Hydrological extremes and feedbacks in the changing water cycle (HydEF)

PhD projects: Mike Simpson – Water resources (IoW)
Tim Foster – Agro-hydro-economics (IoW)
Kirsty Upton – Revised method for gw DO

Steering Group meeting 2,
15th February 2012, Imperial College London

Water Resource Impact and Adaptation under Climate Change for the Isle of Wight

Mike Simpson

Supervisors: Dr. Adrian Butler and Dr. Neil Mcintyre

IW Council, www.islandbreaks.co.uk

Case study on Isle of Wight:

- Develop hydrological / water resource model for the Isle of Wight (using outcomes of other CWC work).
- Use model to assess water resources under climate change.

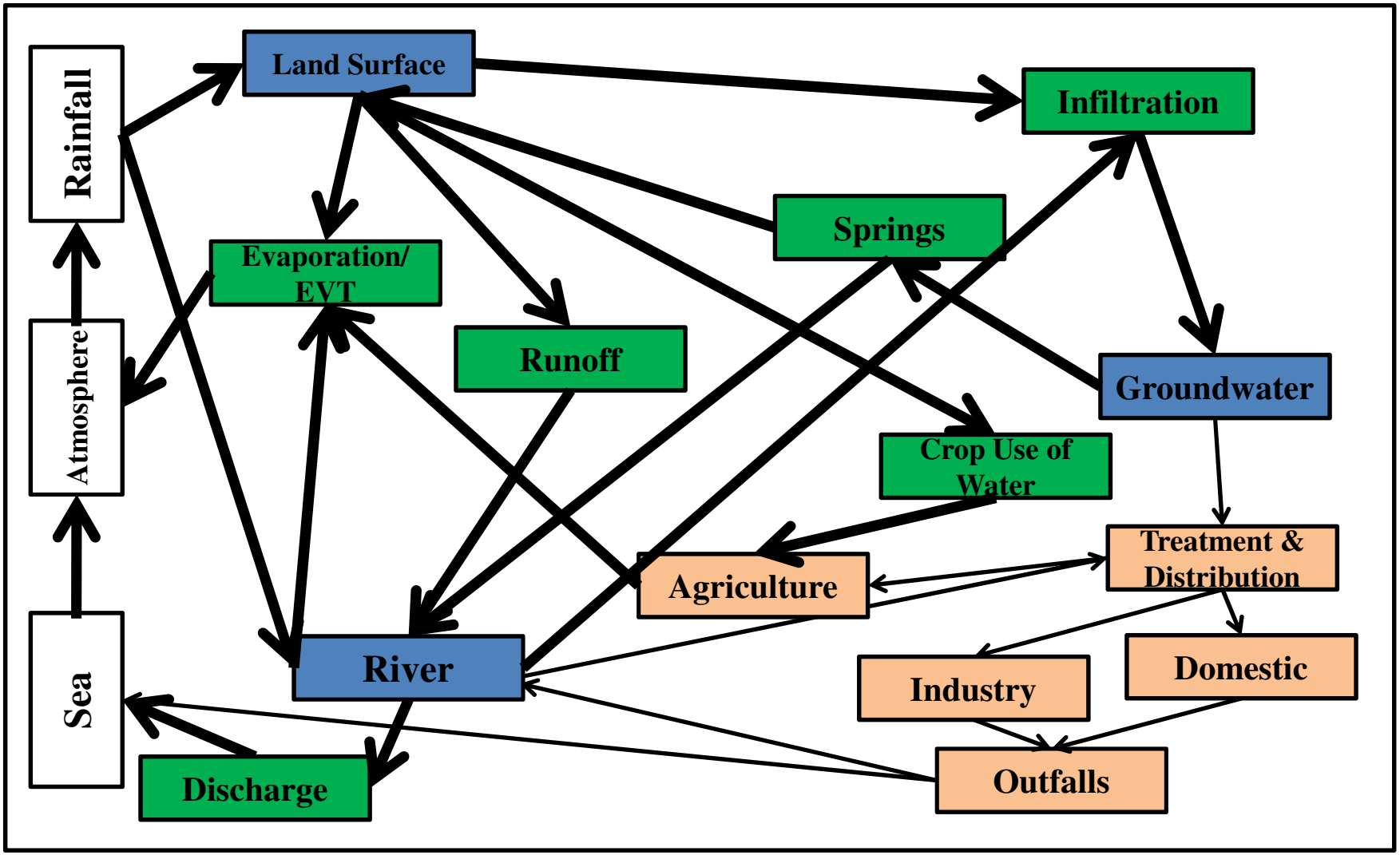
Isle of Wight:

- Selected due to its existing exposure to drought and water shortage.
- Clearly defined boundary conditions and fully metered water supply.
- Geology representative of Southern England.

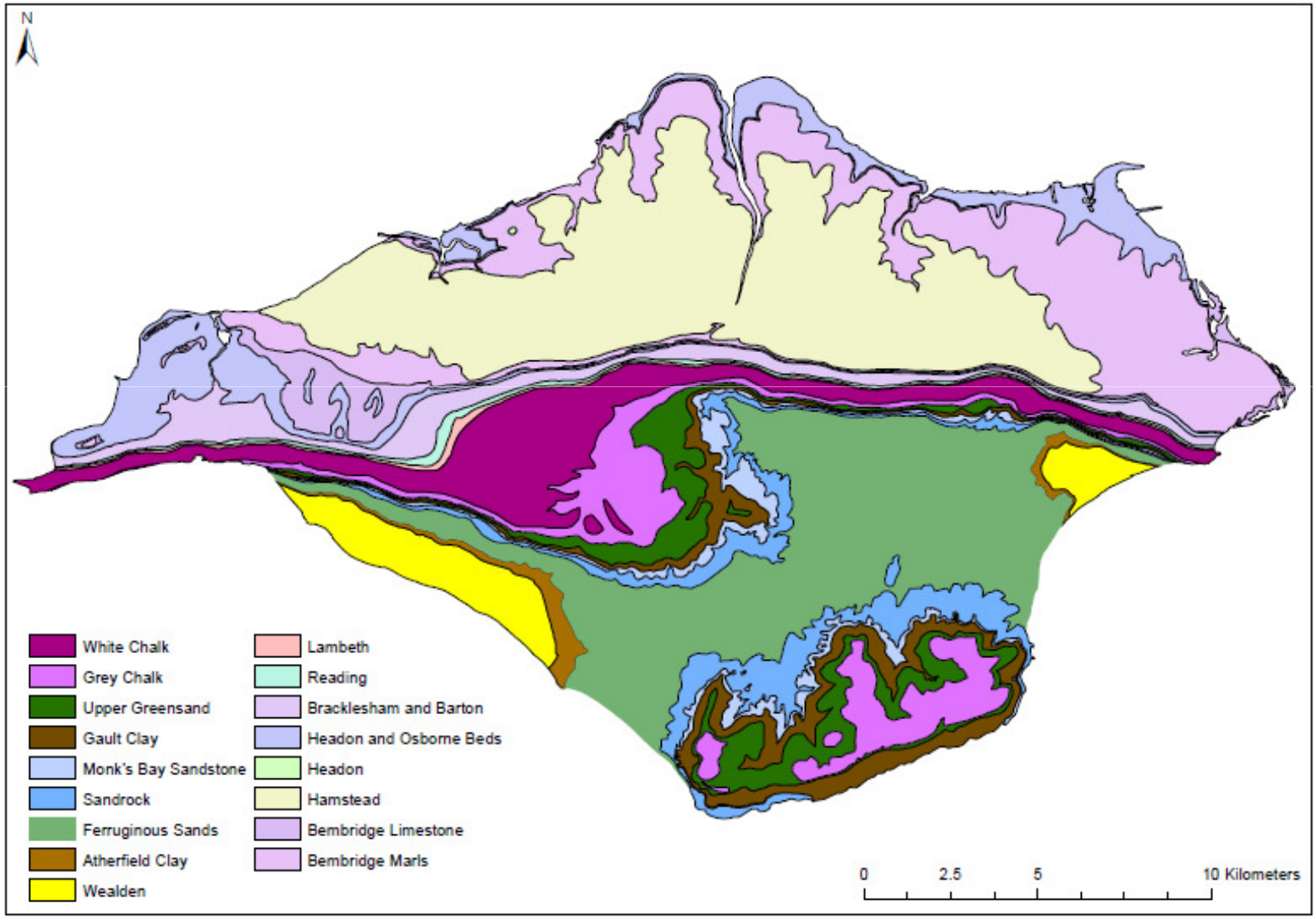
Core research questions:

- What is the appropriate level of model complexity for assessing the resilience of an integrated groundwater/ surface water catchment in Southern England to the impacts of climate change?
- How do the various sources of uncertainty affect the development of strategies to manage system resilience?

