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Developing a prototype tool for mapping flooding from all sources Phase 2: final report

Project: SC080050/R2

Flood and Coastal Erosion Risk Management Research and Development Programme

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Our work includes tackling flooding and pollution incidents, reducing industry's impacts on the environment, cleaning up rivers, coastal waters and contaminated land, and improving wildlife habitats.

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Author(s):
Jon Wicks, Luke Lovell (Halcrow Group Ltd)

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Research Contractor:
Jon Wicks
Halcrow Group Ltd
Burderop Park
Swindon
SN4 0QD
Tel: 01793 812479

Environment Agency's Project Manager:
Jim Walker, Evidence Directorate

Theme Manager:
Jim Walker

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Miranda Kavanagh

Director of Evidence

Executive summary

The MAST (Mapping All Sources Tool) prototype software enables sets of flood mapping data representing flooding from different sources (such as coasts, rivers, surface waters, systems with and without asset failure, reservoir inundation and so on) to be combined to produce a flood map for multiple sources. The MAST method is practical and flexible to use, particularly in situations where fully integrated modelling of multiple sources is not appropriate. It has been developed to help meet the evolving needs of modern flood risk management, such as clearer communication and integrated management of 'all sources' of flood risk (including awareness raising, investment planning, spatial planning and planning for response to flooding incidents).

This Phase 2 final report summarises the outcomes of Phases 1 and 2 of the project and provides a plan for taking MAST forward. The probabilistic method developed in Phase 1 (described in the Phase 1 scoping and conceptual method development report, SC080050/R1, 2010) has been implemented in prototype software and subjected to pilot testing. The feedback from testing was that the prototype MAST software has the potential to be an extremely useful tool in an operational environment. The main technical development tasks remaining are to ensure the software can be efficiently and effectively used by its intended end users - a particular need is compatibility with Environment Agency IT systems to ensure access from the standard desktops of the intended users.

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1 Introduction

1.1 Background

To support more integrated approaches to flood risk management it is necessary to better understand the relative contributions to flood risk made by different sources of flooding. To help boost our understanding, a method for combining flood mapping from multiple flooding sources has been developed and implemented in prototype software.

This report is the final report for the Environment Agency project SC080050 *Developing a prototype tool for mapping flooding from all sources*. This work was carried out as part of the Defra/Environment Agency Joint Research and Development programme on Flood and Coastal Erosion Risk Management within the Modelling and Risk Theme. The report summarises the background to the project and development of the prototype tool (known as **MAST** – Mapping All Sources Tool). It also presents a plan for setting up the tool within operating authorities.

The project was carried out in two phases:

- Phase 1 *Scoping and conceptual method development* looked at the need for the project, carried out consultations, reviewed literature, reviewed sources of flooding and availability of datasets, developed the method and specified the prototype software. The findings of this phase are available in the Phase 1 report (Environment Agency, 2010a).
- Phase 2 involved developing and testing the prototype tool and drafting an implementation plan. The three main outputs from Phase 2 are:
    - MAST software user guide (Environment Agency, 2010b).
    - MAST software CD (available from Environment Agency Evidence Directorate, **evidence@environment-agency.gov.uk**).
    - Final report (this document) which summarises the software development and testing, and sets out the implementation plan.

The intended audience for this report is Environment Agency technical specialists, IT specialists and Flood and Coastal Risk Management (FCRM) directorate staff who need a briefing on Phases 1 and 2 of the project. The report also proposes a structure for the implementation phase which can be used to assist project planning to enable the business benefits of MAST to be realised (Figure 1.1).

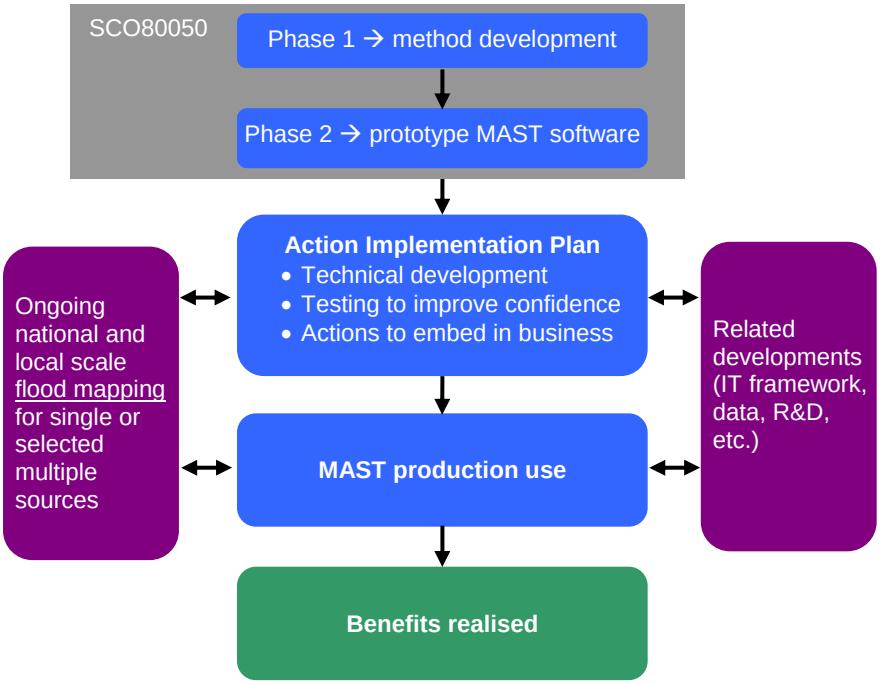

Figure 1.1 Steps needed to realise MAST benefits

1.2 Need for the project

The main drivers for the development of the tool were the EU Floods Directive (now transposed into law by the Flood Risk Regulations 2009) and the Pitt Review, to help the Environment Agency meet its responsibilities in (i) flood mapping at a national scale, and (ii) providing tools, techniques and guidance to help local authorities with local flood mapping (including 'combined consequences' mapping). The 2010 Environment Agency Flood and Coastal Risk Management (FCRM) Modelling, Risk Mapping and Data Strategies set out the need to identify, and where appropriate develop, tools to help the Environment Agency and its professional partners understand risk of flooding from all sources, and the need to clearly communicate the risk information so that appropriate action can be taken (actions include investment planning, spatial planning and planning for response to flooding incidents). In particular the Risk Mapping Strategy states (Principle 1) that **"***Mapping of flood and coastal risk from all sources will be available from one place*". (To access or download go to http://publications.environment-agency.gov.uk/ and enter product code GEHO0310BSBS-E-E.)

