HR Wallingford
Working with water

EX 5445

DTI SAM
Project Overview

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Summary

DTI SAM

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Report EX 5445
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The Dti SAM project aims to develop a new procedure and the tools needed for carrying out a risk based performance assessments of drainage systems in an integrated manner to enable more effective management of these assets. To do this, risk based methods need to be developed. If successful, this project will achieve a step change in the way in which drainage networks are assessed, similar to the impact of the Wallingford Procedure 25 years ago.

As with all leading-edge research, the project objectives and outputs may be modified as the project progresses to maximise project gains and overcome technical obstacles encountered during the work.

This report provides an overview of the DTI SAM project. The report is split into four main headings:

Section 1- Introduction

The need for a system-based management approach to urban flooding is discussed.

Section 2 - Benefits and expected results

The expected benefits and result of the DTI SAM project are described.

Section 3 - Work Packages

The individual work packages of the project are detailed.

Section 4 – Programme

A Programme of works is provided including progress up to and including November 2006.

Contents

1. Introduction

The responsibility for urban flooding is, at present, broadly divided between the water companies (with responsibility for the urban drainage systems), the local authorities for road and rural drainage and the Environment Agency (with responsibility for management of fluvial and coastal floods). This project builds upon the widely recognised belief that, to be effective, flooding has to be managed in a more integrated manner. Such an approach would consider flooding from fluvial, coastal and pluvial sources and all possible management responses (including modification to surface/sub-surface infrastructure). The need for a system-based management approach has been reinforced through a number of recent documents, including: the Foresight Future Flooding project (by the OST); Living with Rivers (by the ICE); and the Defra strategy Making Space for Water. The techniques and technologies to enable a fully integrated risk based assessment of urban flooding and the appraisal of strategic portfolios of options are, however, not yet developed. This project will provide new tools to model the complex urban drainage system and facilitate the delivery of a procedure for an integrated flood risk management approach.

The key innovation lies in the development of a risk based method of approach capable of exploring the performance of multiple flood management strategies within a single coherent analysis framework. Achieving this represents a significant challenge. In particular, systematic techniques to enable options to be tested and appraised within the context of a large-scale and complex system of sources, pathways and receptors of flood risk will need to be developed and proven. To add further difficulty, the urban system is dynamic in time. An understanding of how the system and management options behave over time will also need to be considered for developing strategic management choices. The methods will, therefore, necessarily also reflect the temporal processes and require a whole life comparison of benefits and costs.

2. Benefits and Results

Improved urban flood management will have significant environmental and social benefits. The simulation techniques we propose to develop will enhance current understanding of these impacts and enable improved management of risks that draw upon integrated management solutions (e.g. linking innovative fluvial management solutions such as urban realignment of defences, with innovative drainage solutions, for example real time flow control/storage).

The project results will enable, for the first time, the performance of urban flood systems to be properly evaluated (and management options tested) within a virtual world. This capability will support water companies as well as government and its agencies in working together to deliver efficient and effective flood risk reduction measures. It will support the delivery of both national and international policy; for example the Defra strategy for Making Space for Water and the EC Water Framework Directive both demand integrated action to manage flood risk. Once complete, the project will place UK practice, and UK consultants, at the cutting edge of flood management technology and world-wide best practice.

The project benefits are substantial and wide ranging as outlined below:

1) *Expected benefits - Technological advances.*

A step change reduction in run-time of whole system simulation models enabling system risks to be analysed, the performance of management options explored and efficient solutions selected.

2) Expected benefits – Advancing competitiveness.

The procedure and supporting tools will increase both the price competitiveness and technical differentiator of UK consultants operating aboard. This will further develop the UK's position as leading Europe and the World in flood management methods, tools and practice and the demand for UK know-how and supporting technology. The world-wide consultancy market in flood management is worth in excess of £300m pa and associated construction works of £3000m pa. UK consultants are highly regarded and the techniques and tools resulting from this project should give them a significant differentiator, leading to an increase of market share.

3) Expected benefits – The taxpayer and society as a whole.

