Rapid Expert Review of Flood and Coastal Erosion Risk Management appraisal modelling

Final Report

prepared for

Defra and the Environment Agency

June 2019

Royal HaskoningDHV
Enhancing Society Together

RPA
Risk & Policy Analysts

Rapid Expert Review of Flood and Coastal Erosion Risk Management appraisal modelling

June 2019

Final Report

Quality Assurance	
Project reference / title	J1026/RER FCERM
Report status	Project Report (DRAFT)
Author(s)	Teresa Fenn Elizabeth Daly Emma Cary Fola Ogunyoye Andrew Craig Patrick West
Approved for issue by	Meg Postle
Date of issue	11 June 2019

Document Change Record			
Report	**Version**	**Date**	**Change details**
Interim Report	1.0	15 February 2019	Interim progress for discussion
Project Report	2.0	29 March 2019	Draft final report for comment
Project Report	3.0	11 June 2019	Final Report incorporating comments

Disclaimer

The views and propositions expressed herein are, unless otherwise stated, those of Risk & Policy Analysts or Royal HaskoningDHV and do not necessarily represent any official view of Defra, the Environment Agency or any other organisation mentioned in this report.

Executive Summary

The need for the study

Defra has a leading role in administering and assuring funding for Flood and Coastal Erosion Risk management (FCERM) on behalf of central government. The assurance mechanism for the HM Treasury 5 case model is quite well understood and documented, including sensitivity testing of the business case to scheme costs and assurance through the Large Project Review Group (LPRG), National Project Assurance Service (NPAS), etc. However, the economic business case is heavily reliant on hydrological and hydraulic modelling. Defra was therefore interested to explore a small initial sample of business cases, to understand the variability and potential gaps in the modelling assurance process, and impacts that this might have on business cases for FCERM funding.

The aim of the study

This study analyses a series of five case studies to explore how assurance of flood risk modelling is currently undertaken. The study covers the type of models used, how quality assurance was undertaken, issues that arose during assurance and how these were addressed. From this, the project explores what, if any, changes are needed to improve assurance of flood risk modelling and use of the results in subsequent stages of appraisal.

The approach

Our approach to the study is based on investigation of approaches to assurance used across a sample of five case study schemes, agreed with Defra and the Environment Agency. Each case study entailed a brief review of modelling approaches, followed by an interview with the team involved in the appraisal study assurance.

Our approach is based on interviews set up with representatives from the five Risk Management Authority (RMA) project teams, to examine:

- Suitability of modelling approach given the requirements of Environment Agency's FCERM Appraisal Guidance (FCERM-AG) and the Multi-Coloured Manual (MCM);
- Transparency of approach and ease of assurance by customers in RMAs;
- Practice of assurance of models within RMAs (including the Environment Agency in cases where it assures the work of other RMAs like Internal Drainage Boards (IDBs) and Local Authorities);
- Any lessons for improving modelling and assurance practice, taking due account of proportionality and priorities in terms of biggest impact for least cost/effort.

Key findings of the study

While particular processes and programme related issues and opportunities for improving modelling and assurance practice were identified during the study, none of those reviewed or assessed within the case studies was found to have ultimately led to the wrong scheme choice or appraisal outcome.

The interviews showed significant variability in approaches, which to some extent correlated with the scale and complexity of the project, although not necessarily driven directly by risk or proportionality. In most cases, modelling is carried out by consultant teams. The scope is usually defined in a tender

brief, although some consultants do identify additional needs or modify approaches during the project if appropriate and subject to agreement being reached.

Different approaches are used for quality assurance (QA) depending on the type of project. Independent reviewers (external to the project team - whether in client organisation or external) are sometimes engaged to review the main modelling deliverables. Some RMAs had not considered seeking independent/external review but, when questioned recognised that, for appropriate projects, this could be useful. The time and funding requirements would however need to be pre-planned. Some larger Environment Agency projects included advanced planning and budgeting for reviews; allowing confidence in understanding and decisions to progress incrementally. Smaller projects relied more on consultants internal QA, although documentation of internal QA is not always obtained or checked. In some cases, gaps in early method reviews or independent reviews near modelling completion exposed business cases to risks. Sometimes these risks are identified post outline business case (OBC), leading to modelling and full business cases (FBC) needing substantial overhaul, which is inefficient and causes delays to the scheme delivery programme. However, while there was no evidence gathered from the interviews indicating that substantial changes were required, there were cases where delays to the programme were identified during the case study interviews.

Modelling reports vary in the transparency of reporting uncertainty or limitations in the input data, modelling decisions or expected output accuracy. Many modelling projects did include sensitivity testing, but the choice of sensitivity bands was not always informed by actual model confidence. In addition, although modelling results are used to inform subsequent stages of appraisal, the economic appraisal sensitivity tests are seldom linked to the model sensitivity or uncertainty. Therefore, it is not always clear or evidenced whether business cases might be sensitive to modelling uncertainties.

Respondents were not all clear on how to apply proportionality in deciding the level of detail for modelling and assurance. When a light tough assurance approach is taken for proportionality, this decision is not always documented in a transparent and auditable manner. Whilst some lessons had been learnt by the project teams based on challenges experienced, these lessons had not been actively shared with other teams within or outside the lead RMA. Most respondents agreed that improvements in communication of modelling outcomes through the appraisal process, and improved reporting from modellers, could support more efficient and consistent assurance. There was also general agreement that targeted sensitivity testing in the modelling (reflecting the confidence and realistic uncertainties in the model and boundary conditions) could be improved within the economic appraisal process, whether qualitatively or quantitively.

Suggestions for the way forward

Suggestions for ways forward have been based on the evidence collected through the case study interviews. In addition, the views and opinions of the interviewers, who include experienced reviewers involved in assurance of modelling and appraisals, are also provided to add value.

The five case studies analysed have provided sufficient information to inform how modelling assurance practice can be improved and how the results of modelling can be better used to inform the subsequent stages of appraisal. Therefore, it is not suggested that a larger sample or further in-depth assessment is required. Instead, the suggestions are focused on the approach to and proportionality of assurance, and encouraging greater feedback between the modelling and appraisal teams.

