



British
Geological Survey

NATURAL ENVIRONMENT RESEARCH COUNCIL

Gateway to the Earth

Subsurface information: living with uncertainty

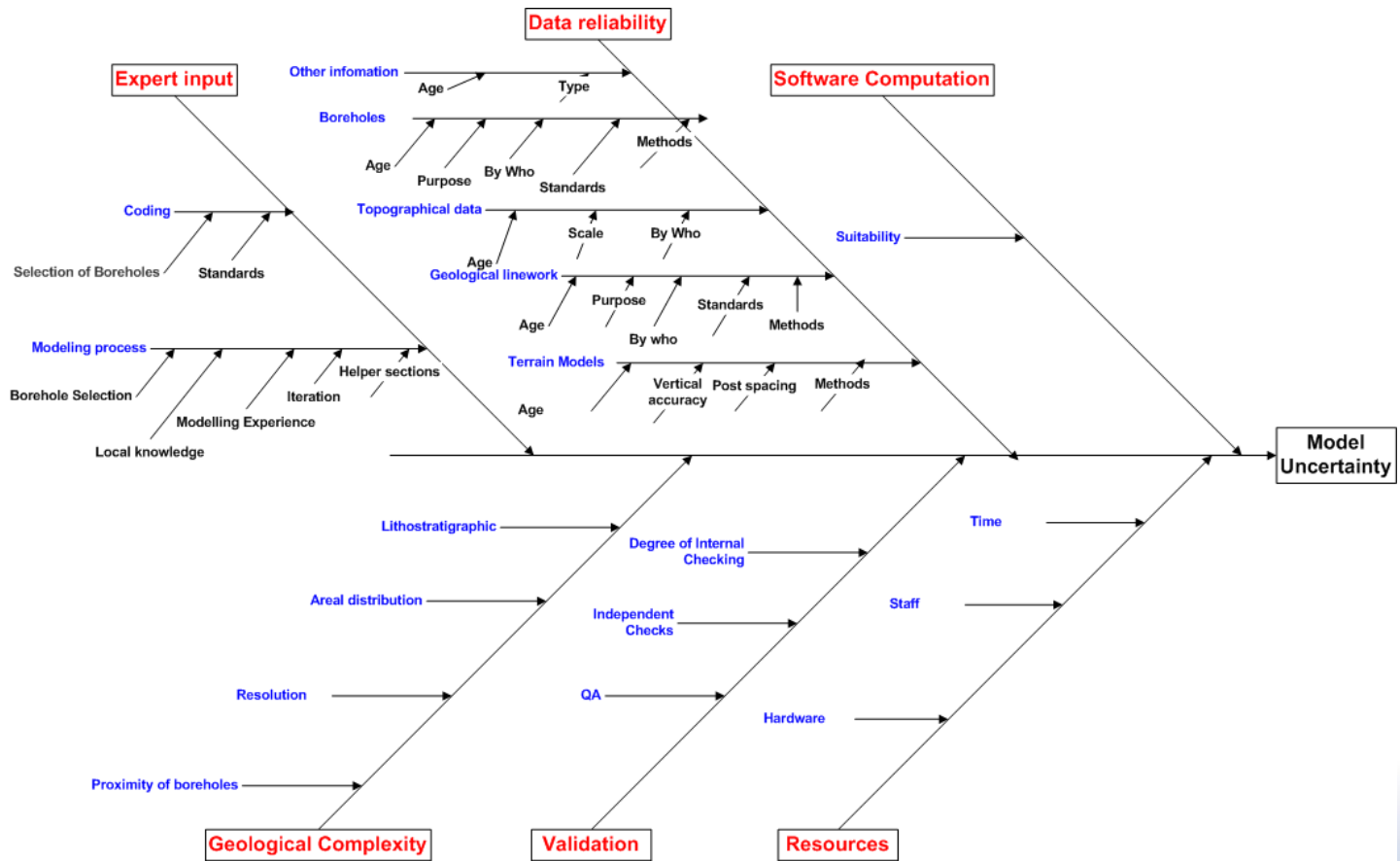
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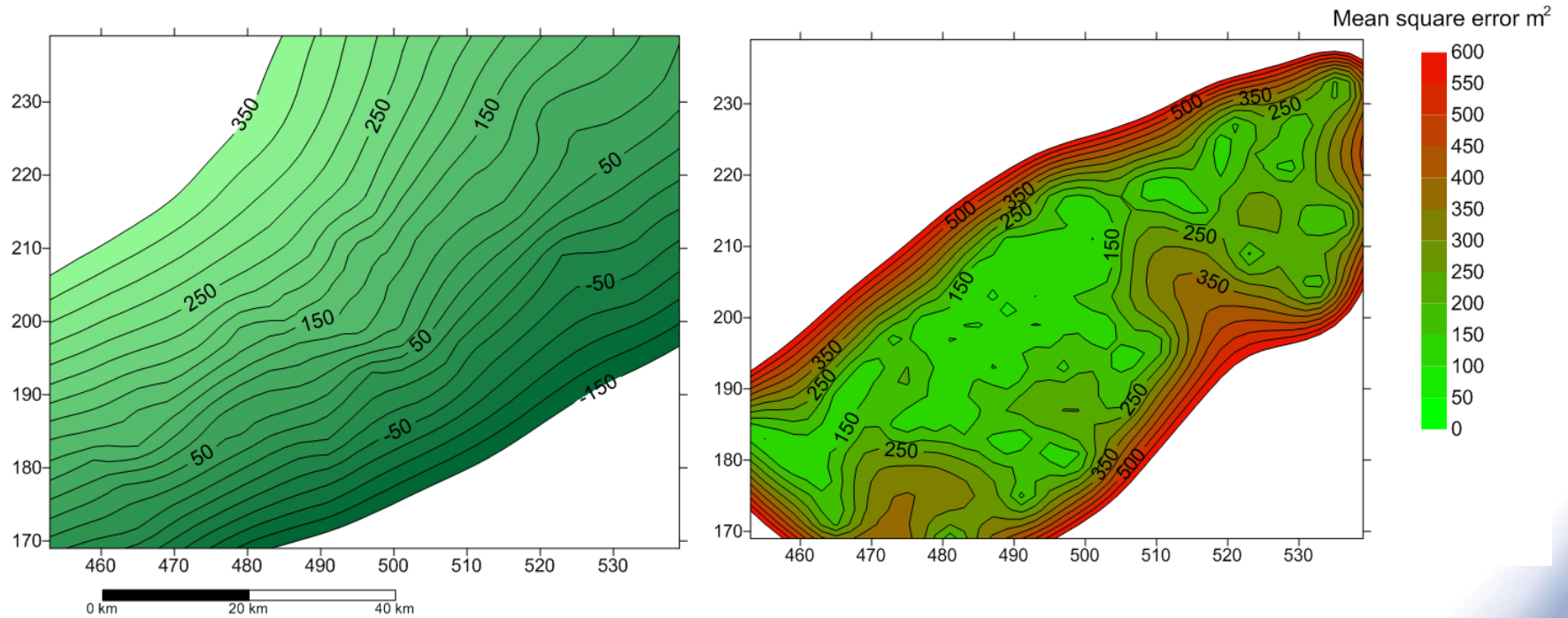
Introduction