The total UK exposure to flood risks from all sources remains unquantified, but is known to be substantial. This lack of base information hinders effective policy making and prioritisation of expenditure. In turn this leads to financial inefficiency both within government and within the water companies. It is anticipated that this project will facilitate the provision of efficiency savings from both water companies and government on maintaining sub-surface and surface infrastructure aimed at flood protection. To achieve these saving this project will result in:

a) A procedure, methods and tools for exploring the effectiveness of future flood management policies and the impact of demographic and climate change on nationalexposure to risk. This will help build an evidence base for key decisions at all levels – from government and its agencies, to water companies to individuals;

b) Better targeted and integrated private and public sector funding (benefiting both the UK taxpayer and the financial position of the water utilities);

c) Insight into key uncertainties regarding the behaviour of the urban flooding system at a level of sophistication hitherto unachievable;

d) A crucial insight into the practicalities of delivering a truly integrated approach to urban flood management and the practicalities of integrating water quality and flood management issues as required under the objectives of the Water Framework Directive.

The timing of this project could not be better. Defra is implementing its strategy for Making Space for Water. The Water Framework Directive is starting to be rolled out across the EU. There is therefore a political will to adopte integrated management strategies and the economic and environmental benefits are well recognised. The technology to make this happen needs to be developed. There is, therefore, a real and recognised industry need for this project. This underlying need will be built upon, and utilised in, both the exploitation and dissemination of the project results as follows:

1) Exploitation will be supported through:

a) An embedded partnership with an industry standard commercial software provider – facilitating rapid progress from development to take-up;

b) Close engagement of Defra, water companies and Environment Agency will fast track policy reform where required and hence practice;

c) Exploitation of the knowledge through increased competitiveness in overseas markets.

2) Dissemination will include:

a) A Steering Group of key stakeholders (including, water utilities, UKWIR, WaPUG, consultants, EA and Defra);

b) an association of interested organisations within the broader research community, building on established academic and industrial networks;

c) journal/conference papers and articles;

d) establishment and maintenance of an active web portal to demonstrations and progress;

e) demonstration through the use of two selected pilot sites –Glasgow, Bradford.

3. Work Packages

3.1 INTRODUCTION

The DTI SAM project has been divided into separate work packages. The following section provides an overview of the main objectives of each of these packages.

3.2 WORK PACKAGE 0 (WP 0) - PROJECT PLANNING

Project management is the responsibility of HR Wallingford. Leading a major consortium of researchers requires careful management control in terms of both technical direction and financial expenditure. HR Wallingford is welll placed to provide both of these requirements.

3.3 WORK PACKAGE 1 (WP 1) - 2D RAINFALL TOOL DEVELOPMENT

At present rainfall is normally applied to drainage simulation models uniformly across the catchment. This has been recognised for a number of years as being a serious limitation. Thames Water has already progressed to using radar data as a rainfall input for large catchments. Accurate radar data at the resolution of one kilometre has only been available for the last five years. Rainfall is spatially very varied across a large area (especially for extreme events) and this factor needs to be represented in studies for large catchments.

The project activity therefore aims to develop a rainfall tool which can produce data that is representative of at least 100 years of rainfall (which statistically may require up to 500 years of data) that is spatially as well as temporally representative across a catchment. This might be hundreds of square kilometres in extent if the urban area needs to be assessed within the context of a river catchment. It is recognised that the development of this tool is at the leading edge of research and the degree of success that can be achieved by this task remains to be determined.

Radar data at 1 km and 2 km resolution will be provided by the Met Office for the 3 catchments of London, Bradford and Glasgow. Imperial College and Newcastle University will develop extreme series stochastic rainfall prototype tool(s) at a resolution of 1km and test its accuracy. Agreement will be needed on output format, so that it can be processed and used in drainage analysis tools.

3.3.1 Assessment of the accuracy of the rainfall tools

Although it is understood that the length of the data sets available limits the accuracy of the prediction of the time series for extreme events, an analysis of the output will be made to establish how realistic the outputs are by looking at i/d/f relationships for point locations and compared to FEH predictions. At this stage it is not clear how extreme spatial aspects might be checked, but this will also be investigated. This assessment will help in application of the output to the pilot studies as well as the possibility of using 2D time series for studies in the future.

A report will be produced commenting on the adequacy of the tool(s) and their potential for general application.

3.3.2 Production of extreme time series

Extreme rainfall series will be generated for the three catchments. The length of the series will be between 100 and 500 years depending on the adequacy of the model, data management issues and the statistical requirements to obtain representative rainfall information.

3.4 WORK PACKAGE 2 (WP 2) - 2D USE OF 2D RAINFALL

Rainfall in urban drainage analysis has evolved from the intensity-duration approach in the Rational Method to the use of design profile storms in the Wallingford Procedure. The use of time series rainfall has become more common-place (recorded or stochastic) in the last decade, but this still assumes uniform rainfall across the whole catchment. The development in this project of 2D rainfall (spatial as well as temporal) adds a further step towards realistic representation and sewerage system analysis.

