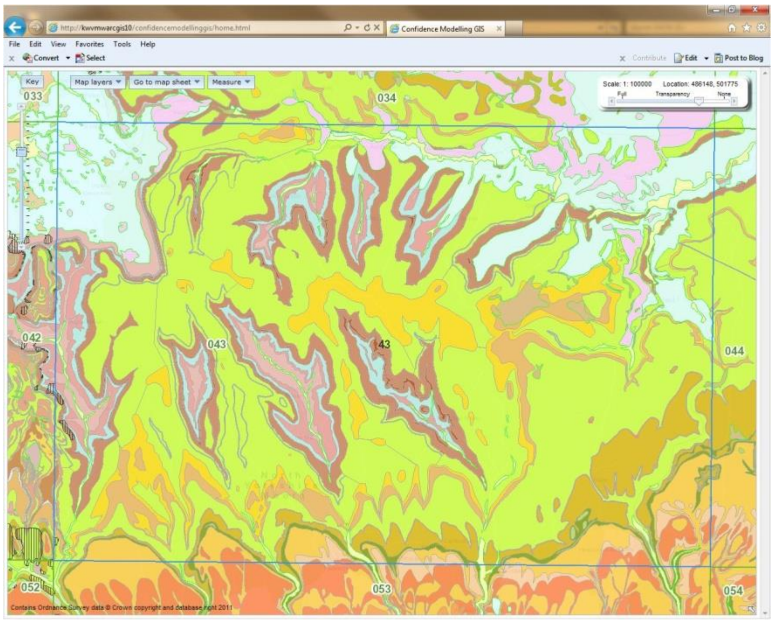
British
Geological Survey
NATURAL ENVIRONMENT RESEARCH COUNCIL

# Confidence Modelling in DiGMapGB-50 for customer needs.

Environmental Modelling Directorate

Internal Report IR/13/051



BRITISH GEOLOGICAL SURVEY

ENVIRONMENTAL MODELLING DIRECTORATE

INTERNAL REPORT IR/13/051

# Confidence Modelling in DiGMapGB-50 for customer needs.

C E Cartwright



*Keywords*

confidence, uncertainty.

*National Grid Reference*

SW corner 455702,489739
Centre point 484845,508766
NE corner 470274,499250

*Map*

Sheet 43, 1:50 000 scale, Egton

*Front cover*

Screen view of DiGMapGB-50 data as viewed by experts during Expert Elicitation process.

*Bibliographical reference*

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# Foreword

This report follows a study undertaken by the British Geological Survey (BGS) to build and trial a methodology designed to quantify uncertainty (or confidence) in the BGS DiGMapGB-50 dataset. The main objective of this study was to develop a methodology to create a layer that indicates the confidence that experts have in the data. This will provide added value to customers who will benefit from the experts evaluation and will prove a valuable guide for customer decision-making processes requiring an understanding of the geology and continued dataset maintenance by future geologists.

# Acknowledgements

A number of individuals in the Geospatial Capture & Solutions team have contributed to the project and helped compile this report. This assistance has been received at all stages of this study. In addition to the expert elicitation exercise and analysis of expert responses, many individuals have freely given their advice and local knowledge on the subject. The author would like to thank Katy Lee, Emma Bee, Claire Dashwood, Gerry Wildman, Alan Smith, Andy Farrant, Tony Cooper, Martin Smith, Jon Ford, Peter Hopson, and particular thanks to Andy Marchant for his continued technical assistance and guidance.

I would also like to thank Kathrine Linley who provided helpful comments on earlier versions of this report.

# Contents



**FIGURES**

# Summary

This report reviews and tests recent internal research on establishing an efficient, reliable method of creating an indicator layer of confidence in the DiGMapGB-50 data, using expert elicitation.

This report provides an overview of work from earlier studies by the BGS with a follow up test based on recommendations (Lee, et al., 2011). The focus of this study was the development and implementation of the follow up procedure which is described in detail.

Recommendations for further development of the methodology are provided alongside a proposed way forward.

# 1 Introduction

It has long been acknowledged that geological models are subjective representations of what is understood to be beneath the Earth's surface (Tversky & Kahneman, 1974; Baddeley, et al., 2004; Curtis, 2012). The processes involved in the creation of geological concepts subject geologists to a vast array of variables that unavoidably result in theoretical models loaded with uncertainties (Lee, et al., 2010; Smith, 2011). Geological models are explicit modes of communication with the potential to hold a significant sway in 'risk-informed' decision making in both public and the commercial sector (Howard, et al., 2009). However, addressing the natural tendency for the user to accept a model at face value is an important exercise when establishing the level of confidence one can place in these data.

Unlocking and formally recording the tacit ideas and opinions of a geologist, with regard to the quality and confidence placed in geological data, is a huge undertaking. The underlying geological science that went into the creation of the BGS 1:50 000 scale geology series mapping underwent a 'back-end' assessment in 1985 and this was followed up by the publishing of 'Geology for our diverse economy: Report of the Programme Development Group for Onshore Geological Surveys' by Lee, et al. in 2001. This is refered to by many within the BGS as 'the Green Book'.

The original geologist 'feedback return sheets', used to assess each 1:50 000 scale tile of data that contributed towards the results published in 'the Green Book', proved impossible to locate in their entirety, as storage of each record was never formally established. Although valuable in the sense that many of the mapping geologists were still available to consult at the time of the exercise, the results are now considered dated due to subsequent revisions to the data since the original survey in 1985.

A return towards establishing new methods of identifying, quantifying and communicating degrees of uncertainty in BGS data developed when the BGS strategy 2009-2014 promoted improved delivery and transparency in all its data with a potential for use in policy and decision making processes across all sectors of society. One aspect of this transparency is to fully inform the end-user of any perceived uncertainty in the geological model.

The term uncertainty is the traditional perspective for studies of this nature (Polson & Curtis, 2010; Cave & Wood, 2002). However, simply transposing the concept of 'uncertainty' into one of 'confidence' in the data reduces negative connotations (Clarke, 2004). From a customer's point of view, measuring 'confidence' in data is a more positive position than highlighting levels of perceived uncertainty.

## 1.1 AIMS OF THE PROJECT

In 2010, the Information Products Programme launched an investigation into establishing a methodology for the creation of indicator layers showing the level of uncertainty (or confidence) in the data in various spatial data products. The impetus behind this was *"the ambition (and need in the longer term) to be able to give users of information products, such as GeoSure, an estimate of confidence in the data BGS supplied in order for them to make more informed and appropriate decisions. For example, the insurance industry, are increasingly moving towards confidence attribution. In the shorter term, it was envisaged that an appropriate methodology could be devised and used in-house to enable prioritisation of revision effort in areas where confidence in the model was low."* (Lee, et al., 2010).

