DWRP Annual Meeting, GEUS, January 28-29, 2010

Nitrate reduction in geologically heterogeneous catchments (NICA)

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Outline

- NICA – project and partners
- Problem to be addressed
- Research questions
- Hypotheses
- Methodology

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NICA – project and partners

Supported by the Strategic Research Council (DSF)

- 2010 – 2013
- Total budget: 20.2 MDKK
- DSF funding: 14.5 MDKK
- 3 PhDs + 3 PostDocs

Partners

- GEUS (Co-ordinator)
- PhD+PostDoc Department of Earth Sciences, University of Aarhus
- PhD Department of Geology and Geography, University of Copenhagen
- Institute of Food and Ressource Economics, University of Copenhagen
- PhD Laval University, Quebec, Canada
- PostDoc Aarhus Geophysics, Aps
- Danish Agricultural Advisory Services
- ALECTIA A/S
- SkyTEM Aps
- DHI
- Municipality of Aarhus
- Municipality of Odder

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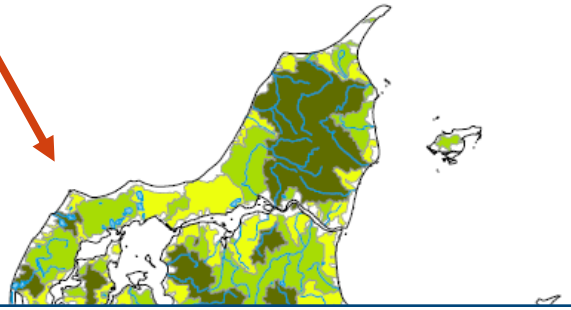
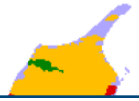
Catchment N balances

- general picture, entire Denmark

- What happens to N leached from root zone ?
  - Reduction in subsurface system
  - Reduction in surface water
  - Load to coastal areas