1.3 Links with other Environment Agency activities

The work reported here is one component of a programme of work within the Environment Agency to improve flood risk methods and datasets. The activities of most relevance to MAST are introduced below and summarised in Table 1.1.

There is an ongoing programme of flood modelling and mapping to ensure the publically available Flood Map for rivers and sea on the Environment Agency's website is up to date. The Flood Map shows predicted extents of flooding for two levels of likelihood for river and coastal sources of flooding only. The Flood Map for rivers and sea can be used as input data for MAST. MAST outputs could also be used to help develop a flood map for all sources, to replace the individual flood mapping products.

The National Flood Risk Assessment (NaFRA) model provides probabilistic outputs which show the distribution of fluvial and coastal flood likelihood within the floodplain. This is calculated using the RASP method (Risk Assessment for System Planning). There is an ongoing programme of work to improve the NaFRA inputs, methods and outputs. NaFRA flood likelihood output datasets can be used as inputs to MAST. MAST can also be used to generate a validation dataset by integrating depth grids that cover a range of flood likelihoods, produced by detailed local hydraulic modelling, and presenting these as probability depth grids for comparison with equivalent outputs from NaFRA.

A national map for England and Wales has been developed to show areas susceptible to surface water flooding, and work has also been undertaken to refine this mapping under the *Flood Map for Surface Water* project. These can be used as input data for MAST.

National work ihas been undertaken to produce Reservoir Flood Maps, identifying areas which may be affected from flooding in the case of dam failures. At present this shows mapped extents for all raised reservoirs with a volume greater than 25,000 m^3. The maps can be used as input to MAST.

The MDSF2 (Modelling and Decision Support Framework) software has been recently developed to enable RASP methods to be used more widely and at a greater range of geographic scales, including at the local level. Use of MDSF2 should enable local improvements to the national scale probabilistic mapping from NaFRA, but is currently limited to fluvial and coastal flood sources. The simpler method to produce probabilistic mapping used in MAST is not restricted to just fluvial and coastal sources of flooding but does rely on availability of pre-calculated flood maps. MDSF2 flood depth/probability outputs can be used as inputs to MAST; also MAST outputs could be used to help assess MDSF2 outputs, and MAST outputs could potentially be imported into MDSF2.

The science project *Validation of probabilistic flood models* (SC090008/WP1) provides a framework for validating flood models. The framework can be used to validate inputs to MAST as well as outputs from MAST.

The science project *Methods for local probabilistic flood risk assessment* (SC090008/WP2) has developed and tested RASP-compatible methods for local use. Application of the method could provide datasets incorporating both ‘no flood defence failure’ and ‘flood defence failure’ data which can form inputs to MAST. Also, there are opportunities for MAST to become the implementation software tool for the SC090008/WP2 probability calculation which would provide cost savings over creating two tools separately.

The FCRM Data, Modelling and Mapping IT Framework is currently being developed to support and improve the management of flood and coastal risk information. It will consider the infrastructure to support data storage and sharing, tools for analysis and reporting, and viewing services. The next stage in the development of MAST needs to fit within this framework.

As can be seen from the discussion above, there are strong links between MAST and other ongoing Environment Agency activities. These activities will be aligned through the FCRM Modelling, Risk Mapping and Data Strategies and the IT Framework which will support implementation of these strategies.

Table 1.1 Summary of links to related flood risk mapping initiatives

Related Initiative	Could provide	Could receive	Comment

	input to MAST	**output from MAST**	
Flood Map for rivers and sea	yes	Future potential	MAST outputs could be used to help develop a flood map for all sources, to replace the individual publically available flood mapping products.
NaFRA	yes	Future potential	MAST outputs could be used to help validate NaFRA.
Areas Susceptible to Surface Water Flooding/*Flood Map for Surface Water*	yes		
Reservoir Flood Maps	yes		Single flood extent with no associated probability so would be excluded from the probability calculations but would appear in the outputs to identify locations at risk from reservoir flooding.
MDSF2	yes	Future potential	MAST outputs could be used to help validate MDSF2 data
Validation of probabilistic flood models (SC090008/WP1)		yes	The validation framework could be used to validate MAST outputs
Methods for local probabilistic flood risk assessment (SC090008/WP2)	Future potential		Outputs from application of the method could provide inputs to MAST. Also, MAST could provide the implementation software for SC090008/WP2 probability calculation.
FCRM Data, Modelling and Mapping IT Framework			Further development of MAST needs to fit within the framework.

1.4 Structure of this report

The report is structured as follows:

- Chapter 2 provides an overview of Phase 1, summarises the Phase 2 process of developing and testing the prototype tool, and highlights the achievements of work to date together with areas where more work is needed.
- Chapter 3 contains an implementation plan, covering the requirements, technical development of a production tool, and actions to embed the tool into the Environment Agency's practices.
- Conclusions are provided in Chapter 4.

- Appendix A contains a peer review of the method as presented in the Phase 1 report.
- Appendix B lists potential future improvements to the prototype tool identified during testing (but not implemented).
- Appendix C summarises the improvements identified during the testing that have been implemented in the prototype tool.
- Appendix D discusses how MAST could be extended to reporting flooding in terms of responsible authority.

2 Method & software development

2.1 Method development

The Phase 1 report (Environment Agency, 2010a) provides details of the findings from the initial stages of the project which covered:

- Reviewing the project drivers.
- Consulting potential users from the Environment Agency, other operating authorities and professionals.
- Assessing the different sources of flooding and availability of suitable data for the most important sources.
- Developing a proposed method.
- Specifying the prototype software

The method is able to generate a probabilistic flood map showing the relative contribution to flooding by different sources. The method uses sets of existing mapped data of flooding (usually from single sources) which are combined to provide an 'all sources' map of flooding (as opposed to a method in which integrated hydraulic modelling is used to route and combine different sources in one model). The method is therefore reliant on the availability of pre-calculated flood inundation data from individual or previously-combined sources. However, the method will help identify situations in which new, local fully integrated (from more than one source) modelling may be required. The method is generic and can be used for national-scale and local-scale mapping. It is consistent with the RASP concepts of a system-based, risk-based hierarchical approach and is compatible with RASP-related products such as NaFRA and MDSF2.

The method is fully described in the Phase 1 report and a shorter technical description is provided in the MAST user guide (Environment Agency, 2010b).