3.4.1 Assessment of sampling 2D rainfall for network analysis

The approach of running all rainfall events on a large catchment (when 2D rainfall is likely to be most relevant) is computationally very demanding. It is therefore important to devise an appropriate sampling strategy which effectively addresses the particular reason for applying 2D rainfall to network analysis.

The analysis therefore needs to compare the results from a proposed sampling process against the results from a complete run of the time series. However, use of any real catchment network will be too model specific to provide reliable quantification of the benefits of 2D rainfall. To try and remove network specific characteristics, it is proposed that a synthetic drainage system is created. This would be based on a 500 km^2 catchment with a pipe serving each square kilometre. The pipe network will be designed not to flood for the 5 year event (using design storms). The performance of the system will then be assessed using the 2D series and the flood performance will be quantified. Although completely unrepresentative of a realistic sewerage network, it allows an effective objective measure against which a sampling process can be judged.

Sampling procedures of the rainfall series will be devised and tested to establish appropriate methods which require a minimum of computational effort without compromising the accuracy of results. To carry out the sampling process and run the models, a simple rainfall processing tool will be developed. The data must be processed into a format which can be applied to the drainage system model.

Once this has been done the network will be reassessed for flooding using a uniform rainfall approach. The flood performance of the two methods will be compared and related to the effect of catchment size on the performance difference. This will enable conclusions to be drawn on the relative merits of using 1D and 2D rainfall and when 2D rainfall is important and needs to be applied.

It would be desirable to follow this analysis with runs on a real catchment, however the budget needed for this stage is not available for this project.

3.4.2 Guidance report on the use of 2D rainfall

A report will be produced that summarises the sampling approach that should be taken and the benefits of 2D rainfall for analysing urban drainage systems.

3.5 WORK PACKAGE 3 (WP 3)

Work Package 3 is to develop an appropriate drainage system model to support the development of the risk based methodology.

3.5.1 Description of work

To support the development of the risk based methodology, an appropriate drainage model needs to be developed. This model will be based on the InfoWorks CS model being used as part of the Glasgow Pilot Study, although modifications will be made as necessary to facilitate the development of the risk based methodology.

To minimise computational requirements, the extent of this model will cover a relatively small urban area and probably will be limited to less than 100 nodes. The model will include a small section of the sewer system together with a short (approximately 2km) stretch of watercourse (with associated embankments and defences) conveying flows from an upstream rural catchment.

The model will be configured such that varying degrees of both sewer and fluvial flooding are generated over a small urban area to enable quantification of flood damage estimates over a range of loading conditions (rainfall) including the failure of drainage assets and fluvial defences.

This InfoWorks CS model will be linked sequentially with a simple Rapid Flood Spreading Tool to enable flood depth and quantification of damage to meet the needs of Work Package 4.

3.6 WORK PACKAGE 4 (WP 4) - RISK BASED APPROACH TO SEWERAGE SYSTEM PERFORMANCE

The probability of a flood occurring is controlled by three aspects; the characteristics of the storm conditions, the performance of the surface and sub-surface infrastructure under that load and the local topography. Traditional deterministic methods fail to capture this interaction to a limited degree, representing one system state for analysis and provide decision makers with very limited information. New techniques will be developed to represent the potential variability in the system state as well as improvements in the representation of spatial and surface information, and provide scenario specific probabilities taking account of both the severity of a range of storm loadings and postulated system state (i.e. possible event related changes to the system within the whole drainage network, including fluvial/coastal defences). These techniques will provide a description of the likely hydraulic characteristics of the urban drainage system at any given time in the future with associated conditional probabilities.

Flood risk assessment involves estimating probability distributions of loading variables (rainfall, fluvial flows, surge tides, waves) and analysing the pathways of water from these sources to places where flooding can cause harm (receptors) in order to derive probability distributions of flood damage and, ultimately, estimates of risk. Risk-based options appraisal and design involves modifying the variables describing the flooding system in order to estimate the effect that proposed flood risk management options will have on flood risk. The risk calculation therefore requires probability distributions for the loadings (that include spatial, temporal and inter-variable dependencies), physics-based models of fluid flows from source to receptor and a mechanism for integrating loading distributions, uncertainties in the model parameterisation and damage functions in order to derive risk estimates.