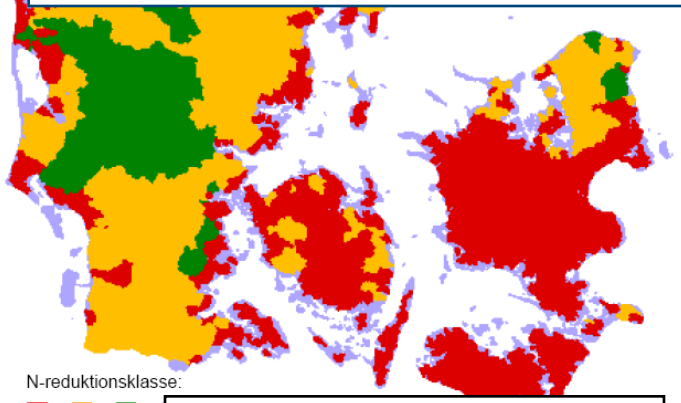




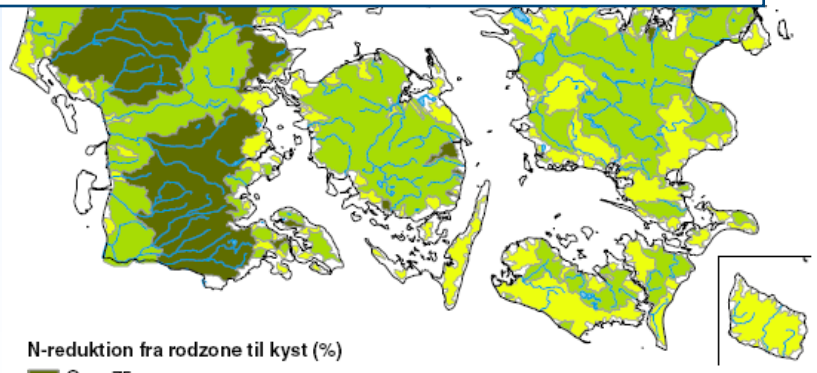
Conclusions

➔Majority of reduction takes place in groundwater system

➔Large uncertainty on these figures/maps



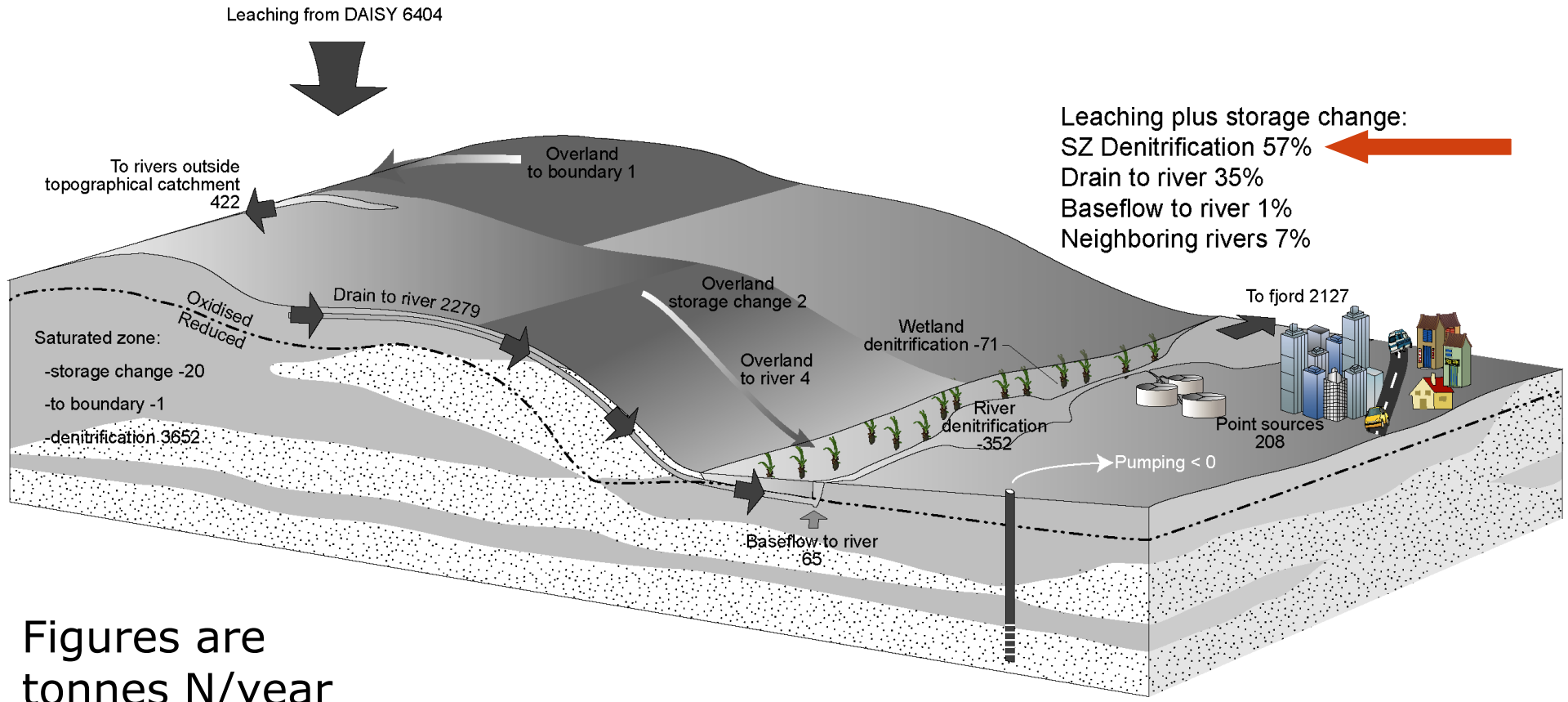
From: GEUS Rapport 2006/93



From: Faglig Rapport fra DMU 616/2007

Odense Fjord catchment N balance

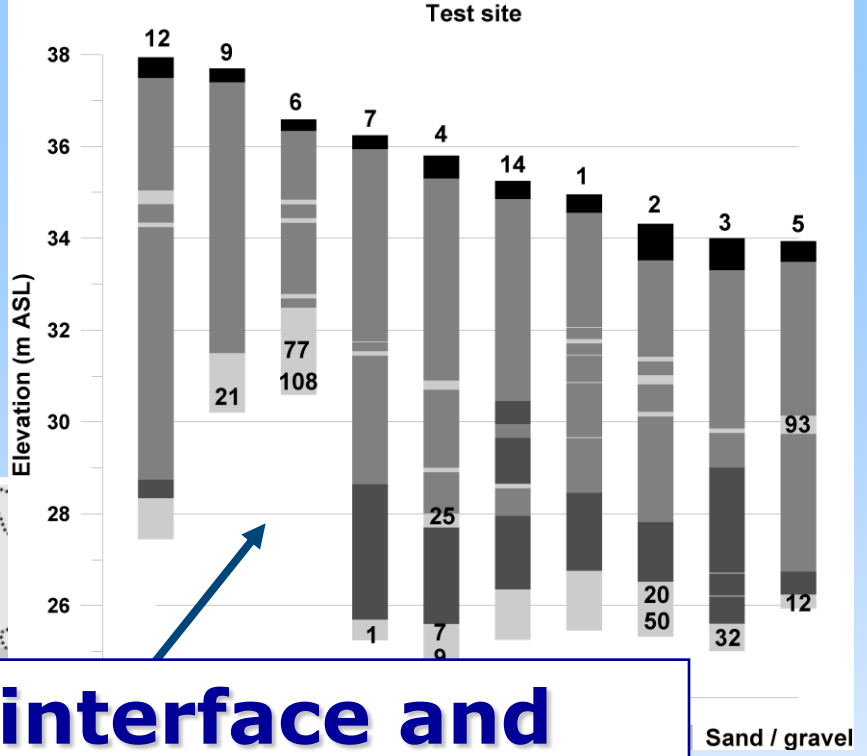
(Nielsen et al., 2005; Hansen et al., 2009)