## 1.2 CUSTOMER CONFIDENCE IN THE DATA

The aim of this report is to follow up the results from the work carried out by BGS during 2010, and to undertake a detailed scoping study of potential Expert Elicitation (EE) methods appropriate for collating and quantifying the intangible knowledge of subsurface geological models held in the geologist's mind. The aim is to develop and test a methodology to assess the suitability of DiGMapGB-50 for specific fields of enquiry, such as permeability, engineering properties, SuDS and natural ground stability, based on geologist's levels of confidence in the DiGMapGB-50 data.

## 1.3 A REVIEW

Geological models are a mode of communication based on a disproportionately small amount of direct observation by the geologist in outcrops and boreholes for example. Confidence in the recorded geology when displayed as a model is significantly higher for exposed, high mountainous areas, and lower in obscured low land and urban areas (Clarke, 2004). As a result, geological models contain a significant level of uncertainty resulting from the inferred data used by a geologist to complete a model. Not all geologists will necessarily draw up the same conclusions. The geologist's knowledge and reasoning behind interpolating observed and known geology with inferred data is difficult to refute at face value (Bowden, 2004; Smith, 2011); it is impossible for another geologist to assess an unfamiliar model without direct experience of that area and data (Clarke, 2004).

However, rather than undermine any effort to assess uncertainty, this highlights the necessity for a reliable method of quantifying these subjective holes in the geological data model, so that users are informed of their validity with regard to their use in 'risk informed' decision making.

The degree of uncertainty inherent in geological models is difficult to evaluate objectively (Clarke, 2004), particularly as the data at the outset is modelled subjectively through the tacit knowledge in the geologist's mind (Baddeley, et al., 2004). It is not impossible though to derive a meaningful assessment of confidence in geological data through a process of EE. Placing any credence on information derived from or based on subjective source methods was traditionally not considered a valid scientific process, and it is fraught with reasons not to be trusted (Abbott, 2004). This is further complicated through bias and subjective judgements by the individual experts taking part in the process. This view is however losing ground as research on improving the methods of procuring data derived from these contexts has developed significantly over recent years and their input in decision making processes across the research spectrum have proved an invaluable addition throughout the public and science community (USEPA, 2009).

Selecting an appropriate EE methodology, that is both robust and inexpensive, proved to be far from straight forward, as the process of EE is not a simple sum of all data uncertainties (Wellman, et al., 2010). A scoping study analysing potential EE methodologies was explored during 2009 and followed up with a report containing some recommendations (IR/11/002), in 2010. This report will follow up on recommendations learned from these formative tests.

## 1.4 A NEW APPROACH

The significant difference of this exercise from previous methods is that it is a 'front-end' assessment of the data. A front-end assessment is one which objectively assesses the digital data at face value, as would be observed by a potential user (BGS staff, planners and developers, engineers, insurers, etc.); not a 'back-end' assessment of the underlying geological science which went into the makeup of the geological subsurface model. Rather than invest time in collating an exhaustive record of whom, when and how the geological data was created, emphasis will focus only on the objective evaluation of the DiGMapGB-50 data at face value, in a specific context relevant to customer requirement e.g. Dissolution, Shrink-Swell, Collapsible, etc.

## 1.5 EXPERT ELICITATION (EE)

Expert Elicitation is a method of quantifying professional judgements of a subject where uncertainty is inherent due to insufficient data. Where there is a significant limit of empirical information providing tangible evidence to support parts of the geological model EE should provide a useful mechanism for measuring uncertainty/confidence across the inferred, theoretically projected parts. However, EE does not come without its problems. Due to the subjective nature of EE, bias in expert judgement can occur, although various techniques have been developed that help to reduce these effects (USEPA, 2009). In determining which method is most appropriate for evaluating confidence in geological models one needs to take into account staff availability and funds.

# 2 Previous Expert Elicitation exercises

## 2.1 PAST APPROACHES

Since the mid 1980s, at least four methods of measuring and quantifying confidence in the 1:50 000 scale geology have been explored with varying degrees of success.

### 2.1.1 50k sheet reassessment

The underlying geological science that went into the creation of the BGS 1:50 000 scale geology series mapping underwent a 'back-end' assessment in 1985 through a process of expert examination for each 1:50 000 scale sheet. The process involved a geologist filling in an assessment sheet containing a facsimile of the map and space to add comments. Each 1:50 000 scale map would be scrutinised by geologists and written accounts and highlights denoted on the sheet, recording their confidence in the data; results were eventually published in the 'Geology for our diverse economy: Report of the Programme Development Group for Onshore Geological Surveys' by Lee, et al. in 2001. This is refered to by many within the BGS as 'the Green Book'.

### 2.1.2 Confidence Grids

In 2010, the Information Products Programme launched an Expert Elicitation Pilot Study on establishing a methodology for the creation of an indicator layer showing the level of uncertainty or confidence in DiGMapGB-50 data. The main aim of this pilot study was to establish a cost effective methodology that would provide and constantly maintain an indicator layer that would help to indicate and prioritise the areas in DiGMapGB-50 which required further research.

The objectives for this pilot study were:

1) To capture the expert confidence in the surface geology as depicted in DiGMapGB-50.
2) To identify the factors that geologists consider most important when determining their confidence in the surface geological representation of DiGMapGB-50.
3) To make recommendations about how the Information Products Programme could determine confidence for some of its information products.

The first method involved the use of two overlapping/offset 50 km$^2$ grids; effectively creating a 25 km$^2$ elicitation grid as a measure for testing elicitation consistency across known 50 km$^2$ tiles and help remove potential bias by creating a grid that did not directly correspond to any individuals mapping area. A combination of both qualitative (what experts felt) and quantitative (agree/disagree sliding scale) answers were used to assess each 25 km$^2$ cell/tile (Figure 1).