The technical peer review (by Professor Gareth Pender, Heriot Watt University and Professor Jim Hall, Newcastle University) found that the proposed method provided a practical solution to the need for 'all sources' flood mapping. Two areas of potential concern were raised in the peer review, firstly a potential weakness in the assumption of independence between various sources of flooding, and secondly, that further consideration needs to be given to the magnitudes of uncertainties. These are difficult areas to address practically; further research and data collection will be necessary. The peer review is provided in Appendix A.

2.2 Development of prototype software

The prototype software was developed in two main modules:

- Main component consisting of the mast.exe application containing the graphical user interface (GUI) and pre- and post-processing modules. This component was written in C# .NET and uses the open source Geographical Information Systems (GIS) component 'MapWindows' for the GIS View.
- MAST calculation engine written in Java.

As shown in Figure 2.1, the MAST GUI and the MAST engine communicate through a XML project file. In normal usage, users will enter or reference data using the GUI; this will write out the XML file and the main MAST input dbf file, and then start the MAST engine through a command line containing the name of the engine component and the XML file name. The GUI then monitors the progress of the engine and takes back control once it is finished.

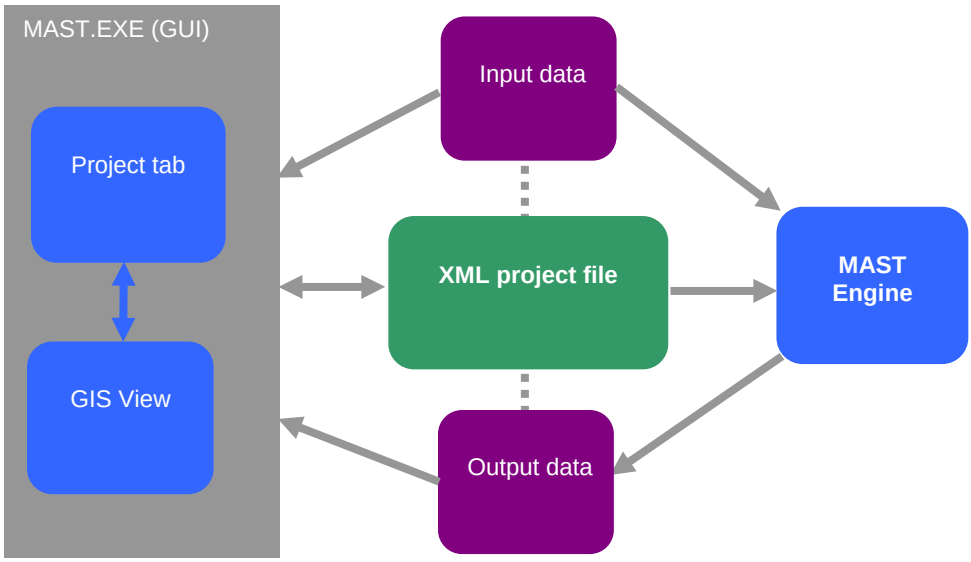

Figure 2.1 MAST prototype software architecture

The engine and GUI were developed as separate applications to enhance the sustainability of the software. The GUI was developed as 'proof of concept' for use in the research and development phase. For the final version, the GUI may be replaced by functionality built into a future Environment Agency integrated GIS analysis tool which could then reuse the existing MAST engine. The prototype software is a desk-top application requiring installation – future versions could reuse the existing engine as a web service supporting a new web-enabled user interface. Use of XML and Java are fully consistent with the Environment Agency's IT strategy (C# and MapWindows are not fully consistent but were selected as most appropriate for the prototype). No commercial third-party components/libraries are used in the prototype system.

The prototype software can be installed from the MAST software CD onto any suitable PC (Windows 2000/XP/Vista/7 operating system with hardware appropriate for technical computing, such as Intel Pentium D or upwards, at least 1GB of RAM, graphics card and sufficient free hard disk space for the size of data files that will be processed). Three freely available third-party components are also required (Microsoft .NET 2.0, Java Runtime 1.6 update 20 or higher, and the MapWindows control) and are provided on the software CD.

The Intellectual Property (IP) rights for the MAST method and implementation in the MAST engine reside with the Environment Agency, as does the MAST-specific code in the GUI. The IP for the third-party components reside with their owners. The use of MapWindows controls within MAST is covered by the Mozilla Public Licence 1.1 which allows free use in commercial software subject to minor conditions such as acceptance

of ‘as is’ basis (no warranty), issuing notices of origin with releases and providing any improvements to the MapWindows code back to the open source community.

A comprehensive user guide (Environment Agency, 2010b) has been written to support use of the prototype software. The user guide is structured as follows:

- ‘Introduction’ describes the intended audience and structure of the guide.
- ‘Software overview’ describes the components of the software, defines terminology and provides an overview of how to do the analysis.
- ‘How to use the software’ contains detailed instructions of how to use the software and highlights benefits and limitations.
- ‘Worked example’ uses example data from the Christchurch area to demonstrate how to apply the software.
- ‘Technical method description’ provides details of the method in the software.
- ‘MAST quick start guide’ provides a quick route into using the software.

2.3 Testing of prototype software

The initial versions of the prototype software (and user guide) were subjected to three stages of testing. The first stage involved testing by the software development team at both module and full system level. Following some improvements, the software was then tested by a group of people external to the development team (from the Environment Agency, a local authority and from within Halcrow). Improvements were then made to the software and documentation before a final stage of external testing. The final ‘prototype release’ of the software and user guide is the version that was improved following feedback from the second and third stages of testing.

The objectives of the second stage testing were to assess the software and user guide in terms of the following main areas:

- Functionality – did the software meet the functional requirements in terms of generating required results without software bugs?
- Usage – was the ‘user experience’ satisfactory?
- Benefits – were the outputs considered to be beneficial to flood risk management?

The second stage testing was undertaken by David Hornby (Environment Agency), John Ray (Environment Agency), Sydney Simpson (Bradford City Council), Joe Clarke (Halcrow) and Daniel van der Leer (Halcrow). The following test datasets were put together jointly with the testers (Figure 2.2):

- Mapplethorpe, Skegness (coastal flooding including breaching).
- Bradford Beck (reservoir dam break, surface water and fluvial flooding).
- Christchurch (coastal, fluvial, and surface water flooding).

