Project CL/10 - Climate change and the design of sewerage systems

Definition report

R B B Kellagher

Report SR 586
August 2001

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HR Wallingford

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Contract - Research

This project aims to meet the requirements of UKWIR to carry out a study on the impact of climate change on drainage systems. It also aims to produce tools or methods which will enable the water industry to meet service objectives for the 21st Century and investigate drainage related issues.

A consortium of companies is led by HR Wallingford which comprises the Met Office, Montgomery Watson Harza and Imperial College. The Met Office (through the use of the Hadley Centre) has the key responsibility of predicting the impact of climate change. Montgomery Watson Harza and Imperial College are involved in implementing the output in interpreting performance and cost implications, and producing tools / methods for design and analysis respectively. HR Wallingford, as well as managing the project, will be evaluating related issues such as drainage modelling standards and the future direction of drainage provision.

The project manager for HR Wallingford is Richard Kellagher. The job number is MAS 0232.

Contract – Research *continued*

Prepared by R Kellagher ....

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Principal Engineer ....

(Title)

Approved by ....

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Date 29/7/2001 ....

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Summary

Project CL/10 - Climate change and the design of sewerage systems

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This Definition Report summarises the scope of the project. It should be read as providing clarification to the offer document and modifications arising from initial project meetings that have taken place. The text of the Offer document is appended to this report.

The structure of this statement is related to tasks that were defined as being Mandatory or Optional activities. It briefly details in outline the scope of work and also indicates the limits of the proposed activities.

Where there is a degree of uncertainty as to the best approach, this is stated. It is intended that discussion and agreement on all tasks is achieved, but where the tasks are less well defined, this discussion is particularly important.

If the steering group require any of the Optional tasks to be carried out, this needs to be defined as early as possible. However, for guidance, a suggested latest decision date is also provided. A decision after this date may result in either additional cost or a delay in the programme, or both.

The project programme, which has been altered to improve on making better use of project task results, is included. This is not the current basis of the contract programme and is to be agreed as soon as possible.

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1. INTRODUCTION

This definition report should be read in conjunction with the offer document. It outlines the method of approach proposed by the consortium for carrying out the work.

Descriptions are provided for both Mandatory and Optional tasks to ensure full understanding of all activities.

2. THE MET OFFICE

The Met Office project manager is Murray Dale.

2.1 Mandatory tasks

The following Mandatory tasks are the responsibility of the Met Office.

2.1.1 RCM model

The Regional Climate Model will be used with a time horizon of 2080. Data is a function calculated on a 50km grid and the results for each 50km grid square will be used for developing the mapping information. The UKCIP 1998 Medium-High scenario will be used for the purpose of producing the hydrological maps, and the possible implications of the other UKCIP 1998 scenarios will be commented upon.

An interim report, which states the assumptions made in the model, will be produced.

Data is based on 24 hour and 6 hour results and extrapolation will be carried out to determine the 15 minute to 12 hour range of information for the hydrological maps. This extrapolation will be based on FEH information. The Met Office will be extracting data to enable Imperial College to look at seasonal effects and dry periods as they are carrying out this analysis.

As part of the task, the climate change model results will be examined to demonstrate its accuracy for predicting present day conditions.

Output of the results would be provided in month 9 to allow Christian Onof (Imperial College) to start his tasks.

<u>Issues:</u>

2080 horizon
Medium/High scenario

2.1.2 Hydrological mapping

This task involves producing maps showing:

FSR / FEH rainfall depth ratio
FEH / 2080 rainfall depth ratio
FEH rainfall depth
7 durations (15 minute – 12 hour), 7 return periods (1 – 100 yr), plus Annual Average Rainfall

FSR / FEH return period ratio
FEH / 2080 return period ratio

FEH data is on a 1km grid while FSR data is on a 3⅓ km grid. The Regional Climate Change Model is on a 50 km grid. It is proposed that the FEH grid density will be used. The FSR data at 1km has been produced by interpolation. Smoothing of the RCM model data to allow effective contouring is an important issue. The application of RCM data onto the FEH data has still to be defined. Specific details of proposals will be provided in an interim statement prior to map production.

The Mandatory mapping at A4 will be based upon JPG or other appropriate electronic format image showing only the map of UK colour scales and value contours of the relevant hydrological data. A coarse OS grid is also to be produced. Details of towns and cities and rivers are not appropriate at A4.

The original offer suggesting FSR to 2080 return period ratio maps should have read FEH to 2080 as currently proposed.

Issues:

Resolution – FEH grid density
Interpolation and smoothing of RCM data.

2.1.3 Spatial high intensity rainfall

Spatial rainfall and high intensity rainfall are two separate issues, but they are closely associated with each other. Spatial aspects are difficult to quantify, but the Met Office will provide an overview as to spatial extent of high intensity rainfall which are a function of storm condition characteristics. The climate change effect on the impact of the spatial extent of storms will be covered. The present and future frequency and severity of storm events will be summarised from the RCM analysis output.

They will also outline the use and abilities of radar to measure both the spatial effects and intensities of events.

HR Wallingford will look at the theoretical constraints of current gully design for coping with high intensity events. Calculations will be made to relate rainfall return periods with excess flood volumes using design storm profiles.

Issues:

-

2.1.4 Support to Imperial College, Montgomery Watson Harza & HR Wallingford

The Met Office will support HR Wallingford, Montgomery Watson Harza and Imperial College in providing rainfall data. Specifically they will provide autographic data for gauges for 4 areas to provide a range of typical conditions for Montgomery Watson Harza and Imperial College to use for their respect principal tasks.

Issues:

-

2.2 Options: (with latest decision time)

2.2.1 Electronic maps

Decision required by July 2001.

The project proposes to use ArcExplorer, a free viewer for ArcView vector and image files, to enable the viewing of electronic mapping. 248 maps is a very large data set and it is possible that more than one disc will need to be produced. The steering group will need to consider the basis for the division of the maps. The number of CDs needed is not exactly certain at this stage.

If higher resolution information is required, the 50,000 scale OS data costs £5000 plus an annual maintenance fee of £1250. The 1:1,000,000 scale OS map can be used or the UK base map which comes free within ArcView can be used.

Issues:

Resolution and detail of contour data
Division of maps to CDs

2.2.2 Rainfall in countries with future UK rainfall

Decision required by April 2002.

In order to provide some form of verification for the results of the climate modelling exercise, it was recognised that it might be possible to examine the climate of other areas in Europe which currently exhibit trends in short-period rainfall that resemble those predicted by the RCM for the 2080s in the UK. In so doing, real precipitation data can be used that have been measured from a climate akin to one we may experience in the future, based on the Met Office GCM and RCM.