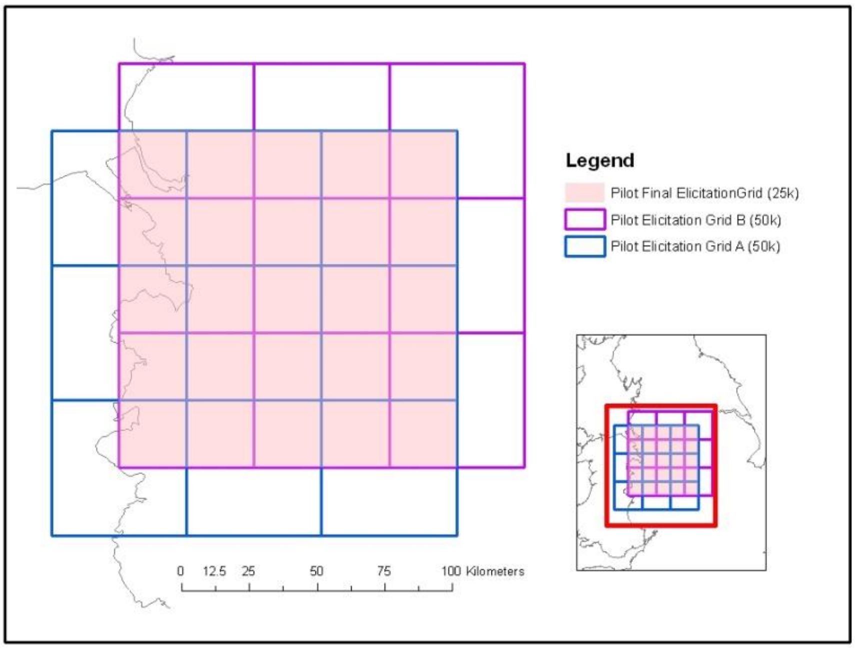
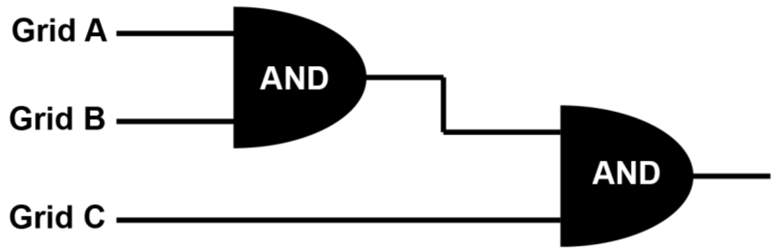



**Figure 1: Pilot study offset elicitation grids. Source Lee, et al., 2010**

The process involved a simple 3-Input AND Gate method (Figure 2), combining values obtained from participant judgements scored on two overlapping 50 km$^2$ grids. These combined results were then directly assessed against an individually scored 25 km$^2$ grid as a control grid in assessing the EE methodology. If the end value from both processes was the same, then confidence in the result was assured and marked accordingly.




| Grid A | Grid B | Grid C | RESULT |
|---|---|---|---|
| 0 | 0 | 0 | ACCEPT |
| 0 | 1 | 0 | REJECT |
| 1 | 0 | 0 | REJECT |
| 1 | 1 | 0 | REJECT |
| 0 | 0 | 1 | REJECT |
| 0 | 1 | 1 | REJECT |
| 1 | 0 | 1 | REJECT |
| 1 | 1 | 1 | ACCEPT |

**Figure 2: 3-Input AND Gate method**

This method was eventually aborted largely due to the significant amount of time required to complete the process.

### 2.1.3 Individual elicitation and the probability wheel

Four experts with a range of geological experience would individually participate in an elicitation process with a facilitator. Multiple choice questions, both qualitative and quantitative, would be recorded and statistically averaged according to a weighting of participant experience.

This method included one question to be expressed (as a percentage) through the use of a probability wheel (Figure 3) as an alternative method of deriving more confident estimates from experts. Studies have shown that participant judgement is easier when visualized in the form of a pie chart percentage. (USEPA, 2009). The confidence ratings from each participant would then be combined and averaged to produce a result for each assessed cell. This method was also aborted largely due to the process taking more time than anticipated.

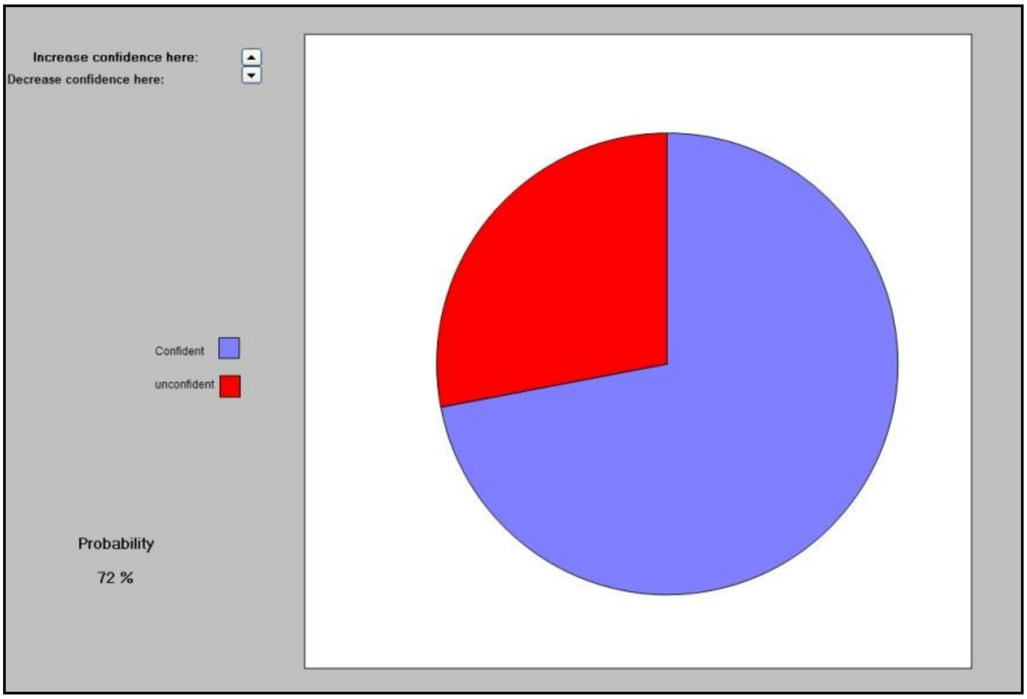



**Figure 3: An example of a probability wheel. Source Lee, et al., 2010**

### 2.1.4 Group elicitation or collective judgement

A re-drafted questionnaire, based on the individual elicitation example used in 2.1.3, was presented to four experts (across the experience range) who were asked to examine each 50 $km^2$ cell as a group, to promote a consensus of expert opinion. One disadvantage of this group elicitation exercise was the effect of group dynamics. Dominant personalities tend to bias thinking towards their judgements.

It was observed that the expert with more experience would place greater emphasis on 'corporate knowledge' (e.g. the reputation of the mapping geologist) as opposed to the younger expert who would rely more on available empirical sources, such as boreholes and any observable outcrops.

All of the Expert Elicitation methods tested above proved to be too time consuming. To pursue these methodologies at full scale would require significant funding. Feedback from experts after the elicitation process pointed out that the further into the process they progressed, the less confident participants became in their answers (Lee, et al., 2010). It was established that a streamlining of all elicitation questions would help to minimise expert analysis time and reduce costs, and help to address the loss of confidence by participants.

## 2.2 STRATEGIC OPTIONS

Building on the experience gained from the previous Expert Elicitation exercises, four options were proposed:

**Option 1:** Apply existing 'back-end' EE methodology with additional GIS data, with a prescriptive approach to time and number of experts involved, as per the 'Green Book' approach 2.1.1.