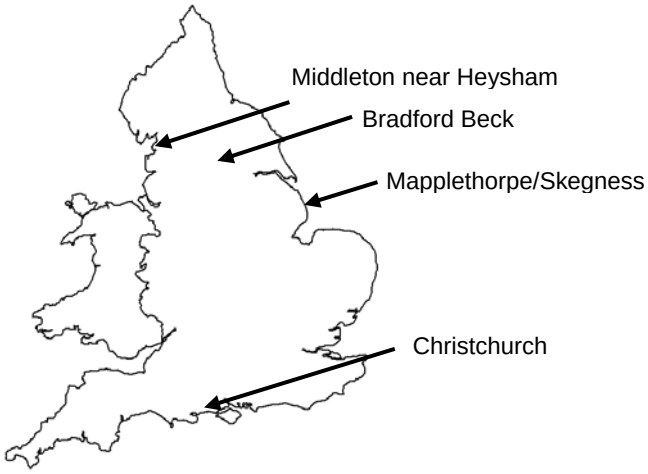

Figure 2.2 Location of test data sites

A structured test plan was developed and issued to the testers. This provided step-by-step guidance on how to approach testing and the feedback required. The test plan also provided space for general comments and for testers to summarise their favourite and least favourite aspects of the software. In addition, a workshop was held on 25 May 2010 to discuss the experiences of using the prototype tool. The completed feedback sheets and minutes from the workshop were then collated to produce a testing report (included on the project CD). The list of potential enhancements and identified software bugs were prioritised and the Project Board decided which needed to be addressed as part of the final 'prototype release' of the software and user guide. The project CD contains the full list which has been marked to show whether and how each item has been addressed. The items which were considered potentially useful, but outside the scope of the prototype release, are listed in Appendix B; it is suggested that these are reviewed for potential action during the implementation phase. Appendix C summarises the enhancements identified during the testing that were implemented in the prototype release.

The third stage of testing was done by Louise Cramp of the Environment Agency North West Region who applied MAST to an area around Middleton near Heysham, Lancashire. Louise had not been involved in the project before being provided with the software and received minimal help in applying MAST. She found use of the software 'relatively unproblematic' and reported a positive experience of using the software recognising the potential of MAST. Louise identified five potential improvements which are listed in Appendix B and one improvement to the user guide (to clarify naming protocols for folders) that has been made in the prototype release.

Feedback from the testers was that the prototype MAST software has the potential to be an extremely useful tool in an operational environment. The testers identified some relatively minor enhancements that could greatly increase usability of the prototype tool and these are now implemented in the prototype release (summarised in Appendix C).

The testers reported that MAST was, in general, a simple to use tool that could generate useful and innovative outputs to better describe the risk of flooding. A reported secondary benefit of the tool for Environment Agency Area teams is the ability to output data which can be used to help validate NaFRA, particularly where there are no defences, by combining best available flood extents from detailed, local models to output a depth probability grid. The testers also stated that if the tool is to be more widely used in the future, further development will be required, particularly better installation and compatibility with Environment Agency IT systems. The aspect of testing that was least adequately assessed was the accuracy of the results (particularly joint probabilities) and it is suggested by Halcrow that further validation is attempted during the implementation phase.

2.4 Uses and users of MAST

The principal use envisaged for MAST is the generation of mapping of flooding from multiple sources, which will provide users with a rapid understanding of how each source contributes to flooding in a particular area, and whether there are any joint dependencies that need to be better understood. The outputs from the tool provide useful information for decision support and the simple pie chart, which shows the contribution of each source to local flooding, will provide a valuable communication aid that can be understood by a wide range of people.

There are also several secondary uses for the MAST software, including analysis of multiple asset failure and rapid production of integrated depth probability or probability depth grids for a single source, which can then be used to support the economic, social and environmental impact analysis of flooding. MAST can also be used to help validate other methods, such as the RASP-based NaFRA and MDSF2 outputs.

MAST is expected to be used predominantly by the Environment Agency, in particular Area Flood Risk Mapping and Data Management, and Asset Management teams. However, the relative simplicity of the tool, and its stand-alone nature, means it is also likely to be attractive to other operating authorities, including local authorities, British Waterways and various utility and transport infrastructure organisations.

3 Implementation plan

3.1 Introduction

The primary aim of this project was to develop a practical probabilistic method to consider flood mapping from all sources of flooding and deliver the method as a prototype software tool. The prototype needs further development and embedding within the Environment Agency's practices. This chapter provides a plan for this next step should the Environment Agency choose to take it, the outcome of which will be aproven, practical and readily accessible software tool for Environment Agency staff, or the Environment Agency's flood and coastal partners, to generate mapping of flooding from multiple sources and thus improve understanding and management of all sources of flood risk.

The suggested plan identifies the following key tasks:

- Task 1 – **short review** of needs and updating of the plan to cover any changes in drivers, internal processes and so on between the time of writing (October 2010) and the time the plan is implemented.
- Task 2 – **technical development**, including formal design, software development and testing.
- Task 3 – **actions to embed in the business**, including data needs, process development and initial training.
- Task 4 – **planning for ongoing sustainability**, including ongoing support and maintenance.

The above tasks are described in more detail in the following sections, together with an outline programme and cost estimate. The information is intended to be used to help support a formal business case (but does not provide one).

3.2 Proposed tasks

3.2.1 Task 1 – Short review of needs and plan

This short initial task provides an opportunity for the outputs from the project to be updated and refined prior to implementation. The task will produce an initial report which could include the following sections.

1. Introduction – summarising the background to the implementation phase and the overall and specific objectives.
2. Requirements – drawing from the Phase 1 report (Environment Agency, 2010a) and updating where there have been changes, describe the project drivers, needs and requirements.
3. Tasks – drawing from this report, specify the tasks necessary to achieve the objectives.
4. Programme – define the programme including milestones and outcomes.

5. Project administration – define lines of communication and project governance.
6. Communications and engagement plan – raise awareness and help staff and partners prepare for the project outputs.

The initial report will provide clear definitions of required items of software functionality. These will include the good ideas listed in Appendix B that were generated during the prototype testing (but not implemented). It will also include consideration of the functionality and activities listed in Appendix D which discusses how the tool can be used to identify flood sources by responsible authority. The requirements list will be subject to change control processes during the project and linked through to the test plan (to provide an audit trail and facilitate project sign-off).

The report will also describe how the software fits in with associated tools and systems as defined in the FCRM Data, Modelling and Mapping IT Framework.

3.2.2 Task 2 – Technical development

Requirements

The first work item in Task 2 will be the production of formal detailed requirements specification. This will build from the requirements listed in Task 1 and will require working with the Environment Agency Corporate Information Services (CIS) and others to ensure all requirements are adequately defined. The scope of the requirements will include functional requirements (for example what calculations are necessary) and non-functional requirements (qualities of the system such as response time and compliance with CIS standards).