It is felt that the examination of a climate with mean temperature statistics similar to those predicted for the UK in the 2080s might be a useful exercise since the short-period rainfall statistics (e.g. up to 2 hours) are very likely to be the result of convective systems, driven by heating of the land surface. Therefore, while a city such as Bordeaux, France, may not represent the future UK climate, for the reasons stated above, it may experience extremes in short-period rainfall which could be compared to those predicted by the RCM. There is meteorological research which indicates that, while the degree of instability may not be directly related to surface temperature, the saturation vapour pressure increases with temperature and hence the amount of precipitable water will increase with temperature.

<u>Issues:</u>

Data availability

3. IMPERIAL COLLEGE

Imperial College is providing expertise in rainfall, particularly stochastically generated series. Christian Onof is the project manager.

3.1 Mandatory tasks

Mandatory tasks are the production of a design event uplift for TSR and design storms.

3.1.1 Design event uplift for 2080

Using the Met Office rainfall depths for durations of 15 minutes to 12 hours, and for return periods of 1 to 100 years, a simple scaling factor is applied to the rainfall profiles so as to obtain design storms for 2080. The same profile as that in FEH will be used, which is consistent with it being applied to obtain the Met Office depths for time-scales below 6 hours.

<u>Issues:</u>

Storm profiles in 2080
Regulatory approval of methodology

3.1.2 TSR uplift 2080

Since it is not feasible or desirable to re-produce the whole of the work which underpins STORMPAC, the following approach shall be adopted:

1. Starting either with local hourly raingauge data or a STORMPAC simulation, estimate statistics of rainfall at 1, 6 and 24 hours for that location. These are chiefly the mean and variance (and eventually the skewness).

2. Since the distribution of rainfall at hourly and 6-hourly time-scales is approximately Gamma, the above statistics (characterising the long-term mean behaviour) together with change in rainfall characteristics provided by the RCM model (using return periods up to 100 years) will be used to calibrate a rainfall generator.

3. This generator will simulate hourly rainfall to replace the original hourly data or STORMPAC output. The StormPac disaggregator would then be needed to disaggregate the data to 5 minutes.

The methodology will be transparent and allow software service providers to reproduce the processes involved.

<u>Issues:</u>

Intensities produced by StormPac
Regulatory approval of the methodology

3.2 Options: (with latest decision time)

3.2.1 Disaggregator (autographic pattern recognition and uplift)

Decision required by July 2001. Definition of MSc lead time and close linkage with uplift rainfall task.

Two scaling methods will be compared and the best selected for the purpose of rainfall disaggregation from 1 hour down to 5 minutes. Both methods will require the use of high resolution local raingauge data (autographic) for pattern recognition which will be provided by the Met Office. These two methods are based upon the observed multi-scaling properties of rainfall. The existence of such properties makes it possible to generate rainfall at a finer time-scale by using a random cascade. This can occur in two ways:

1. A canonical cascade (which has a better theoretical foundation) will produce fine-scale rainfalls which, when aggregated, have the same mean properties as the observed data.

2. A microcanonical cascade will produce fine-scale rainfalls which sum up exactly to the observed rainfalls.

An uplift methodology will also be applied in this task to incorporate climate change effects on rainfall intensity for short duration periods.

The methodology will be transparent and allow software service providers to reproduce the processes involved.

<u>Issues:</u>

Improved accuracy of high intensity rainfall
High intensity rainfall modification for climate change
local characterisation of data.
Regulatory approval of software

4. MONTGOMERY WATSON HARZA

The project manager is Amer Rafique. Key staff include David Balmforth and George Hare.

4.1 Mandatory tasks

4.1.1 System performance evaluation and costs

Sewer networks

Five sewer models will be used in the study. The models will represent different aspects of networks i.e. type, size, degree of urbanisation and topography: -

A large, relatively steep, urban catchment
A small to medium sized, relatively flat, suburban catchment
A medium sized to large, relatively flat, urban catchment
A small, relatively flat, semi-rural, possibly bathing water urban catchment
A medium sized urban coastal catchment.

The models will be those before inclusion of AMP3 (or AMP2) solutions.

Each model will be tested at four different locations within the UK. These locations will be determined after the rainfall analysis has been completed. The locations will be selected to provide representative results indicative of the predicted changes across the UK.

The five sewer models and four locations will therefore be representative of twenty notional catchments.

Rainfall

Rainfall sets will be generated for three scenarios – Flood Studies Report, Flood Estimation Handbook and Projected 2080. Antecedent wetness indices (UCWI or API30 as appropriate) will be determined based on the different climatic characteristics for each scenario. Each rainfall set will be generated for four locations within the UK, giving 12 overall rainfall sets.

Each model will be run with a range of rainfall inputs to include:-

1 in 5 year and 1 in 30 or 40 year design storms
A subset of a "typical year" from a rainfall series
A small subset of the 10 year annual series

Changes in the pattern of dry periods between rainfall events are likely to be as significant as changes in the intensity and distribution of individual events. It is likely that future modeling work will focus more on continuous rainfall simulation and the study will reflect this.

Results Analysis

Flooding

Flooding would be the most demanding level of service requirement to evaluate as upgrading for flood control usually involves both storage and sewer upsizing. Percentage increases in flood volume at significant locations will be determined for trigger (1 in 5 year) and design (1 in 30 or 40 year) return periods. Solutions will be developed using storage only, but the robustness of this approach will be evaluated more thoroughly on one of the catchments.

Bathing Waters
Increased storage requirement for 3 spills per bathing season will be determined using event based analysis. A continuous simulation for one model is currently proposed. 1800 simulations will be carried out representing 60 different catchment/location/rainfall scenario combinations.

River Impact
Identification of the following parameters is to be considered for analysis of the river impact results:-

Identify percentage increase in spill rate for 1 in 5 year
Identify increased spill frequency, annual spill volume, spill duration
Identify annual (and/or seasonal) pollutant load increase
Identify increased volume to WwTWs, Pumping Stations

<u>Cost and UK wide extrapolation of results</u>
Evaluation of cost to be undertaken using sewerage length, per capita or per CSO with extrapolation of results to national scale.

Results from the test catchments would be scaled up to give national figures. This requires discussion between the partners but values could be scaled up on the basis of cost, using AMP2 and current AMP3 spend for different Water Companies, or scaled using Water Company asset statistics for population number, population density, length of sewers, number of CSOs, asset value etc.

<u>Issues:</u>

Clear definition of performance criteria
Agreement on output details and formats
Assumed use of proposed disaggregator

4.1.2 Groundwater influence

It is considered that infiltration response is based on both groundwater levels and event related response. The proposed approach is to use information on flow rates at sewage treatment works and their increased inflows in winter to determine the effects of both the predicted longer and higher levels of rainfall as well as groundwater changes. It is thought that models would not provide a useful method for establishing this information. The implications for treatment costs and treatment processes will be highlighted.