**Option 2:** A simplified 'back-end' thematic questionnaire with the aim of reducing respondent ambiguity, answered on a sheet by sheet basis.

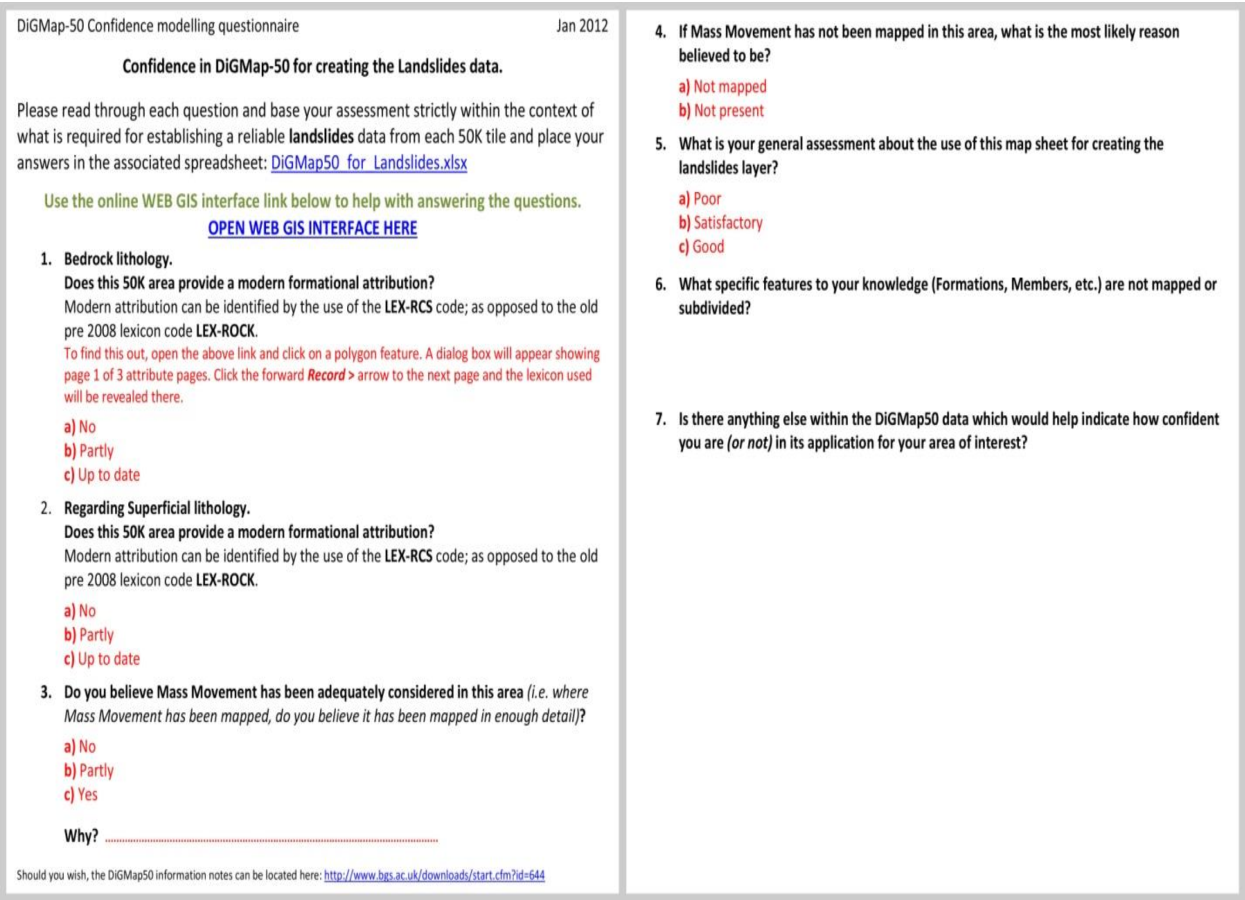
**Option 3:** A 'front-end' customer lead confidence questionnaire, requiring experts to make judgements on specific contexts. With potential users in mind, the experts would assess only the aspects of the DiGMapGB-50 data that are relevant, on a sheet by sheet basis.

**Option 4:** To help avoid assessing data on a grid basis confidence scores can be based on the geology (i.e. Groups, Formations and Members) for whole regions, providing a framework for a ‘Group confidence’ model. One elicitation ‘advantage’ to this method is that the removal of the grid may reduce the effects of bias toward one individual’s mapping.

Option 3 was chosen as the way forward, as it fulfils the principle objective of providing a confidence model for customers to make appropriate ‘risk informed’ decisions based on the data BGS currently hold. Options 1, 2 and 4 were deemed too time consuming.

# 3 Methodology

Building on Option 3 outlined above, a customer lead confidence questionnaire, involving a minimal set of relevant/appropriate questions applicable to all DiGMapGB-50 data, was drafted (Figure 4). The aim of this exercise was to design a ‘front-end’, objective assessment of the DiGMapGB-50 digital surface data as observed by the user; not a ‘back-end’ assessment of the underlying geological science that underpins the geology represented on the surface. To help achieve this, each questionnaire was tailored to the scientist’s area of expertise and restricted to no more than ten concise questions. This helped to maintain participant confidence, reducing the effects of questionnaire fatigue and avoiding the possibility of recording misleading information beyond the expertise of the participant.



DiGMap-50 Confidence modelling questionnaire Jan 2012

**Confidence in DiGMap-50 for creating the Landslides data.**

Please read through each question and base your assessment strictly within the context of what is required for establishing a reliable **landslides** data from each 50K tile and place your answers in the associated spreadsheet: DiGMap50_for_Landslides.xlsx

Use the online WEB GIS interface link below to help with answering the questions.

OPEN WEB GIS INTERFACE HERE

1. **Bedrock lithology.**
   **Does this 50K area provide a modern formational attribution?**
   Modern attribution can be identified by the use of the **LEX-RCS** code; as opposed to the old pre 2008 lexicon code **LEX-ROCK**.
   To find this out, open the above link and click on a polygon feature. A dialog box will appear showing page 1 of 3 attribute pages. Click the forward ***Record >*** arrow to the next page and the lexicon used will be revealed there.
   **a)** No
   **b)** Partly
   **c)** Up to date
2. **Regarding Superficial lithology.**
   **Does this 50K area provide a modern formational attribution?**
   Modern attribution can be identified by the use of the **LEX-RCS** code; as opposed to the old pre 2008 lexicon code **LEX-ROCK**.
   **a)** No
   **b)** Partly
   **c)** Up to date
3. **Do you believe Mass Movement has been adequately considered in this area** *(i.e. where Mass Movement has been mapped, do you believe it has been mapped in enough detail)*?
   **a)** No
   **b)** Partly
   **c)** Yes

   **Why?** ..........................................................

4. **If Mass Movement has not been mapped in this area, what is the most likely reason believed to be?**
   **a)** Not mapped
   **b)** Not present
5. **What is your general assessment about the use of this map sheet for creating the landslides layer?**
   **a)** Poor
   **b)** Satisfactory
   **c)** Good
6. **What specific features to your knowledge (Formations, Members, etc.) are not mapped or subdivided?**
7. **Is there anything else within the DiGMap50 data which would help indicate how confident you are *(or not)* in its application for your area of interest?**

Should you wish, the DiGMap50 information notes can be located here: http://www.bgs.ac.uk/downloads/start.cfm?id=644

**Figure 4: Introductory questionnaire**

To reduce costs and maintain efficiency, it was decided that an EE procedure allowing the expert to proceed on an individual basis would be the best way forward.

