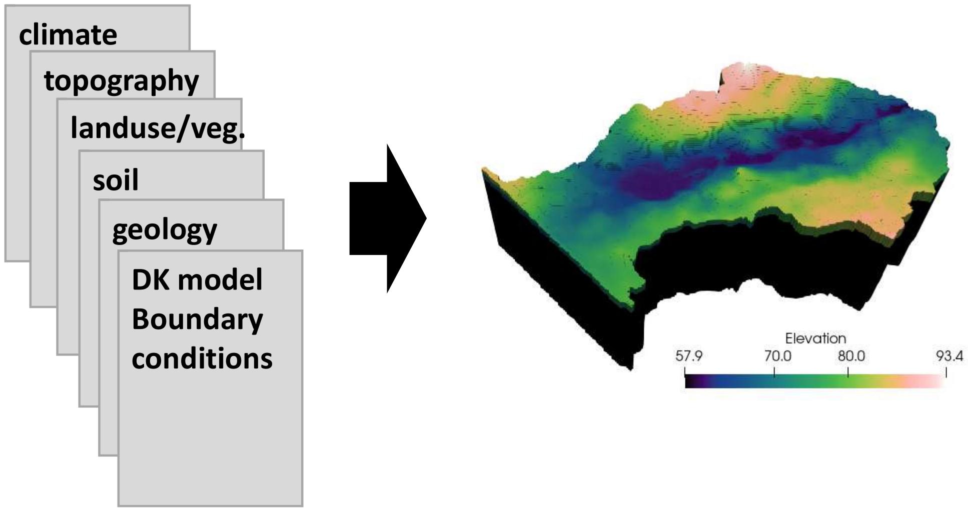
- **Nationally available data sets** (climate, topography, land use, soil data) &
- **Danish Groundwater Resources model** (DK model: model covering all of Denmark)

Without additional calibration to the specific riparian lowland model!!!!

IF this is shown to be possible, additional riparian lowlands may be selected (for which we have no site specific data) for simulation with a *certain* amount of confidence in the simulated water balance.

Small scale and the water balance

National scale data

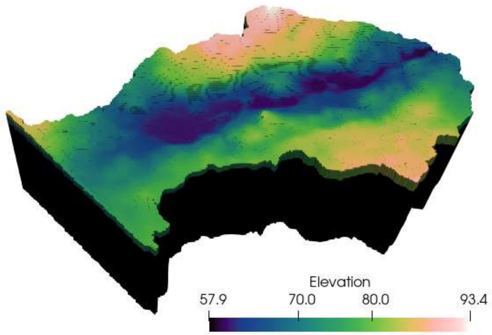


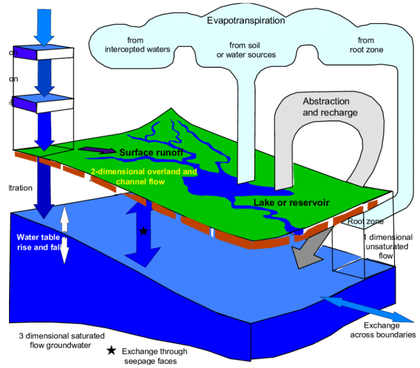
Initial simulations have focussed on the Fensholt Catchment