- The sustainable management of the subsurface cannot be achieved without information about its structure and properties.
- All information has some attendant uncertainty, but there is less clarity on how to deal with it.
- We identify three key tasks
 - **Understand** uncertainty (quantitatively)
 - Analyse its implications for **decisions**
 - **Communicate** it effectively to all stakeholders

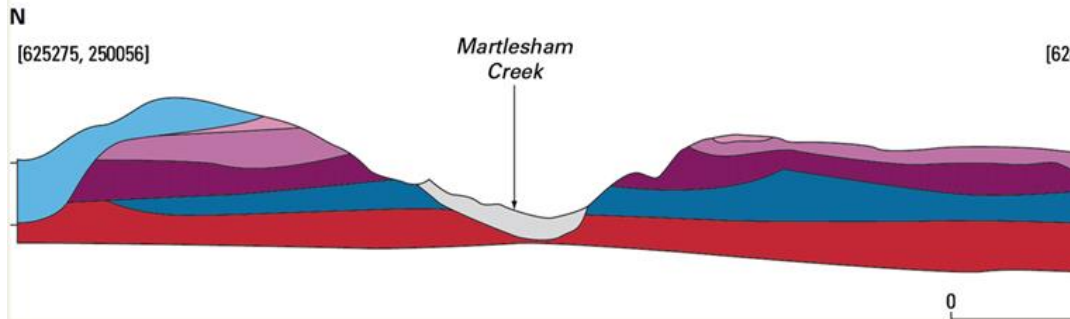
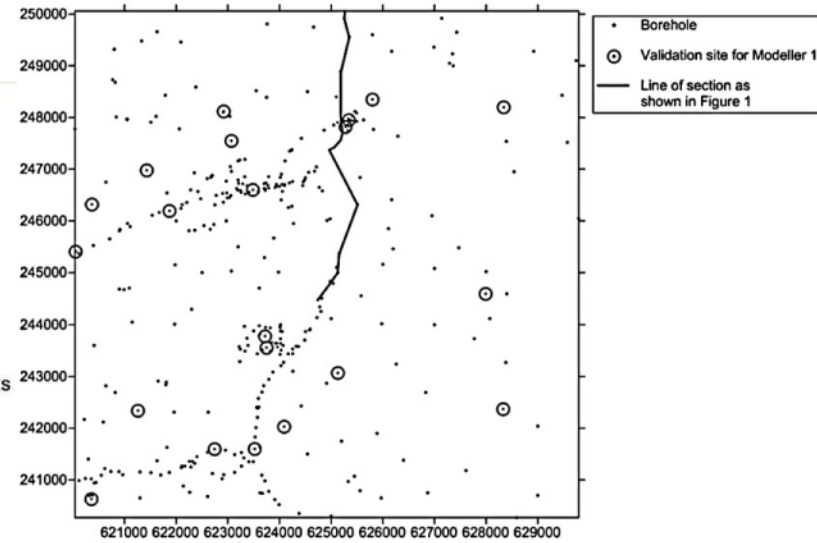
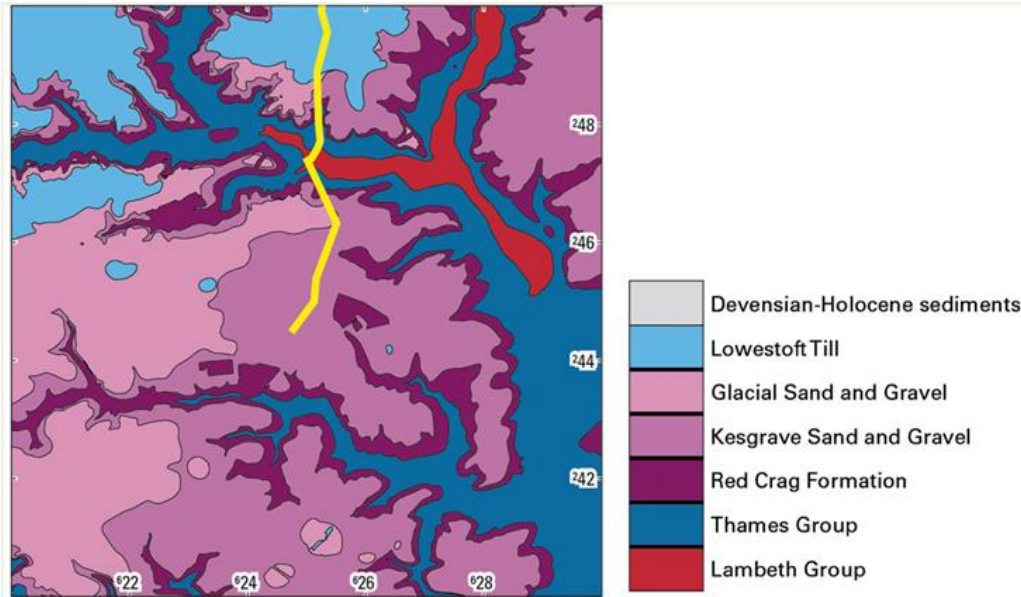
Understanding uncertainty



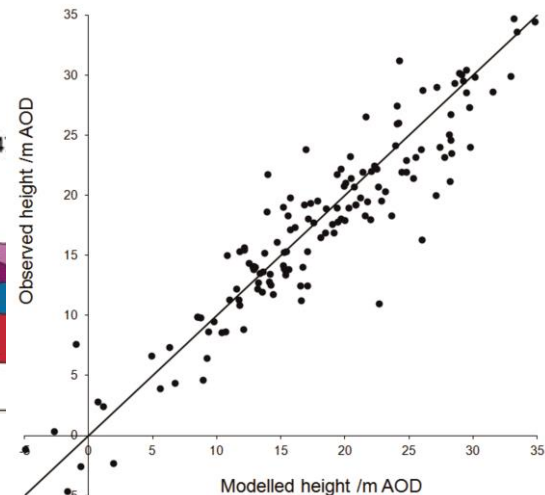
Quantifying uncertainty: statistical models