A key aspect of this work item will be defining requirements which enable the software to be efficiently and effectively used by its intended end users,for example, ensuring the model can be readily deployed to the standard desktops of the intended users. It is suggested that the test plan is drafted as soon as the requirements are agreed.

Design

The requirements specification will be used to identify design options. These options will include issues such as reuse of modules from the prototype, selection of development languages, and logical and physical deployment architectures. It is anticipated that the computational engine used for the prototype software will be able to be reused with only minor modifications, whereas the graphical user interface is more likely to need to be replaced.

The options for physical deployment architecture will be strongly influenced by the decisions on target users and on integration with other systems. For example, if the only target user group is Environment Agency staff, the new graphical user interface could be an integrated (single point of entry) web-based GIS interface serving many reporting and analysis functions in the Environment Agency. However, if other operating authorities and consultants are also part of the target user group, a stand-alone (perhaps desktop) user interface may be required instead or in addition to the integrated interface.

Development

Following the design stage, new software development would commence. The development language(s) would have been defined in the requirements or design. The test plan would be developed further in the design stage and testing would start with unit testing (of specific modules) followed by integration and system testing.

Documentation

The requirements specification will have defined the documentation needs. The user guide developed for the prototype system will provide the basis for the user documentation and it is suggested that it is deployed as online (context sensitive) help. Technical documentation will also be required for the test and integration team and for future programmers (although most of this can be through self-documented code).

Testing

Following the completion of the alpha testing (unit, integration and system testing in the development phase), formal beta testing of the system will be required by representatives of the target user group not involved in the system development.

As noted in Section 2.3, the aspect of the prototype system that was least adequately tested was the accuracy of the results (particularly concerning joint probabilities leading to informed statements on the limitations of the approach). We recommend that this be given particular attention in the implementation phase. This validation testing could form part of the beta testing, or it could be (partially) addressed earlier in Task 1 or Task 2. Addressing this issue earlier would enable any remedial activities to be programmed into the Task 2 design and development stages.

3.2.3 Task 3 – Actions to embed the tool in the business

The outputs from Task 2 will be tested software (with user documentation) capable of being readily deployed onto the computer desktops of the target users. However, this is only one of the 'components' that need to be in place before the business benefits can be realised. The main activities that will need addressing as part of the implementation plan are: data (availability of input data and management of output data), processes (such as operational instructions), training, and software deployment/licensing and so on.

Data

The MAST method relies on the availability of pre-calculated, usually single flood source, depth-probability datasets. The Phase 1 report (Environment Agency, 2010a) analyses the availability of data for the full range of sources of flooding and makes suggestions for overcoming data availability issues. Datasets for each of the flooding sources are assessed in terms of scale, coverage, data structure, intellectual property rights, accuracy, resolution and ease of use within MAST. The Phase 1 findings should be reviewed and an action plan initiated to address significant data deficiencies aligned with the key needs (from Task 1).

A data plan will also be required to deal with reporting, storage, transfer and auditing of the data generated by the MAST process. Custodianship will require defining for both the software and the generated data.

Processes

Formal process descriptions (such as operational instructions and/or service-level agreements) may need updating to cover the use of MAST. Specifications or guidelines may be required to define coverage, formats, scales, and so on to ensure input and output data are suitable and that the software is used in a consistent and appropriate way.

Training

Training material and a training plan need to be developed. Training could be provided through e-training materials as these will be more flexible for users (and should reduce costs). Example datasets will need to be supplied with the software (and these will need any licensing issues resolved to ensure the data are available to all target users).

Deployment/licensing/other

The current typical approach taken by the Environment Agency's CIS function to deploying systems to users' desktops involves the following steps (based on the process used for the ISIS software):

- Assignment of a technical release and implementation manager who will plan and oversee the rollout.
- Site acceptance testing to confirm that the new application is compatible with existing systems.
- User acceptance testing during which representatives of the target user community test the software in a controlled environment to assess whether it meets their requirements.
- If the system passes these two sets of tests, it is made available for deployment through the application launcher.

The actual method used to deploy the proposed system may follow the above approach or may be quite different (for example due to the expected move to a predominantly 'thin client' IT environment). Through close engagement with CIS, the best way of implementing the proposed system will be identified based on cost, ease of continued management of the system and usability.

Other issues that may need addressing at this stage (although planned for Task 2) include:

- implementation of any essential IT hardware updates;
- deployment of any necessary third party software;
- links with other systems/programmes/processes;
- statement of intellectual property rights;
- definition of licensing terms for use by other operating authorities and third parties.

The Data Modelling and Mapping IT Framework will cover many of these issues at the programme level.

3.2.4 Task 4 – Planning for ongoing sustainability

Task 4 covers the planning for activities that will occur after formal release of the proposed system. The main activities will be the provision of support services and ongoing maintenance and version control of the software, documentation and training materials. It is anticipated that support would be provided through the standard CIS help desk. A costed plan for these activities will need to be developed during Task 4.

3.3 Programme

A programme for the implementation phase is shown below.

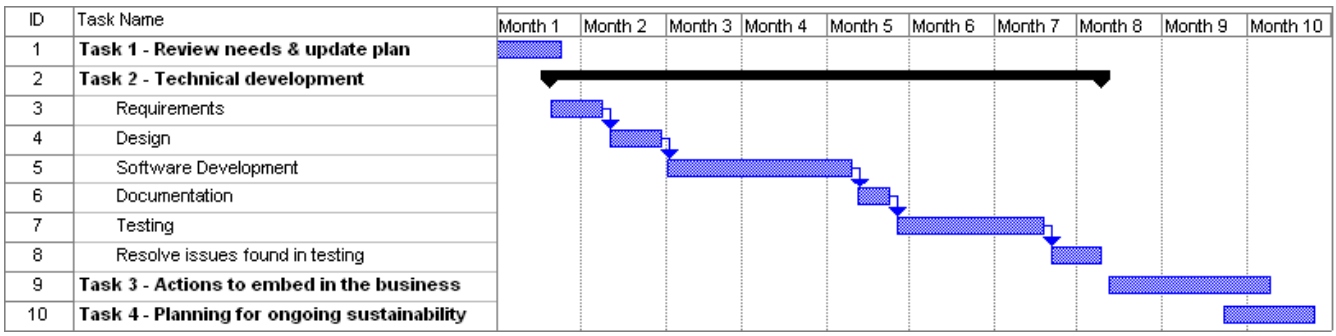

Figure 3.1 Programme for implementation phase

3.4 Outline cost estimate

An outline cost for the implementation stage has been estimated at £85,000; this cost estimate is considered suitable for use in business planning. The cost estimate allows for inputs from the project team, but excludes the costs of end user input (such as beta testing) and expenses. Note that the cost estimate has been derived by Halcrow (without CIS input) based on the assumption that the production version of the system will be similar to the prototype version.