For systems with small numbers of variables and computationally inexpensive models, numerical implementation of the risk calculation using Monte Carlo methods are feasible. In complex urban drainage systems it raises a number of substantial challenges that will be addressed in this task, namely:

1. the dimensionality of spatial-temporal rainfall and other random boundary conditions
2. asset failure (in its broadest sense)
3. risk attribution

Finally the approach must be designed to inform decision-making with regard to maintenance and management of the system.

Methodologies will be developed to address these problems and these will be tested and developed on a test catchment.

3.6.1 Integrating over spatial-temporal rainfall

WP 1 will generate a new spatial-temporal rainfall models and data. WP4 will demonstrate an efficient mechanism for integration of these conditions with fluvial boundary states in order to generate risk estimates.

For the case study the effect of spatial-temporal sequencing upon the risk estimates will be explored and hence establish an efficient sampling and integration methodology.

3.6.2 Asset ‘failure’

A key modifier of flood risk is the probability of failure of flood defence and drainage systems. Methods for reliability analysis of flood defences (Dawson and Hall 2006) will be incorporated, with modification as necessary, into the proposed work.

The sensitivity of flood damage to ‘sewer’ failure within the sub-surface system will be tested selecting critical assets and applying a discrete statistical model.

3.6.3 Risk attribution

The contribution towards risk from different flooding sources and components of flooding pathways, including infrastructure components, is critical information to support risk-based decision-making. Two approaches to risk attribution have been identified (Hall et al 2006):

1. *standards-based attribution*, which is close to existing work conducted in urban flood management in the UK

2. *sensitivity-based attribution*, which apportions risk between the variables that influence the total risk.

A possible approach to tackling this problem for large urban systems is by hierarchical simplification of the system, with the attribution analysis being applied at several levels, from a very broad scale to identify the main influences on flood risk, to a detailed scale for small well defined problems, to identify the system components that are responsible for flood risk.

Standards based attribution and various approaches to sensitivity-based attribution will be tested on a small case study site developed for this research task.

3.6.4 Output

A report will be produced along with code and guidance for implementation of the methodologies.

3.7 WORK PACKAGE 5 (WP 5) - RISK BASED URBAN DRAINAGE ASSET MANAGEMENT PHILOSOPHY AND PROCEDURE

WP 5 will produce a method statement and guidance on the application of the risk based approach to integrated drainage established in WP4. This will take the form of two documents; the first a general statement which informs and guides the water industry as to the risk based approach, and a second document which will detail the technical procedure of applying the methodology. This will be aimed at drainage practitioners and also Wallingford Software to provide a clear understanding of the software development requirements needed.

3.7.1 Risk based philosophy for integrated urban drainage systems

Risk analysis is based on probability of failure and the consequence of its (flood) impact. It also needs to take account of uncertainty. This uncertainty relates to many things, but includes the range of failure probabilities associated with drainage assets. How uncertainty is handled within the risk based approach will be investigated, including how the uncertainty is characterised, propagated, analysed and communicated to decision-makers.

This document will be the starting point of producing an integrated urban drainage philosophy based on risk. As the focus of this project is aimed specifically at flooding, at this stage, this document will not be generic in covering all other drainage issues such as environmental impact. The document will highlight where there are difficulties (either due to complexity or uncertainty) in applying a risk based method for assessing drainage systems for flooding and asset management guidance.

3.7.2 Risk based procedure for urban drainage asset management

A procedure statement will be produced which provides guidance to users on using a risk based approach to asset management decision making for flooding. In producing this document Wallingford Software will also gain an insight into user needs as to exactly what is required for tools development to apply the procedure.

3.8 WORK PACKAGE 6 (WP 6) - SOFTWARE TOOLS DEVELOPMENT

Effective exploitation of the new methodology will be dependent upon the availability of supporting tools needed to implement it:

The following developments will be undertaken by Wallingford Software:

3.8.1 Develop InfoWorks CS to utilise 2D rainfall

InfoWorks CS needs to incorporate 2D rainfall for use with models and also the management facilities proposed as a result of work package 2 to process the data. The incorporation of the stochastic rainfall model and processing tools remains to be decided depending on the results of work packages 1 and 2. For the project, HR Wallingford will be producing a prototype rainfall processor tool.