1. **Suggestions in relation to approach to assurance**: the review shows that assurance is, for the most part, working well but some improvements could be made to make approaches more consistent across projects:

What	How
Promoting the value of good programming of modelling and reviews, including early discussions with prospective reviewers to help reduce inefficiencies and delays and this reduce the risk of delays in delays to business case preparation	Update of the Environment Agency's Operational Instruction 379_05 'Computational modelling to assess flood and coastal risk', and making it more accessible outside the Environment Agency Inclusion of signposting to other documents, such as FCERM-AG, where applicable
Highlighting the value of informed model sensitivity testing that assesses realistic potential variability in design flood levels	Encouraging a section or appendix of self-review including where constraints (budget, time) have affected the approach or sensitivity of outcomes
Investigating further where research is needed on key areas of uncertainty, e.g. hydrological methods, and how that uncertainty could be reduced	Model scoring mechanism that incorporates key elements, such as boundary conditions that could inform development of a meta database that collates key sources of uncertainty and could be used to identify future research priorities
Developing best practice examples from a sample of ongoing business cases that show how uncertainties in modelling have been assessed and used in subsequent stages of business case development	Review of existing business cases to identify best practice that could be referenced as examples for others to consider when assessing how to undertake assurance

2. **Suggestions in relation to proportionality of assurance**: the review shows that teams are taking different approaches to assurance but this can be more due to current practice within the teams rather than potential need or benefit of assurance. Some projects seem to demand an independent review regardless of need while other teams have not given consideration to the benefits of independent review:

What	How
Providing guidance on when an independent expert review is recommended. This could be linked to review checklists that could be used to help project teams identify whether an independent review is likely to be warranted. To retain proportionality, the checklists could identify whether any review is required and then what scale may be most appropriate (linked to uncertainties and assumptions made during the modelling process)	The checklist could be developed as an update to the Environment Agency's 'WEM modelling scope'; 'evaluation checklists for intermediate and detailed review' and/or 'checklist for reviewing flood estimates' but would need to be applicable to all RMAs Clarifying the role of the EA evidence and risk teams and how, when and why engagement with them could provide value to modelling and assurance

3. **Suggestions in relation to collaboration amongst the wider appraisal team**: the review shows that there is a need for improvement in communication amongst project team

members. This would help to reduce risks by improving the ability of different specialists to cross-check earlier work and improve the quality and robustness of appraisals by better enabling uncertainties to be tested, e.g. through sensitivity analysis:

What	How
Highlighting the value of good model reporting, including transparent reporting of assumptions, model limitations, level of confidence and uncertainties. This information should be summarised in a manner that makes it easy for non-modellers to interpret and to take into account during sensitivity testing on damages in the economic appraisal	Updating modelling guidance, e.g. to the approach that was applied previously through the Environment Agency's 'SFRM performance scope'
Encouraging early communications so the wider appraisal team is aware of uncertainties and assumptions in modelling from an early stage. Continuation of engagement to enable collaborative discussion on uncertainties and their potential influence on outcomes or decision tipping points	Changes to tender briefs Communication of the needs of different team members so there is improved understanding of the requirements of different activities Updating of FCERM-AG to specifically cover how modelling uncertainties can be used to inform sensitivity testing in economic appraisal

Table of Contents

Glossary

Defra	Department for Environment, Food and Rural Affairs
EA	Environment Agency
E&R	Evidence and Risk (which includes the former Modelling and Forecasting team)
FBC	Full Business Case
FCERM	Flood and Coastal Erosion Risk Management
FDGiA	Flood Defence Grant in Aid
FEH	Flood Estimation Handbook
ICM	Integrated Catchment Modelling
IDB	Internal Drainage Board
LA	Local Authority
LPRG	Large Projects Review Group
MC	Monte Carlo
MCM	Multi-Coloured Manual
NCPMS	National Capital Programme Management Service
NPAS	National Project Assurance Service
NPPF	National Planning Policy Framework
OBC	Outline Business Case
OM	Outcome Measure
QA	Quality Assurance
ReFH	Revitalised Flood Hydrograph
RMA	Risk Management Authority
SFRM	Strategic Flood Risk Management
UKCP18	UK Climate Projection 2018
WEM	Water and Environmental Management

1 Overview of approach

1.1 Study objectives

Defra has a leading role in administering and assuring funding for FCERM on behalf of central government. The assurance mechanism for the HM Treasury 5 case model is quite well understood and documented, including sensitivity testing of the business case to scheme costs and assurance through LPRG, NPAS, etc. However, the economic business case is heavily reliant on hydrological and hydraulic modelling. Defra was therefore interested to explore a small initial sample of business cases to understand the variability and potential gaps in the modelling assurance process, and the impacts that this might have on business cases for FCERM funding.

The objectives of the research therefore were set as follows:

- To determine and agree a small sample (of 5 cases) of appraisal modelling exercises, and to meet with representatives from the Risk Management Authority (RMA) staff responsible for overseeing scheme appraisal. Explore issues in terms of ease of assurance, particularly for modelling analysis. The cases should be examined in terms of:
    - Suitability of the modelling approach given the requirements of EA's FCERM Appraisal Guidance (FCERM-AG) and the Multi-Coloured Manual (MCM);
    - Transparency of the approach and ease of assurance by customers in RMAs;
    - Practice of assurance of models within RMAs (including EA in cases where it assures the work of other RMAs like IDBs and Las);
    - Any lessons for improving modelling and assurance practice, taking due account of proportionality and priorities in terms of biggest impact for least cost/effort.
- To prepare a report for the Environment Agency (EA) and Defra on the findings and suggestions for ways forward.

1.2 Our approach to the study

Our approach to the study is based on investigating approaches of assurance that are used across five case study schemes, agreed with Defra and the Environment Agency, namely:

- Bacton to Walcott Coastal Management Scheme;
- Essex County Council Surface Water Management projects, covering a number of example projects and the internal capital programme as a whole;
- Oxford Flood Alleviation Scheme;
- Southsea Coastal FCERM Scheme Appraisal and Design; and
- Rochdale and Littleborough Flood Management Scheme

Each case study entailed a brief review of modelling approaches, followed by an interview with the team involved in the appraisal study assurance.