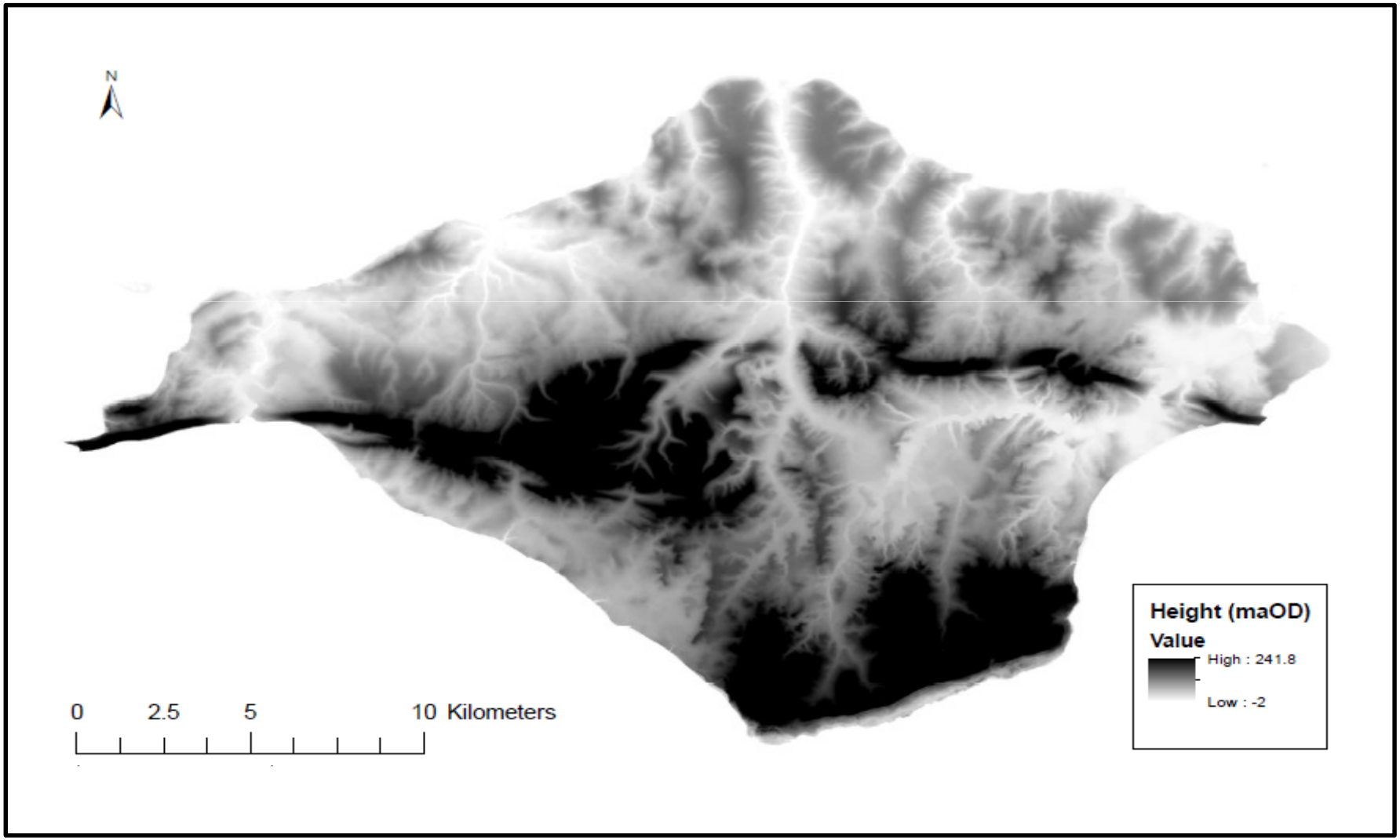
Water connections



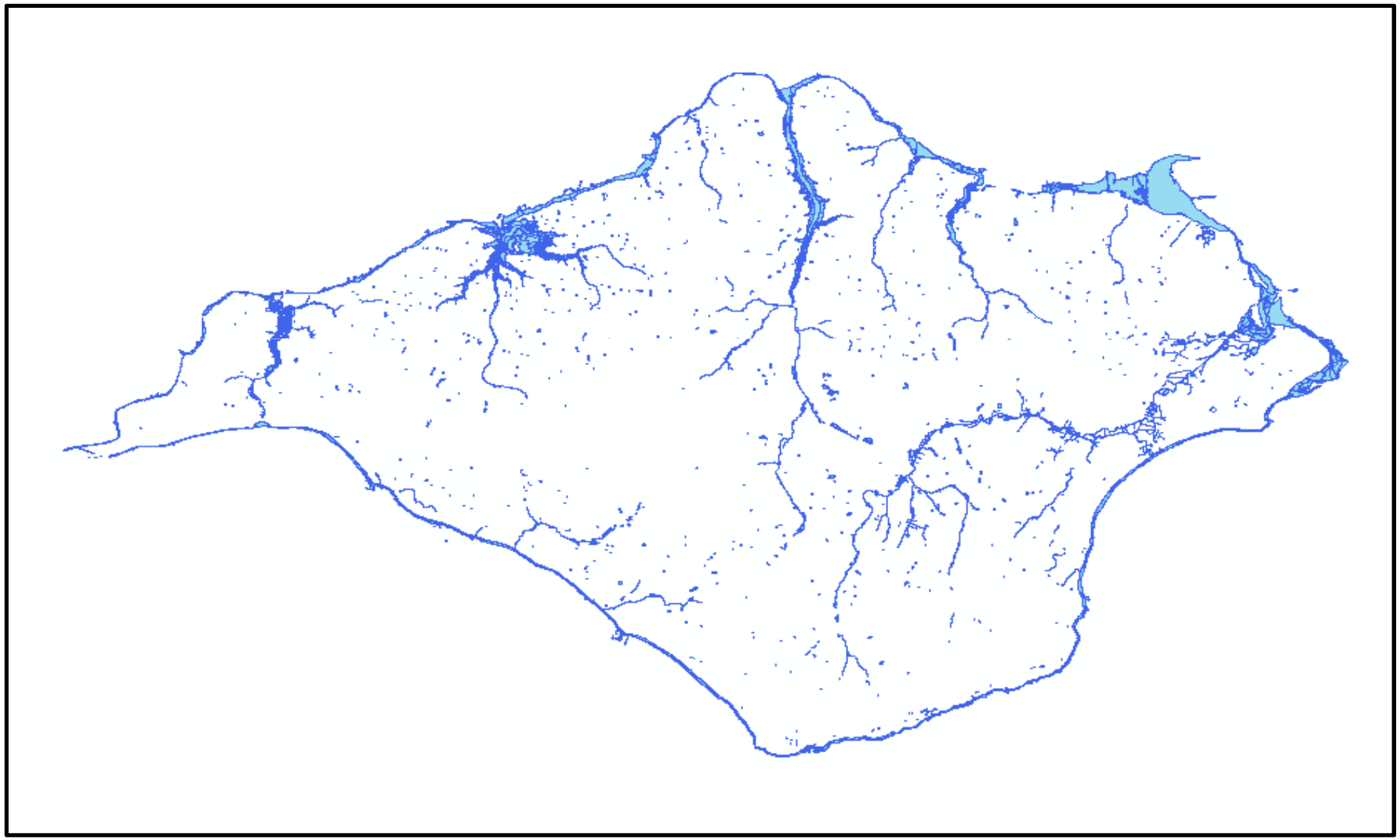
Geology


N
White Chalk
Grey Chalk
Upper Greensand
Gault Clay
Monk's Bay Sandstone
Sandrock
Ferruginous Sands
Atherfield Clay
Wealden
Lambeth
Reading
Bracklesham and Barton
Headon and Osborne Beds
Headon
Hamstead
Bembridge Limestone
Bembridge Marls
0
2.5
5
10 Kilometers