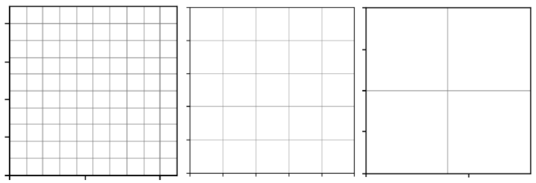
Small scale and the water balance

National scale data

climate
topography
landuse/veg.
soil
geology
DK model
Boundary
conditions





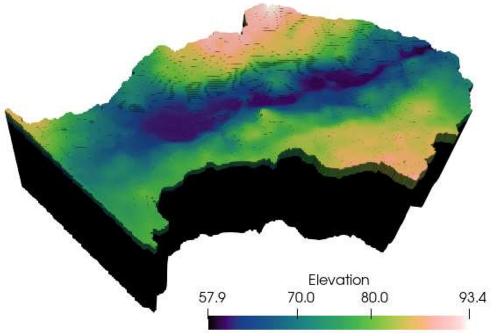


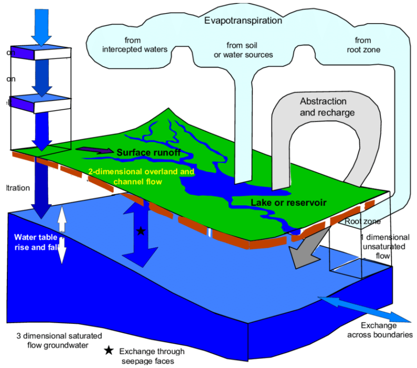
- The model was built in MIKE-SHE, structured similar to the Danish Groundwater Model (DK model: currently run at a 500 m grid resolution).
- Refinement of the grid and input data were the main modifications. Grid resolutions of 10m, 20m, 50m, and 100m where tested.
- All parameter values (e.g., vegetation characteristics, surface Manning's N, soil characteristics, groundwater flow parameters) where unchanged from the Danish Groundwater Model.

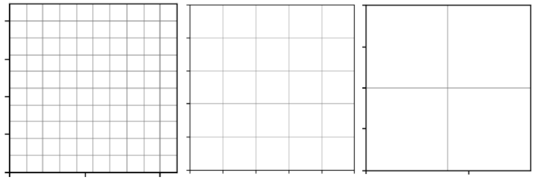
Small scale and the water balance

National scale data

- climate
- topography
- landuse/veg.
- soil
- geology
- DK model Boundary conditions