The project objectives were broken down into the following research questions which were used to shape and steer the interview process and evaluation:

1. What models have been used, who has applied them and over what timescale, and why were those models chosen?
2. What issues arose during assurance and how were these overcome?
3. How was an appropriate level of QA ensured, regarding each of the modelling components?

4. Are you confident with how to select and procure/apply the appropriate level of assessment for various scales of project? If not, what would help you?
5. How did you carry out assurance and is this an easy process?
6. What information would assist you in your assurance role?
7. How did issues raised internally or externally affect the outcomes of the scheme and what were the effects?
8. What lessons were learnt?

The following sections give a flavour of the responses to these questions, to qualitatively illustrate the variability between different projects, a sample of issues raised, gaps and potential opportunities. Due to the small sample size, we have not attempted to derive any statistical significance from the sample. We have not sought to reproduce all answers in this report, or to assign issues raised to projects, as a level of confidentiality was agreed with the EA, Defra and the case study interviewees. After providing a summary of relevant issues raised, Section 10 of this report provides suggestions for ways forward, based on the evidence collected through the case studies and the views and opinions provided by interviewees and interviewers, including experienced reviewers involved in assurance of modelling and appraisals.

2 Models used and why chosen

2.1 What models have been used and why?

In principle, the choice of model and its level of detail should be made based on its ability to provide the necessary information needed to make decisions, in a manner that is proportionate to the scale and nature of the project. Potential model choice and level of detail, particularly for a new model build, has evolved considerably over the last 20 years based on wider software choice and affordable computing power.

However, the choice of model is often influenced by the type, coverage and quality of existing model(s) for the study area or catchment. The option to enhance an existing model is often seen as a more cost-effective approach, provided appropriate checks are done. Due to these factors, model choice is sometimes specified in the tender brief. The chosen model type can sometimes be influenced by the expertise that the modellers and/or reviewers have of a particular model software.

Flood Modeller-Tuflow models are often used for fluvial Outline Business Case (OBC) studies since this software has often previously been used for Environment Agency Water and Environmental Management (WEM) Lot 1 flood mapping studies. For coastal studies Mike 21 is a commonly used package, and for Surface Water Management studies Infoworks ICM is often used, although for each of these disciplines other modelling software packages are available. Occasionally, multiple model types can be applied on a single project, to allow for improved representation and understanding of selected processes, and project teams occasionally involve external or even international reviewers to inform or confirm approaches during the early stages of a project.

In the case studies, existing models have been updated and refined to accommodate the project objectives. This decision has been based on the extent and accuracy of the existing model and the degree to which the existing model requires development to be suitable for decision making. Models are commonly improved and refined using additional surveyed topographic data and updated hydrological or boundary condition data. Updates often include calibration to recent flood events where data is available. For fluvial schemes, hydrology is commonly reflected by the Flood Estimation Handbook (FEH) peak estimation methods, with the Revitalised Flood Hydrograph (ReFH/ReFH2) being used for hydrograph shapes. Whilst this is current best practice in the UK, good hydrology for calibration and/or derivation of design events can still prove challenging due to limitations in FEH methods, availability of long and accurate flow records with reliable rating curve extensions, information on reservoirs or structure operation, representing spatial variation in critical storm duration, challenges with permeable catchment response, reservoirs, and climate change.

Sometimes in other projects (not in the 5 case studies), the client may specify in the tender brief that an existing baseline model should be adopted for use in the OBC or detailed design, without the consultant reviewing its accuracy or applicability for the intended purpose. Depending on the type of baseline situation and nature of interventions being considered in the OBC, this approach could result in undesirable propagation of uncertainties. If evidence of the confidence scoring of the model is not well documented in existing model reports provided, then an early model review and/or higher uncertainty allowances in the appraisal sensitivity testing may be advisable. This information needs to be clearly communicated to the economic appraisal to ensure that the appropriate levels of sensitivity analyses are undertaken. Currently, it appears that this communication is often not undertaken, or is not sufficiently clear so the uncertainty allowances in appraisal sensitivity testing do not reflect the level of confidence in the model.

Sometimes, model spatial extent or boundary forcing conditions (hydrology, sea levels, or waves) have been updated during the progression of a project, as new data and improved understanding highlights factors that need to be considered in greater detail than first anticipated. Unless planned for, this can introduce delays to the overall project delivery programme.

2.2 Who is involved and what are their roles?

Modelling for appraisal is usually carried out by consultant teams. The modelling scope is usually defined in the tender brief, although the selected consultant may identify additional needs or modified approaches during the project if appropriate. For coastal and fluvial 'main river' projects, the Environment Agency's Evidence and Risk (E&R) team is usually consulted for their input on the accuracy and suitability of any existing models and/or proposed modelling approach, although the timing and amount of consultation may vary. On larger schemes, the proposed modelling approach may also be independently reviewed at an early stage of the project.

During the calibration and review of baseline models, the EA and RMAs may contribute observed flood data, and/or may be involved in reviewing the calibration reports. Independent reviewers (external to the project delivery team) are sometimes engaged to review the main modelling deliverables. Additional stakeholders with local knowledge (such as various levels of local authorities, Natural England or other environmental bodies) may get the opportunity to comment on flood maps through stakeholder and public consultation. Some RMAs had not really considered seeking independent or external review. When questioned, they recognised that independent review could be useful, but are not currently undertaking this. The decision not to seek independent or external review may be influenced by experience and perception in the client team on the need/value of independent / external review, including perception of proportionality, and constraints on funding and project timescales. However, the decision and reasons were not documented, which would be useful in the future.

2.3 What types of decision are being made and how are they informed?

Assessment and decisions are being made at different scales and levels of detail. These include identifying the most at-risk areas and then focusing the modelling effort so these areas can be assessed in more detail. Sufficient detail is also required in areas contributing to or influenced by the scheme, which may span a wide geographical area. This can sometimes lead to the need to further improve previously accepted baseline models or methods, as discussed in Section 2.1.