The rationale behind this approach was based on the following:

1) The expert can participate at their own convenience within a pre-defined timeframe. This may allow an expert to participate at a time and place that affords them best comfort, resulting in a more reliable assessment.
2) The expert can participate, without exposure to group dynamics which previous work shows can distort judgements as a result of submissive or overconfident behaviours within a group; avoiding convergence of opinions, divergence or herding tendencies for instance.
3) Once in place, the methodology can conveniently be utilised by experts as and when new data becomes available, at a modest cost.

## 3.1 SAMPLE SITE SELECTON

Each expert was provided with a map showing a selection of ten 1:50 000 scale map sites across mainland Britain: 6 sites in England, 2 in Wales and 2 in Scotland (Figure 5). All sites were chosen on a random spatial distribution. No bias towards any area of geological or topological interest influenced the decision for site selection. The only criteria employed during distribution were that it should include a minimum of 2 sites each for Scotland and Wales; and all sites had to contain 100% data coverage i.e. inland areas with no coastline. This provided a measure of consistency.

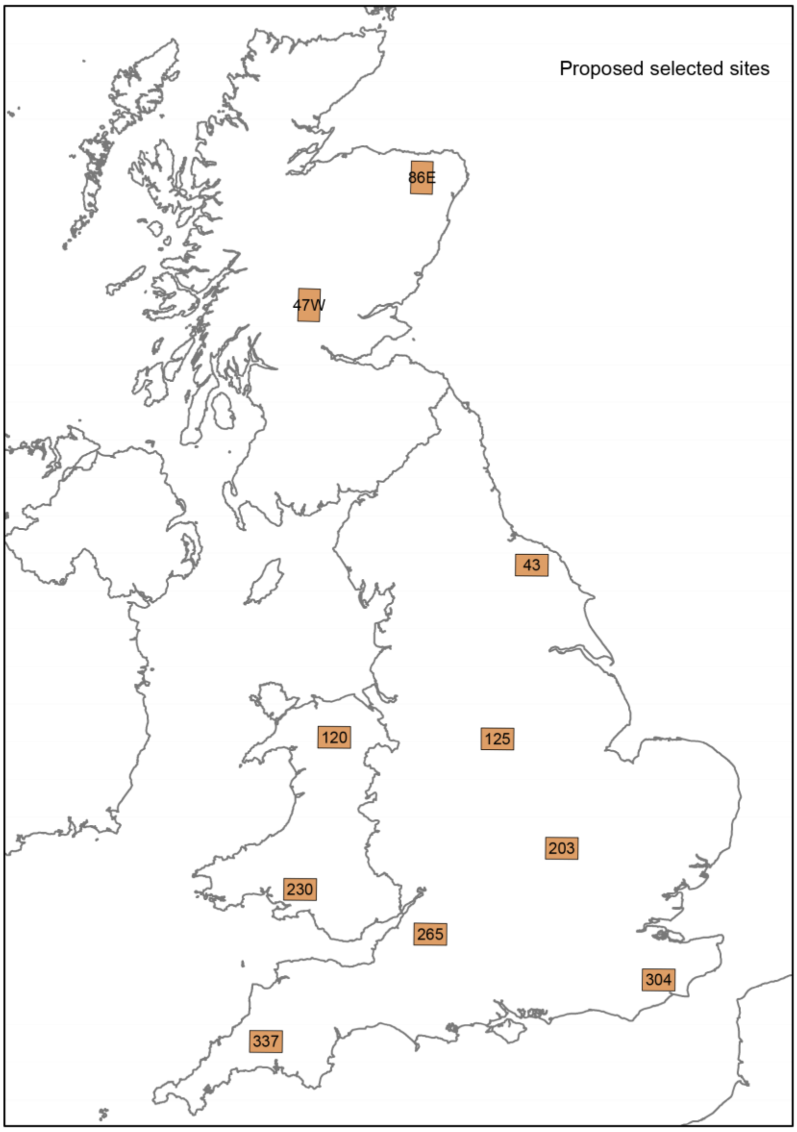



**Figure 5: Sample site selection map**

## 3.2 DIGMAPGB-50 DIGITAL INTERFACE

Each expert was provided with web access to the DiGMapGB-50 dataset through the use of an ESRI JavaScript API (Figure 6). This application interface could be accessed via a hyperlink displayed at the top of the questionnaire Figure 4, providing full access to the DiGMapGB-50 dataset for the assessment. Each site could be viewed in the context of adjacent data cells/tiles. Relevant layers of data could be activated simply by clicking check-boxes listed in the ‘map layers menu’, where appropriate, as an added aid to answering each question within the desired field of expertise. Figure 6 shows the selection of ‘Egton’ 1:50 000 scale map (Sheet 043) with data appropriate for landslides activated.

## 3.3 TIME ALLOCATION

Due to budget limitations, only one day of staff allocation time was available for each EE participant to assess all ten selected areas on the site location map (Figure 5); creating an average of 45 minutes time available for expert assessment on each area.