4 Conclusions

Phase 2 of the project has been successful in developing a prototype software tool which has been shown, through pilot testing, to be able to generate a map of flooding from multiple sources through a probabilistic combination of flood mapping data derived for single sources, be they rivers, sea or surface water. The feedback from the testing process was that the tools developed in the prototype MAST software have the potential to be extremely useful in an operational environment. Further enhancements identified during the testing process should be readily implementable.

A suggested implementation plan can be used if the Environment Agency decides to progress the next phase of this work. The main technical development tasks remaining are needed to ensure the software can be efficiently and effectively used by its intended end users - a particular need is compatibility with Environment Agency IT systems to ensure access from the standard desktops of the intended users.

As with all new methods, it is important that users understand the capabilities and limitations of MAST. The MAST method is based on sound, peer-reviewed science. However, further validation work is suggested and as the availability of input datasets becomes clearer and the ultimate use of the outputs is better defined, it becomes more straightforward to describe the likely confidence in outputs. The aspect of validation that was not adequately assessed during the prototype testing was the confidence we can place in the results where there were dependencies between sources of flooding; it is suggested that this aspect is given particular attention during the implementation phase and guidance is produced to help users decide when fully integrated modelling is required.

5 References

Environment Agency, 2010a. *Developing a prototype tool for mapping flooding from all sources. Phase 1: Scoping and conceptual method development*. Science Report – SC080050/R1.

Environment Agency, 2010b. *Developing a prototype tool for mapping flooding from all sources. Phase 2: MAST user guide*. Science Report – SC080050/R3.

6 Appendices

Appendix A: Peer review

A1 – Introduction

The MAST methodology was peer reviewed by Professor Gareth Pender (Heriot Watt University) and Professor Jim Hall (Newcastle University). Prof Pender reviewed the whole Phase 1 final report whereas Prof Jim Hall only reviewed the method description. The Phase 1 final report (Environment Agency, 2010a) was modified in response to their comments. Their comments on the draft Phase 1 report are provided below.

A2 - Peer review by Professor Pender

Overview
The report describes two methodologies for mapping flooding from all sources, a “high level approach” that combines national (and local) flood inundation predictions assuming that the sources of flooding act independently and the “fully integrated approach” which includes modelling flood inundation from combined sources. The final recommended methodology is a hybrid of both methods. The advantage of this approach is that it has a sound theoretical basis for combining existing data information in a probabilistic framework, coupled with the flexibility to integrate more accurate information in high-risk areas.

I agree with the author’s assessment that the hybrid approach provides a practical solution to addressing the Environment Agency’s needs as identified in the Introduction.

The one potential weakness in the technique is the assumption that the various sources of flooding are indeed independent. This is necessary to implement the “high level approach”. From a practical perspective this seems to be a reasonable assumption and is certainly a sensible basis upon which to progress the current project. However, it would be worth testing this through practical application in Phase 2.

It would also be worth giving further consideration to the magnitude of uncertainties in Phase 2. It is clear that the methodology will be able to handle these from a theoretical perspective, however, little consideration has been given to how large these may be in some circumstances. Figure 8.4 shows how the method will handle uncertainty but the data used is clearly hypothetical. Some indication of how significant the uncertainties may be in reality would therefore be beneficial. Similarly, the upper and lower bounds of probability illustrated in Figures 8.5 and 8.6 appear to be so wide as to be of little value.

Chapter 9 provides a useful overview of how the information may be present but clearly considerable further work is required using real data to ensure that the approach is valid in a variety of circumstances.

Detailed comments on each chapter are provided below.

Chapter 1

- No comments.

Chapter 2

- Page 4, the first sentence should make it clear that the present project will only deal with communicating flood hazard from inundation, refer to sketch on page 47.

- Page 5, same point as above, optional features refers to “total flood hazard”.

Chapter 3

- Page 8, refers to “basic hydraulics”, some of the techniques used in the fully integrated approach are at the forefront of available techniques.

Chapter 4

- No comments.

Chapter 5

- In my view the fully integrated approach will only be appropriate in special circumstances due to the extensive data needs and computational requirements. I think this point should be made more forcefully.

Chapters 6 and 7

- No comments.

Chapter 8

- With the exception of the comments made below, the chapter provides a good overview of the high level approach.

- Page 34, refers to producing a single measure of combined flood risk for each spatial element, such as floodplain cells. It may be worth giving some consideration to what is meant by a floodplain cell so that it coincides with the way in which other socio-economic data is held, that is, emuneration districts used in the National census data, see Haynes, H., Haynes, R., and Pender, G., 2007, *Water and Environment Journal*, doi:10.1111/j.1747-6593.2007.00086.x

- Page 36, I found Figure 8.2 to be confusing for the high-level approach. Should the combination of sources not be occurring at receptor level? Is the interaction box not illustrating the use of the fully integrated approach within the high-level approach? Why do the arrows contain the word “response”? I think that part of the problem is that the figure is trying to illustrate the approaches within the source-pathway-receptor framework which may be too restrictive.

- Page, 37, the first sentence should be strengthened, I suggest, “*At a workshop held in July 2009, stakeholders confirmed that the approach was valid and satisfied the project remit*.”

- Page 38, I’m not convinced that extension to other hazards will be straightforward, modelling pollution and velocities will require greater refinement

and more computational resource. Additionally, the uncertainties in the prediction of these variables are likely to be considerably greater.

- Page 38, Section 8.2.2 doesn't make much sense to me! The variables yG and yL need to be defined.

- Page 39, it would be better to show "X(m)" in Figure 8.3 as or "Depth (m)" to be consistent with Figures 8.4, 8.5 and 8.6.

- Page 39, it would be worth illustrating what is meant by "*The depth-probability curve is represented as a range of probabilities …*", presumably this could be achieved by joining the ends of the error bars in Figure 8.4.

- Page 40, the example in Figure 8.4 looks rather trivial compared to Figure 8.3. It would be better redrawing this and Figures 8.5 & 8.6 in a similar style.