Generally, the existing flood risk and damage estimations (i.e. Do Minimum scenario) are modelled using the refined model to generate an agreed baseline understanding. This allows those areas at greatest risk to be prioritised, facilitating the development of practicable options without the need to simulate an excessive suite of options.

A list of possible options, once screened for constraints, is then evaluated by modifying the baseline model to include proposed changes, to test the hydraulic efficacy. The reduced damages and scheme costs for the selected shortlist are then used to calculate initial benefit-cost ratios. The preferred option, sometimes with additional iterative refinements, is then selected through the OBC. The detailed design of the preferred option from the OBC is then developed and optimised further using refined options modelling. In some cases, the refined options modelling for detailed design may include further refinements to reflect more recent change in the study area, including additional survey data, improved local data/evidence including recent events, or updates in guidance/methods

such as climate change allowances. This is used to optimise the detailed design. Decisions are also informed by environmental considerations and contractor input.

In some cases, the modelling team is not the same as the economic appraisal team so there can be a lack of communication of hydraulic modelling uncertainties, especially where these are not recorded in the modelling report in a way that they can be easily interpreted and used within the economic appraisal. These can mean that there is a limited extent to which uncertainties from modelling are reflected within the economic appraisal, either in the main assessment or as part of sensitivity analysis.

3 Issues arising and how they were overcome

3.1 What issues arose and how were they addressed?

Depending on the type of project and the approach taken to quality assurance, there can be different ways to report on and address issues arising.

In some larger projects, advance planning has included sufficient budget and programme for modelling approaches and interim deliverables to be reviewed, with individual responses documented and addressed to the satisfaction of client and reviewers. This allows confidence in the model and outcomes to progress incrementally. For one case study, it was recognised by all partners that there were trade-offs involved due to the uncertainties shown by the modelling. Developing trust between the consultants, client and wider expert group allowed refinements to the modelling approach based on the project team's expertise. The final decisions on the project design were informed by discussions at design workshops. Applying similar incremental assurance approaches on smaller projects in a proportionate and efficient way is not always easy, although the potential does exist.

On some projects, there is more reliance on the consultants' own internal QA, with the client team reviewing flood outlines and reports for obvious inconsistencies. This might not capture some smaller issues (which an independent or external review may or may not detect depending on scope of review). However, this approach might not encourage sufficient detail in the report to present a representative assessment of model confidence and uncertainties that are accessible to non-modellers and can inform the appraisal uncertainty testing. This can then restrict the extent to which uncertainties in modelling, for example the number of properties or assets flooded, can inform the economic appraisal.

Poor project description between the RMA project lead or the supplier lead and the modellers can sometimes lead to abortive or unproductive work. Similarly, even if the modelling is considered adequate, some RMAs have felt the need to put in additional effort to improve or re-write the OBC after the consultant has provided its outputs. The draft OBCs before re-writes were not available for review, so it cannot be confirmed if the proposed re-writes related specifically to modelling assurance.

Sometimes, needing a substantial revisit of the hydrology or other aspects of modelling (in some cases post-OBC) delays getting on with the appraisal and/or engineering design, which can in turn delay delivery of the scheme and associated Outcome Measure (OM) targets. As indicated in Section 2.1, hydrological uncertainty can vary considerably due to limitations in FEH methods, availability of long and accurate flow records with reliable rating curve extensions, information on reservoirs or structure operation, representing spatial variation in critical storm duration, challenges with permeable catchment response, reservoirs, and climate change. Sometimes unexpected results or failures to calibrate within a reasonable tolerance prompt a significant change in hydrological approach or a more rigorous update and comparison of different methods. This can have knock-on impacts on appraisal with this needing to be re-worked in some cases.

On other occasions, updating surveys and modelling may not significantly change properties at risk compared to earlier strategic modelling. Transparently tracking confidence in models (notably boundary conditions and topographic information) informed by sensitivity testing, may help to target investment in modelling where it matters most, with a lighter touch in other areas. Once data gaps or uncertainties are identified, an understanding of the expected scale of impact of further data collection or modelling on the appraisal outcomes is not always visibly evidenced prior to undertaking further work.

Transparent and consistent application of property thresholds in the modelling and/or damage assessment is important. This was not evidenced across all case studies. Approaches can vary somewhat depending on the scale and level of detail of the modelling, but it is important to present and justify decisions clearly for the appraisal audit trail and for subsequent users of the results. Economic appraisal needs clear communication of the assumptions and limitations in a way that is meaningful in terms of being used as input data to an assessment.

Transparent recording of data provenance, assumptions and sensitivities was found to be varied. Transparent recording of reasonings behind decisions made along the appraisal journey was not always done. As a result, information from early part of the appraisal does not seamlessly inform the later stages, and are unlikely to feed into post-appraisal stages and decisions.

3.2 What was the impact on the final decision?

Assurance helps to provide confidence, which is important to funders and stakeholders, even if decisions might not change. The case studies showed that assurance sometimes identify relatively minor issues that can be readily resolved, providing confidence in a short timeframe. Sometimes delays in addressing and revisiting issues results in additional pressure on limited EA or RMA resources. However, sometimes significant issues are identified, such as hydrology, that can introduce significant delays and potentially result in significant changes to the design.

Changes in options and refinements to design can depend on a number of factors such as engineering costs, landowner requirements, partnership funding, maintenance issues, comments from ecology teams, with assurance only being one element that influences the choice of preferred option.

In some studies, problems with the hydraulic modelling led to delays in OBC submission, and/or a substantial overhaul of hydrology/modelling and the appraisal during what ought to have been detailed design stage. The primary impact was on programme delays and increased cost of the appraisal. While non-identification, or resolution of, issues identified within hydrology or hydraulic modelling at a late stage could also lead to a project which was deemed economically viable at OBC stage to be at significant risk of being unviable or unaffordable at the Full Business Case (FBC) stage, the delivery of a sub-optimal scheme delivering less Outcome Measures compared to that envisaged at OBC, or over/under accounting of benefits or Outcome measures, there was no evidence gathered from the five case studies indicating that this had occurred, even though the risk was identified .