3.8.2 Develop InfoWorks CS with a fast network solver for risk based approach flood assessment studies

The InfoWorks CS engine is very efficient, as well as being extremely stable. However the current approach to drainage of running a limited number of model runs will change in a risk based approach which will require very many runs to be made. Although computer processor speeds have increased dramatically over the years, there will be a need to provide a step change in performance to allow risk based methods to be used as a realistic proposition. This will be achieved by further efficiency gains to current techniques and development of new solution methods which, although continuing to be robust and stable, will enable significant speed gains.

3.8.3 Development of an Overland flood flow model integrated with InfoWorks

Overland flow models are needed for both sewer system and river models. These require both the conveyance elements, such as roads, to be included in the model as a surface network and also the surrounding topography needs to be represented. There are currently no models in existence which do this in an integrated manner. In addition to routing of water on the surface, there is the need to be able to accurately predict flood depths at all flood locations and preferably also velocity. A key issue is ensuring a fast, but robust approach to routing of flows.

Two models will be developed to enable overland flood routing and flood depths to be predicted. The first tool is aimed at providing a very rapid analysis with reduced accuracy to enable a risk approach to be used. The second tool, based on a full hydrology-dynamic solution, will enable more accurate flood modelling to be undertaken for detailed evaluation and confirmation of drainage system performance.

3.8.4 Incorporate damage cost functions into the flood model;

To enable an evaluation of flood impact it is important to have flood depth /velocity /damage cost functions developed. These cost functions will be financial and probably also social impact, including mortality risk. There is a considerable body of work in existence which provides ‘cost’ functions to flood depths. This information will be incorporated in the risk methodology and rapid flood spreading tool.

3.8.5 Implement model run and management features to enable a risk-based approach to the analysis of drainage systems

The project aims to produce a risk methodology which is radically different to current practice in drainage system evaluation. Existing tools will therefore not be suited to applying this new risk based procedure, and totally new methods of model management will be needed

The method of approach defined by HR Wallingford and Newcastle University in WP4 and WP 5 will be taken by Wallingford Software to define new software development needs that will enable the new procedure to be implemented and used by all drainage engineers. This tool will not be produced as a project deliverable, as its form and viability of its application is yet to be established. It is envisaged that such a tool will evolve to meet the drainage industry needs over the following 5 years.

3.9 WORK PACKAGE 7 (WP 7) - BRADFORD PILOT STUDY

Two case studies are proposed for testing the procedure methods and tools. These have been selected based on known catchment wide problems and the existence of good data and models. Keighley has been used for other research work by Sheffield University and therefore they are best placed to carry out this work. Glasgow (Dalmarnock catchment) has been selected for the other pilot catchment and this will be carried out at HR Wallingford. To maximise the benefits of the two pilot studies, it will be important for the two teams to define a common approach and to have regular meetings to discuss the implementation of the procedure.

The study needs to demonstrate the effectiveness of a risk based approach to drainage asset management as well as the use of the tools developed for this purpose. Sheffield University will have data provided by, and be supported by, Bradford City Council, Yorkshire Water and the local Environment Agency to ensure all relevant stakeholders are effectively represented in carrying out this task.

The project output will establish how effective the procedure is and what future development should take place.

3.9.1 Catchment description

The proposed case study is the township of Keighley within the City of Bradford Metropolitan District. The township has been affected by fluvial and pluvial flooding over recent years. The Stockbridge district of Keighley was one of the worst hit areas in the country during the autumn 2000 fluvial flooding, and subsequently a major flood defence scheme has been implemented. Keighley and Worth Valley have also suffered from numerous incidents of pluvial flooding involving urban runoff, runoff from rural margins and urban green space and flooding from ordinary watercourses. City of Bradford MDC, Yorkshire Water Services and the Environment Agency are all stake holders partners with the Pennine Water Group at the University of Sheffield in RPA6 of FRMRC and all three are working together towards improved flood risk management.

The Stockbridge flooding is well documented and a hydrodynamic river model has been developed for the River Aire catchment flood management plan which is at an advanced stage of development.

Yorkshire Water Services have developed a sewer hydraulic and quality model of the Keighley drainage area. It was verified in two parts, the Low Level system in 2000, and the High Level system in 2002. Models of the current sewerage system are also available.

The Environment Agency, Yorkshire Water Services and City of Bradford MDC all have data bases of flooding incidents relevant to their own sphere of operation, which are available for calibration of models.

The study area is data rich. CBMDC commissioned a 52 Km, 1m horizontal resolution Lidar survey in December 2004, and the Environment Agency has a 2m horizontal Lidar survey of the River Aire, which generally takes in a 2Km swathe either side of the river.