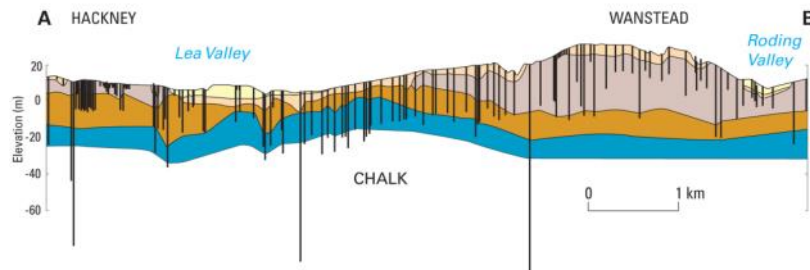
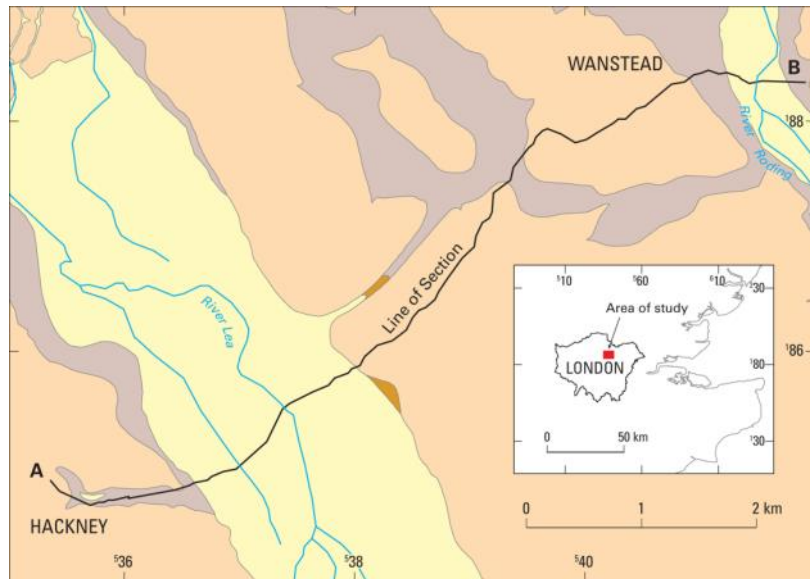
Quantifying uncertainty: experiments



Modelled and observed height of all proven bases



Quantifying uncertainty: experiments



Superficial
Alluvium
River Terrace Deposits
Borehole

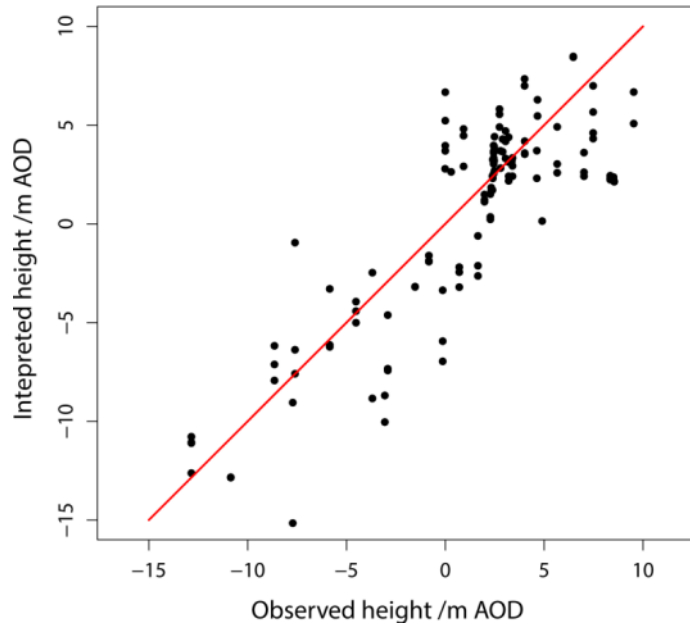
Bedrock
London Clay Formation
Lambeth Group
Thanet Formation

Model error for base of London Clay assessed at validation boreholes

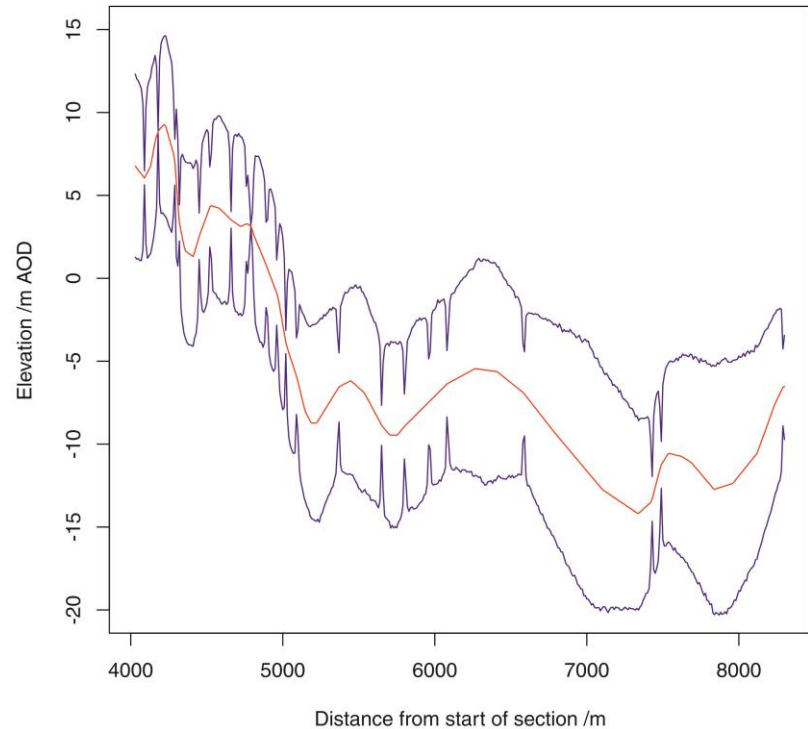
Error variance modelled as a function of:

- Geologist's experience
- Distance to nearest borehole

Quantifying uncertainty: experiments



Between-geologist variance				
Experience	None	Some, <6 months	6 months – 2 years	>2 years
	4.44	2.25	1.32	0.46



Lark, R.M. Thorpe, S., Kessler, H. Mathers, S.J. 2014. Interpretative modelling of a geological cross section from boreholes: sources of uncertainty and their quantification. *Solid Earth*, 5, 1189–1203.

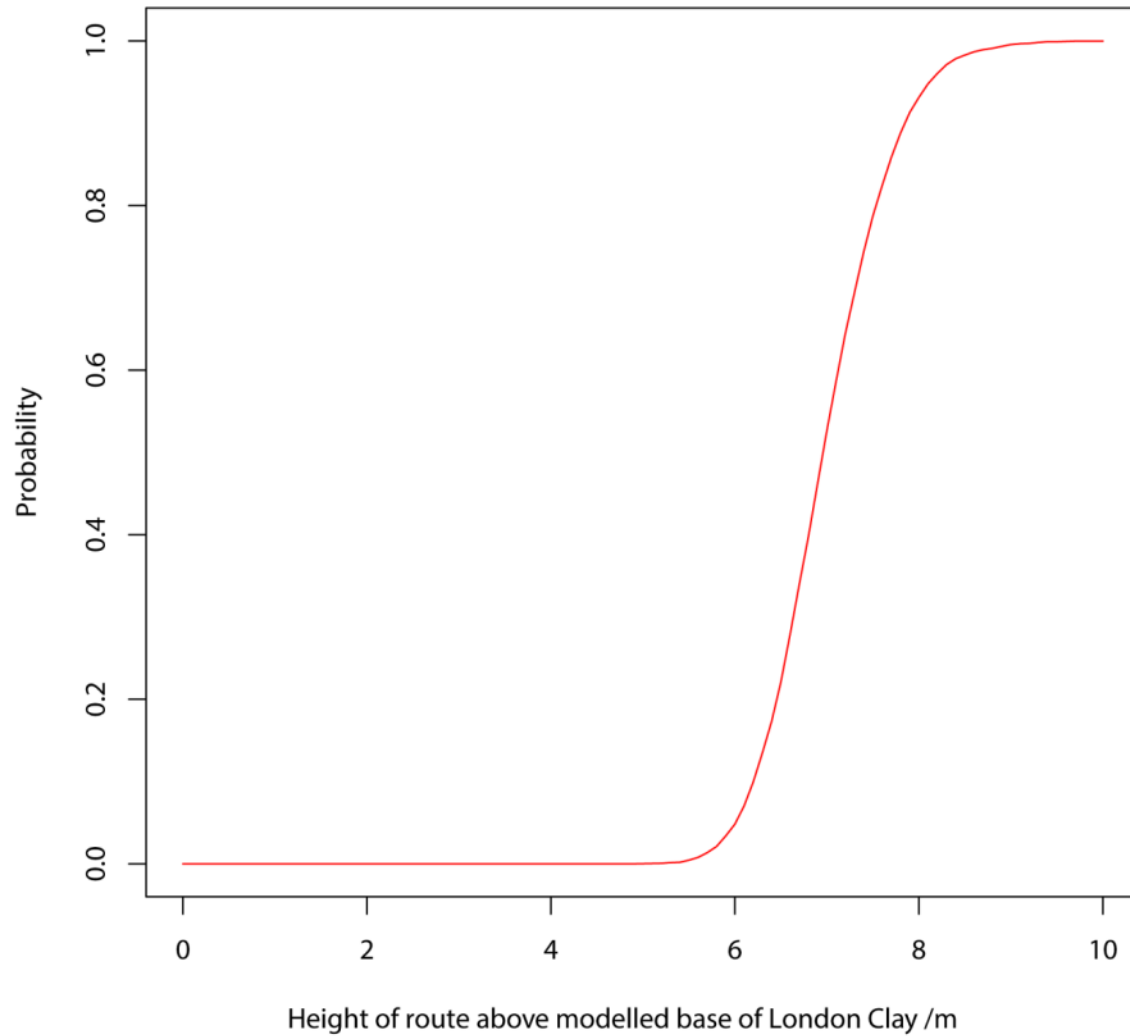
Analysing decisions

- General measures of uncertainty have some value but the implications of uncertainty for a particular problem depend on:
 - the decisions that are to be made
 - the costs of particular outcomes conditional on those decisions
- The general confidence interval for the base of the London Clay gives the user an impression of the uncertainty in the information, but a more detailed decision analysis is required.