The Met Office will assist in providing SMD information relating to Climate Change effects.

The implications of reduced pipe capacity (due to increased infiltration) will be explored, considering CSO performance and additional flooding.

<u>Issues:</u>

Use of STW recorded flows

4.1.3 Summary of international drainage design

An overview of international design standards will be undertaken. Comments will be made on key aspects and those which present particular problems with regard to climate change implications for the UK.

<u>Issues:</u>

Steering group feedback / guidance on Water Company emphasis

4.1.4 Flood litigation

In recent years litigation has grown with regard to the impact of flooding, notably in places such as Canada and North America. Compensation claims for damages due to flooding will be discussed drawing on international experience.

Issues:

Steering group feedback on Water Company experience

5. HR WALLINGFORD

5.1 Mandatory tasks

5.1.1 SMD change and its impact

Soil Moisture Deficit is a measure of the wetness of the ground. It is used in computer runoff models to reflect the additional runoff that will take place from permeable (vegetated) areas. An evaluation of increased soil wetness will be made by the Met Office and this will then be used to investigate the impact of runoff in terms of modelling.

This issue is distinct from that of groundwater and infiltration covered earlier.

Issues:

-

5.1.2 SOIL and HOST – the impact of FEH

This does not have a direct link to climate change, but if FEH rainfall with climate change is to be the basis of future drainage analysis, consideration of this issue is important.

Urban drainage modelling uses two types of Wallingford Procedure runoff models. The New PR equation uses a decay function which is based on the FSR categorisation of soils into 5 SOIL types. SOIL is also a function of the Old PR equation. The implications of the change to HOST classes in the FEH to determine runoff needs to be considered for urban drainage runoff modelling and the implications that this has for the Wallingford Procedure runoff models.

A summary of HOST values and their approximate relationship to SOIL will be provided to assist in using FEH for urban drainage design.

Issue:

Correlation of HOST to SOIL

5.1.3 Water quality effects on rivers

HR Wallingford has defined a method of selecting major polluting events on a UPM study. This procedure will be used to demonstrate the increase in potential water quality impact on rivers due to climate change using a present and future time series. In addition information will be collated on river state changes from expert sources such as Arnell of Southampton University and work commissioned by UKWIR and the Environment Agency.

Montgomery Watson Harza will use this information in carrying out an assessment of pollution loads and water quality impact using one of the system assessment models. They will also take into account the likely changes in river flows. More generally climate change influence in summer on water quality impact on rivers will be undertaken by identifying and assessing spill, frequency, annual spill volume, spill duration.

Issues:

The availability of the Optional disaggregation tool for 5 minute data.
Inter-task timing to feed into Montgomery Watson Harza activities
Existing and current research by UKWIR and other research organisations

5.1.4 Impact of rising water levels in rivers, lakes and sea

Data would be collated by HR Wallingford on sea level change and predicted monthly river level changes. The impact of reduced periods of gravitational drainage and increased periods of pumping would be assessed theoretically from tide curves and a range of assumptions. The issue of hydraulically locked CSO and stormwater storage tanks will be discussed. An evaluation of national assets affected by sampling and extrapolation is not proposed.

Montgomery Watson Harza will take account of receiving water level changes in their system analysis to provide some indication of national implications.

Issues:

Data availability
Inter-task timing

5.1.5 Major and minor systems

The use of extreme event drainage will consider the concept of designing for overland flooding. The potential for greater above ground flows will be explored enabling an understanding of whether extreme events are likely to lead to the approaches being adopted by some countries, being applied in the UK.

Issues:

Other authorities – road design, planning guidance

5.1.6 Launch Seminar

An "end of project" seminar will take place at HR Wallingford.

Issues:

Speakers
Date
Venue
Charging for attendance

5.2 Options: (with latest decision time)

5.2.1 Software development and linkage

Decision required by August 2002. Definition of MSc lead time and close linkage with uplift rainfall task

This task is limited to meeting with software manufacturers to facilitate UKWIR's needs in developing these utilities. Detailed and extended technical discussions and assistance are not envisaged.

Issues:

2 meetings proposed.
Decision on option can be late in terms of managing the project. However Software development schedules are usually planned 6 months ahead and it is advised that a decision on this aspect is taken earlier.

5.2.2 NAPI – the impact of FEH

Decision required by April 2002.

The New Antecedent Precipitation Index is used in the more recent Wallingford Procedure runoff model. The value of NAPI that should be used for design events has yet to be resolved. This subject will need to be assessed some day, but is not in the brief, though it could be carried out. The climate change study will allow an evaluation of the increase in NAPI value for different regions from Time Series rainfall.

Issues:

Design event NAPI values
Assumes the availability of disaggregated data

5.2.3 DTM models for overland flow

Decision required by April 2002.

This task extends the study on major and minor systems. It will look at the use of DTMs as they are now used and could be used in the future with respect to routing and prediction of flooding.

Issues:

-

5.2.4 SUDS and climate change

Decision required by April 2002.

Drainage design has recently been involved in a debate on the use of other methods of dealing with rainfall runoff which have a number of environmental benefits as well as reducing the impact on drainage systems. The use of many of these options is limited for existing development and experience in their robustness is still being established. However it must be recognised that these drainage methods are going to become more commonly used.

It is therefore proposed to briefly evaluate the implications of using these methods in the light of the expected effects of climate change. At present there is some concern over the volumetric aspects of long wet winter events.

Issues:

Brief overview
Use of Time Series data

5.2.5 Separate and combined systems

Decision required by April 2002.

Current concerns over the environmental implications of twin systems will be assessed for their advantages and disadvantages against combined systems in the light of climate change impact. A simple InfoWorks model looking at pollution loads will be used to quantify pollution loads. A brief resume of the key issues will be summarised in the light of possible future changes in regulatory requirements.

Issues:

Brief overview
Use of default water quality parameters

5.2.6 Study on spatial rainfall

Decision required by April 2002 for selection and preparation of appropriate catchments.

It is suggested that two small highly detailed models (around 100ha) are used to model the effects of system inflow constraints, overland flooding and flood routing using extreme events of 100 year return period.

Issues:

Modelling of future extreme rainfall using TSR events is dependant on the disaggregation option being carried out.

5.2.7 Launch in Scotland

Decision required by April 2002.

A seminar could be given in Scotland (to ensure wide dissemination). The proposal is based on the "end of project" seminar being replicated, but this could also apply to the possible interim seminar proposed as an Option.