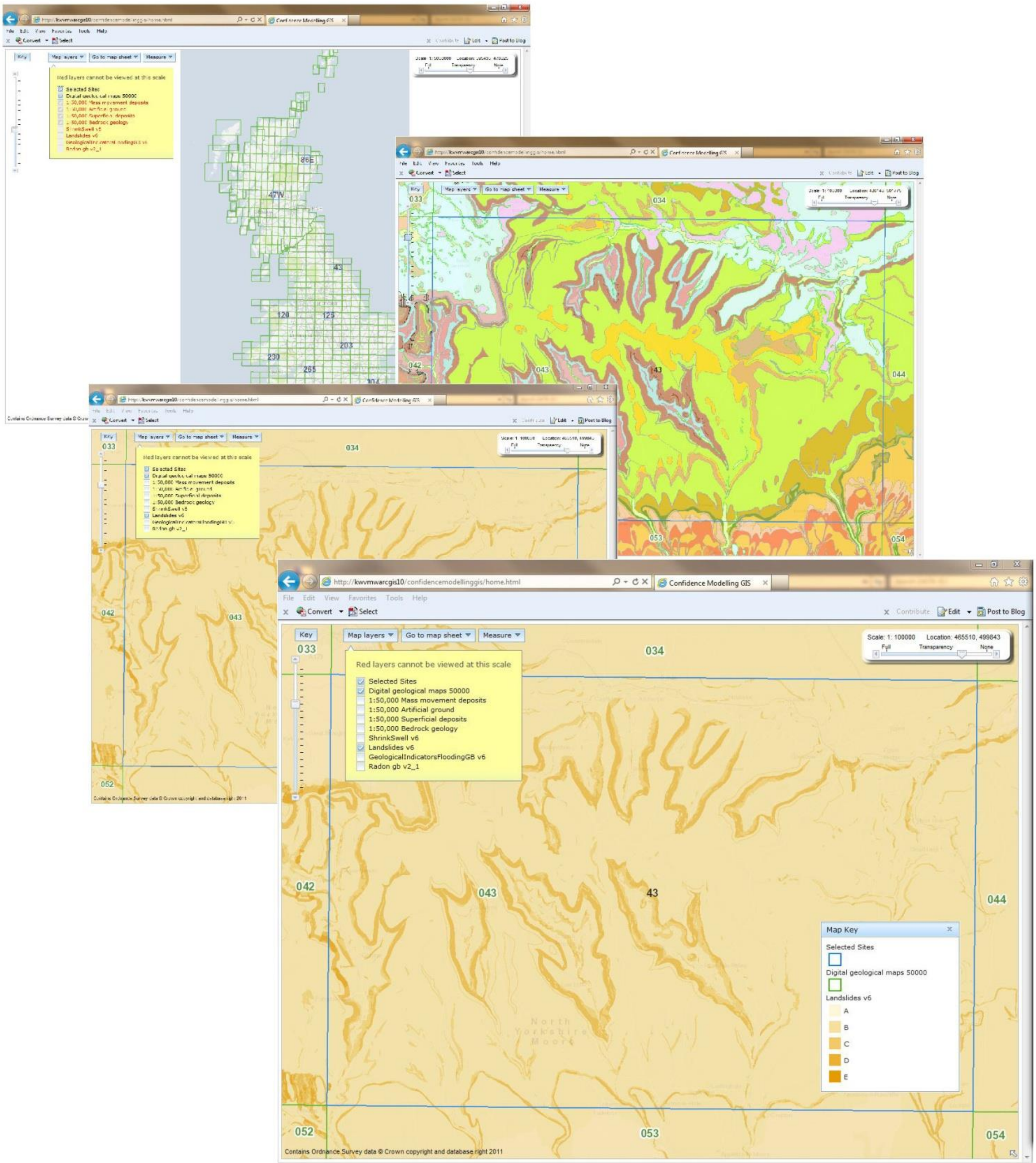
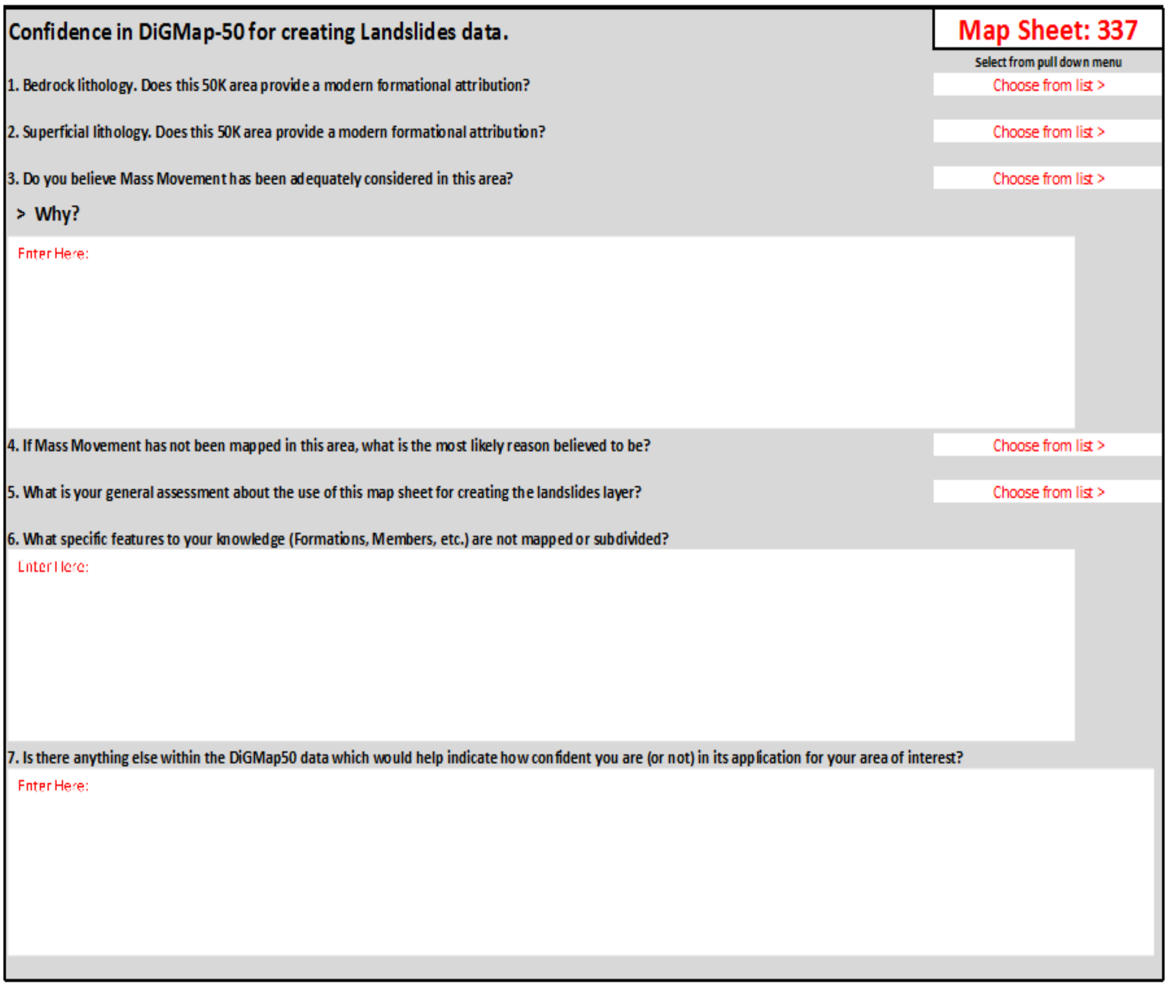



**Figure 6: Interactive JavaScript interface showing ‘Landslides’ v6 data**

## 3.4 QUESTIONNAIRE

An expert elicitation questionnaire was created using a series of basic multiple choice questions. The questionnaire was presented to the expert in two formats: a Word document (Figure 4) and an Excel spreadsheet (Figure 7). Each questionnaire was tailored to an appropriate theme relevant to the expertise of the participant. These themes can be used in any context appropriate to the participant (Section 1.2). For the purpose of this test, confidence in DiGMapGB-50 for creating landslides data was the appropriate theme selected, based on staff availability with expertise in this field.