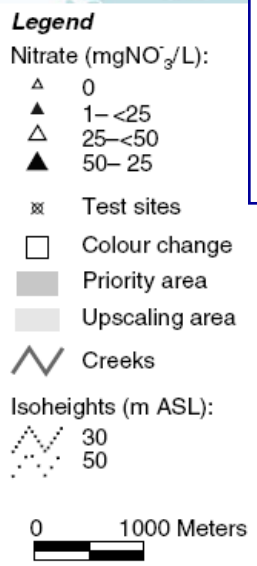
Figures are tonnes N/year

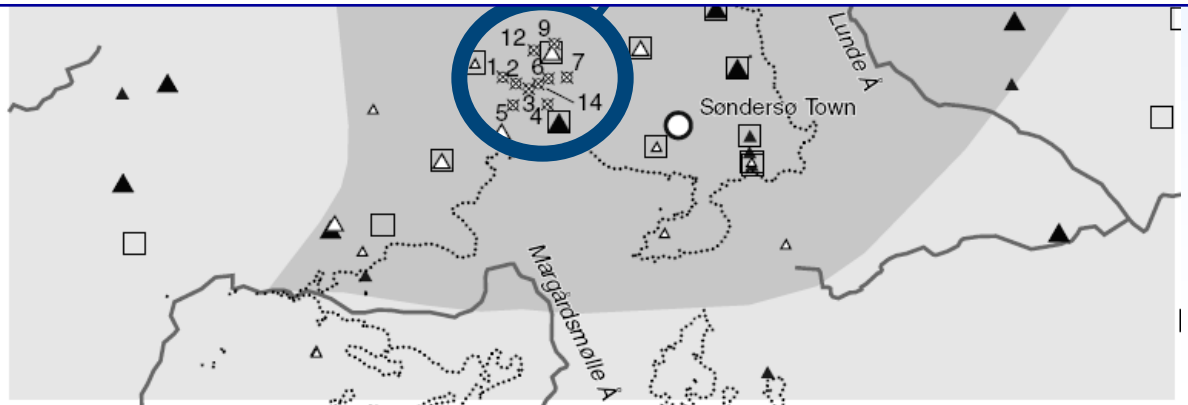
Local scale geological heterogeneity

(Hansen et al., 2008)



Depth to redox interface and aquitard thickness vary spatially at a length scale that is smaller than model grid size