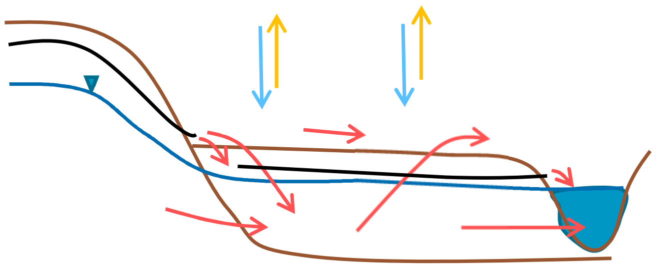




The water balance for the transects was extracted from the simulations

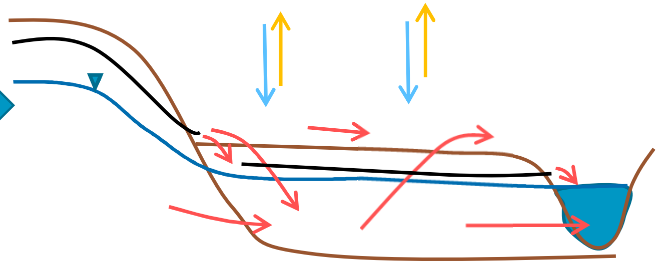
Water balance
- Catchment
- Transect

Measured transect scale Water balance



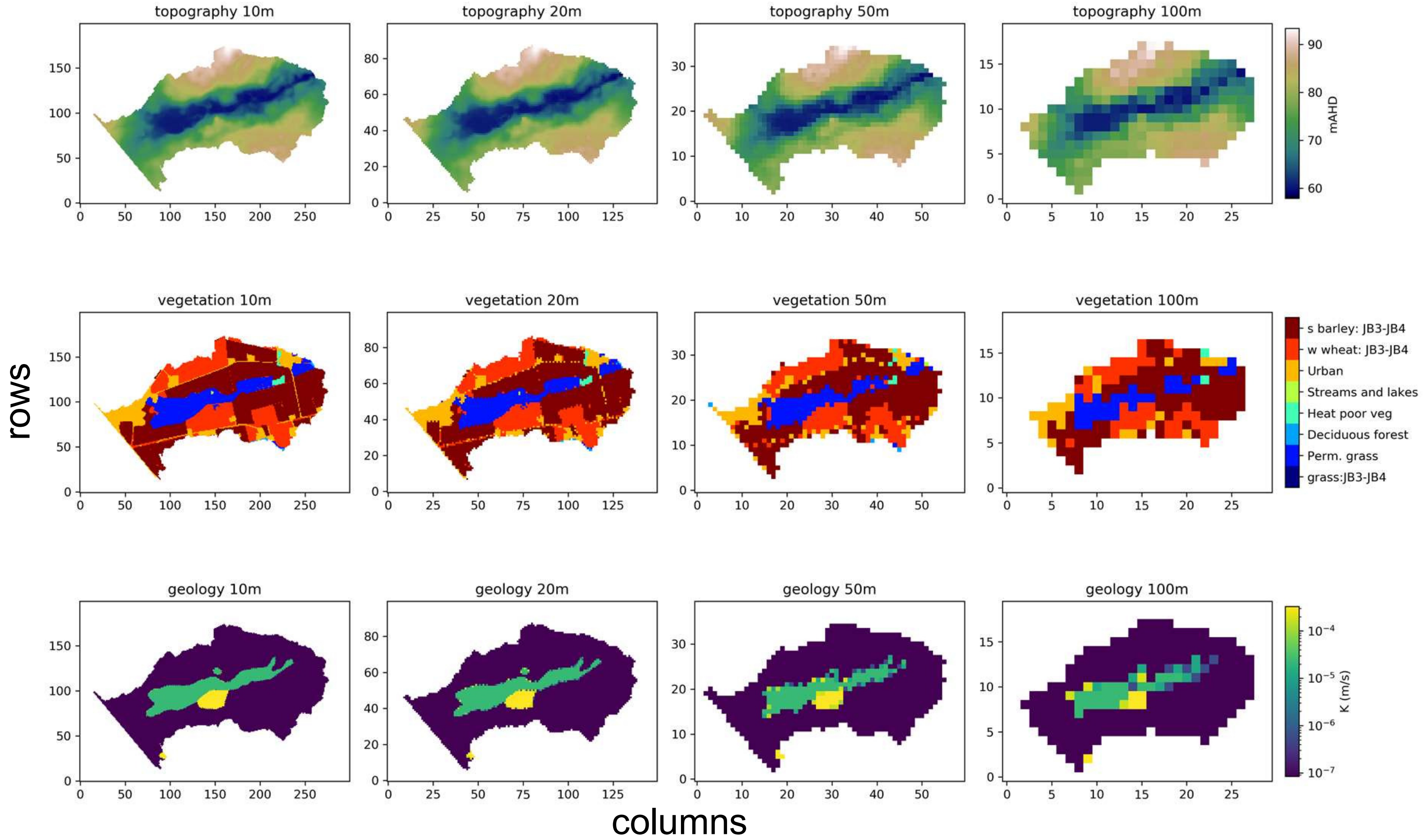
Comparison of the simulated and measured water balance for the different model resolutions