Issues:

Provision of conference facilities by a Scottish Water Authority.

5.2.8 Interim launch

Decision required by December 2001.

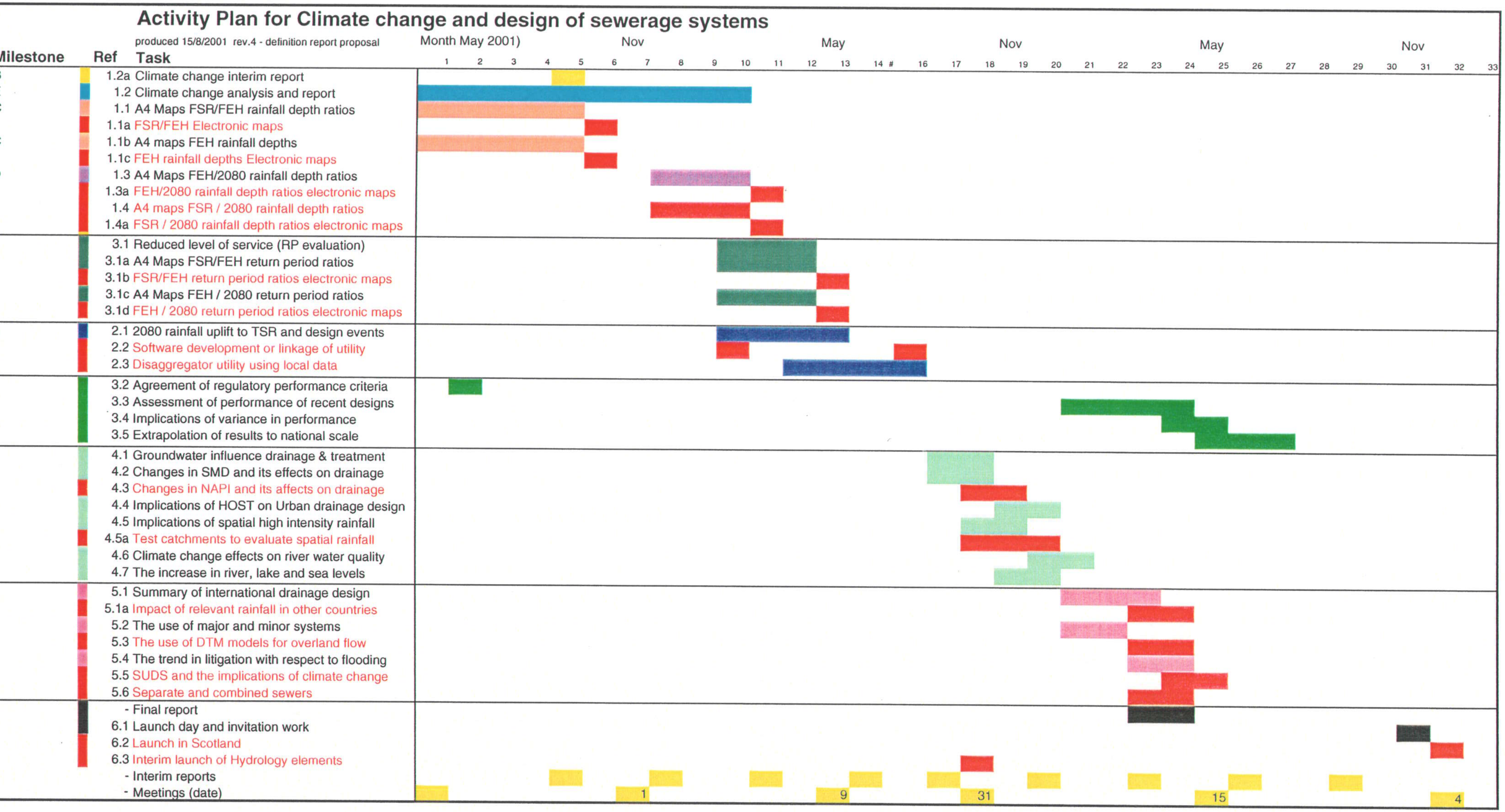
The early output of the RCM model and maps will be of value to the industry ahead of any analysis relating to costs and impact evaluation.

Issues:

Timing and location and facilities

UKWIR Project - Fee summary

Contract Project Milestones	Task Ref	Task Description	Mandatory Elements Cost (Total)	Optional Elements Cost (Total)
A	-	Project start	£0	£0
C	1.1	A4 Maps FSR / FEH rainfall depth ratios	£10,100	
	1.1a	Electronic Maps FSR / FEH (Optional)		£2,000
C	1.1b	A4 Maps FEH rainfall depths	£8,100	
	1.1c	Electronic maps FEH rainfall depths (Optional)		£2,000
C	1.1x	Retention	-£1,200	
B	1.2a	Climate change Interim report - criteria and assumptions	£15,000	
E	1.2	Climate change analysis and report	£27,000	
E	1.2x	Management	£900	
D	1.3	A4 Maps FEH / 2080 rainfall depth ratios	£8,100	
	1.3a	Electronic maps FEH/2080 (Optional)		£2,000
	1.4	A4 Maps FSR / 2080 (Optional)		£6,000
	1.4a	Electronic maps FSR / 2080 (Optional)		£2,000
G	2.1	2080 rainfall uplift to hourly TSR and design events	£17,500	
	2.2	Software development or linkage of utility (Optional)		£1,500
	2.3	Sub-hourly disaggregator utility using local / regional data (Optional)		£17,500
G	2.1x	Management	£1,000	
F	3.1	Analysis of reduced level of service (RP evaluation)	£3,000	
F	3.1a	A4 Maps FSR / FEH (Return Periods)	£4,000	
	3.1b	Electronic maps FSR / FEH (Return Period) (Optional)		£2,000
F	3.1c	A4 Maps FEH / 2080 (Return Period)	£4,000	
	3.1d	Electronic maps FEH / 2080 (Return Period) (Optional)		£2,000
F	3.1x	Management	£1,000	
H	3.2	Agreement of regulatory performance criteria	£3,000	
H	3.3	Assessment of performance of recent designs	£28,500	
H	3.4	Implications of variance in performance	£6,000	
H	3.5	Extrapolation of results to national scale	£5,000	
H	3.5x	Retention	-£500	
I	4.1	Groundwater influence on infiltration, treatment volumes etc.	£8,000	
I	4.2	Changes in SMD and its effects on drainage	£6,000	
	4.3	Changes in NAPI and its affects on drainage (Optional)		£5,000
I	4.4	Implications of HOST on Urban drainage design	£4,000	
I	4.5	Spatial high intensity rainfall - implications for DG5	£6,000	
	4.5a	Test catchments to evaluate spatial high intensity rainfall (Optional)		£16,000
I	4.6	Climate change effects on river water quality	£4,000	
I	4.7	The increase in river, lake and sea levels	£4,000	
I	4.7x	Retention	-£200	
J	5.1	Summary of international drainage design	£8,000	
	5.1a	Impact of relevant rainfall in other countries (Optional)		£6,000
J	5.2	The use of major and minor systems	£5,000	
	5.3	The use of DTM models for overland flow (Optional)		£4,000
J	5.4	The trend in litigation with respect to flooding	£4,000	
	5.5	SUDS and the implications of climate change (Optional)		£4,000
	5.6	Separate and combined sewers (Optional)		£4,000
J	5.6x	Management	£1,000	
R	-	Final report	£0	
R		Retention repayment	£10,000	
T	6.1	Launch day and invitation work	£6,500	
T	6.1x	Management	£2,000	
	6.2	Launch in Scotland (Optional)		£3,000
	6.3	Interim launch of Hydrology elements (Optional)		£6,500
Z		Project completed	-	
		TOTALS	£208,800	£85,500
	7	Meetings & Management - redistributed	£14,000	