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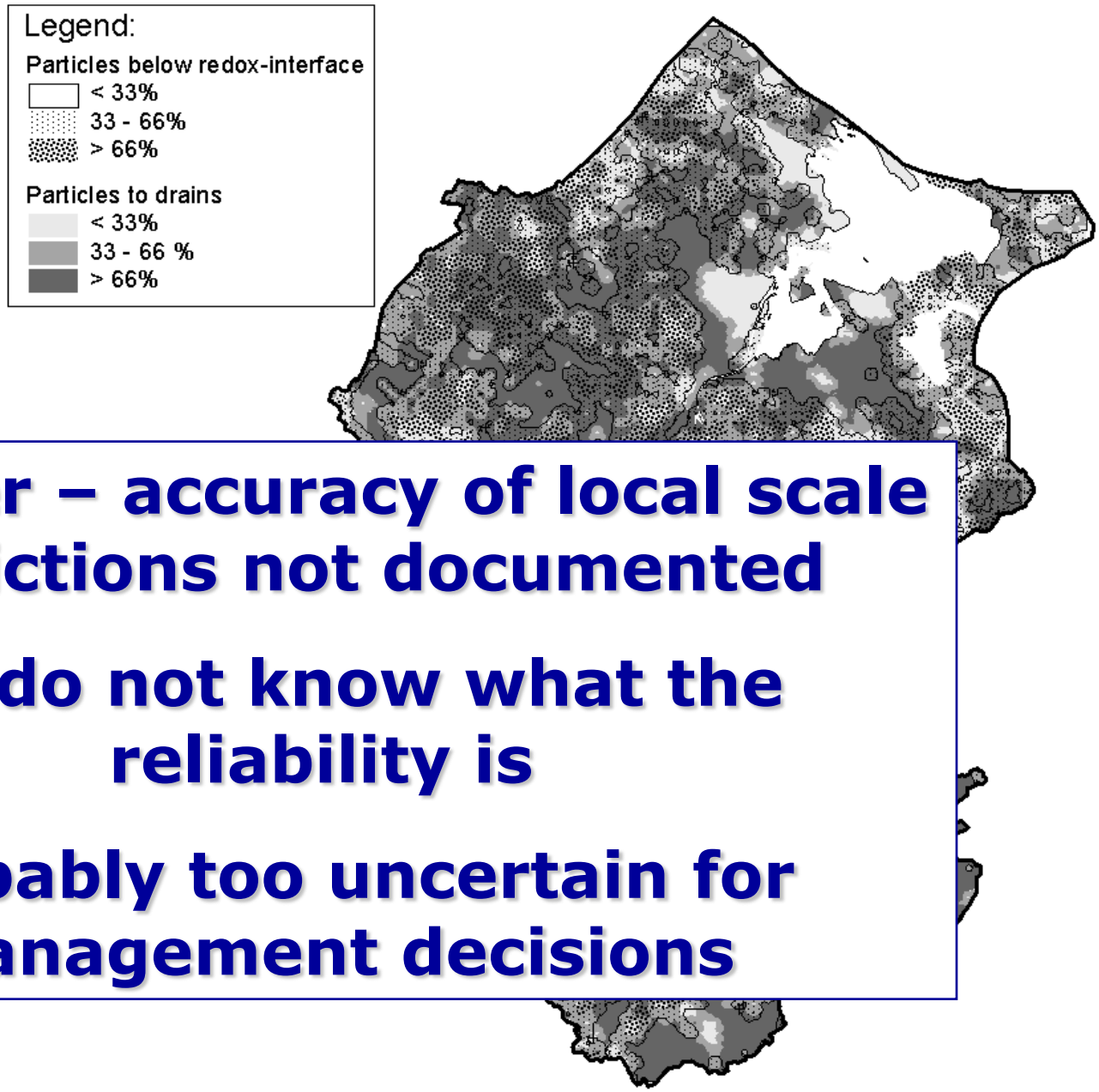
Models can simulate flow paths and reduction at small scale



However – accuracy of local scale predictions not documented

We do not know what the reliability is

Probably too uncertain for management decisions

NICA – Research questions

- How can we improve the assessment of local scale geological heterogeneity?
- How can we assess the heterogeneity of the location of the redox interface and the implications of this heterogeneity on subsurface nitrate reduction?
- How can we identify the smallest potential scale (RES) at which a hydrological model can have predictive capability?
- What is the smallest possible scale at which nitrate reduction in the subsurface can be assessed with a specified uncertainty for Danish catchments?
- What are the potential economical benefits of more precise, local scale agricultural regulations?

Using (new) methodologies and tools that have the potential for operational use in Danish water resources management

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NICA – Hypotheses

- **Geological heterogeneity** at local scale (< 100m) resulting in small scale spatial variations in flow paths and location of redox interface is a dominating process when upscaling subsurface nitrate transformation to larger scales (> 100m)
  - Geological heterogeneity can be described adequately by new geophysical techniques (MiniSkyTEM and MRS)
  - Heterogeneity of depth to redox interface can be inferred from geological heterogeneity
  - The minimum spatial scale at which a hydrological model potentially has predictive capability is governed by the length scale at which local scale geological heterogeneity can be described deterministically

- Measures to reduce N-load to surface water can be **implemented most cost-efficiently**, if they are differentiated, based on specific local (< 100 m) knowledge, and if farmers are actively involved in deciding which measures to adopt

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NICA – Planned methodologies

- Field sites
  - 1 or 2 LOOP experiemental agricultural catchments (~10 km^2)
  - Norsminde, 101 km^2 (moraine till)
- New geophysical instruments
  - MiniSkyTEM
  - MRS (Magnetic Resonance Sounding)
- Field work
  - Ground truth for geophysics
  - Geological heterogeneity
  - Depth to redox interface
  - N-measurements in stream – Norsminde only
- Geological modelling
  - Manual interpretation
  - Stochastic geology (TProGS)
- Hydrological modelling
  - MIKE SHE/Daisy
  - HydroGeoSphere
  - RWHET
- Scale analysis – Representative Elementary Scale (RES)
- Water management
  - Involvement of farmers
  - Economis assessments

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MiniSkyTEM – a new instrument

- Smaller frame
- Larger flight speed
- Improved resolution of upper layers (0-30 m)