Implied certainty where uncertainties are not reported may make appraisal more straightforward but could undermine reliability of the results, or future decisions made with the outcomes in an unknown way. Without information on the hydraulic modelling uncertainties, economic appraisal cannot test the impacts through sensitivity analysis or even as a range of property numbers or flood depths within the main appraisal in a meaningful way. As such, it is then not possible to identify what the impacts of underlying uncertainties may be and instead the results can be presented as ‘accurate’ without any indication of potential variance or possible impacts on decisions.

Lack of proper documentation of assumptions and decisions through the appraisal process and in the reporting has led to the lack of use of such information to inform what issues the sensitivity or robustness of the schemes should be tested for, and to inform post-appraisal activities, e.g. freeboard allowances.

4 How was an appropriate level of QA ensured?

4.1 What level of QA was defined as appropriate?

As discussed in Section 2.2, there can be some variation in perception of what level of review and assurance is proportionate and appropriate, although in general the level of review will follow some degree of correlation with scheme size/cost/complexity but not necessarily driven directly by proportionality or risk. Sometimes the review requirements are set out in the project tender invitation, having been informed by previous discussions with the Environment Agency's' E&R team. In some cases, the review requirements develop through discussion with the consultants and potentially external experts, particularly if modelling approaches are still being refined through the life of a project. Involving economic appraisers in these decisions could be useful. They may be able to communicate where uncertainties are more likely to affect the choice of preferred option, helping to identify which uncertainties may need to be refined further. The timing of activities may be an important constraint, however, and involvement of those undertaking economic appraisal during discussions on modelling may require re-planning of activities. The interviews and case studies highlighted the variability of approach. In some cases, some risk-based approach was taken to deciding the scale or form of QA. In others, a standard QA approach was used, without a demonstrable review of appropriateness for the scale or complexity of the project.

The responsibility for defining appropriateness and signing off assurance ultimately rests with the project executive of the lead RMA, although is often informed by members of the RMA project team, and potentially EA E&R teams and/or external reviewers.

An important aspect of QA comes from ensuring that consultants commissioned to develop appraisals have good modelling expertise and internal quality management systems to ensure the quality of their work. All case studies demonstrated this first level of QA by ensuring organisations with competent modellers with appropriate QA are employed through their procurement processes at framework or project levels.

Additional independent review (external from the project delivery team) can help to identify inconsistencies in input datasets, model approaches, calibration parameters, model results, or places where reports may not contain sufficient detail for realistic objective assessment of model confidence. This independent review may be carried out by Environment Agency or RMA in-house staff with modelling experience and/or detailed local knowledge, or let to external experts. The choice of whether to go external, and what level of independent review is proportionate, may be influenced by real or perceived pressures on cost, programme, limited or already stretched suitably qualified in-house reviewers, or lack of process for determining when or how to engage external reviewers.

For EA led schemes, the EA E&R team generally support the modelling assurance, whether internally (although sometimes resource constrained due to throughput of EA and external projects needing input/review), or helping to write scopes for external reviews.

For RMA led schemes, the RMA flood risk management team members are often involved in QA, linked to their roles, specific areas of expertise and/or detailed local knowledge. The RMAs review the draft reports including assumptions, but are not always aware of what is reasonable in terms of ranges around certain variables or may not detect additional assumptions that are not in the report. They use consultants to undertake the modelling as they are the experts. They assume anything fundamental is picked up as the study proceeds, but they do not know this for sure. Some RMAs have not used independent expert reviews when undertaking QA of modelling/reports. The potential for

independent or external review needs to be related to the size of the project and the likely influence of uncertainties on the decisions being made.

It would appear from the small sample of case studies and broader discussions during the interviews that modelling carried out for an EA-led project always has some level of independent review, many including external reviewers. In the case of other RMAs, there appears to be more reliance on the QA systems of the modelling teams and some internal reviews within the RMA, which could vary from a superficial common-sense check to more detailed check depending on the expertise available to the RMA. In some cases, support from the EA's Evidence and Risk team is sought for reviews. Independent external reviews were seldom the norm. Further exploration of the reasons for the apparent differences highlighted issues of scale and complexity could have played a part, but there may also be cultural reasons.

From the client perspective, assurance in one case study covered who was involved and what sort of models were being used. Initial (informal) assurance was based on the individuals and companies involved in the project. The use of international experts (and companies/individuals with whom the Environment Agency and local authority were already familiar) enabled trust to be built from the start. The requirement for this level of assurance, even if it is informal, will need to reflect the type of decision that is being made, the likely value of any scheme that is being proposed and the extent to which a study is building on previous models or developing new approaches where uncertainties may be greater.

4.2 How were modelling uncertainties used?

When deciding on proportionality for review, consideration needs to be given to managing risk associated with uncertainty. For example, what is the likelihood of errors, the potential magnitude and impact of those uncertainties on project outcomes. In other words, what would be the consequences of errors, and can those risks or uncertainties be managed accordingly – whether through additional review, through sensitivity testing within the modelling and appraisal processes, and whether the issues identified are likely to be important in terms of choice of preferred option.

Whilst many modelling projects contain some sensitivity testing, this does not always correlate to model confidence. Sometimes, modelling uncertainties are not quantified, and the appraiser may be reliant on qualitative expressions in reports relating to model confidence that may be hard to find or evaluate. In addition, these qualitative expressions may not be directly relevant to inputs needed for the appraisal, making them difficult to take into consideration. The Appraisal guidance suggests that assumptions and uncertainties should be noted and carried through appraisal and important residual ones tested as part of the sensitivity analyses. This does not appear to occur regularly. It would be worth highlighting this and perhaps providing a template that enabled logging of uncertainties and assumptions through the process and an appraisal of their impact through sensitivity or other testing to support the appraisal or subsequent phases.

Options modelling results are used to inform the subsequent stages of appraisal. The appraisal process contains sensitivity testing on scheme costs, but appraisal sensitivity tests on damages are not linked to the results of model sensitivity tests. There was a general acceptance that more could be done in communicating uncertainties, and making better use of the uncertainty information within the appraisal and design phases. There needs, therefore, to be recognition and understanding of modellers of the needs of economic appraisal, but also of appraisers of what can be delivered through modelling. Both aspects are determined by assumptions that underlie the assessments and there may need to be stronger linkages between the teams working on the two processes to enable appraisals to benefit from the outcomes of assurance.