Analysing decisions

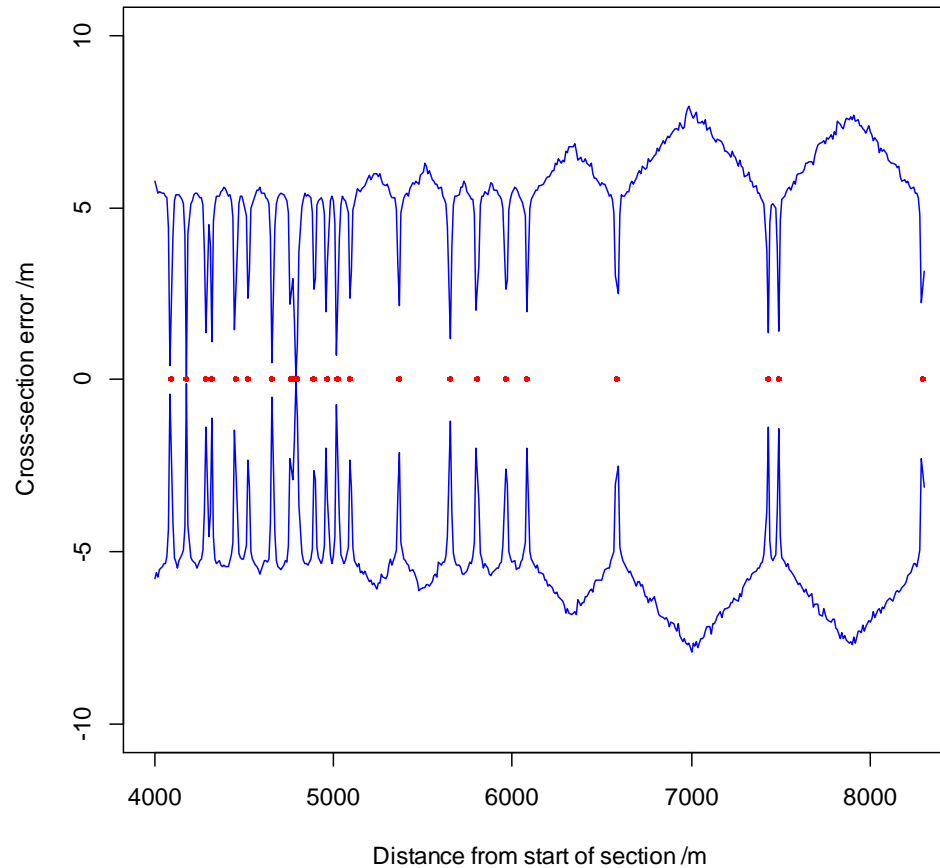
- For example, how close to the modelled base of the London Clay could we place a route or structure so as to be sure that it intrudes on the underlying Lambeth Beds over no more than 1% of the route?
- This question can be addressed by interrogating realizations of the stochastic error model