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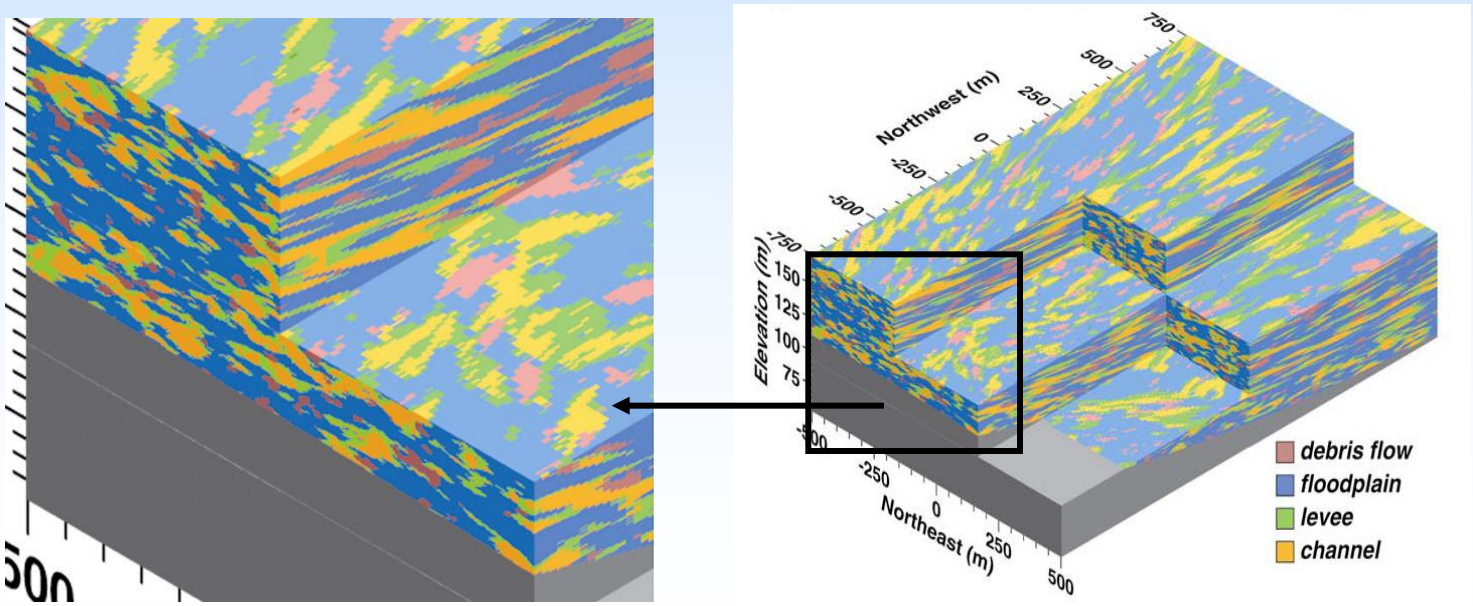
Geological modelling

- Etablish new geological models based on
  - Existing borehole data
  - New geophysical data (in particular MiniSkyTEM)
  - New borehole data
- Stochastic interpolation geologies (TProGS)
  - Incorporates facies architecture
  - Different geological realisations