- Figures 8.5 and 8.6 are useful in illustrating the flexibility of the method in coping with extrapolation and single point data, however they also illustrate how large the uncertainties become in such circumstances. This is an unavoidable fact, but the consequences and how this will be illustrated to users' needs to feed through into Chapter 9.

Chapters 9, 10, 11

- No comments.

Chapter 12

- Page 62, the idea that the proposed methodology is a hybrid approach doesn't come out in the conclusions. It is important that the option of using the "fully integrated technique" is maintained in the methodology, even if data and computing demands mean its use is likely to be infrequent. I suggest that the conclusions refer back to Figure 8.1 to make this clear.

- In the recommendations for future Environment Agency science, an investigation into the validity of the underpinning assumption that national scale flood sources can be treated independently for mapping purposes should be added.

G. Pender
24 September 2009

A3 - Peer review by Professor Hall

I've now been through the SC080050 report which is nice. Well done in extracting a method with some good theoretical content from a daunting practical problem. I have a few comments as follows:

- P8 refers to "conservative assumptions". This is not universally the case in what you do. Some of the assumptions are sensible but not necessarily conservative. Bounding assumptions would be a better thing to strive for.

- P8 in the passage on "The fully integrated approach" you should also mention that this would have to attend to event duration and coincidence.

- Equations 8.3 and 8.4 could do with some discussion of the limitations. The validity of the assumption in Equation 8.4 decreases with an increasing number of events (the probability of joint events goes up).

- Equations 8.8 and 8.9: These bounds are conservative if you are supposing the events to be independent. If you are prepared to assume independence then you could use linear error analysis to come up with the combined bounds.

- P42 I agree with your remarks about potential confusion from introducing epistemic uncertainty into probability estimates.

- P48 I can see why you do the "3 point search" but is it well justified. Some analysis of this would be useful.

J. Hall (by email to Matt Horritt)
4 November 2009

Appendix B: List of potential future improvements

The following table contains the log of potential improvements to the system that were identified during Phase 2 but were not implemented. These items should be considered for implementation during future phases.

ID	Potential improvement	Origin
1	Improve the software installation process to make it easy for users (and readily achievable on standard Environment Agency PC).	Phase 2 testing
2	Add ability within the user interface to generate an irregular polygon to define the calculation area	Phase 2 testing
3	Clearly differentiate between basic and advanced features to make the software seem simpler. For example, 'hide' advanced feature by default with them only becoming visible after a 'show advanced options' button is pressed.	Phase 2 testing
4	Predefine sets of options/features/settings that are best suited for specific needs and/or input datasets (such as Flood Zones)	Phase 2 testing
5	Ensure the user interface is easy to navigate, for example allow users to tab between the 'value', 'lower bounds' and 'upper bounds' fields rather than having to click on the fields.	Phase 2 testing
6	Provide guidance on how to interpret the results (including the uncertainty outputs) of the tool.	Phase 2 testing
7	Automatically update the map view with any new GIS layers that are added within the simulation interface.	Phase 2 testing
8	Extend the formats of input GIS data that are accepted by the software (eg ESRI format grids, .grd format, MapInfo formats).	Phase 2 testing
9	Further consider the approximate onset of flooding advanced feature. How sensitive are results to it? Should it be allowed to vary spatially? Should there be one value for defended areas and one value for undefended areas? Could use be made of the Areas Benefiting from Defences data? Should default values vary by source of flooding?	Phase 2 testing
10	The colour legend used for GIS themes should be improved with good defaults and the ability to specify ranges.	Phase 2 testing
11	The User Guide needs to be appropriate for the target audience. The User Guide for the prototype tool was considered to be less appropriate for 'non-modellers' and for the production version this comment needs taking into account.	Phase 2 testing
12	Software could provide feedback on how input data validation checks are progressing (eg by 'ticking off' checks while processing a scenario).	Phase 2 testing
13	Add ability to 'copy' or 'clone' existing scenarios to make it easier to create (similar) new scenarios.	Phase 2 testing
14	Improve the speed of loading large ASCII grids into the map view.	Phase 2 testing

ID	Potential improvement	Origin
15	Ensure there is user feedback when actions take a long time to process. For example, add a progress bar when applying a colour theme to data layers in the GIS view if it takes more than, say, five seconds.	Phase 2 testing
16	Enable easy processing of flood defence asset failure, such as multiple breach inundation datasets, including multiple breaches. Other asset failures that could be included in the sources of flooding include blockages of bridges/culverts and failure to operate of sluices, barriers and pumps.	Phase 2 testing
17	Need to increase evidence of our confidence in the outputs (including uncertainty information).	Phase 2 testing
18	Consider enhancing and/or demonstrating the method/tool for use with hazard data such as velocities and functions of depth and velocity.	Project team
19	Ensure probabilities are defined in the same form for all inputs and outputs (in the prototype there is a mixture of percentages and decimals, like 1% and 0.01). Suggestion is that percentages are used throughout.	Project team
20	Provide example input datasets with the application.	Project team
21	Develop functionality to enable MAST to report contribution to flooding by responsible authority. See Appendix B for details.	Project team
22	Add a concise project set up guide to help users quickly understand how to create a new project using their own data.	3rd stage testing
23	Add a navigation tool which allows grid references to be inputted. This would be especially useful where a specific location is being investigated within a larger dataset.	3rd stage testing
24	Within the set colour scheme option, add the ability to change the presentation of a polygon to ‘no fill’ with an outline and also add the ability to change the transparency of layers.	3rd stage testing
25	Provide functionality to export output data as a map (considered as a low priority given the compatibility of the output files with other GIS packages which could also be used for map generation).	3rd stage testing
26	Flexibility of folder names needs improving – the engine currently does not allow spaces in folder names.	3rd stage testing
27	Investigate extending functionality to enable likelihood of flooding (from all sources) to be attributed to receptors (e.g. property points).	Pioneer comment

Appendix C: List of improvements made following testing

The following table contains a summary of improvements to the system that were identified during Phase 2 testing and implemented in the prototype release.