Topography

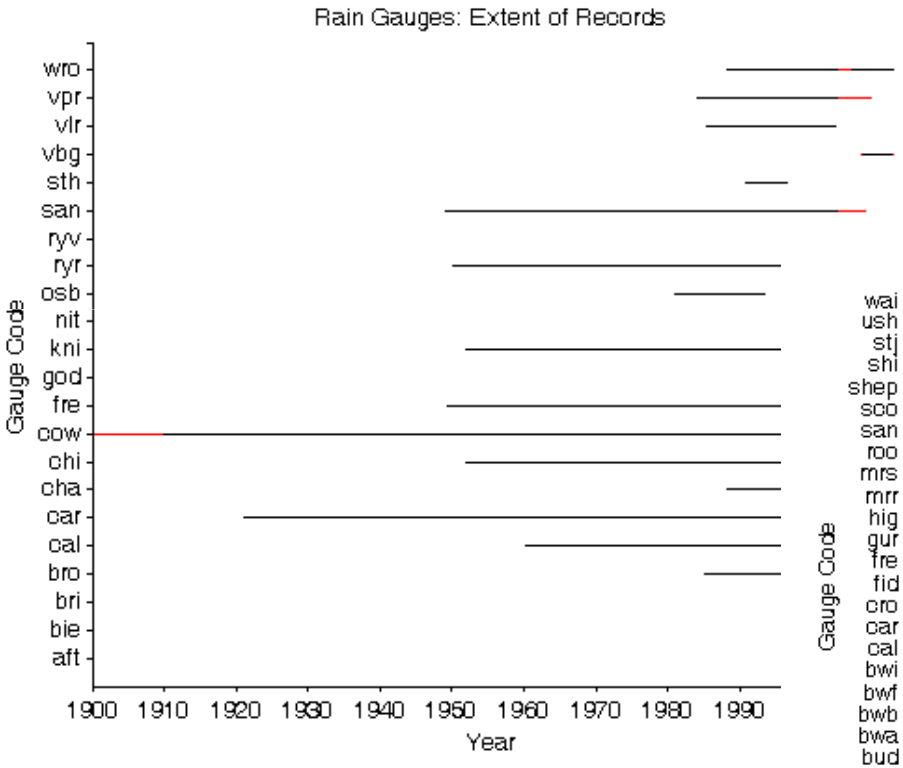


Drainage

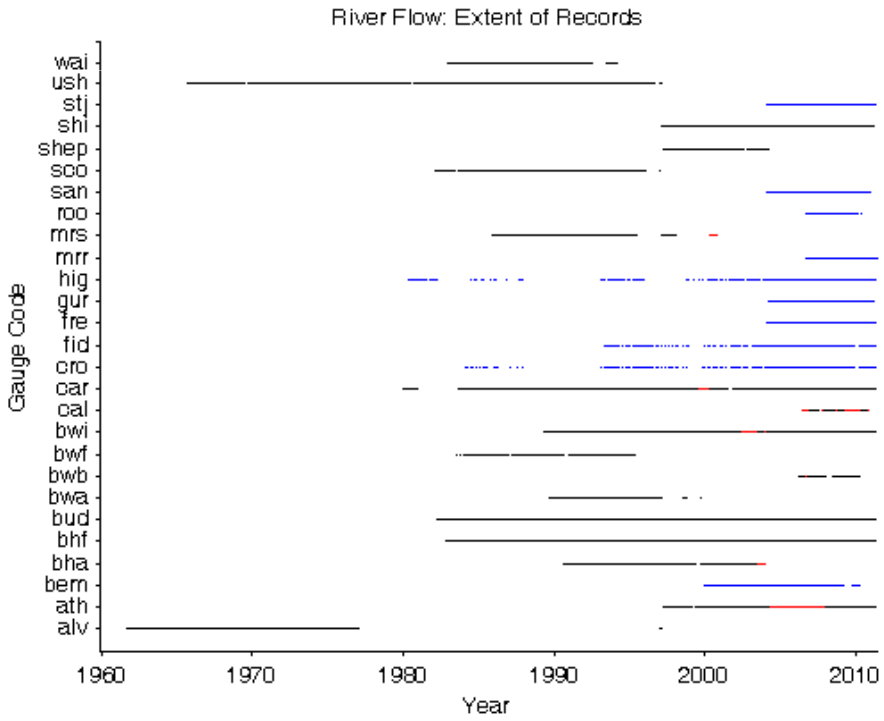


Data acquisition

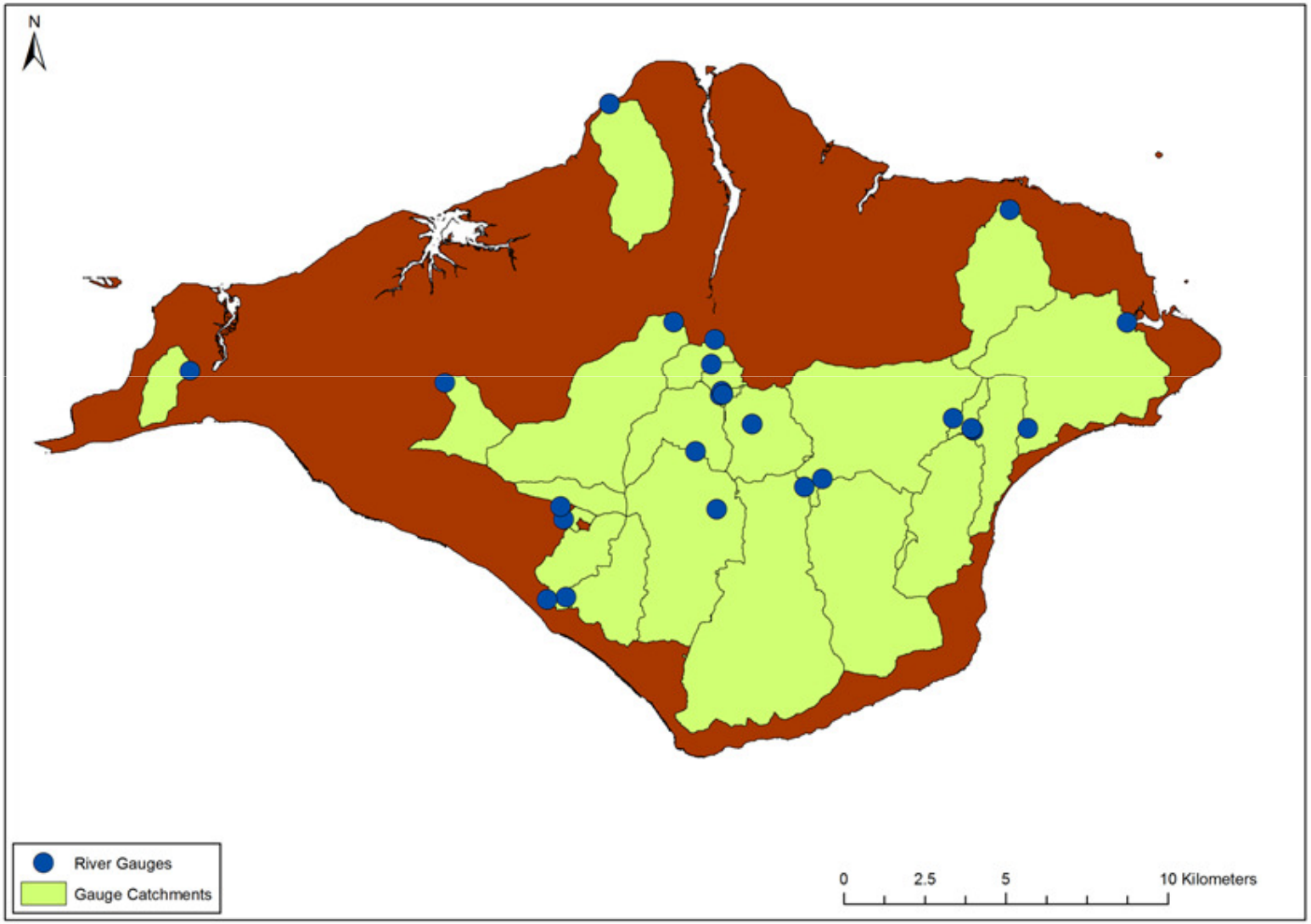
Rainfall



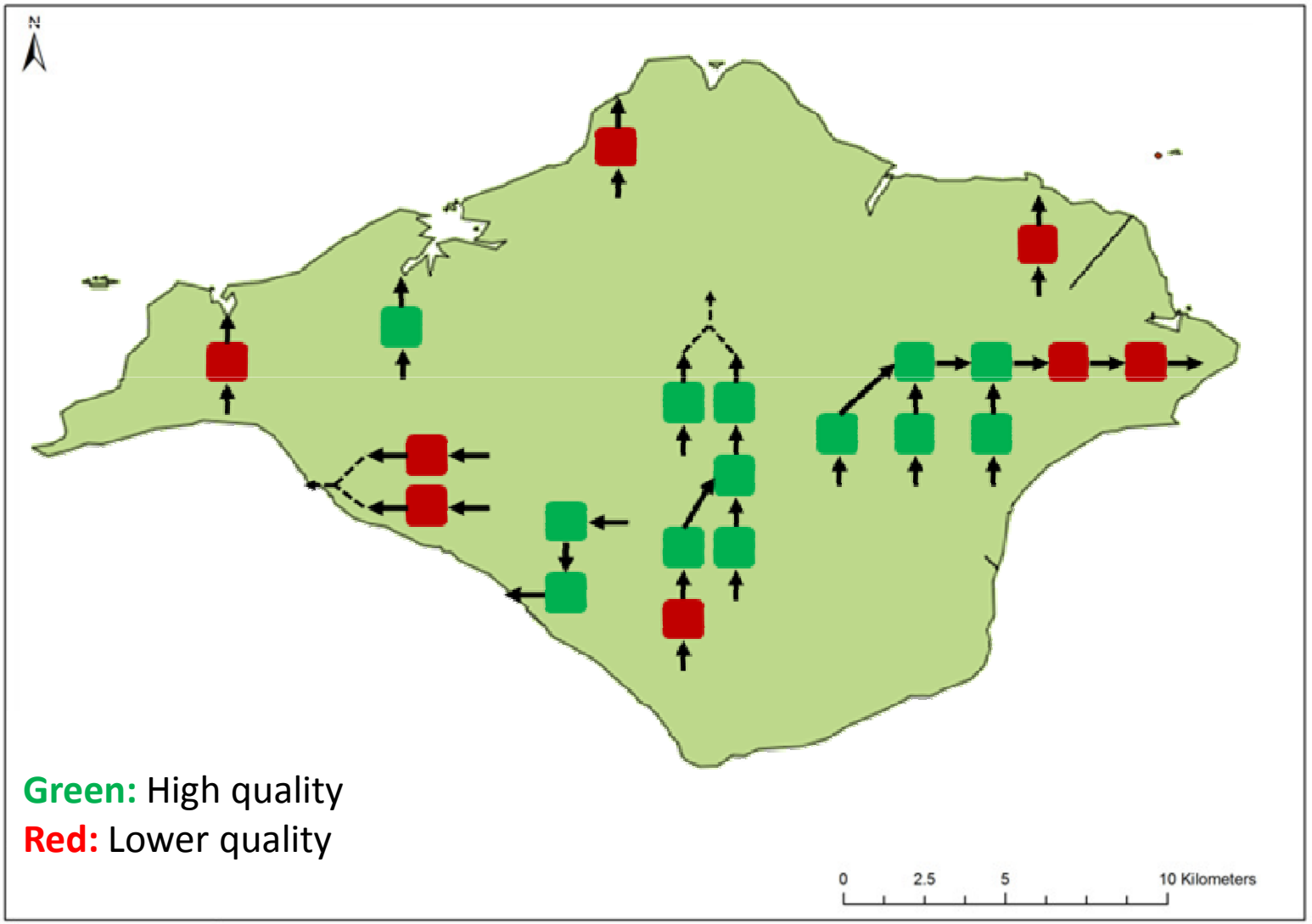
Streamflow



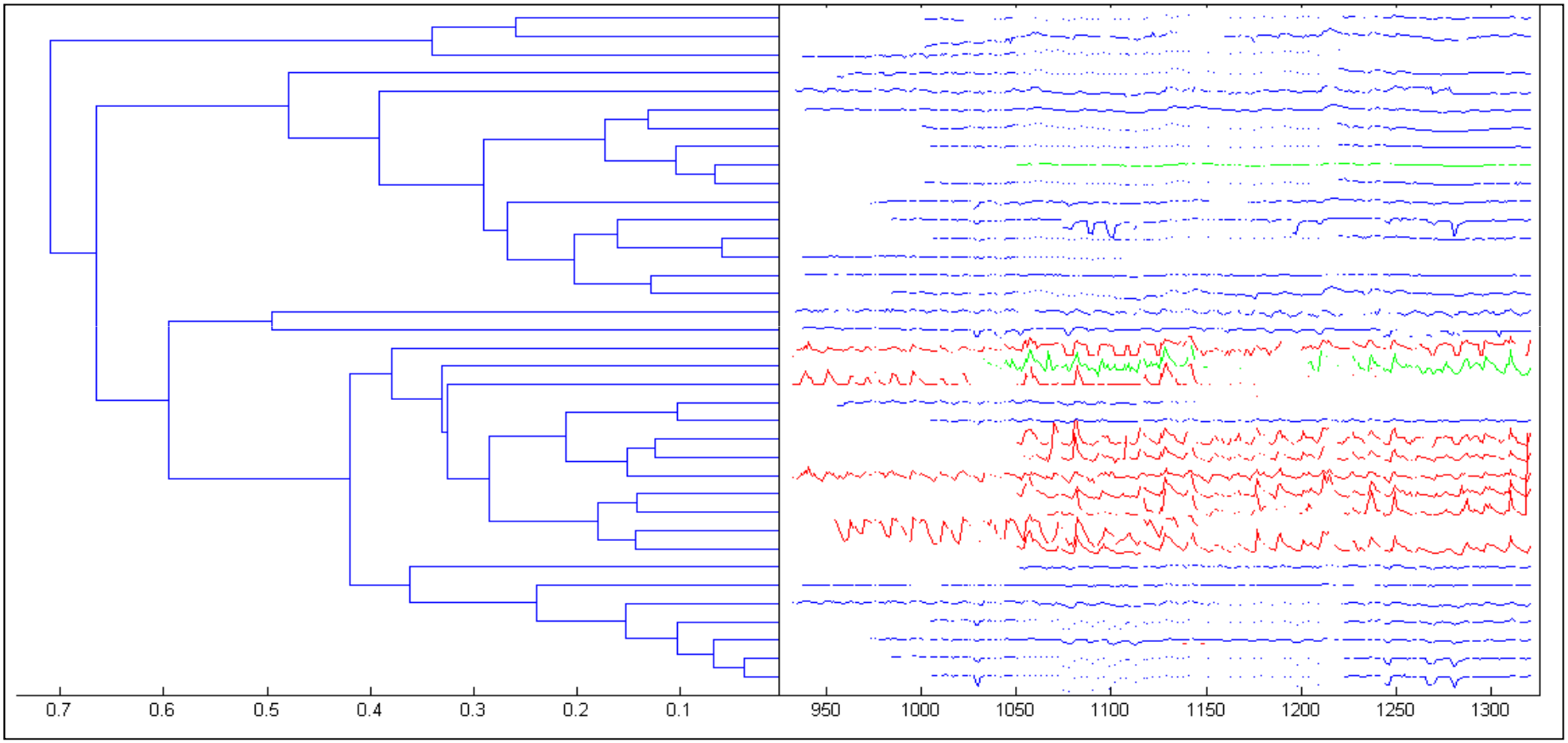
Data acquisition: stream flow



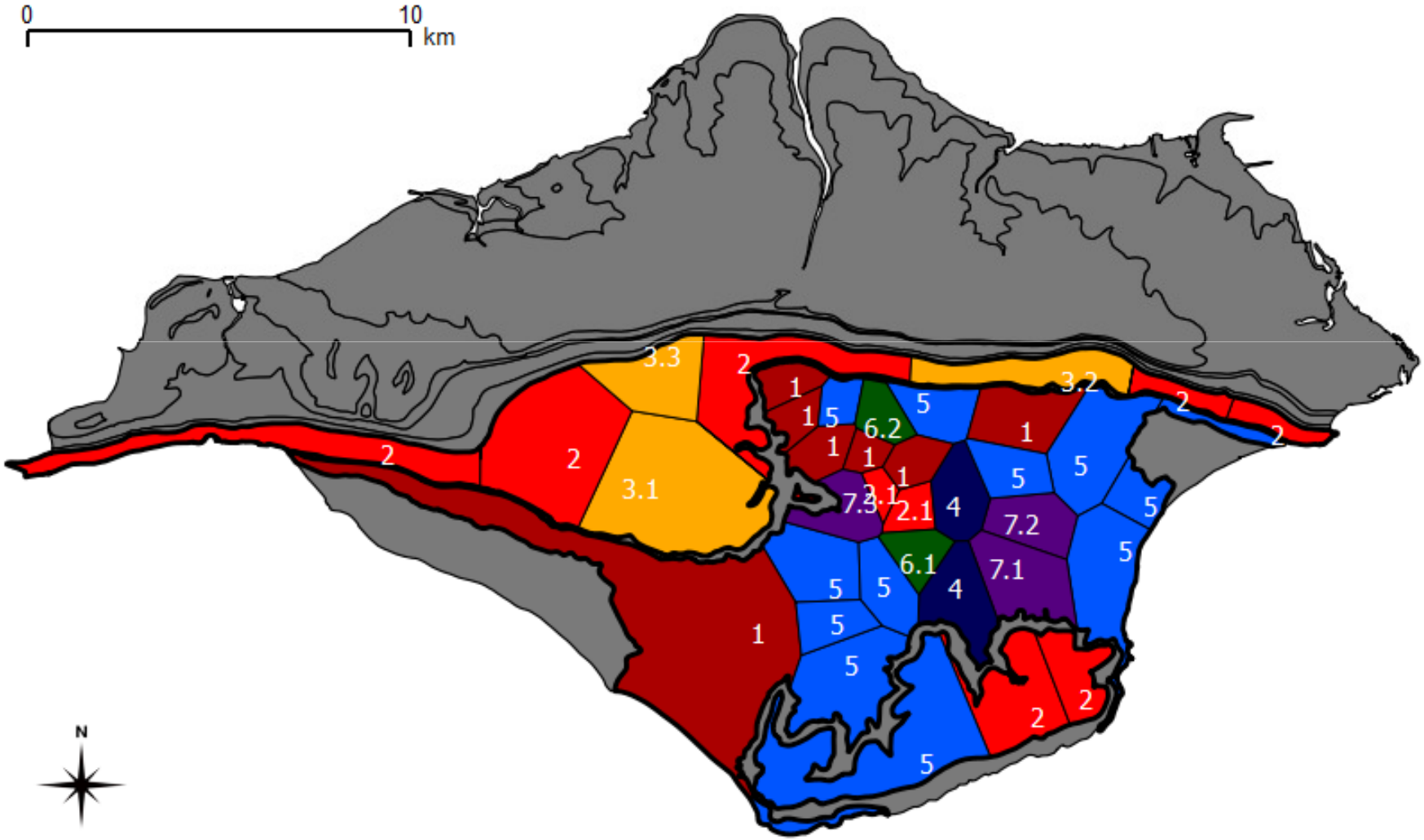
Sub-catchment modelling



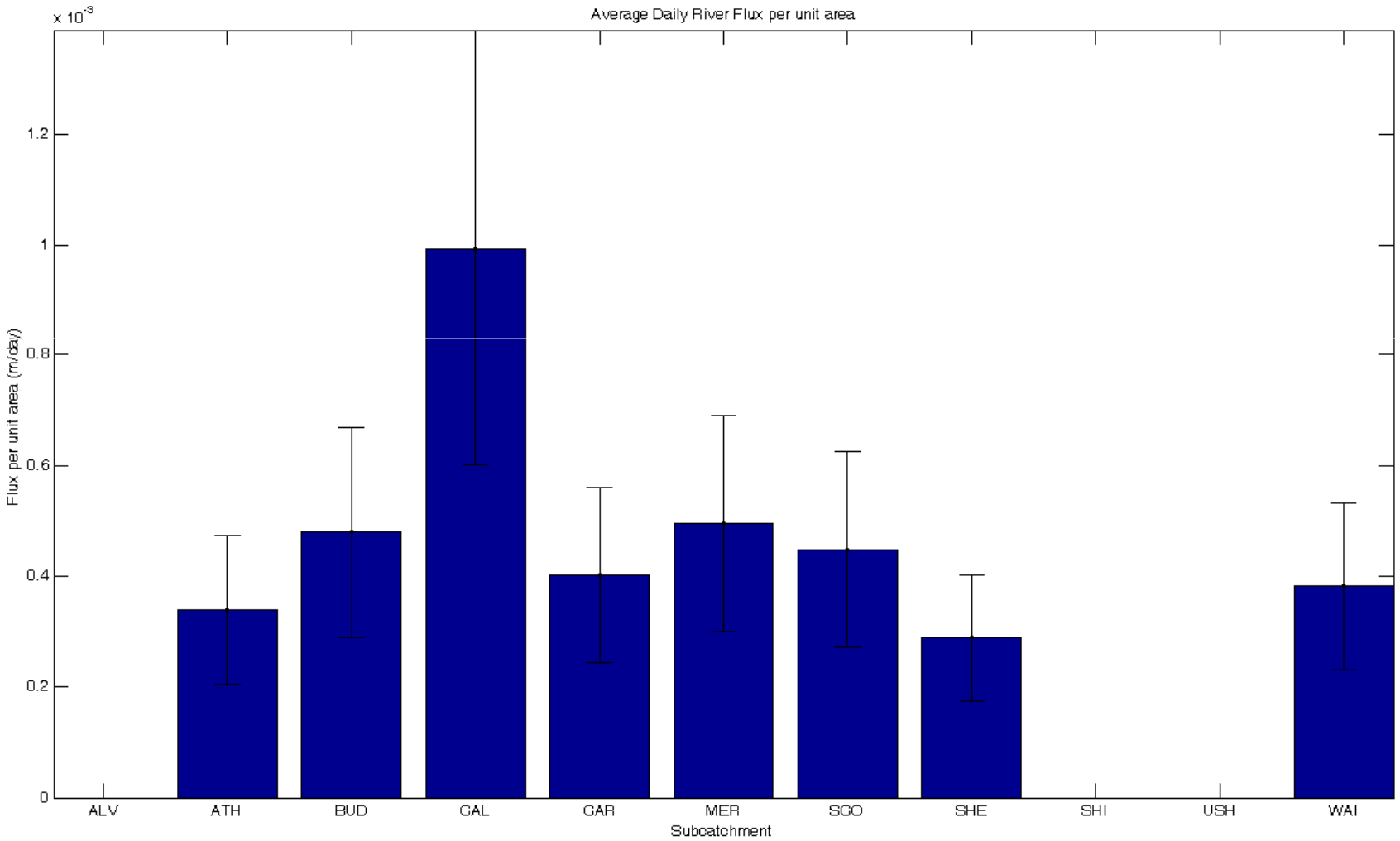
Cluster analysis of gw responses



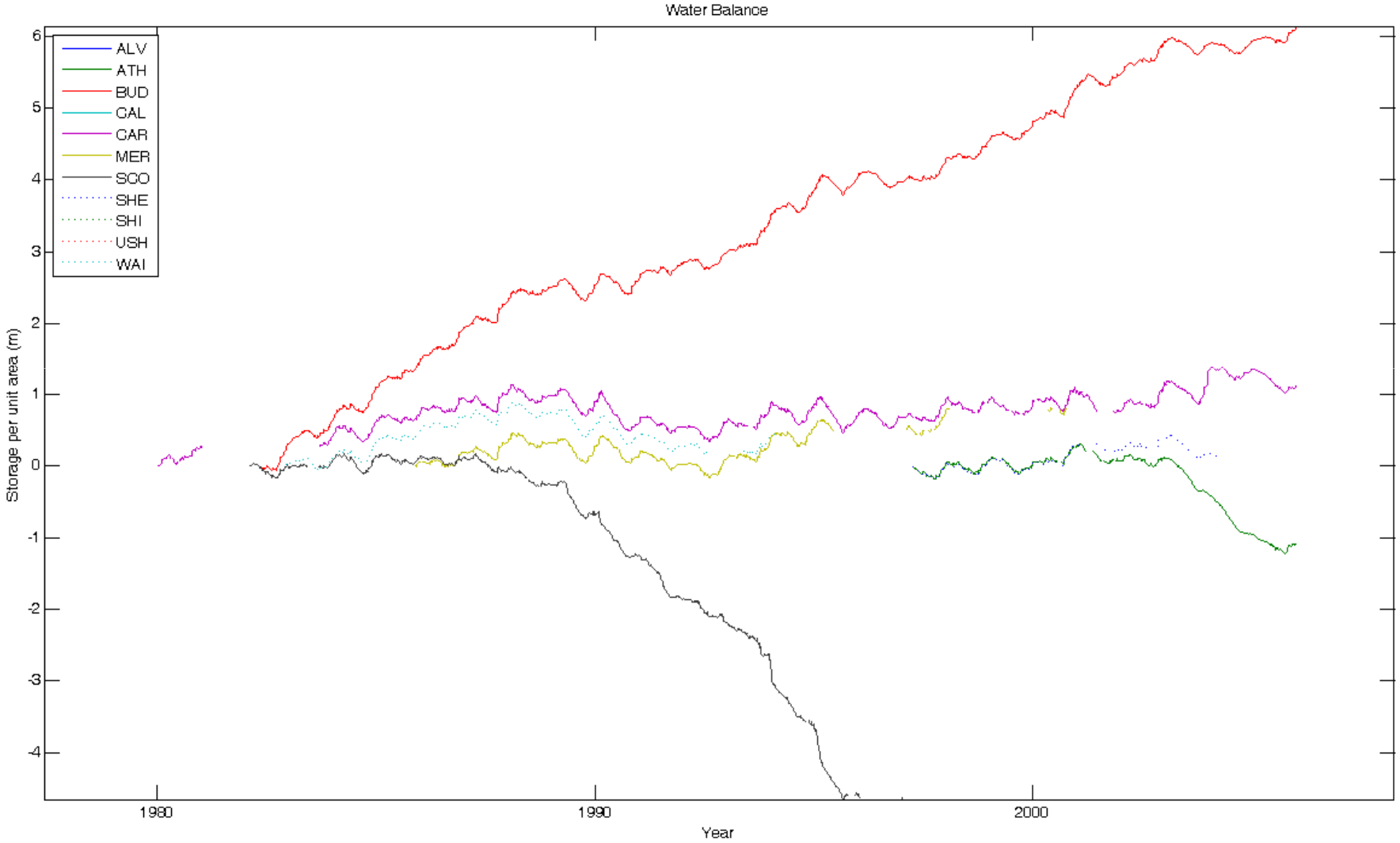
GW area delineation



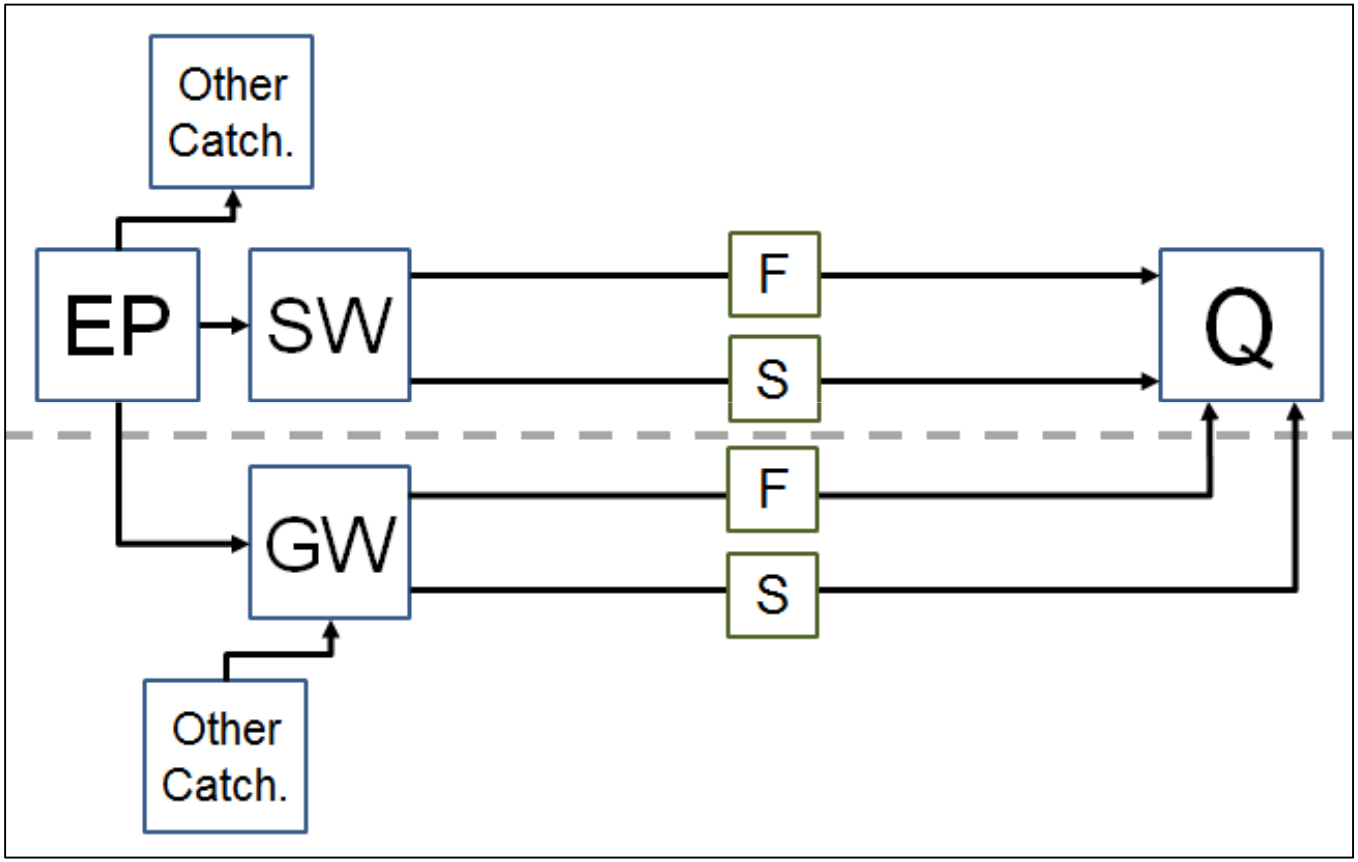
River fluxes



Water balance (storage change)



Conceptual model development



Future work

1. Categorisation and Spatial Identification of Consistent Groundwater Units
    i. Cluster Analysis
    ii. Interpolation between boreholes
    iii. Comparison with Geology

2. An Integrated Groundwater/Surface Water Model of the Isle of Wight
    i. Model Structure
    ii. Assessment of model performance for calibration and skilfulness scoring