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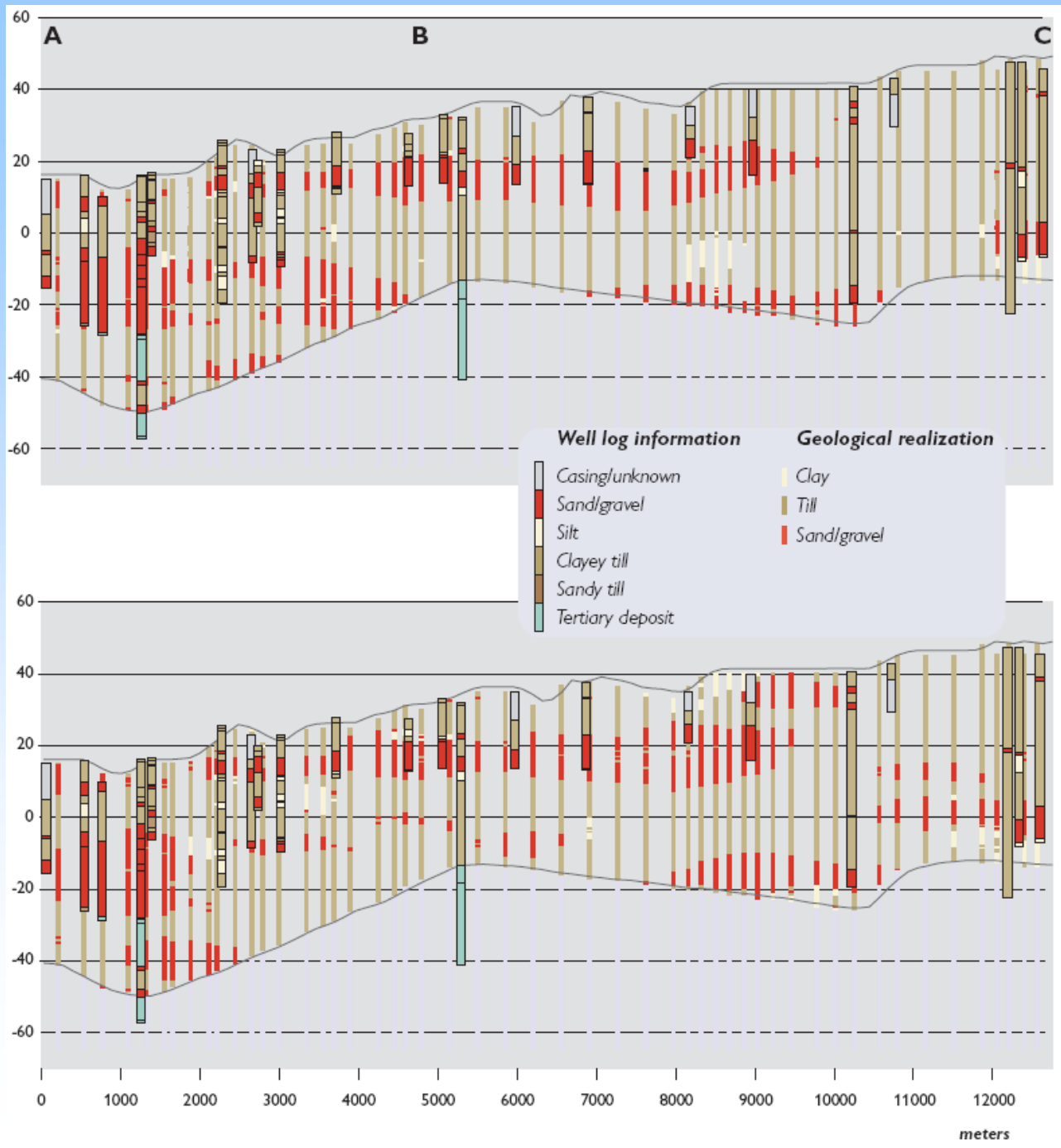
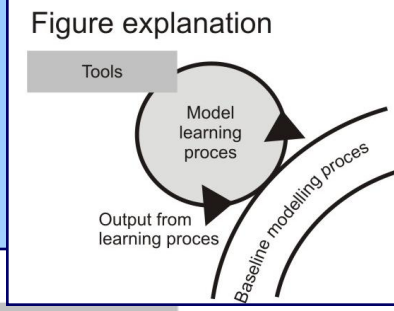
Stochastic geology

Example:

Two alternative, equally probable geological interpolations between boreholes



Modelling tools and new data



HydroGeoSphere
RWHET

Flow paths in catchment

Improved transport model

MIKE SHE / MIKE11

Improved geolgical model

TProGS

Data on geology

Field investigations

MiniSkyTEM
MRS

MIKE SHE

CATCHMENT MODEL

MIKE SHE / MIKE11

N-balance

Field investigations

Redox interface

Improved conceptualisation

HydroGeoSphere

Operational N calculation

N leaching

Daisy - MIKE SHE coupled
Daisy standard
N-balance

Scale analysis

- Representative Elementary Scale (RES)

RES = The smallest spatial scale at which a model potentially has predictive capability

- Catchment characteristics exhibit local scale heterogeneity
- We will never get sufficient data to describe local scale heterogeneity deterministically
- But we can describe local scale heterogeneity geostatistically by use of probability density functions and semi-variograms
- Many plausible realisations of local scale characteristics exist
  - Generate 5-10 geological models
  - Calculate the effects of the differences between the 5-10 models with respect to subsurface nitrate reduction for different size sub-catchments