Probability that
the route is in Lambeth Group for no more than 1% of its length



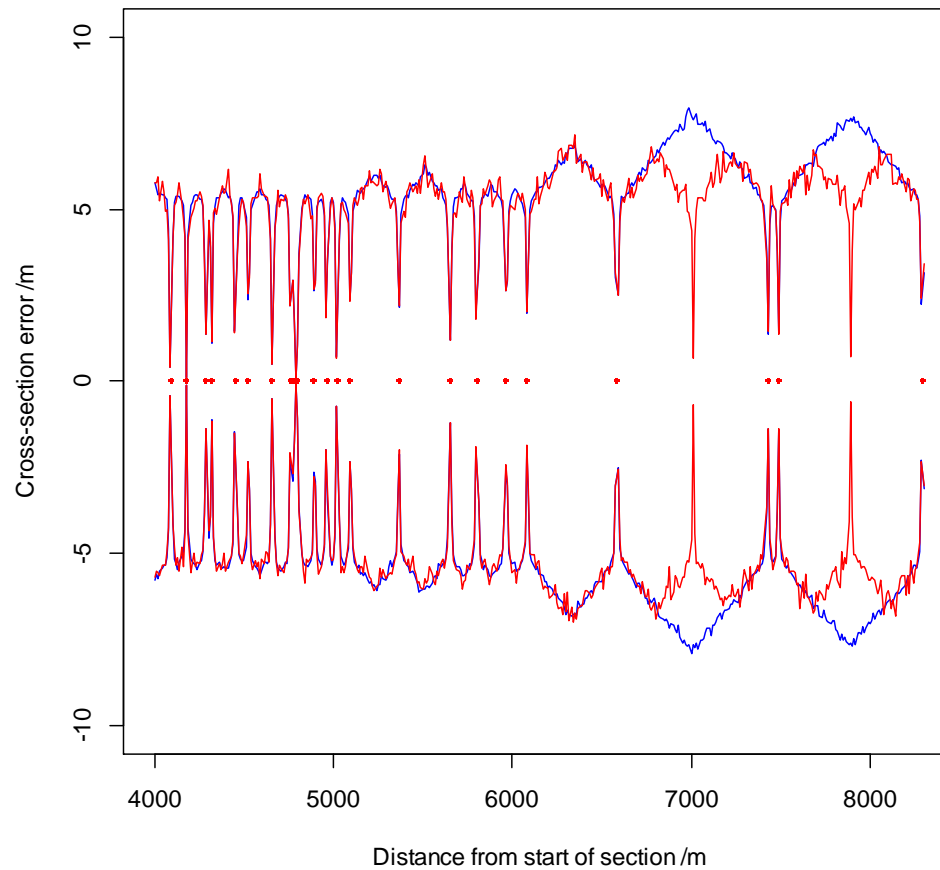
Analysing decisions

- What would be the effect of adding two new boreholes?



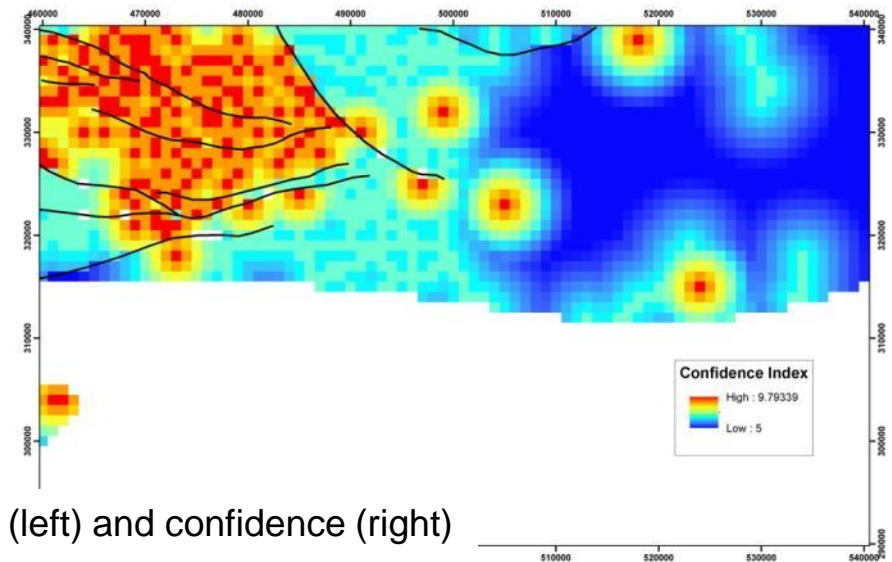
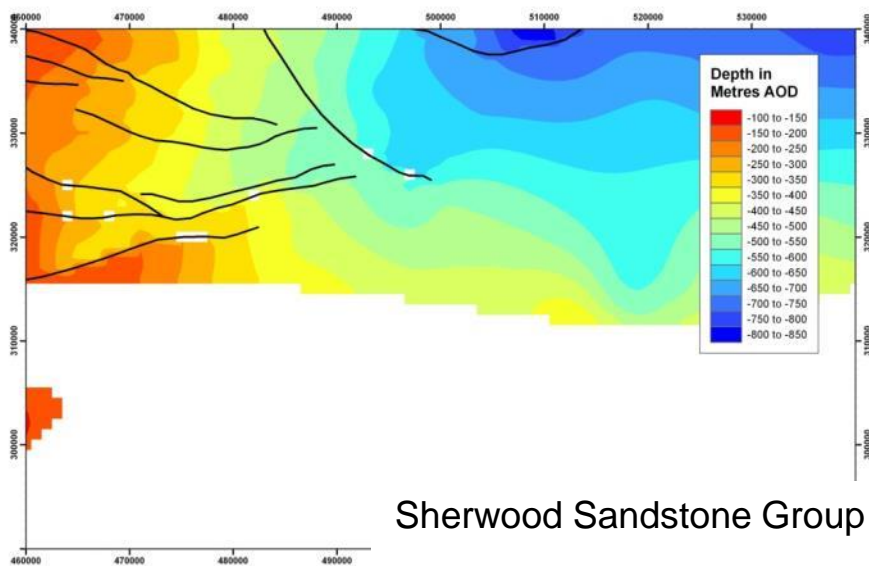
Analysing decisions

- What would be the effect of adding two new boreholes?