Activity Plan for Climate change and design of sewerage systems
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Task
1 2 3 4 5 6 7 8 9 10 11 12 13 14 # 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33
1.2a Climate change interim report
1.2 Climate change analysis and report
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2.3 Disaggregator utility using local data
3.2 Agreement of regulatory performance criteria
3.3 Assessment of performance of recent designs
3.4 Implications of variance in performance
3.5 Extrapolation of results to national scale
4.1 Groundwater influence drainage & treatment
4.2 Changes in SMD and its effects on drainage
4.3 Changes in NAPI and its affects on drainage
4.4 Implications of HOST on Urban drainage design
4.5 Implications of spatial high intensity rainfall
4.5a Test catchments to evaluate spatial rainfall
4.6 Climate change effects on river water quality
4.7 The increase in river, lake and sea levels
5.1 Summary of international drainage design
5.1a Impact of relevant rainfall in other countries
5.2 The use of major and minor systems
5.3 The use of DTM models for overland flow
5.4 The trend in litigation with respect to flooding
5.5 SUDS and the implications of climate change
5.6 Separate and combined sewers
- Final report
6.1 Launch day and invitation work
6.2 Launch in Scotland
6.3 Interim launch of Hydrology elements
- Interim reports
- Meetings (date)
1
9
31
15
4

Appendix A

The original Offer of Services – description of activities and methodology

Appendix A The Original Offer of Services – description of activities and methodology

Project Activities

The project activities that are summarised in the five points of the project objective can be unpacked and defined as a number of tasks. These are itemised under the five objectives as individual tasks and subsequently discussed and the method of approach explained.

Objectives 1a and b
1a *Evaluate the likely characteristics of rainfall in the coming decades*
1b *Evaluate the difference between FSR and present day rainfall characteristics.*

Study tasks
1. Establish the difference in rainfall depth between the FEH and FSR methods for the whole UK. Produce these as A4 maps and digital maps. 49 plots for 7 return periods and 7 durations plus 1 for SAAR. Colour and contour factors to highlight differences. Produce set of 49 maps of FEH rainfall depths.
2. Evaluate the latest research projections regarding potential changes to rainfall characteristics for the next 100 years over the UK. Regional rather than high resolution evaluation. (Current best available knowledge). Report to evaluate range and accuracy of predictions using some form of confidence measure.
3. Produce the same factoring of rainfall depth of FEH (assumed as present day) for 2080. 49 A4 and digital maps plus SAAR.
4. Produce same factoring of rainfall depth of FSR to 2080. 49 A4 and digital maps plus SAAR.

Objective 2
2 *Provide the methods/tools which will enable appropriate design of drainage systems for the future*

Study tasks
1. A utility that regionally factors both TSR events and design storm events to take account of climate change for the future.
2. Linkage to Wallingford Software products to allow global usage by drainage practitioners throughout UK.
3. Produce a rainfall dis-aggregator which uses recorded data to produce 5 minute data trained on autographic "training" sites.

Objective 3
3 *Establish the level of service (reduction) and cost implications of meeting Regulatory requirements on drainage related matters.*

Study tasks
1. Assessments of the reduced level of service of drainage structures built to FSR criteria, for present day and design horizon (2080) by determining change in return period for any given FSR return period. 49 x 2 maps – A4 and digital.
2. Agreement of appropriate regulatory performance criteria.
3. Assessment of the performance of recent designs through post-project appraisals of 40 selected case studies.
4. Implications of variance in performance.
5. Extrapolation from case studies to national scale.

Objective 4

4 *Investigate the potential significance of other indirectly related rainfall issues of climate change that might affect drainage design and operation*

Study tasks

1. Groundwater influence on infiltration, treatment volumes, treatment processes and spill frequency.
2. The influence of changing SMD on drainage modelling.
3. The derivation of NAPI for design events.
4. The impact of increasingly spatial effects of high intensity rainfall and the future use of radar.
5. The climate change influence in summer on water quality impact on rivers.
6. The impact of the increase in sea, river and lake levels.

Objective 5

5 *Re-visit the subject of design standards and appropriate drainage systems in the light of changing weather conditions and modern sustainable drainage practice*

Study tasks

1. Produce a summary of drainage design practice elsewhere in the world with particular emphasis on trends in the developed world especially where rainfall is of a similar nature to that likely to be found in UK in the future.
2. The use of major / minor systems for extreme event drainage and the related issue of DTM modelling of overland flows.
3. The trend in litigation relating to flooding.
4. The influence of climate change on the current debate on sustainable drainage.
5. The choice between separate or combined systems with respect to climate change.

Method of Approach

1. Inception meeting

The project start will involve the development of a work plan and project procedures which will ensure that project progress can be managed and reported and the quality of the work is assured. Any points of clarification outstanding from the submission will be resolved. The work plan will be discussed and agreed at the inception meeting with the steering group.

2. Steering group

The steering group are assumed to be representatives from all the Water Companies. The points of view of delegates will be taken on-board by the project within the constraints of the funding proposed.

It is proposed that Steering group meetings will be held at HR Wallingford. Any location is a compromise, but this is thought to be the most appropriate one in terms of distances to be travelled by the research team representatives and the Water Company representatives.

As the total cost of the project is quite high and a number of optional subject areas are included in the proposal, it will be important to be clear what is and is not covered by the study. This also applies to the depth of the analyses as many of the areas, for instance infiltration and its impact, could be very large studies in their own right. This first meeting will therefore be very important in clearly defining the detailed scope of the project.