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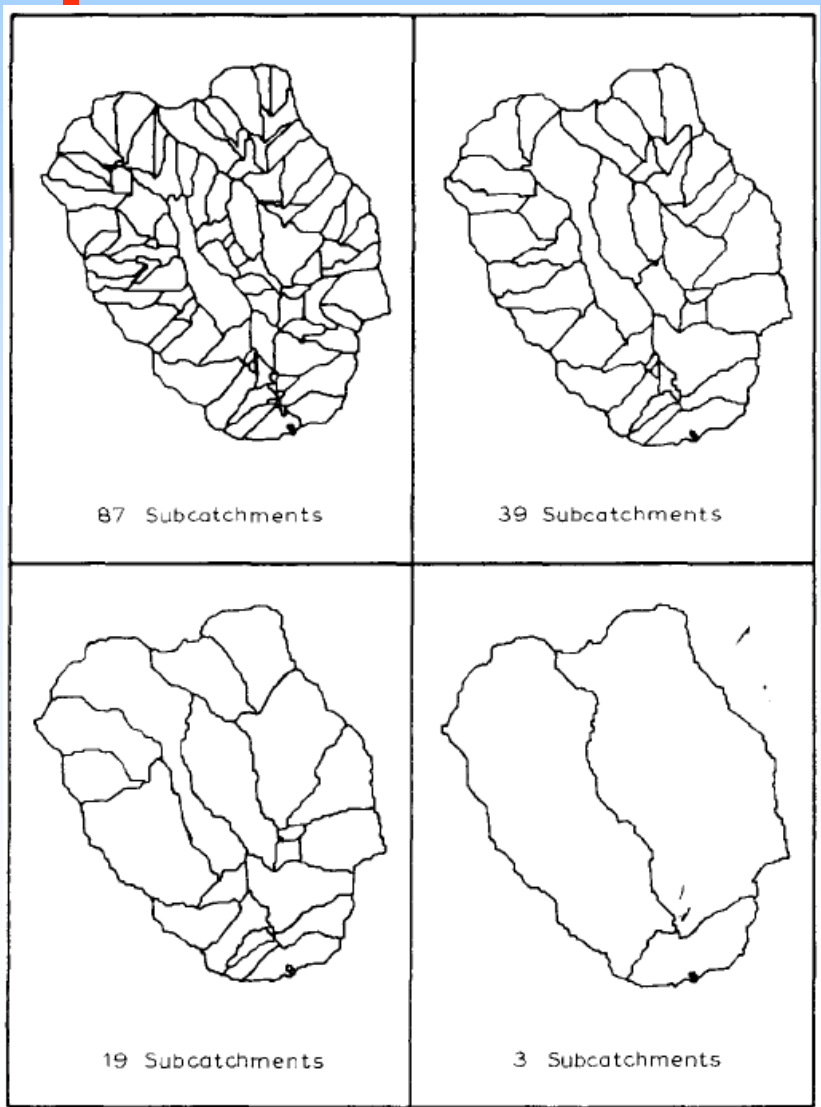
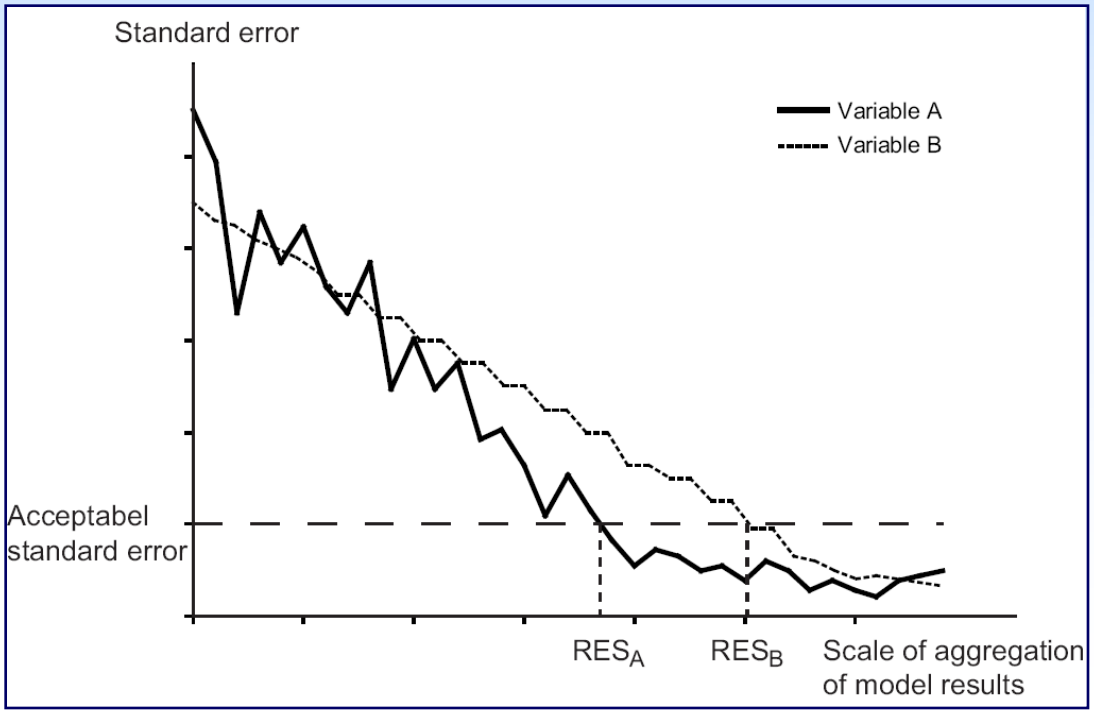
Representative Elementary Scale (RES) - principle of calculation