    iii. Gauged and Ungauged Subcatchments

3. Use of Climate Change Models in developing Adaptive Strategies for Water Resource Management
    i. Climate Modelling
    ii. Impacts Map
    iii. Evaluation of Adaptive Measures

Future work

- Further work on abstraction/discharge
- Climate Modelling Process
  - Acquisition of perturbation data
  - Translation into spatial/temporal inputs
- Water Resource Impacts Mapping
- Adaptive Strategies Review

Hydro-economic modelling of agricultural resilience to climatic and socio-economic changes on the Isle of Wight

Tim Foster – Grantham Climate Change Institute PhD Student

Supervisors: Dr Adrian Butler, Dr Neil McIntyre

Imperial College London

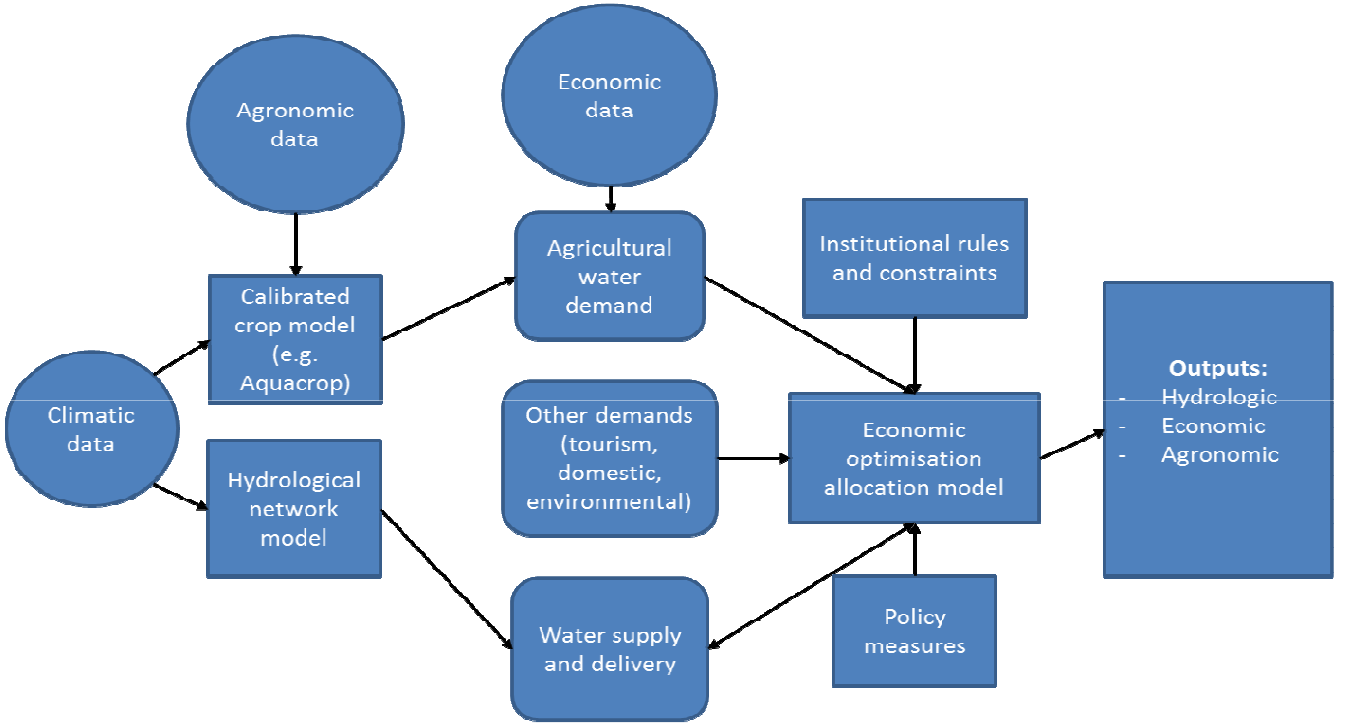
Grantham Institute for Climate Change

Economics as a tool to manage water resources

- In a mature water economy where demand exceeds supply the relevant concept is water scarcity not water shortage.
- Scarce water should be allocated to maximise the gains it provides to society.