3. Objective 1

Objective 1 is aimed at providing the water industry with the reference information needed to relate the current rainfall design standard (FSR) to the updated standard (FEH) and to the projected future status of rainfall in the year 2080. Although FSR might be regarded as the present design standard, FEH has shown that it does not reflect present day rainfall conditions. The FEH should be regarded as the best approximation of present day rainfall to allow the comparison to be made with the differences that climate change will make.

Objective 1 – task 1

Establish the difference in rainfall depth between the FEH and FSR methods for the whole UK. Produce these as A4 maps and digital maps. 49 pages for 7 return periods and 7 durations plus 1 for SAAR. Colour and contour factors to highlight differences. Produce set of 49 maps of FEH rainfall depth.

Task 1 involves establishing the difference between the FSR hydrological status around the country and the "present day" condition. The assumption that the FEH work represents the present day is only approximately true; both because science can never be perfect and also the data set, being based on 1961 – 1990, is historic. However at present there is little alternative to this assumption. This comparison allows a country-wide resolution which is detailed, whereas task 2 (the effects of climate change) is both a much lower resolution and less certain. It is therefore essential to use FEH as the base line for comparison with both the past (FSR) and the future (Climate change).

There are only two organisations capable of providing this (FEH / FSR) information on a country-wide basis; CEH and the Met Office, as both have access to the underlying data set behind the FEH rainfall. Other drainage engineers need to purchase FEH and carry out an assessment for each location to determine the difference between FSR and FEH rainfall for any particular return period and duration. The resolution of this work is in the region of 1.3 km^2, which is extremely high. It is important for drainage engineers to be able to get a rapid and easy understanding of the differences between these two methods and therefore it is proposed that all the relevant return periods and durations are produced as A4 maps for reference. These maps will provide rainfall depth ratios for the whole country. These will be contoured and coloured to draw particular attention to ratios where differences are large. The return periods to be used are 1, 2, 5, 10, 25, 50 and 100 years with durations of 15 and 30 minutes and 1, 2, 3, 6 and 12 hours. This will be a book of 49 maps. Finally one more map will be produced which will be the depth ratio of SAAR (the average annual rainfall). As all the information will be ratio information, there will need to be either a background layer of rainfall depth contours (based on FEH) to enable depth of rainfall to be calculated, or a second set of maps. The latter will be less confusing.

An optional additional development of this work will be the production of a CD of the maps which will allow close scrutiny (and therefore high resolution information) of the particular location of interest. A base map of UK from Ordnance Survey showing towns and rivers and the National Grid will be used to overlay the maps to allow people to locate the area of concern easily.

Objective 1 – task 2

Evaluate the latest research projections regarding potential changes to rainfall characteristics for the next 100 years over the UK. Regional rather than high resolution evaluation. (Current best available knowledge). Report to evaluate range and accuracy of predictions using some form of confidence measure.

The Met Office has been involved in research into climate change and the effect this is having on rainfall across Britain. The Met Office's Global Circulation Model will be used which feeds data as input to the more refined Regional Climate Model (RCM). The RCM models a predicted future climate over 20 years from 2080 to 2100, and it is this climate, and rainfall, that will represent the "future climate" against which the "current climate" will be compared in this project. This is a wide ranging issue which relates to resource reliability, crops, ecology and river flooding, to name just a few. This project however will focus specifically on the likely hydrological changes that might be expected over the next 100 years for events from 15 minutes to 12 hours. The context of more extreme events and longer durations and seasonal issues will not be ignored, but particular emphasis will be placed on the hydrological conditions which are particularly relevant to the Water industry and drainage systems. (The related issue of spatial effects is also to be covered and is dealt with under Objective 4). An envelope of change will be produced based on a range of possible future scenarios related to the "drivers" created by the developing world.

This work will be a stand-alone document. A useful addition to this document, will be a reference of other national and international studies recently carried out on climate change effects on related subject areas.

Objective 1 – task 3
Produce same factoring of rainfall depth of FEH (Present day) for 2080. 49 A4 and digital maps plus SAAR.

The results of the Met Office study will be used to define a median probable hydrological condition for a target year of 2080. It is possible that this figure may be altered at the inception meeting, but as the Met Office model uses 2080 as the target year any change to this would add significantly to the cost of the project. The predicted conditions would consider the same envelope of events at a resolution that is considered realistic by the Hadley Centre. From this information a second set of 50 maps will be produced giving the depth ratio information between present day events and those in 2080.

Objective 1 – task 4
Produce same factoring of rainfall depth of FSR to 2080. 49 A4 and digital maps plus SAAR.

As the current concern is that much of the existing infra structure has been designed and built to FSR rainfall data, it is thought that a final set of reference maps showing the difference between FSR and project conditions for 2080 should also be produced. This can be determined by examination of the previous two sets of maps and calculating a value for the FSR / future state rainfall ratio, and is therefore not strictly essential. However this would be tedious and as a great deal of concern relates to structures designed to FSR, it is thought this this set of maps is also important to produce.

4. Objective 2

The industry currently uses a stochastic generator to generate time series rainfall and symmetrical rainfall design events. There is a need to provide a method to take account of the changes that are predicted to take place in the future for both types of rainfall data sets.

Design rainfall profiles are produced by FEH based on a data set from 1971 to 1990. The depths are location specific based upon an analysis of rainfall characteristics throughout the country. In general these might be considered to be representative of present day conditions and are more or less accurate for any point in the country.

The Stochastic time series method is a two stage process; the first is the generation of hourly information, the second is the processing of this hourly data set (or a real hourly data set) and production of a 5 minute data set. To take account of climate change there will be a need to process the hourly data (real or stochastically generated) and modify it, taking into account seasonal effects as well as anticipated annual changes. This would probably be a non-linear process to ensure hourly intensity profiles reflect the expected increases in intensity as well as volume and duration of rainfall.

The second stage of dis-aggregation could therefore continue to use the existing dis-aggregation tool. However work carried out seems to indicate that extreme events are significantly under-predicted by the current tool for the 5, 15 and 30 minute periods. Although investigations into this limitation have not been extensive, there is general unease about this aspect of the tool. It is therefore proposed that the same tool is modified or a new one built using the same hydrological principles, but with the addition of correlation tool which is "trained" on one or a group of representative autographic gauges in the area of interest. This tool would establish the intensity frequency relationship for short extreme events and ensure the dis-aggregation process matched this information. This could then be enhanced for climate change effects as a second stage, if it is thought that the short duration rainfall intensities were likely to change in the future. This would ensure greater accuracy and ensure the information was more representative for every location.

Whatever is done must be made readily accessible to industry. To this end Wallingford Software will make this information available, subject to satisfactory discussions related to IPR and copyright.