ID	Improvement implemented following testing
1	Improve installation instructions.
2	Miscellaneous minor issues with the user interface and calculation engine.
3	Allow use of irregular polygon bounding boxes.
4	Clearly identify the more advanced options so that new users know to leave them at default values.
5	Automatically load results following a run.
6	Provide clearer guidance on data formats.
7	Improve ‘accessibility’ of documentation through adding a glossary and other changes to help ‘non-modellers’ use the system.
8	Add an example using real data to the User Guide to help users understand what is required.
9	Provide separate progress bar for each scenario and provide more information on progress in different stages of the calculation.
10	Speed up the data processing.
11	Include guidance in the User Guide covering secondary uses for assessing defence failure and in association with NaFRA.
12	Add a ‘zoom to layer’ feature.
13	Reduce size of the ‘dbf’ output file.
14	Improve clarity in the documentation on naming protocols for folders.

Appendix D: Identification of responsible authority

B1 – Introduction

During Phase 2, it was agreed to run three additional activities to explore and document the future use of the MAST tool to report by responsible authority. These activities were:

- **Concept development**: Consider how additional information on responsible authorities could be included and carried through to the results in the calculation. Incorporate any 'quick wins' that would facilitate this functionality in the future.
- **Discuss use**: Discuss the concept of flood likelihood attribution by responsible authority with the pioneer team and obtain their views.
- **Reporting**: Document the concept, summarising benefits and issues, and present a detailed explanation of what further changes would need to be implemented with the tool to add the ability to output by responsible authority.

This note completes activity (c), reporting the outcomes of activities (a) and (b).

B2 - Concept development - Method

In this section, the preferred method for reporting the responsible authority is presented. Our investigations have concluded that relatively simple changes would be required to the user interface and the calculation process to enable the tool to report contribution to flooding by responsible authority.

To create the additional functionality, the following components of the MAST software would need to be updated:

- Graphical User Interface (GUI)
- XML file and schema
- MAST engine.

The GUI would need to be modified to enable users to attribute each source with information that also describes the responsible authority tasked with managing flood risk for a flood source. The user would only be able to attribute one responsible authority per flood extent. In some cases, a flood source may be the responsibility of more than one authority across a study area (such as the local authority or Internal Drainage Board at the top of a catchment, and the Environment Agency elsewhere). In such cases, the user would be guided in the documentation to cut their flood extents to the area covered by each responsible authority before using the flood extents within MAST. To attribute the responsible authority, we propose the user would be presented with a pre-populated dropdown list (rather than a free field). The user would be asked to select a responsible authority from a pre-defined list, which would include options for 'unknown' and 'other'. Each entry on the list would be given an associated code to reduce the string length and maintain the quick computational speed of the analysis engine. Further changes to the GUI would be required to add a 'tool' that would allow a user to define an aggregation extent, so that results could be reported for, say, a community or subcatchment. Ideally this tool would enable users to draw their own extents or import a pre-defined extent as a polygon shapefile.

The XML file and schema (xsd file) would both require modification to accept the additional information attributed to each source. Once it is clear information will be input to the GUI and viewed in GUI's map viewer after processing, the changes needed to the XML file and schema should be straightforward and easy to implement. The changes will not be visible to the end user.

The MAST engine would need to be modified to carry through the additional information on responsible authority, which it would attribute to the combined flood outputs, following the same method used to report the source. The engine would also need to be developed to carry out the calculation that can aggregate results to a user-defined area. This would allow the contribution to flooding to be reported against responsible authority for whole communities and catchments. Again, these changes to the engine would not be visible to the end user.

B3 - Concept development – Implementation

During Phases 1 and 2, the MAST software was developed in a manner to maintain flexibility for future developments. To implement the development that would enable combined flood extents to report the contribution to flooding by responsible authority should take around two weeks of input (from one full-time resource).

B4 - Future needs/use

At the scale of an individual grid cell, reporting the contribution to flooding by responsible authority would be expected to produce the same split in contribution to flooding as analysing results by source. However, because different operating authorities can be responsible for the same source (e.g. fluvial or reservoir sources), results aggregated for several grid cells (e.g. at a catchment or sub-catchment scale), could look different when presented by responsible authority, compared with when they are reported by source. If this functionality is going to be added to MAST, the way that results would be viewed and used would need to be discussed further, as part of the initial work during the implementation phase.

The development of MAST in this way could provide useful inputs for business planning, by helping to split funding for flood risk management equitably amongst the various responsible authorities in each catchment. It could also help with targeting key partners in managing flood risk in particular locations.

Whilst the development required to the software is relatively straightforward and deemed to be low risk, there are wider limitations and issues which would need to be reported and brought to the attention of potential users. For example, it is too simplistic to assume that if each responsible authority is responsible for managing a third of the total combined flooding reported by MAST, that it would cost each authority the same to effectively manage this flooding. Receptors will typically be unevenly spread around a catchment or community and each source will usually be managed differently, with different associated costs. This illustrates the type of thinking that needs to be further developed before the functionality to report responsible authority could be usefully embedded within MAST.

B6 – Pioneer perspectives

As part of the initial investigation into how useful the function to report outputs by responsible authority would be to flood risk management practitioners in local authorities and the Environment Agency, comment was invited from the MAST pioneer group. Sydney Simpson (Bradford City Council) and David Hornby (Environment Agency Flood Risk Mapping and Data Management) provided their thoughts which are summarised and discussed as follows.

Both pioneers agreed that being able to output results by responsible authority could be useful, but David noted that the end users would need to be determined before it would be possible to confirm exactly how it would be of use to MAST users.

Commenting on the way such data would be reported and aggregated, both pioneers agreed it would be beneficial if the tool were able to work more flexibly with different polygon shapes, and export to pre-defined boundaries such as flood warning areas or CFMP policy units.

Sydney Simpson questioned whether the proposed analysis by responsible authority could be done by post-processing existing output from MAST in another GIS, but we consider that this would not work as intended, because more than one authority can be responsible for a source of flooding. He also recognised that there would be potential challenges associated with communicating the output, but felt that this should not represent a barrier to implementation.

David Hornby made an alternative suggestion: rather than report by responsible authority, he suggested it would be useful to report probability of flooding against different receptors (such as properties, roads, environmental sites of interest) by enabling the tool to work with the National Receptor Dataset. This is a distinct suggestion, and has been recorded separately in the list of potential improvements (Appendix B).

B5 - Suggested way forward

At an early stage during implementation, this option should be given further consideration as to the business need for this additional functionality. To implement the changes to the software is not a big task and is considered to be reasonably low risk. However, further thought would need to be given to how this information would/could be used, to ensure relevant limitations and possible misuses are identified, and clearly described or mitigated for users of the software.

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Environment Agency
Horizon House
Deanery Road
Bristol, BS1 5AH
Tel: 0870 8506506
Email: enquiries@environment-agency.gov.uk
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