- However this principle is not applied in the UK where water rights are treated as fixed and static.

“Managing water as an economic good is an important way of achieving efficient and equitable use, and of encouraging conservation of water resources” (UN, 1992)

Novel hydro-agro-economic modelling framework for S. England



Stage One
Review the agricultural sector in terms of crops, water use and economic drivers

Stage Two
Calibrate a crop model and use to provide demand curves for key crops

Stage Three
Develop an economic representation of farmer decision-making

Stage Four
Integrate with hydrological network model (based on model by Mike Simpson – CWC student)

Stage Five
Apply to the IOW to assess resilience and adaptive capacity to future changes

Application to the Isle of Wight

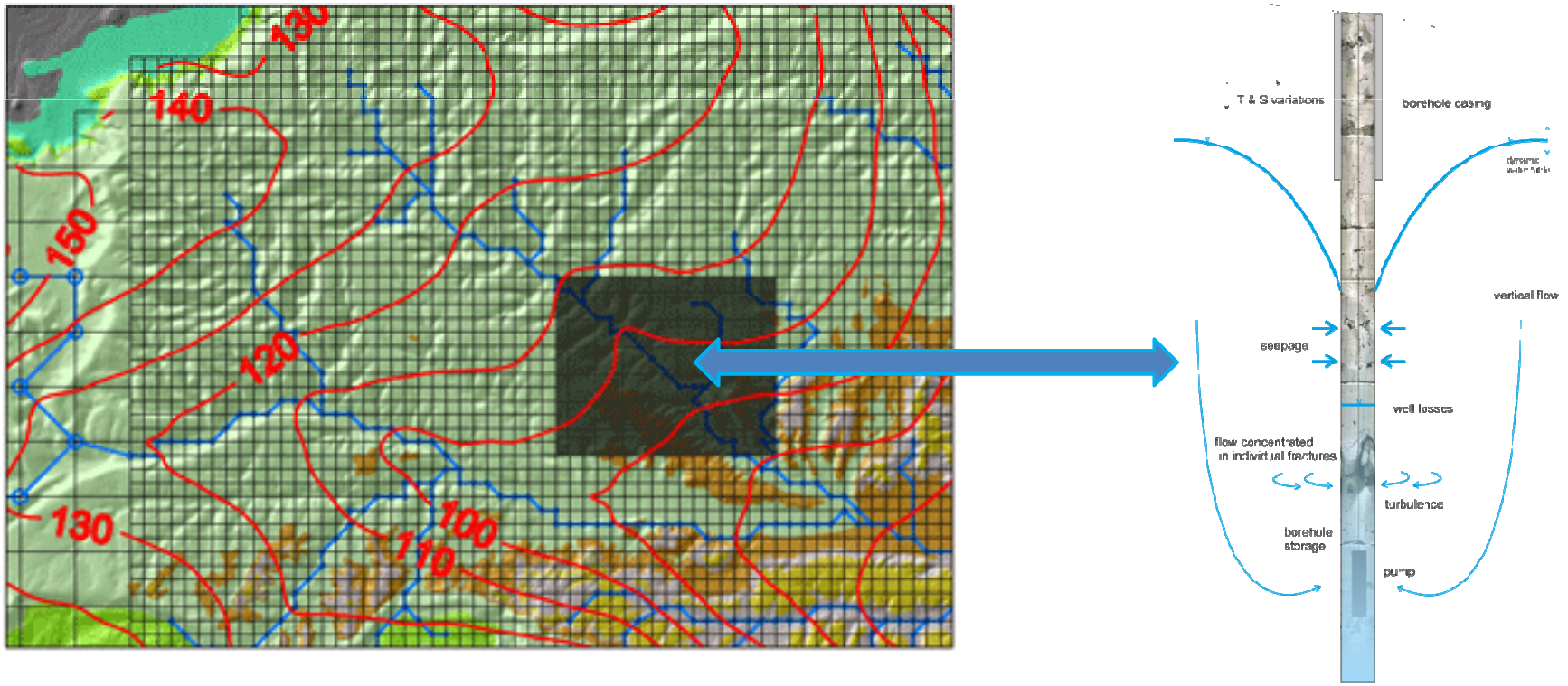
- Agriculture, incl. water intensive crops, is a major component of the island's economy.
- Significant competition for scarce water resources both within agricultural sector and between sectors.