Objective 2 – task 1
A utility that regionally factors TSR events and design storm events to take account of climate change for the future.

A tool or methodology is needed to provide the necessary uplift to design events and TSR data. This uplift on both the TSR data set or design events will take account of regional differences and also the varying characteristics which are a function of duration and return period. Again the target year will be 2080.

This correction factor may be a simple one based upon anticipated volume differences, but it is more likely to be more complex and alter the intensity profile ratios that currently are used. The correction factors will also consider the anticipated seasonal changes which are expected with climate change. This is particularly relevant for modifying time series rainfall. However these issues can not be pre-judged at this time and will be determined by the study. The output from task 2.1 will either be a tool or a detailed specification for a tool depending on discussions between Imperial College and Wallingford Software.

Objective 2 – task 2
Linkage to Wallingford Software products to allow global usage by drainage practitioners throughout UK.

Because of the importance of universal access to these tools, Wallingford Software will either implement the specification or arrange for integration or linkage of these facilities into their drainage software, which is used throughout the UK, subject to discussion on issues relating to IPR and royalties.

Objective 2 – task 3
Produce a rainfall dis-aggregator which reads historical hourly data and produces 5 minute data trained on regional or individual autographic "training" sites.

The current stochastic dis-aggregator used as part of the stochastic rainfall generator used in Britain is not specifically based on local data. It is proposed that more emphasis is placed on autographic real data close to the site of interest to "learn" the local event characteristics and then to transform hourly data, either real or stochastically generated, to 5 minute information. Again climate change will be taken into account by appropriate factoring of this processed information. This tool will effectively use the most relevant (and up to date) information to produce the best available set of events for design or analysis.

This is an optional development, but as the FEH work has shown, there is far greater variability of rainfall across the UK than is found in FSR. It is felt that much greater emphasis is therefore needed on using real local data than is currently done. Work carried out recently has suggested that high intensity rainfall of short duration is under predicted by the current dis-aggregator. It is therefore considered important to provide a modified dis-aggregator for producing 5 minute information from hourly data.

At present the price for this element is based on using autographic data from only a few gauges in order to test the methodology. The proposed methodology does not need to use all 68 autographic gauges (from the Met Office) to develop this tool. If, in discussions, the direction of this element of the research is changed by the steering group and requires the use of all 68 gauges, the Met Office would only charge an additional £10,000 for this information. This only represents the time to provide the information and no charge would be levied for the data itself.

5. Objective 3

The objective of this task is to identify whether designs undertaken in recent years are adequate and appropriate to meet required regulatory performance criteria in the face of the predicted changes in rainfall patterns. If, as is to be expected, performance is not adequate, this task is to estimate the scale of the variance from future needs including the cost implications for future investment. We propose that this work be divided into the following tasks:

1. Estimate of changes in return periods.
2. Identification and agreement of regulatory performance criteria
3. Assessment of post-project performance of selected case studies.
4. Estimation of scale of variance and cost implications
5. Extrapolation from case studies to national scale

Each of these tasks is outlined in the following sections.

Objective 3 – task 1
Assessments of the reduced level of service of drainage structures built to FSR criteria, for present day and design horizon (2080) by determining change in return period for any given FSR return period. 49 x 2 maps – A4 and digital.

The implication of climate change for drainage structures is not linear. Therefore the effect of climate change needs to be assessed using network models (which is the subject area of Objective 3 – task 2). However a rapid evaluation of the potential under design of a structure can be related to the reduced return period of any (FSR) design rainfall used for the design or analysis. This information is easily transformed from the mapping information produced as an output from Objective 1. Again this could be considered as an option as the basic information is already produced as rainfall depth and ratio maps as part of Objective 1. However, it is thought that the additional cost of providing another set of maps would be worthwhile for this project.

Two sets of 49 maps will be produced showing the reduced return period of any event for a given duration to provide a rapid indication of the reduced protection level. One set will illustrate the difference between FSR and FEH, and the second will be the difference between FSR and 2080.

Objective 3 – task 2
Agreement of appropriate regulatory performance criteria

Sewerage systems are currently designed to comply with a range of regulatory performance criteria agreed with the financial and environmental regulators. These criteria include: flooding, spill frequency (from CSOs), aesthetics (e.g. screening), receiving water quality (percentile standards, UPM standards, bathing waters etc). Before assessing performance of systems under predicted future rainfall and the cost implications of any performance variance, the level of service to be achieved needs to be agreed. Two alternative approaches that suggest themselves are to target compliance with all relevant existing standards or to aim for "no deterioration" based on actual current performance of systems. This and other permutations, will need to be agreed in detail at the Inception meeting in order to ensure the work is targeted to meet the needs of the Water Companies.

Objective 3 – task 3
Assessment of the performance of recent designs through post-project appraisals of selected case studies.

It is expected that the case studies will generally be limited to sewerage networks that have been studied either under AMP2 or now under AMP3. Montgomery Watson, having term contracts with many English Water Companies and Scottish Water Authorities, have experience of a wide range of sewerage catchments. With the permission of their water industry clients, Montgomery Watson would be able to draw upon a very large data set of models and information on sewerage systems and CSOs. These models will be used, together with the performance criteria agreed in Task 3.2, to arrive at the performance implications of climate change.

The first part of this task will involve identifying sources of project case studies and selecting suitable examples. The case studies will be selected to represent variations in sizes and types of catchments. We have allowed for carrying out case studies of 10 verified and audited models of different catchments. This is based on investigating combinations of a range of catchment sizes (small/medium/large), catchment types (urban/rural/mixed). The network models would be run in combination with different receiving waters, representing discharges to both coastal and inland waters. Montgomery Watson can assist in identifying suitable models from their previous work and we are assuming that permission will be given to use existing verified network models for this purpose.

After reviewing the data and existing models for each case study and revising/updating the models where necessary, simulations would be carried out to compare performance under present and future climate scenarios.

Objective 3 – task 4
Implications of variance in performance

The implications of the difference (variance) in performance under current and future rainfall patterns may be expressed in two ways:

- The reduction in levels of service if no corrective action is taken;
- The costs to maintain the desired level of service.

We consider it will be necessary to interpret the findings of the case studies in both these ways. The first measure will indicate the severity of the effect on performance criteria such as spill frequency, flooding and water quality. The second measure will indicate the capital and operating costs associated with maintaining the desired level of service. These costs will include the up-rating of sewerage elements such as CSO structures and screens and also modified operating costs associated with pumping and treatment at WwTWs of different flows.

If desired, an evaluation could be made of the environmental costs of the impacts avoided (i.e. the benefit from the investment to maintain levels of service) so that a cost-benefit assessment could be made. However, we have not allowed for the economic evaluation of impacts in our present proposal.