For one case study, modelling uncertainties were presented partly as a narrative. This included an explanation of what the model was saying and whether there were any fundamental issues. There was fine tuning based on the qualitative narrative on uncertainties. In addition, full Monte Carlo (MC) simulation was used in early stages, and more pragmatic sensitivity testing was used for the OBC to confirm the preferred option.

5 Confidence in identifying appropriate scale of assessment

5.1 Confidence in identifying the level of assessment required

By this stage in the interview process, confidence or otherwise in identifying appropriate or proportionate assurance had generally been discussed, as outlined in Sections 2.2 and 4.1.

Whilst most project teams reported feeling relatively comfortable with their decisions to date on the level of assessment and/or assurance, some acknowledged that these decisions were not always clearly documented (with justification for decisions). Capturing views on model confidence and assurance may help to inform and provide an evidence base behind sensitivity testing within the appraisal. This can also help to manage stakeholder expectations, to confirm and evidence that the appropriate level of modelling and assurance has been carried out to inform decisions, and that a reasonable balance has been achieved between detailed modelling and evaluating and managing uncertainties through the appraisal process. Inclusion of specific requirements to report how uncertainties in modelling have been used or taken forwards into economic appraisal should also help improve confidence.

Confidence and decisions around modelling and assurance may also be influenced by how marginal (economically) a scheme is thought to be from initial assessments. Higher numbers of concentrated properties at risk usually allow more funding (FDGiA and other contributions), which helps to justify more thorough approaches. Where benefits are more marginal relative to scheme costs, efforts are made to minimise expenditure on all items, which may include assurance, for fear of rendering the scheme and outcomes measures unaffordable. However, it is important for project teams to remember that a reasonable and documented quality assurance process is still necessary to provide evidence to local stakeholders regarding the relative benefits and costs of a scheme, even if it turns out unaffordable. Reporting of uncertainties could help as it may not always be necessary to have a very detailed or updated model, instead reasonable assumptions and simplifications may be sufficient to enable testing of likely viability at the outset. Work could be undertaken to reduce uncertainties where schemes are identified as viable in a proportionate manner, for example, by identifying what is driving the benefit-cost ratio and focus efforts to improving modelling outcomes that capture those particular assets. This approach does require modelling to permit a gradual change in level of detail, which may not always be possible; some models may require step changes in detail or approaches that limit the extent to which iterations around key uncertainties could be made.

5.2 Gaps affecting confidence and how these are addressed

As indicated above, funding can influence decisions, as can real or perceived pressured on programme to deliver projects to meet stakeholder drivers and government Oms. For example, some Environment Agency teams are reportedly spread thin at times, which may influence their availability to review (or scope external input) within the desirable timeframe. The process of procuring services can also sometimes be slower than first anticipated. Planning in advance and providing plenty of warning for pending reviews can help to mitigate this risk, which some projects did successfully. Perception of consultant capability or speed of responding to issues raised may influence or shape the raising of assurance issues. Involvement of appraisers overseeing appraisal at an early stage could help highlight where more detail/refinement may be needed, potentially reducing the need for some model runs. This could include, for example, economic appraisers identifying how the outcomes of the economic appraisal is affected by hydraulic modelling uncertainties so that effort can be put into where those uncertainties could change the choice of preferred option or affect the outcomes that an option would deliver. However, care would be needed to avoid too much iteration.

6 Ease of assurance

6.1 Level of time and effort required

The size of RMA area or project teams, and their collective history of recent similar projects delivered, may influence their ability to predict and effectively manage modelling and its assurance, whether baseline improvements and/or for scheme appraisal. Even with considerable experience, most teams report that at least some elements of the modelling and assurance process was more difficult or time consuming than they had first expected. The experience of the consultant team was also a factor in some studies, which influenced effective communication around dates and expectations for reviews, and their ability to make pertinent information and assumptions readily accessible in model reports. This can in turn influence effort on the part of the reviewers or project teams.

There was a significant amount of Environment Agency time allocated to some projects (even if not necessarily EA led), supporting not only the technical side but also smoothing the communication pathways of the project through liaison with stakeholders, reviewers, LPRG and other funding/approval bodies. This may be applicable to larger schemes, but not always easy to mimic in a proportionate way on smaller schemes.

6.2 Constraints on assurance and ideas for addressing them

Whilst some ideas are presented within this section, a summary of ideas for the way forward is presented in Section 10.

Programming of modelling and reviews can be a challenge. Sometimes this is due to additional model improvements that get identified part way into the project as understanding of the issues develops, the scale of which is difficult to foresee from the outset. Other ways to help manage this could include better quality scoring metadata on existing models, potentially a model and boundary condition review early in a project (if not done recently), and ongoing planning and communication about anticipated review periods to ensure suitable review resources are available when needed to minimise delays. Depending on the project complexity, early independent review of proposed approaches can help to focus effort where it matters most and can also help to streamline subsequent reviews. Other factors may include programme pressure and inclusion of adequate programme float, plus awareness of proportionality in modelling and assurance. For example, hydrological and hydraulic model sensitivity testing could be used to inform economic case sensitivity testing, which may show whether key decisions or tipping points are sensitive to modelling uncertainties.

Funding for independent expert review can be a challenge if the economic viability of a scheme appears marginal. The RMAs would want to retain control of the review, in light of tight project timescales and pressure from funders and stakeholders to deliver outcome measures at pace and without escalating costs. However, the need and minimum requirements for independent review could benefit from guidance. Also, better reporting from consultants on model assumptions and quality/uncertainty evaluation would also help inform the decision, in conjunction with proportionate risk-based approach, on when to seek independent review, and to inform how residual uncertainties can be translated into sensitivity testing within the appraisal process. Unfortunately, this level of evaluation might only become available very near the time of the main model review, which links back to the programming challenge. Separating the baseline model review from the options model review, as done in some projects, can help to mitigate this risk to some extent. Involvement of an economic appraisal expert could also help at this stage as they should have a feel for what the baseline outputs

could mean and hence what types of options might be appropriate in terms of likely economic viability. This could benefit planning of options modelling.