- Model will be used to assess:
  1. Efficiency of current allocation system.
  2. Effects of future climatic and socio-economic changes (e.g. warmer summers, changes to CAP).
  3. Alternative allocation policies under current and future conditions (e.g. water markets)
  4. The merits of different adaptation options (e.g. deficit irrigation)

Development of a continuous simulation methodology to evaluate the long-term risk to groundwater resources in the Chalk

Kirsty Upton

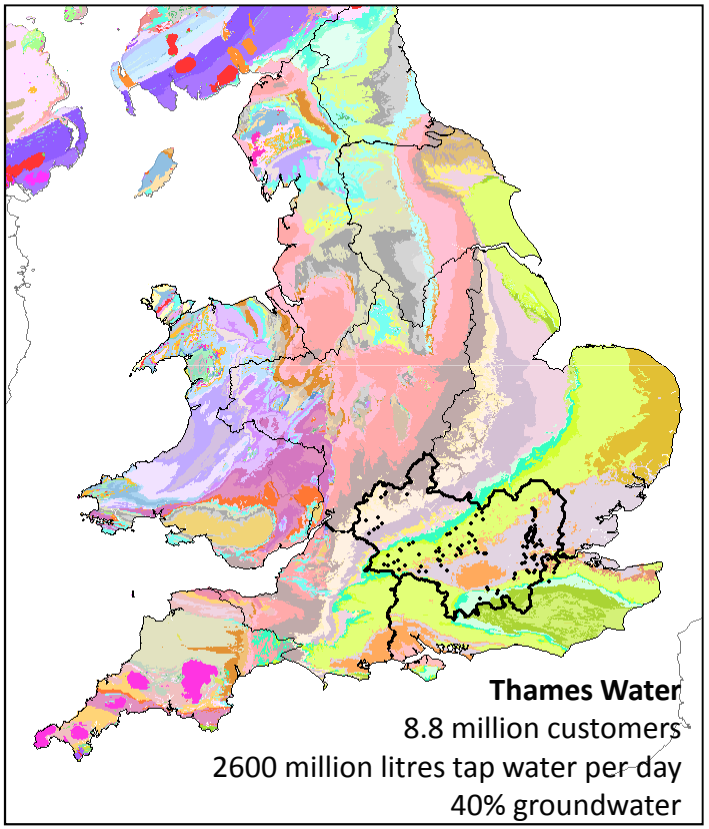
Supervisors: Dr. Adrian Butler and Dr. Chris Jackson (BGS)
Project partner: Thames Water Utilities Ltd (Mike Jones)



Deployable Output

Managing a groundwater resource

- Supply-demand balance
- Drought conditions/high demand
- Water Resource Management Plan (Environment Agency)
- Asset Management Plan (Ofwat)



Deployable Output

Assessing the available groundwater resource

- Deployable Output

- Reliable output of a source as constrained by:

Physical properties of the aquifer and abstraction borehole

+

Licence

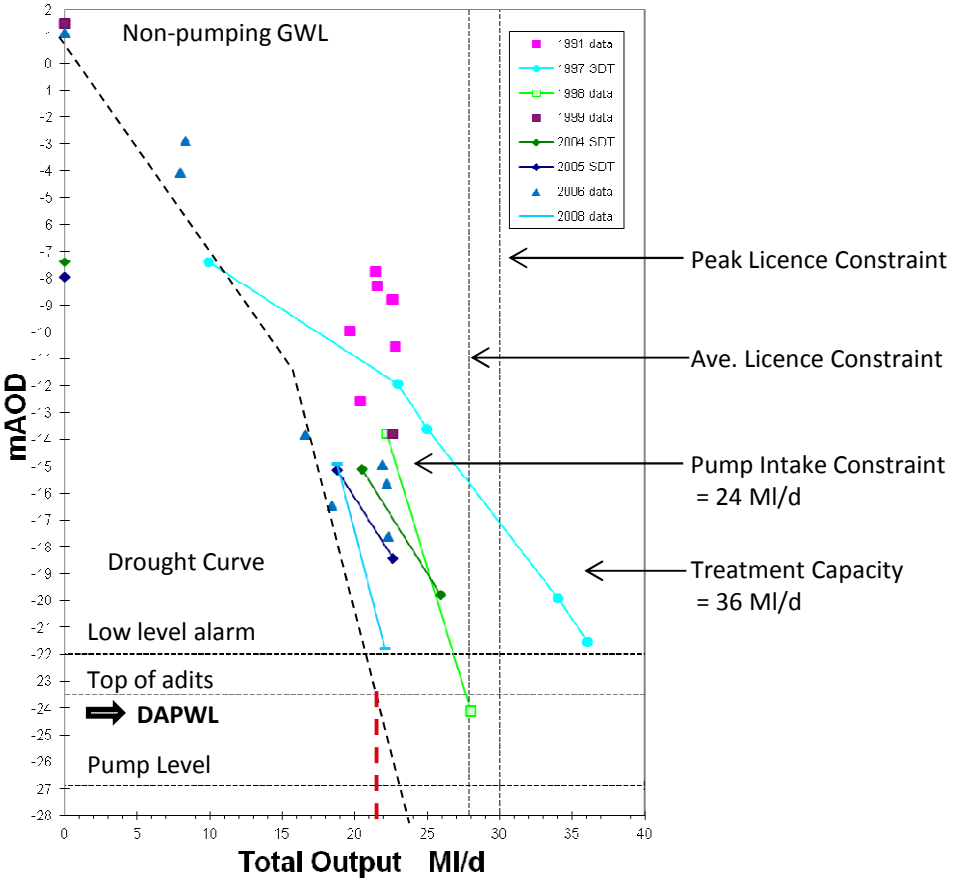
Environment

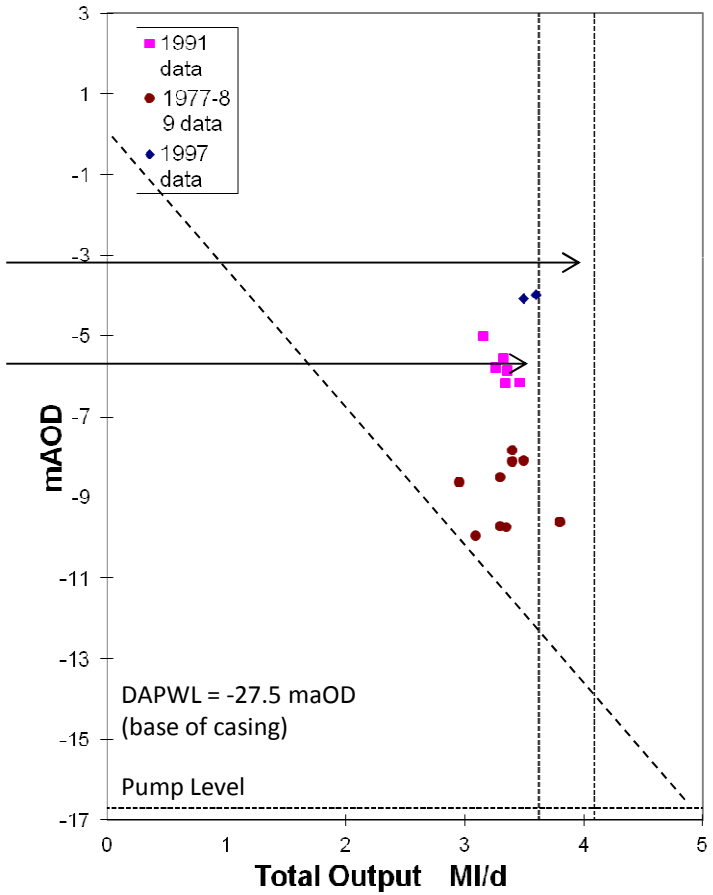
Quality

Sourceworks

Deployable Output

Current Groundwater Methodology (UKWIR, 1995)





Deployable Output

Limitations of Current Groundwater Methodology

- Data availability & quality (drought periods, RWL)
- Subjectivity of drought curve
- Lack of data to define DAPWL
- Sources considered in isolation
- Incompatibility of GW and SW methods
- Does historic data reflect current source performance?
- How does the yield vary under different RWLs?
- How to incorporate levels of service?
- How to determine potential impacts of climate change?