Confidence in DiGMap-50 for creating Landslides data.

Map Sheet: 337

Select from pull down menu

1. Bedrock lithology. Does this 50K area provide a modern formational attribution? Choose from list >

2. Superficial lithology. Does this 50K area provide a modern formational attribution? Choose from list >

3. Do you believe Mass Movement has been adequately considered in this area? Choose from list >

> Why?

Enter Here:

4. If Mass Movement has not been mapped in this area, what is the most likely reason believed to be? Choose from list >

5. What is your general assessment about the use of this map sheet for creating the landslides layer? Choose from list >

6. What specific features to your knowledge (Formations, Members, etc.) are not mapped or subdivided?

Enter Here:

7. Is there anything else within the DiGMap50 data which would help indicate how confident you are (or not) in its application for your area of interest?

Enter Here:

**Figure 7: Screen view of the participant submission form**

The resulting questionnaire contained 7 questions including both multiple choice and free text (see Figure 4). Creating multiple choice questions helped to streamline the post-elicitation process of establishing an overall expert consensus (Section 3.5). It was also believed that streamlining the questionnaire would help to reduce costs and participant questionnaire fatigue.

The questionnaire went through several iterations prior to the final release. During the drafting process, focus on objectivity for each question was addressed with an emphasis on looking at the presented data at ‘face value’. Each judgement had to be based purely on the data shown on the interface (Figure 6).

## 3.5 POST-ELICITATION

It was understood that different geologists will show differences of opinion and alternative interpretations for any given area (Bowden, 2004). Limiting the assessment of each block of 1:50 000 scale data to one expert is naturally fraught with potential dangers, e.g. anchoring, overconfidence, etc. (Baddeley, et al., 2004; Polson & Curtis, 2010). One method of overcoming individual bias is to stage a post-elicitation workshop where a number of experts re-evaluate each individual EE assessment as a group. This approach is beyond the scope of this current study.

For the purpose of this study, a simple averaging of all EE results for each area assessed would potentially provide the consensus required. Should further funding become available other options include:

1) Ensuring at least three expert assessments for each area were recorded and later statistically combined to produce a consensus of opinion. Results from traditional scientific experiments allow for standard aggregation methods due to the empirical nature of data; EE results on the other hand are based on judgements and beliefs (tacit, intangible thoughts from the experts mind), that cannot follow standard aggregation methods to which traditional science is accustomed.
2) Other methods of normalising the opinions of those who differed from the consensus could be used, for example averaging between two or more opinions (known as 'convergence') or Baysian approaches: a process that uses statistical techniques to identify or extract hidden/tacit information contained in datasets or group knowledge (USEPA, 2009).

# 4 Lessons learned

It was anticipated that the pre assessment briefing on the importance of objectivity for each question, with an emphasis on looking at the presented data at in the context of the customer needs, would have been sufficient preparation for the participant prior to the EE process. In practice however, this proved not to be the case. Once the participant began the EE process, the concept of assessing an area of geology at face value proved impossible to achieve.

Knowledge of who the geologist responsible for the creation of the geological model was proved to be too important to ignore. For the participant to make a reasonable judgement of the data, access to background knowledge of its creation was essential.

Value placed on corporate knowledge of the data background was such that without access to this knowledge or allowing the facility to express opinions of this nature, the process lost credibility.

Likewise, a facility to submit background knowledge associated with data during an assessment process was equally believed important, especially where more than one scientist would be involved in assessing the data, either communicated on paper on an individual basis or as a group elicitation exercise.

During the tests, an observer was present to help facilitate the progress of the visual analysis. On each occasion, the scientist voiced concerns regarding the format of the questionnaire.

Key concerns identified:

1) The apparent randomness of site selection. This was in part due to the participants holding preconceived ideas about where 'more appropriate' sites existed and in some areas they did not know enough about the geology of the areas they were being asked to assess. The scientist believed that it was a waste of time assessing a site that, in their opinion, 'clearly' did not possess any geology appropriate to the theme being assessed.
2) A need to identify which scientist(s) mapped the area in question.
3) All participants expressed a requirement for more time to analyse beyond the allocated time limit of 45 minutes per area.

As a result of these issues, it became apparent that the EE process required further revision.

# 5 Conclusions

As outlined in section 1.3, a geologist's knowledge and interpretation of the geology between known (observed) data points (e.g. outcrops) are difficult to refute at face value (Bowden, 2004; Smith, 2011). It is unlikely that another geologist can assess an unfamiliar model without direct experience of that area and further information behind its creation (Clarke, 2004).

Asking geologists to assess areas of data objectively can be problematic. Where a lack of confidence occurs due to unfamiliarity, the geologist naturally requests further information (both in explicit form such as solid evidence and inferred, expert judgements from fellow geologists) in order to make an informed assessment. Sourcing such information would require more time; however results from such activity may reinforce an erroneous consensus of opinion away from an expert's initial impression.

# 6 Recommendations

The principle aim of this study was to try and establish a 'front-end' assessment of the DiGMapGB-50 digital data from the context of the customer, based on one of the recommendations provided from an earlier scoping study released during 2011 (Option 3: in IR/11/002). Conclusions drawn from continued exploration along the lines of 'Option 3' have produced further considerations/recommendations for future research in this area.

## 6.1 CONCEPTS

### 6.1.1 Front-end approach

Continue with the front-end approach proposed in this report, but with greater emphasis on pre-assessment conditioning.

Pre-assessment conditioning may have been more successful if it was carried out by an experienced geologist, who would empathise with the desire for such subjective background information, but would equally consider the objective surmising of the geological data. Professional bias towards fellow colleagues both within an organization and beyond can often be negative, potentially inhibiting genuine objective analysis of geological model created by known geologists. Time might potentially help to reduce these issues, as new scientists with less experience, replace long established staff that hold such corporate knowledge.

### 6.1.2 Back-end approach in theme context

If pre-assessment conditioning proves difficult to achieve, revision of background knowledge might be necessary to facilitate progress. It might be helpful to allow time for geologists to judge geological models based on a collective knowledge of its developmental history and the staff behind its creation. Adding scaled qualitative questions will help to meet the geologists' needs and facilitate the elicitation procedure.