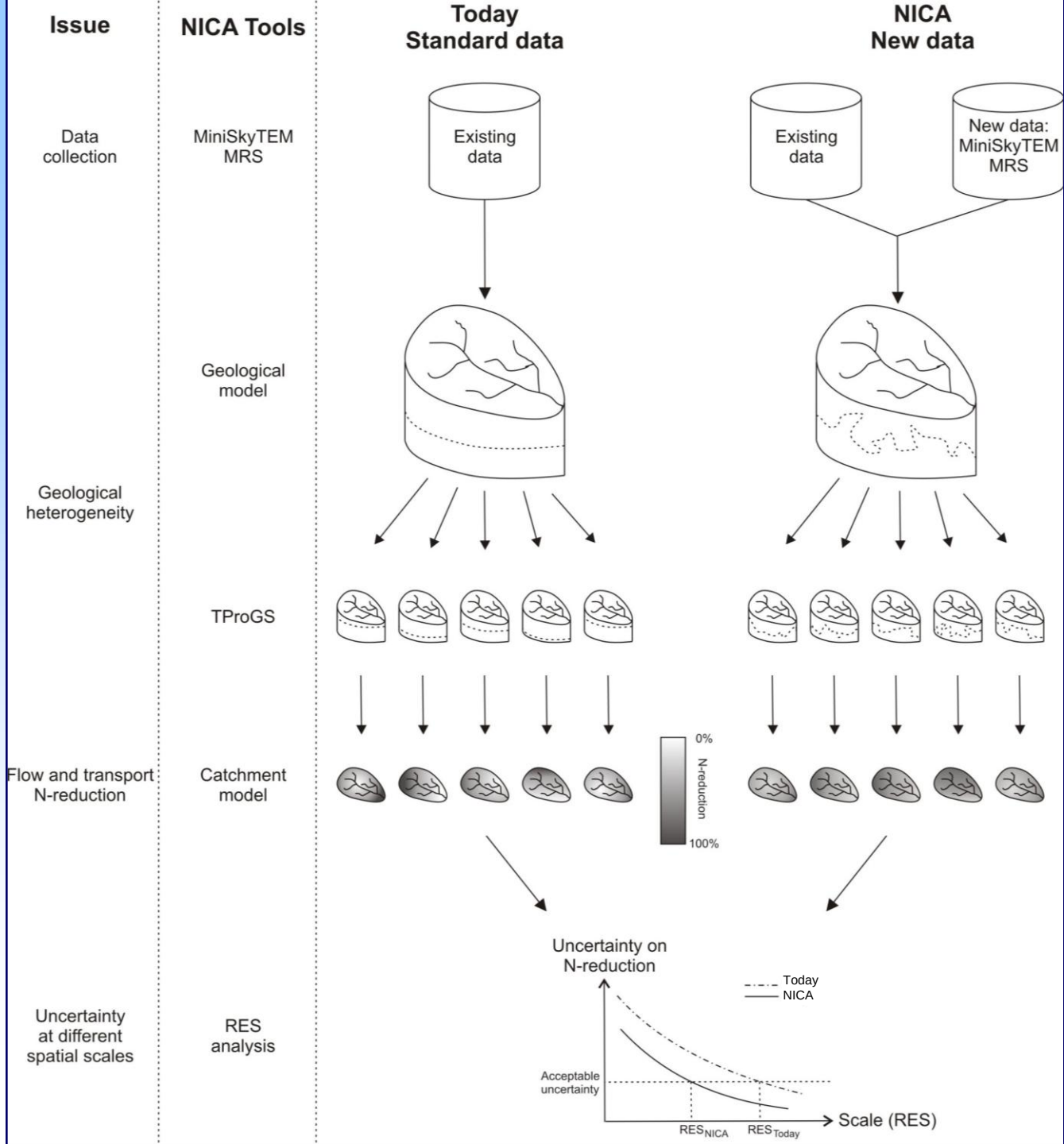


Heterogeneity – stochastic generation

- Geology
- Depth to redox interface
- Net precipitation / N-leakage (?)



General approach



Further information

- Web site under construction

- jcr@geus.dk

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