In addition to the 9 EA logging rain gauges within a 10KM of Stockbridge, and the rain gauges installed for the short term sewer flow surveys for the verification of the sewer models, logging rain gauges were installed by Yorkshire Water in the adjacent Bradford Beck catchment for the recent UPM study, and by CEH as part of a NERC Urgent project. CBMDC have also installed a network of 15 rain gauges in the Wharfe, Aire and Worth Valleys. This was commissioned in July 2005.

Therefore, the catchment provides the opportunity to test the SAM procedure and tools..

3.10 WORK PACKAGE 8 (WP 8) GLASGOW PILOT STUDY

Glasgow (Dalmarnock catchment) has been selected for the second pilot catchment and this will be carried out at HR Wallingford.

The study needs to demonstrate the effectiveness of a risk based approach to drainage asset management as well as the use of the tools developed for this purpose. HR Wallingford will have data provided by, and be supported by, Glasgow City Council, Scottish Water and SEPA to ensure all relevant stakeholders are effectively represented in carrying out this task.

The project output will establish how effective the procedure is and what future development should take place.

3.10.1 Catchment description

A part of the Dalmarnock catchment was seriously flooded in 2000 which has resulted in a major city wide development study. Scottish Water Solutions together with Hyder and Glasgow City Council and SEPA have carried out an integrated catchment study looking at foul and surface water drainage, sewage treatment and river impact. The Dalmarnock catchment suffered from such extreme flooding that a unique approach to the analysis was made using an InfoWorks CS model together with an overland flood model using Mike Urban.

This pilot study therefore has the benefit of using an in-depth drainage plan and models on which to test the risk based procedure.

The initial task is to understand catchment specific drainage details and the modelling work carried out to date. Although Scottish Water will facilitate this, it is important to involve other stakeholders, not only because of their interests in the catchment but also because some of the IPR for the data and models resides outside Scottish Water. All stakeholders will be informed of the aims and objectives of the project and the pilot and a detailed method statement will be agreed (in tandem with the work proposed at Bradford).

3.11 WORK PACKAGE 9 (WP 9) - PROJECT EVALUATION & DISSEMINATION

Work package 9 is aimed at both evaluation of the procedure developed by the project and also disseminating the progress and outputs to the water industry and other interested parties during and at the end of the project.

An evaluation of the procedure will be undertaken at the end of the project to establish whether the concept developed is appropriate for general application and what further developments are needed to make it more effective. The project will also be assessed against current national policy on flood protection and drainage asset management.

Two project reports will be produced; the first providing an in-depth evaluation of all the technical elements of the project and the second looking at the project in terms of the national programme of MSfW and the practicality of rolling out the procedure on a national basis. These documents, along with seminars hosted by UKWIR during and at the conclusion of the project, will ensure wide-spread dissemination of the procedure and its results.

4. Project Outputs Summary

	Reports	Free Tools (with code)	Free Tools (executable)	Commercial Tools (enhancements)	Guides / Procedures	Other
WP1	Effectiveness of 2D TSR Tools	-	2 Prototype Tools*	-	-	100 yrs 2D TSR for - London - Glasgow - Bradford
WP2	Benefits of 2D TSR Compared to 1D TSR	Event Selection and Processing Tool**	-	-	-	-
WP3	-	-	-	-	-	IW CS Model for WP4
WP4	Risk based research report on methods and results	Risk based method *** and supporting code	-	-	-	-
WP5	-	-	-	-	Risk based procedure and guidance	-
WP6	Statement on tools development	-	-	- Enhanced IWCS engine - RFSM Tool (with damage-cost functions) - 2D finite-volume tool (within IW CS) - Risk based tool****	-	-
WP7	Pilot Study (1) – Report on application of procedure and tools	-	-	-	-	IW CS Model (1) *****
WP8	Pilot Study (2) – Report on application of procedure and tools	-	-	-	-	IW CS Model (2) *****
WP9	The Study Effectiveness and the way forward including policy implications	-	-	-	-	-

*Expert support advised when using these tools. **Subject to confirmation of HRW R&D strategy on tools IPR. *** Facilitating research, not a deliverable output of the project. **** Not within the framework of the project as a deliverable. Subject to project results, development of such a tool in the long term (1 to 5 years) is possible. ***** Subject to 'owners' approval – Glasgow City Council and Yorkshire Water.

5. Programme