Simulated transect scale Water balance

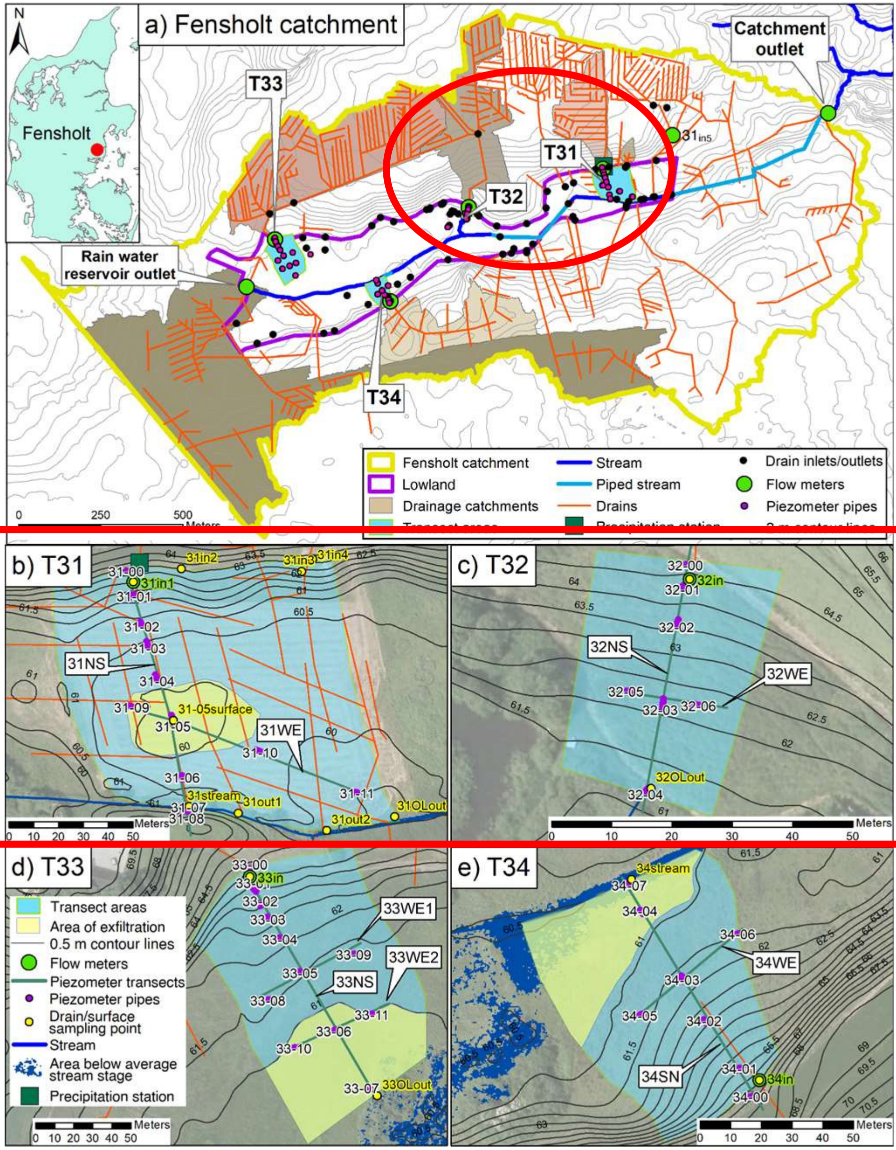


Fensholt Catchment: MIKE-SHE models

This figure shows the impact of grid resolution on the modelled topography, landuse, and surface geology…



GEUS



Fensholt Catchment: Water Balance: Sep 2016-Sept 2017

- Focus on two transects: T31 and T32. These transects have different drain flow inputs into the transects.
- NB. Upland drain networks are disconnected and discharge at the surface, therefore drain flow is simulated by including it with precipitation.

	mm/year	T31	T32	T33	T34
IN	P	**865**	**865**	865	865
	Drain flow	**471**	**12,114**	3,757	4,003
	GWxy	**29**	**1,096**	116	393
	Sum In	**1,365**	**14,075**	4,738	5,261
OUT	ET	**612**	**662**	662	662
	Drain flow	**230**	**0**	0	0
	Overland flow	**432**	**9,873**	3,655	3,580
	GWxy	**37**	**3,587**	419	979
	GWz	**13**	**13**	15	35
	ΔS	**51**	**12**	22	57
	Sum Out	**1,375**	**14146**	4773	5313

P: precipitation, ET: evapotranspiration, S: storage, GWxy: lateral GW flow, GWz: vertical GW flow

Petersen *et al.* (2020) Riparian lowlands in clay till landscapes Part I, WRR

Measured Water Balance Details

		Data type	Data Source
IN	**P**	Directly monitored	Weather station onsite
	Drain flow	Directly monitored	Flow meter@drain outlet
	GWxy	Calculated (Darcy's Law)	Piezometer data (K and hydraulic head)
OUT	**ET**	Indirectly monitored	Pan evaporation data onsite
	Drain flow	Calibrated	-
	Overland flow	Calibrated	-
	GWxy	Calculated (Darcy's Law)	Piezometer data (K and hydraulic head)
	GWz	Calculated (Darcy's Law)	Piezometer data (K and hydraulic head)
	ΔS	Calculated	Piezometer data (K and est. specific storage)

Water Balance Uncertainties

Due to uncertainties in the estimation of the water balance components, in particular:

- Drain flow out (calibrated),
- Overland flow out (calibrated),,
- GW flows (2D calculation),

the **measured water balance can only provide an approximation of the flow partitioning within the transects.**

Simulated Water Balance Details

		Data type	Data Source
IN	**P**	Directly monitored	Weather station onsite
	Drain flow	Directly monitored	Flow meter@drain outlet
	GWxy	Flux through cells at the upstream transect boundary	MIKE-SHE output
OUT	**ET**	Calculated from cells within the transect	MIKE-SHE output
	Drain flow	Calculated from cells within the transect area	MIKE-SHE output
	Overland flow	Calculated flow through cells at the downstream transect boundary	MIKE-SHE output
	GWxy	Flux through cells at the downstream transect boundary	MIKE-SHE output
	GWz	Flux through cells at the base of transect area	MIKE-SHE output
	ΔS	Calculated from cells within the transect area	MIKE-SHE output

Water Balance Uncertainties

GW flow uncertainties related to matching the numerical geological structure to that used in the measured WB pose a challenge.
Similarly, only flow along the transect was considered in the calculation of GWxy and overland flow. ΔS is calculated within the transect, therefore a 3D est.
The simulated WB provides an approximation of a 2D WB for the transects.