## 6.2 PROPOSED EXPERT ELICITATION STRUCTURES

The results of this scoping study indicate that a return to a form of group Expert Elicitation may prove to be the most successful method, however clearly known issues of group bias would need to be addressed (Curtis, 2012). To help safeguard results from the hazards of bias resulting from cognitive heuristics (reasoning based on preconceived mental biases gained through personal experiences) between experts, a combination of both individual and group elicitation exercises may deliver positive results.

Consideration should be given to methods known to help reduce the effects of individual bias. For example staging a post-elicitation workshop where a number of experts re-evaluate each individual EE assessment, either as a group or individually.

### 6.2.1 The Delphi method

One recommendation that includes a post-elicitation exercise was the Delphi method (USEPA, 2009). Each expert anonymously re-evaluates each individual EE assessment contributed from other participating experts. These re-assessments are then statistically combined to produce a consensus of opinion.

To reduce costs, initial 'first round' EE results that display a uniform consensus of opinion among all experts can be accepted without further post-elicitation. A further reduction in costs and time can be achieved if the post-elicitation exercise was carried out as a group. Certain types of bias caused as a result of group dynamics e.g. overconfidence, motivational, anchoring and adjustment, are known to reduce once an array of first round expert opinions are presented (USEPA, 2009). For example, it was observed that a degree of emancipation was enabled for the less confident/experienced expert by the presence of these anonymous 'first round' results.

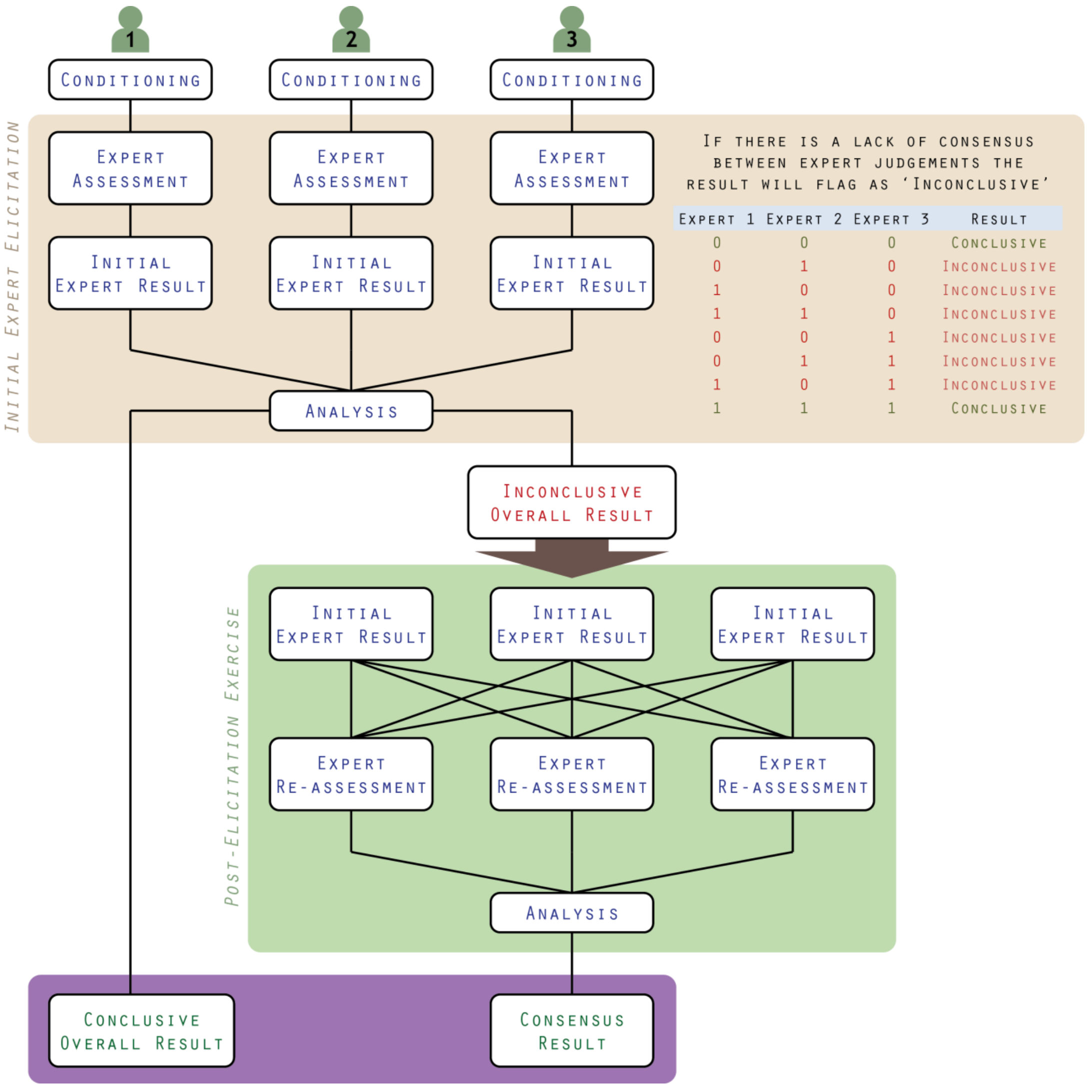



**Figure 8: Proposed Expert Elicitation Structure**

### 6.2.2 Statistical method

Should the use of expert time for two rounds of EE prove prohibitive, there are alternative methods of normalising outlier opinions towards a general consensus, for example, averaging between two or more opinions, known as 'convergence', or using Baysian approaches: a process that uses statistical techniques to identify or extract hidden/tacit information contained in datasets or group knowledge (USEPA, 2009).

# Glossary

| | |
|---|---|
| *Anchoring* | A bias towards a group norm, consensus or known position through personal experience. A reluctance to move too far from an original position or idea. |
| *Baysian approaches* | A process that uses statistical techniques to identify or extract hidden/tacit information contained in datasets or group knowledge. |
| *Cognitive heuristics* | Reasoning and predicting complex scenario outcomes based on little data or information in a relatively short space of time. Based on preconceived mental biases gained through personal experiences. |
| *Convergence* | A grouping, or clustering, of opinions similar to a generally understood norm or a dominant personality within the group. |
| *Expert Elicitation* | Is the synthesis of opinions of experts of a subject where there is uncertainty due to insufficient data or when such data is unattainable because of physical constraints or lack of resources. |
| *Overconfidence* | A belief of one's own judgement at the expense of reasoned thought, or reflection. To provide a judgement without considering valid view points from others. |
| *Tacit information* | Knowledge contained within the mind. Hidden ideas, theories or knowledge, learned through personal experience. Information not easily articulated in writing or orally exchanged. |

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