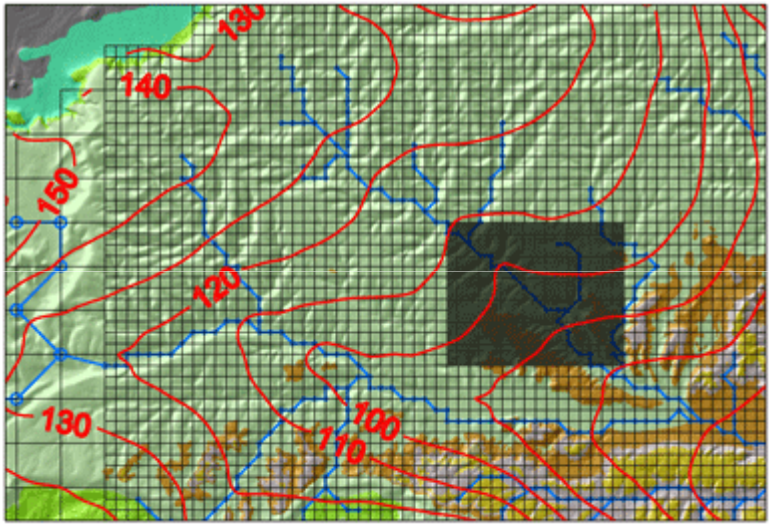
Aim

Develop a modelling tool that allows the accurate assessment of groundwater resources (DO) in the Chalk aquifer

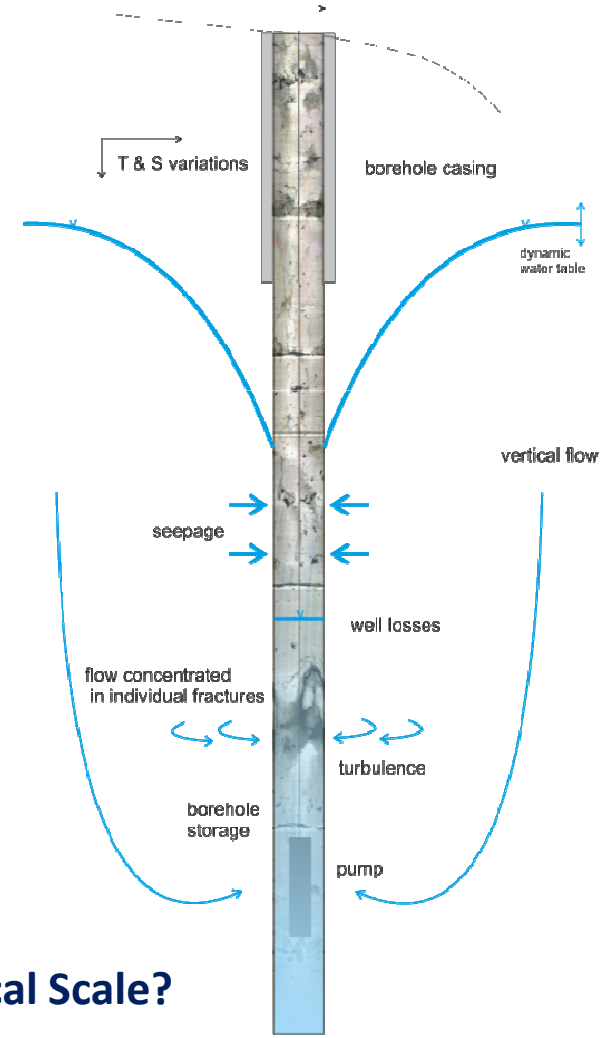
- Continuous simulation: climate change impacts, assessment of yields under different ambient conditions
- Multi-scale: level in a borehole, regional context, neighbouring abstractions
- Operation and management procedures
- GW-SW coupling: integrated assessment of resources

Multi-scale Modelling

Regional Scale: ZOOMQ3D



- Heterogeneity of the Chalk
- Dynamic water table
- Multiple boreholes

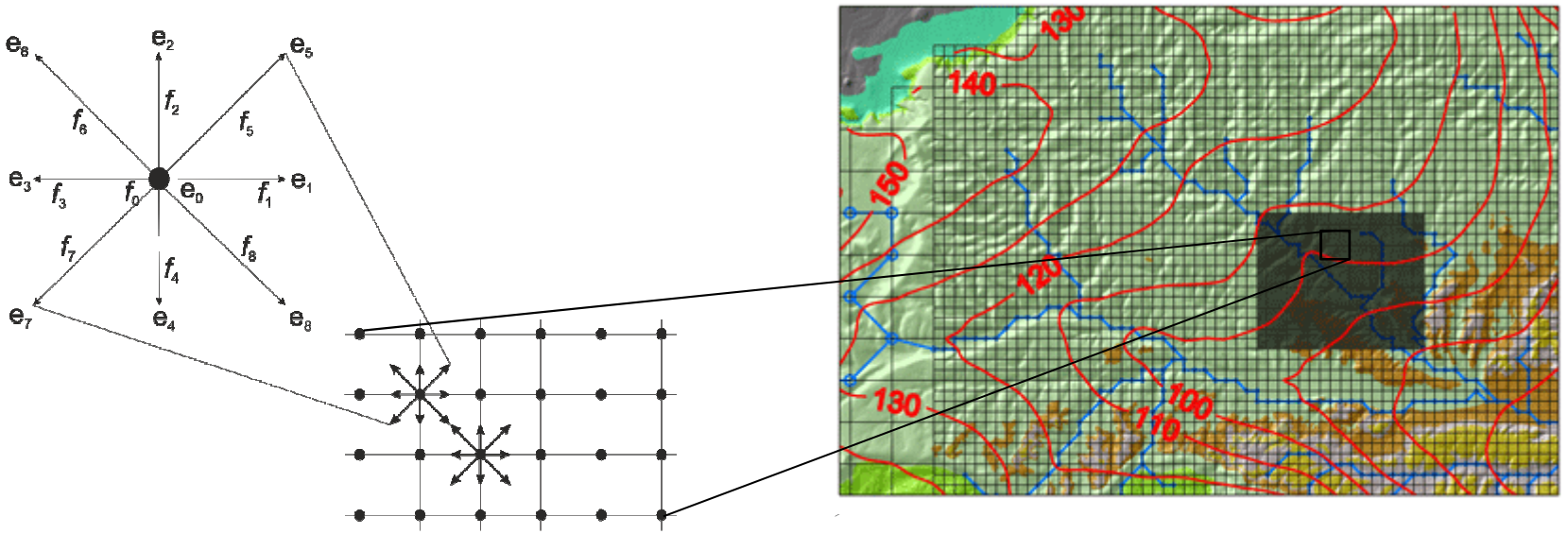


Local Scale?

Multi-scale Modelling

Lattice Boltzmann Method

- Simple lattice structure
- Multiple flow directions
- Coupling with finite difference model
- Models laminar and turbulent flows



Lattice Boltzmann Method

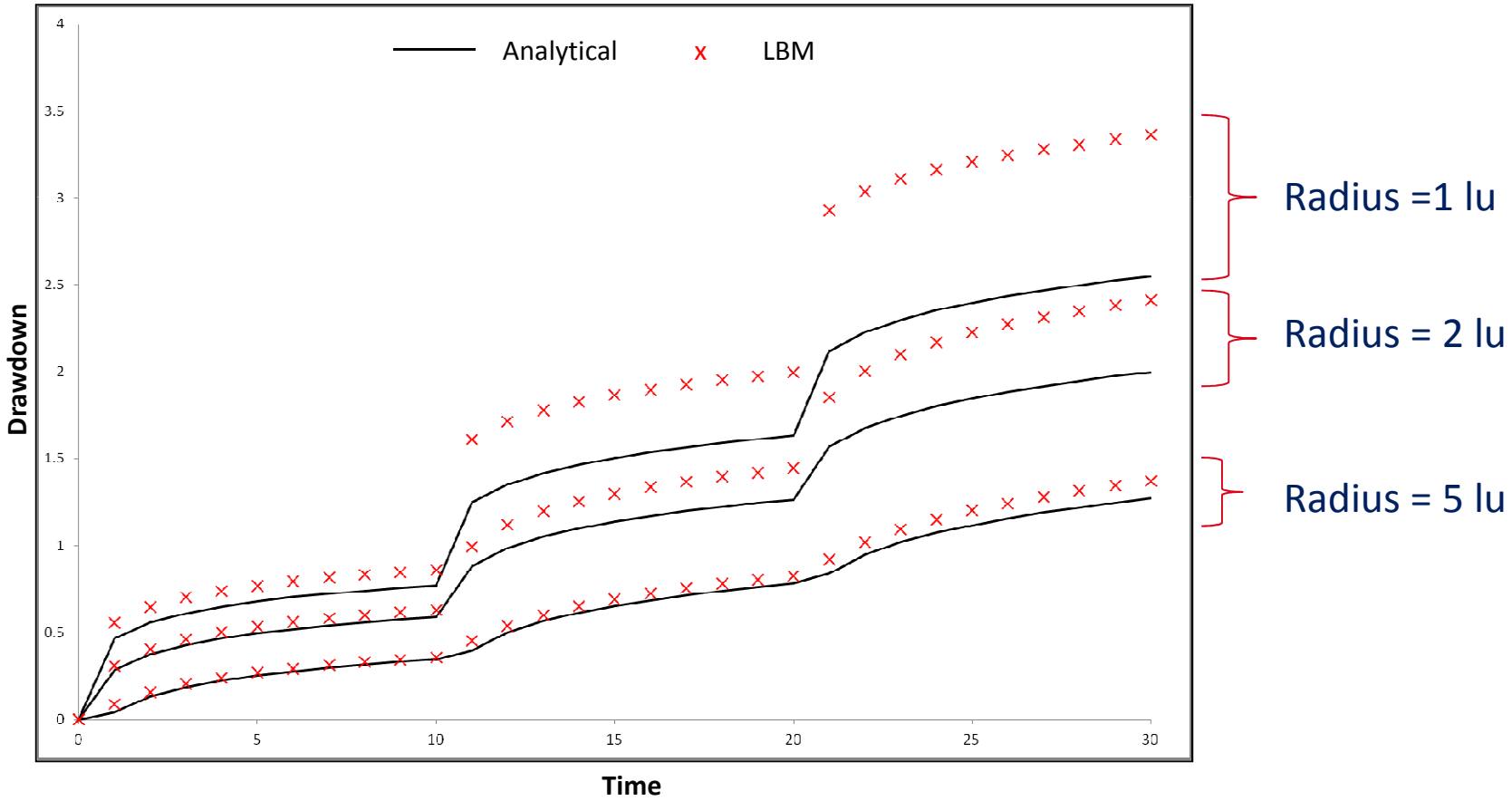
Model Testing

- Analytical solutions of drawdown in an abstraction borehole
  - Theis solution of drawdown in a confined aquifer (linear losses)
  - Jacob solution of drawdown in a confined aquifer (non-linear losses)
- Comparison with other models
  - Darcy-Forchheimer model which incorporates non-linear flow
- Simulation of pumping test data