Access to selected modelling software for reviewers, as well as suitable experience in the selected software, can influence whether the Environment Agency or RMAs can effectively review certain model types in-house or may need to seek external support. Guidance on reporting to include model assumptions, parameters and review checklists could enable a reasonable level of review in some cases without actually having the software. Support on problem definition (model scoping and approach) could help in some cases, although it would be important to identify a starting point for seeking such support.

Funding for software and reviewer training was mentioned as a potential constraint by some EA and RMA teams, although the mechanisms and funding decisions would require further consideration. Part of the solution may be a better understanding of proportionality for model review, what can be done by in-house teams (who may not be full-time modellers, but perhaps with light-touch training to better enable them), or when to secure an external reviewer.

7 Information that would assist with assurance

7.1 What assistance is needed and why?

Whilst some discussion was held during interviews on potential solutions, both in earlier questions and at this point, further assimilation of recommendations is provided in Section 10.

Access to the EA E&R teams is considered useful, although sometimes resource constrained at times when early input and/or reviews are needed. Their early input may also serve as a check on proposed methods and on realistic forward programme for the modelling and review stages.

The project teams interviewed felt that updated guidance could be useful, to improve consistency and streamline decisions on proportionality including smaller schemes. Requests include:

- making existing modelling guidance and review checklists more **accessible**, in addition to selected **updates/enhancements**;
- improving consistency on **proportionality expectations and approval criteria** within the EA and RMAs, and shared externally for consultants to know what level of detail and evidence is likely needed to obtain Environment Agency approval for modelling and funding;
- identifying when to obtain an **independent review** (external to the project team – whether in client organisation or external);
- explaining how to best select **sensitivity tests** to evaluate and **describe** confidence and uncertainties in hydraulic modelling reports; and
- discussing how uncertainties from hydraulic modelling can be translated for **use in the appraisal process** to ensure robust business cases that are not sensitive to modelling uncertainty or are informed by it and adapted accordingly.

Guidance and more transparent reporting of both confidence and assurance will help streamline delivery, reduce delays, and improve confidence with stakeholders and funding approval bodies.

Research and guidance are needed on hydrological methods, e.g. improvements to ReFH for calibration, handling permeable catchments and reservoirs, ways to understand and visualise/evaluate hydrological uncertainty, improvement in probabilistic extrapolation for higher return period events, catchment process-based models, etc.

Guidance on application of climate change allowances needs to be updated in light of UKCP18, and should be clear about handling of different emissions scenarios and epochs in different circumstances.

7.2 Who should provide the assistance?

Guidance on modelling parameters and review processes outlined above should ideally be led by EA E&R, with input from external suppliers (whether for capacity, steering group input or review). Other RMAs could also be involved in reviewing this guidance to help ensure ease of use, including at the smaller end of project scale. Experts in economic appraisal would also be needed to update appraisal guidance on how to translate and test model uncertainties through the economic appraisal process, in a streamlined way.

8 Impact of issues on outcomes

While particular process and programme related issues and opportunities for improving modelling and assurance practice were identified and described in earlier chapters, none of those assessed within the case studies was found to have ultimately led to the wrong scheme choice or appraisal outcome.

By this stage in the interview process, as described in the previous sections, many of the issues and their effects on project outcomes had already been discussed. For example, having to review the hydrology or adjust the modelling approach or extent, which tended to cause project delays but in the process of addressing led to improved overall confidence in the decisions and outputs. Unfortunately, some of these issues came into focus relatively late in the OBC, or even after the OBC, which therefore also had a larger impact on costs for revisiting the appraisal and design. It is good that at least these risks were identified and resolved, even if late, but it would have been more efficient and cost effective if they were identified earlier. Gaps in the assurance process increase the chance of such risks remaining undetected, which could result in schemes being built that do not fully deliver the claimed Outcome Measures. However, there was no evidence gathered from the interviews indicating that this has occurred.

Some of the assumptions behind the modelling are included within the modelling reports. However, the content and level of detail of reporting varies, as does the evaluation of confidence, uncertainty and their significance (through experienced reviewers and through evaluation of intelligently selected sensitivity tests).

The consultants should be encouraged through accessible guidance to openly identify and explain uncertainties and their possible implications. This could help them to internally identify and resolve some issues, would aid reviewers, and would inform application of sensitivity testing in the appraisal process. This would enable uncertainties to be tested in appraisal, with this being especially important where the uncertainties affect number of properties or assets affected, depth of flooding, timing of flooding/failure of defences, etc.

Different approaches to evaluating uncertainty have been tried in some studies, e.g. Monte Carlo, although this approach often still needs key assumptions to be made so it was decided that a narrative approach was the best way of communicating uncertainties. Sensitivity analysis was used throughout this study and informed the choice of preferred option.

Hydrology is a large source of uncertainty that can impact on scheme viability and design. It may be feasible to tailor hydrological sensitivity testing based on various weighting factors, such as data quality in the catchment (length and quality, including gauging and rainfall, rating curves, information on reservoirs, etc.), catchment homogeneity and permeability, calibration performance, whether multiple storm durations have been applied for all return periods, etc. The extent to which each of these is needed should be considered in the context of the likely impacts on economic appraisal and scheme design, hence, on the likely end effects of key model outputs.

9 Lessons learnt

9.1 Changes made to assurance processes

Some lessons learnt have already been covered in previous sections, and are therefore not repeated here in detail.

Some RMAs have taken lessons learnt from previous experience, to improve foresight and/or contingency on cost and/or programme for modelling and reviews, or for applying climate change or for satisfying funding approval bodies. However, it is difficult to predict whether the same or similar issues will occur on subsequent projects.

Early engagement with modellers on problem definition (methods, scoping, outcomes) has been identified by some teams as potentially useful. Similarly, some studies benefitted from open collaborative arrangements between modellers and reviewers at key stages in the project to minimise technical and programme risk. It can be useful to have reviews at the right stages, prior to moving onto the next stage covering, for example, hydrology, model build and calibration/validation, prior to making multiple runs and options testing or detailed design. Consideration should ideally also be given to impacts on the economic appraisal as well, as this could help identify where to focus sensitivity testing.