Preliminary Results
Fensholt Catchment : Sep 2016-Sept 2017

To directly compare the behaviour of the different models to the measured water balance (WB), the measured drain flow at the transects were used in the simulations.

		T31	MIKE-SHE model grid resolution			
	mm/year	WB	10m	20m	50m	100m
IN	P	865	865	865	865	865
	Drain flow	471	471	471	471	471
	GWxy	29	450	473	619	217
	Sum In	1,365	1786	1809	1955	1553
OUT	ET	612	592	533	580	604
	Drain flow	230	705	266	500	834
	Overland flow	432	15	69	26	9
	GWxy	37	161	34	83	17
	GWz	13	4	15	25	54
	ΔS	51	5	3	5	2
	Sum Out	1,375	1494	952	1021	1642
	Error	-10	304	889	736	33

GW flow in and out of the transects tends to be overestimated

Overland flow out is underestimated

Drain flow out of the transect is overestimated

- **T31 WB: ET and Overland flow dominate the outflows**
- **T31 Sim.: Drain flow dominates the outflows**
- **Sim. WB by the 20 m appears to best approximate the measured WB**

* P: precipitation, ET: evapotranspiration, S: storage, GWxy: lateral GW flow, GWz: vertical GW flow

Preliminary Results
Fensholt Catchment : Sep 2016-Sept 2017

To directly compare the behaviour of the different models to the measured water balance (WB), the measured drain flow was used in the simulations.

		T32	MIKE-SHE model grid resolution			
	mm/year	WB	10m	20m	50m	100m
IN	P	865	865	865	865	865
	Drain flow	12,114	12,114	12,114	12,114	12,114
	GWxy	1,096	1189	4562	2224	1643
	Sum In	14,075	14168	17541	15203	14622
OUT	ET	662	620	631	547	560
	Drain flow	0	0	0	0	0
	Overland flow	9,873	8625	5103	1205	0
	GWxy	3,587	4094	2246	2301	176
	GWz	13	153	122	267	122
	ΔS	12	26	15	18	22
	Sum Out	14,146	13535	8377	3914	387
	Error	-71	650	9,424	10,865	13,742

- P: precipitation, ET: evapotranspiration, S: storage, GWxy: lateral GW flow, GWz: vertical GW flow

Increase in GW flow within the transect is only reproduced by 10m sim.

Overland flow out is underestimated, the 10m sim produces the best results

ΔS in the transect is in the correct order of magnitude

- **T32 WB: Drain and GW flow dominate the inflows, resulting in overland and GW dominating the outflows**
- **T32 Sim.: Overland flow tends to dominate the outflows**
- **Sim. WB by the 10 m appears to best mimic the measured WB**

Review of findings

- Where drain inflow dominates the other inflows, the 10m grid resolution model appears to perform best in reproducing the overland flow out and groundwater flow behaviour, as seen in T32.
- Where drain flow is not the dominate inflow and drains are present within the transect, the simulated outflow is dominated by drain flow out. Indicating a possible issue with simulated drain implementation within the model.
- Overall, the measured WB can be approx. reproduced using a simulation with a finer grid resolution (10m or 20m)!

Thanks for your attention!

Saskia Noorduijn (*sano@geus.dk*)
Anker Højberg (*alh@geus.dk*)

Tuesday 5 May 2020

References:
Petersen, R. J., Prinds, C., Iversen, B. V., Engesgaard, P., Jessen, S., & Kjaergaard, C. (2020). Riparian lowlands in clay till landscapes: Part I—Heterogeneity of flow paths and water balances. *Water Resources Research*, 56, e2019WR025808. https://doi.org/10.1029/2019WR025808

G E U S