Lattice Boltzmann Method

Model Testing

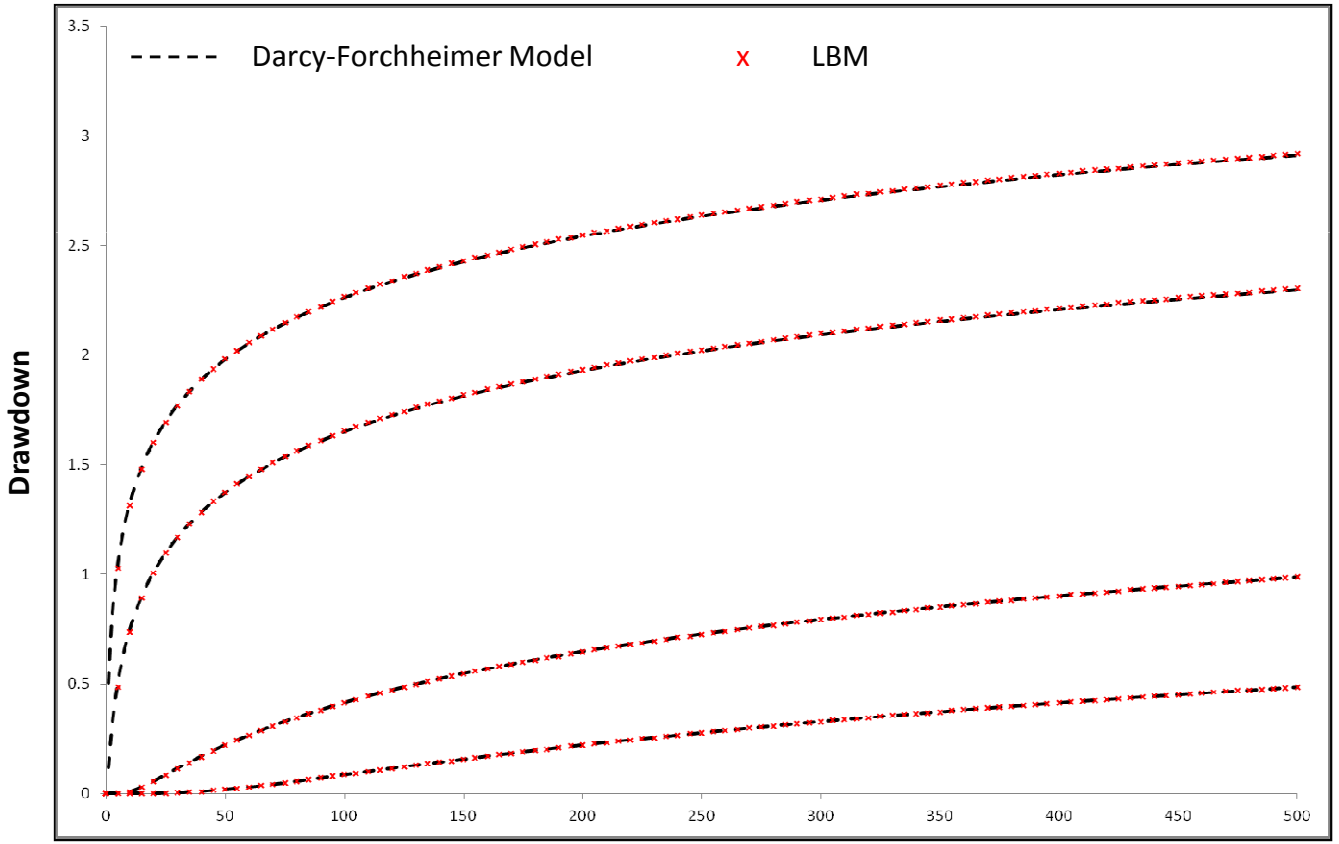
Drawdown at varying distances from the abstraction well



Lattice Boltzmann Method

Model Testing

Drawdown at varying distances from the abstraction well (Forchheimer vs LBM)



Radius =0.25 lu

Radius =1 lu

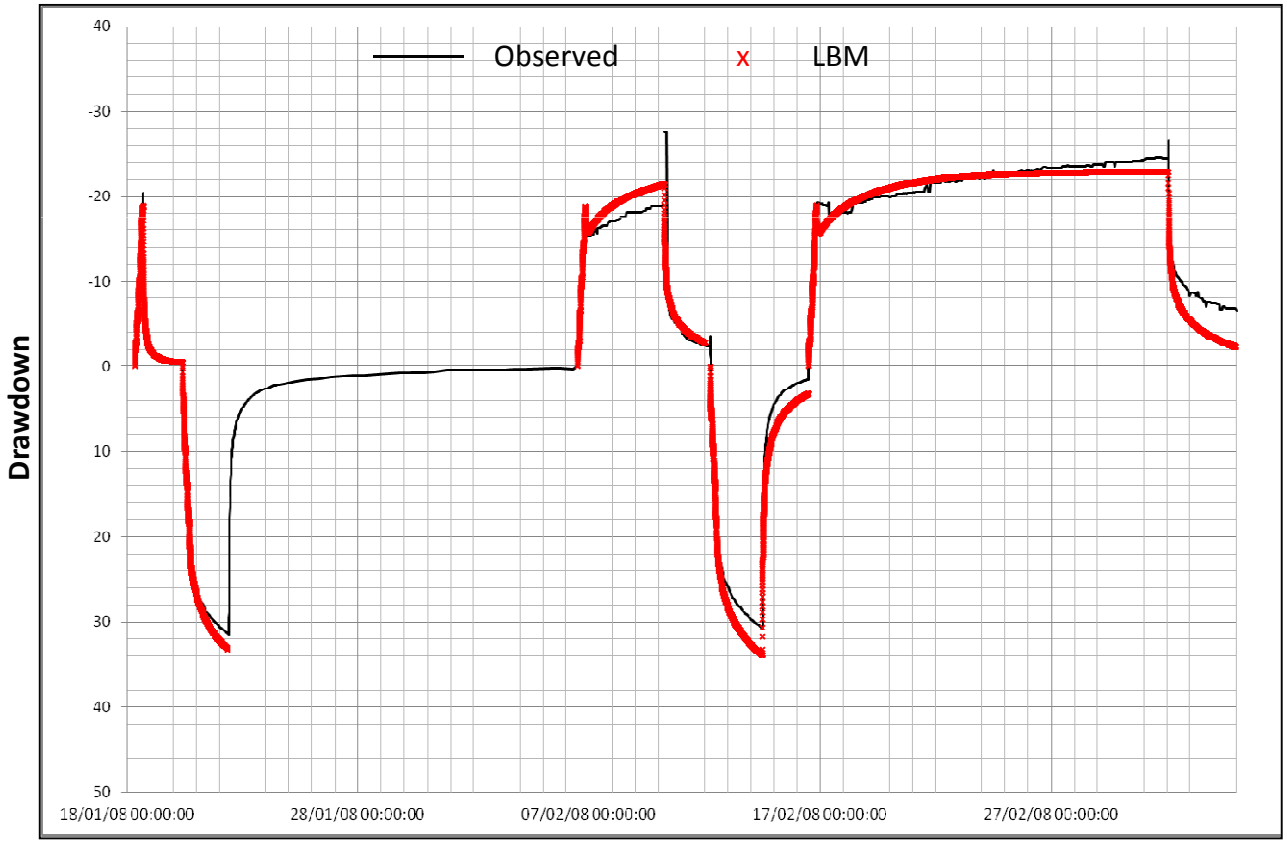
Radius =10 lu

Radius =20 lu

Lattice Boltzmann Method

Model Testing

Simulating abstraction & injection test data (observation borehole)



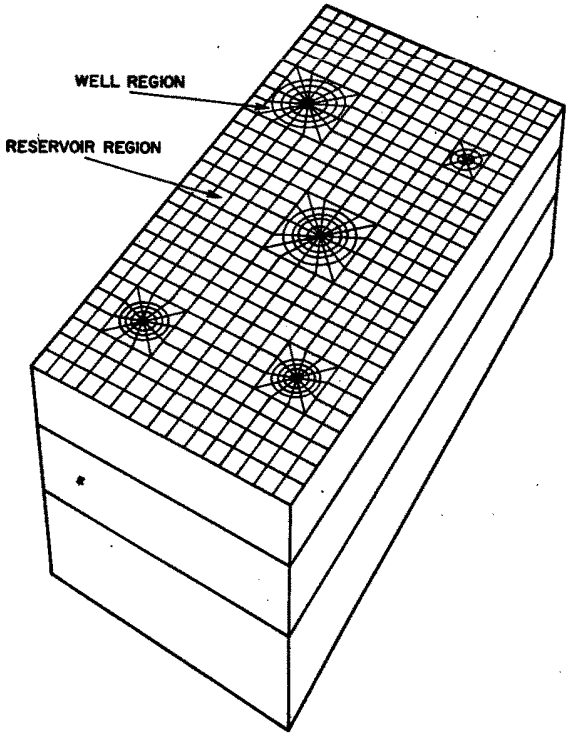
Injection phase

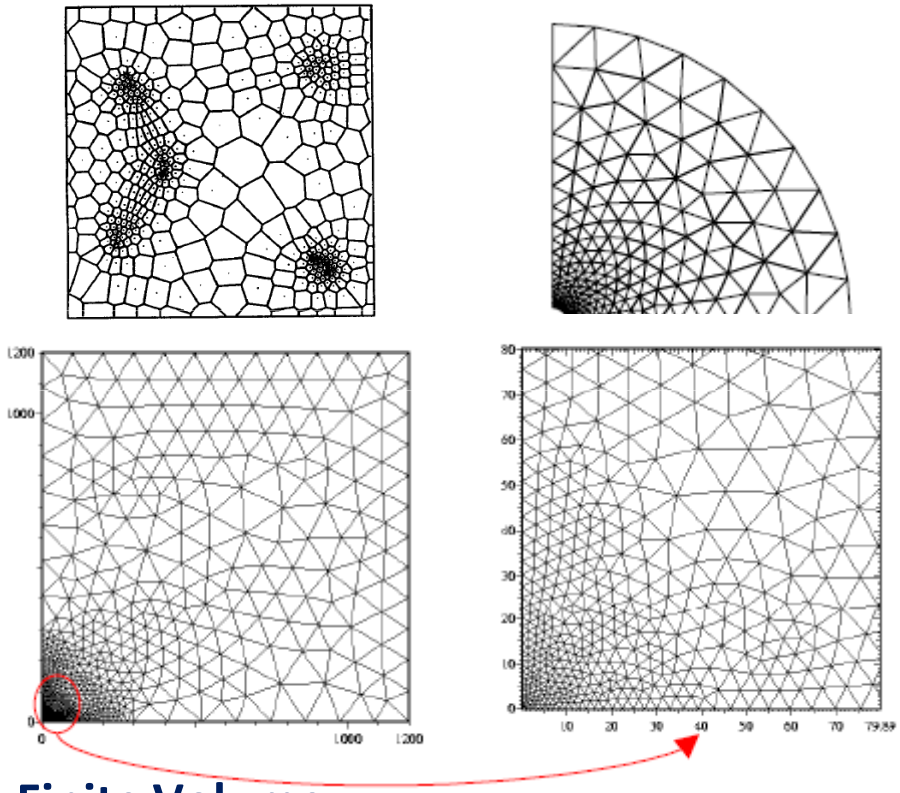
Recovery phase

Multi-scale Modelling

Hybrid Cartesian

- Simple gridding/solution methods
- Boundary conditions?
- Flexibility for multiple wells?





Finite Volume

- Smooth transition at boundary
- Flexible grid for multiple wells
- Grid generation?

Summary

- Aim: develop a multi-scale groundwater model for assessing the DO of abstraction boreholes under climate change
- Lattice Boltzmann borehole model
  - Developed in 2D
  - Parameter testing
  - Testing against analytical and numerical models
  - Simulation of pumping test data with linear losses
- Future work
  - Further testing of the non-linear drag parameter
  - Comparison with numerical models (Darcy-Forchheimer)
  - Further development of the model, e.g. representation of the borehole
  - Integration with BGS ZOOMQ3D regional model