Communicating uncertainty

- The confidence index: visualizing geologists' understanding of contribution of different sources of uncertainty given spatial dependence of variations around regional trends



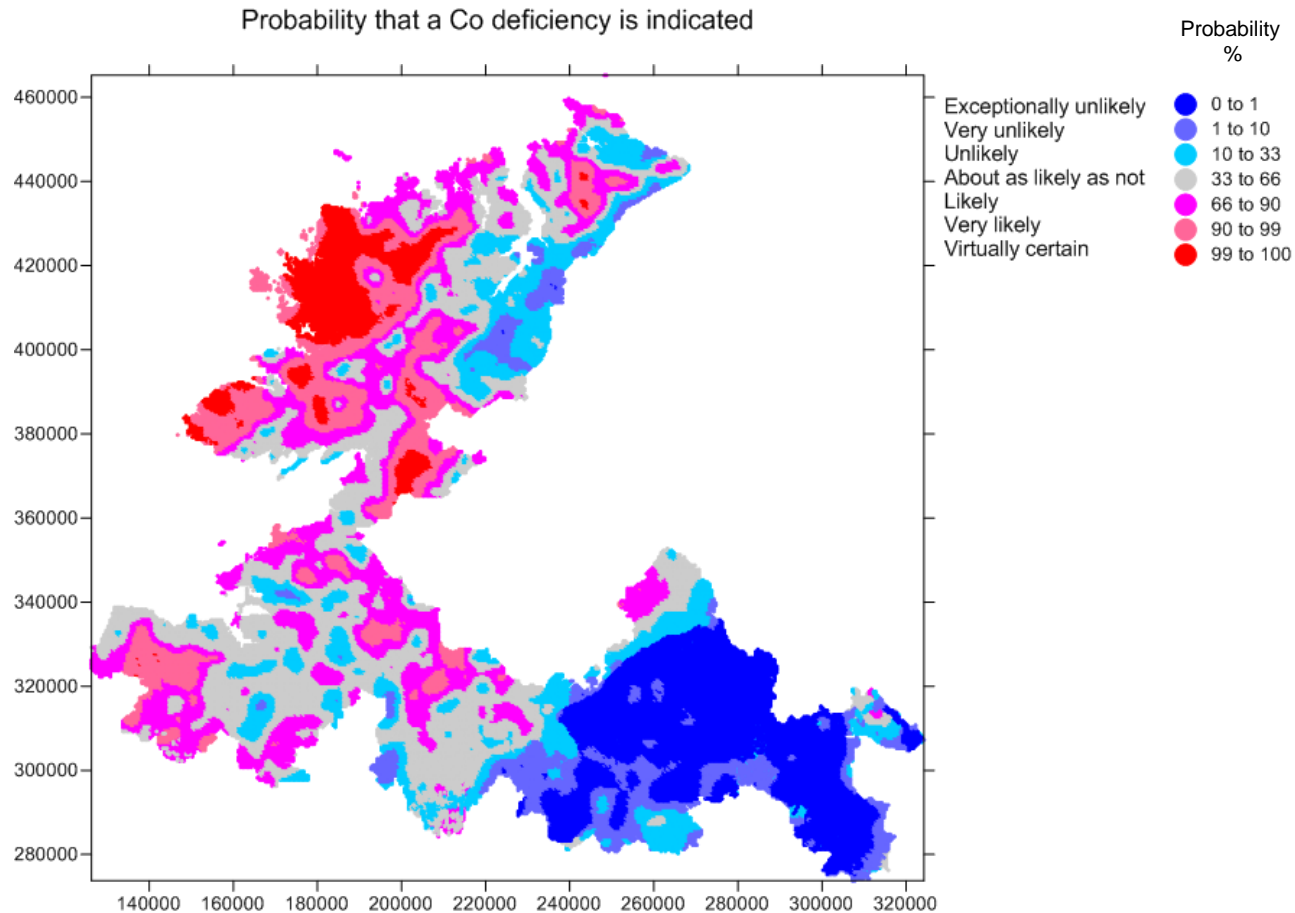
Sherwood Sandstone Group base (left) and confidence (right)

Lark, R.M., Mathers, S.J., Marchant, A., Hulbert, A. 2014. An index to represent lateral variation of the confidence of experts in a 3-D geological model. Proceedings of the Geologists Association, **125**, 267–278.

Communicating uncertainty

- Requires input from psychology c.f. problems with the IPCC verbal scale for communicating uncertain information
 - severity bias
 - regressive interpretations

Communicating uncertainty



Summary

- We have made progress in understanding uncertainty in 3-D geological information. New work is planned, e.g. in expert elicitation.
- Further progress requires specific case studies on decisions, loss functions and the value of information (collaborations gladly welcomed).
- The contribution of psychology to effective communication must not be overlooked (c.f. new BGS/UCL PhD collaboration).