The importance of engaging effectively with the right stakeholders was highlighted by multiple case studies. This could potentially help with provision of additional data in the catchment, reduce objections from sceptics, raise profile and connect with influencers, and hence, help increase confidence in the outputs of the appraisal.

9.2 Sharing of lessons learnt

Whilst some lessons have been learnt, these have generally not been actively shared with other departments or other RMAs. Hence there may be potential, when collating guidance, to gather feedback from multiple RMAs. Some projects have received considerable interest from the media and interested parties even outside the area, and information has been shared in various presentations, although not necessarily covering the modelling assurance in detail.

There is an apparent lack of use of hydraulic modelling confidence or uncertainty, informed through sensitivity test results, propagating through the economic analysis to inform business case sensitivity testing (e.g. changes in flood depths on depth-damages or flood extents on assets likely to be affected) and designs (e.g. freeboard assessment and identification of tipping points in options choice). Identifying and sharing good practice and opportunities to optimise this information will be of benefit. This could then feed through to appraisal in terms of how to use information on hydraulic modelling uncertainties to help improve the robustness and reliability of the appraisal outputs. This may not necessarily just be through sensitivity analysis, although reporting of a range of benefits across different options may be problematic in fitting with other processes, e.g. the Partnership Funding calculator.

10 Suggestions for the way forward

Suggestions for ways forward have been based on the evidence collected through the case study interviews. In addition, the views and opinions of the interviewers, who include experienced reviewers involved in assurance of modelling and appraisals, are also provided to add value.

The five case studies analysed have provided sufficient information to inform how modelling assurance practice can be improved and how the results of modelling can be better used to inform the subsequent stages of appraisal. Therefore, it is not suggested that a larger sample or further in-depth assessment is required. Instead, the suggestions are focused on the approach to and proportionality of assurance, and encouraging greater feedback between the modelling and appraisal teams. Where possible, the focus is on ensuring that existing resources and references are used to the fullest extent possible, potentially with minor updates, rather than introducing new documents or processes that may introduce overlaps/confusion and not be fully utilised as a result.

Suggestions relating to the approach to assurance:

1. **Suggestion to promote the value of realistic programming for model development and model review processes that are proportionate to project complexity and risk**. This should include early engagement with prospective reviews on modelling approaches to reduce the inefficiencies and delays that could lead to delays in business case preparation. Early engagement can also help secure appropriate reviewer resource at the time it is needed, again helping to reduce the risk of delays. This can be encouraged by updating the Environment Agency's Operational Instruction 379_05 on 'Computational modelling to assess flood and coastal risk' and by making this updated instruction accessible outside the Environment Agency.

2. **Suggestion to highlight the value of informed model sensitivity testing that assesses realistic potential variability in design flood levels**. This information can then be used to provide more targeted sensitivity testing. This can be encouraged through the inclusion of a section or appendix in the modelling report on the self-review used by modellers to show which issues have been resolved and which have not (and why), and what improvements the modeller would have made with fewer constraints on budget or time. The impacts of any outstanding issues or implications of constraints on uncertainties can also be recorded to help inform independent reviews and to inform future research priorities (linked with suggestion 3).

3. **Suggestion to investigate further where research is needed on key areas of uncertainty and how that uncertainty could be reduced**. A scoring mechanism to capture key elements of uncertainty, e.g. linked to boundary conditions, or key limitations, e.g. linked to hydrological methods, could be used to help inform intelligent sensitivity testing. The information captured through the scoring mechanism could be captured in a meta database and used as the basis for identifying and prioritising future research needs.

4. **Suggestion to develop best practice examples from a sample of ongoing business cases that show how uncertainties in modelling have been assessed and used in subsequent stages of business case development**. This could be used to demonstrate best practice and streamline the methods and presentation of sensitivity tests. The best practice examples should cover smaller as well as larger schemes so that proportionality of approach can be illustrated.

Suggestions relating to proportionality of assurance

5. **Suggestion to provide guidance on when an independent expert review is recommended**. This could be through the development of a review checklist that identifies whether an independent review is needed and, if so, what level/detail of review may be required. Existing checklists such as the Environment Agency's 'WEM modelling scope', 'Evaluation checklists for intermediate and detailed reviews' and 'Checklist for reviewing flood estimate' could provide a starting point. The checklist proposed would need to be applicable to all RMAs and consider the range of project types and sizes to ensure proportionality is maintained. The checklist is likely to need to include project complexity/risk, approaches used to estimate and manage uncertainty, limitations and constraints. Consideration should be given also to the scale and potential impacts of uncertainty as it may not always be necessary to reduce high levels of uncertainty; in some situations it may be more proportionate to accept and record uncertainty.

Suggestions relating to collaboration amongst the wider appraisal team

6. **Suggestion to highlight the value of good model reporting**. This should include transparent reporting of assumptions, model limitations, level of confidence and uncertainties. The information should be summarised in a manner that makes it easier for non-modellers to interpret and take into account during sensitivity testing on damages in the economic appraisal. The importance of presenting and justifying decisions to ensure a clear audit trail needs to be emphasised. Updated guidance could be based on the previously applied 'SFRM performance scope'. There should also be recognition that modelling and reporting needs to be realistic to avoid it becoming cumbersome to apply on smaller projects.

7. **Suggestion to encourage early communication to ensure that the whole team is aware of uncertainties and assumptions and their likely implications at an early stage**. This may require changes to the way that projects are developed and may require inclusion of the requirement in tender briefs. It could also be encouraged through enabling modellers and economic appraisers to better understand how the requirements of each activity affect the other. This could be done, for example, by clearly setting out within the model reports where the outcomes would inform appraisal. This is linked to the suggestion associated with good model reporting (see suggestion 6) but is focused on the need for modellers and appraisers to engage in collaborate discussion on uncertainties and their potential influence or outcomes or decision tipping points.

Risk & Policy Analysts Limited
Farthing Green House, 1 Beccles Road
Loddon, Norfolk, NR14 6LT, United Kingdom

Tel: +44 1508 528465
Fax: +44 1508 520758
E-mail: post@rpaltd.co.uk
Website: www.rpaltd.co.uk