A wide range of different engineering solutions might be adopted to achieve the required level of service. For the purposes of this task, conventional solutions (e.g. additional storage in the sewer system) will be adopted rather than innovative approaches such as increased use of permeable surfaces or washlands. The scope for innovative solutions will be investigated in Objective 5 and the costs of conventional solutions developed in this task (Task 3.4) will provide a benchmark against which to compare alternatives.

Objective 3 - Task 3.5
Extrapolation from case studies to national scale

The cost implications from the case studies will be scaled up, based on an assessment of the extent of catchments with similar characteristics, to give an estimate of the additional investment required for the UK as a whole.

6. Objective 4

The principal aims of the study are those in Objectives 1 to 3. This enables drainage engineers to proceed with assessment of existing drainage systems and design new ones. The cost implications will also have been summarised.

However there are a number of issues related to climate change which the industry would usefully investigate to make sure that all the implications of climate change that might affect drainage are considered. Objective 4 looks at modelling issues and other hydrological aspects and reports on their potential influence on drainage systems and to highlight what investigative work might be required in the future.

There are a whole range of possible items to investigate, some being less obvious than others. For instance socio-economic and demographic changes caused by global pressures and not just local changes may well have a significant effect on population growth and changes in effluent volumes. Other aspects such as ground drying and shrinkage in summer causing more failures and adding to the infiltration problem, the growth of rodent populations, the possibility of septic sewage, the effect of water seeking tree roots and general vegetation and land use changes; all these might have significance. However to limit the scope of the project, many of these are not proposed as they are not considered to be of primary importance for this study.

Objective 4 – task 1
Groundwater influence on infiltration, treatment volumes, treatment processes and spill frequency

The influence of groundwater on infiltration into sewer systems is well known. The importance of the subject is easily seen by examination of inflow records at WwTW. This task area will try and quantify the potential for increasing (and possibly decreasing) levels of the groundwater table. Increasing water table levels are clearly likely to increase inflows, but ground drying also creates situations in some soils of higher risk of pipe fractures. An assessment will be made of the likely change (both in terms of level and duration) by contacting the Environment Agency and other sources of groundwater expertise.

The results of this investigation will lead on to an assessment of a number of potential impacts on drainage systems. The first is the effect on treatment volumes. In addition to the effect of additional rainfall causing additional volume of effluent to treat, the potential additional volume due to infiltration could be even more important due to the extended period of time that high inflows take place during dry weather periods. The analysis of a number of inflow flow recorders at WwTW together with an analysis of daily or monthly rainfall will provide a useful practical starting point to quantify the problem. Projected changes of wetter winters and drier summers will then enable projections to be made.

In addition to volumes to treatment, WwTW processes will also be affected by the increased dilution of effluent in winter. This aspect will be investigated and take account of the much higher expectations of consents and the move to more advanced treatment processes which will tend to be used in the coming decades.

Infiltration is often a significant part of dry weather flows in systems. CSOs are designed to only pass a certain additional storm flow in combined systems and the implications of additional base flows will be examined to try and quantify the level of increased spill frequency. Separate systems are even more affected by infiltration, as little allowance is provided for additional flows other than waste flows. The increased risk of pipes being under capacity due to infiltration will therefore also be examined.

Objective 4 – task 2
The influence of changing SMD on drainage modelling

Soil Moisture Deficit is a measure of the wetness of the ground. It is used in computer runoff models to reflect the additional runoff that will take place from permeable (vegetated) areas. An evaluation of increased soil wetness will be made by the Met Office and this will then be used to demonstrate the (probable limited) impact of runoff in terms of modelling and discuss the implications for drainage systems.

Objective 4 – task 3
The influence of changing NAPI on drainage modelling

The New Antecedent Precipitation Index is used in the more recent Wallingford Procedure runoff model. The value of NAPI that should be used for design events has yet to be resolved. This subject will need to be assessed some day, but is not in the brief, though it could be carried out. However the climate change study will allow an evaluation of the increase in NAPI value for different regions for both design events and Time Series rainfall.

Objective 4 – task 4
The use of SOIL in urban drainage modelling and HOST in the FEH procedure

Urban drainage modelling uses two types of Wallingford Procedure runoff models. The New PR equation uses a decay function which is based on the FSR categorisation of soils into 5 SOIL types. SOIL is also a function of the Old PR equation. The implications of the change to HOST classes in the FEH to determine runoff needs to be considered for urban drainage runoff modelling and the implications that this has for the Wallingford Procedure runoff models. This does not have a direct link to climate change, but if FEH rainfall with climate change is to be the basis of future drainage analysis, consideration of this issue is important.

Objective 4 – task 5
The impact of increasingly spatial effects of high intensity rainfall and the future use of radar

DG5 flooding is often linked to intense short events which cause serious flooding but usually over a confined area. Radar images over recent years have regularly shown that these events are very limited spatially. Climate change is likely to cause an increase in these types of events. An in-depth study of the subject would require extensive evaluation of archived radar data, but an overview of the expected increase of such events due to climate change will be considered. This subject is already an issue for use of rainfall in design as the use of Areal Reduction Factors (ARF) currently is based on FSR which is generally based on longer events and therefore frontal rainfall.

A brief study on one or two test catchments can be carried out to investigate the effect of spatial events of high intensity and compare the results with the current use of ARF which aims to take account of spatial rainfall. As this is not an essential feature of the bid, the study of test catchments should be considered as an option.

Objective 4 – task 6
The climate change influence in summer on water quality impact on rivers

Climate change is not only expected to increase both total rainfall depth and intensity, it is also likely to increase the duration and frequency of periods of drought. This will have an impact on rivers and their water quality. This would initially not seem to be an issue for the water industry, but the build up of pollutants on the catchments and their washoff into rivers during short sharp events, will have a considerable negative affect on these water courses and lakes. In summary therefore this task will consider the probability of the increase of droughts, the impact on river flows and the increase in pollution that is likely to take place from urban drainage sources.

The depth of analysis will be very limited as the subject area is very large and diffuse.

Objective 4 – task 7
The impact of the increase in rivers, lakes and sea levels on drainage design and operation in the next 100 years.

Sea level rises are now accepted to increase in level over the next century. In contrast the rise in level of rivers is both less certain and the durations when they are in flood are limited. However the impact on these changes will be felt in a number of areas. Examples are:

- Pumping stations will be pumping water against slightly increased heads.

- Gravity drainage tanks (on the coast) will have less of the tidal cycle within which to discharge and more of the cycle to provide storage.
- Hydraulic gradients, and therefore the capacity of outfall pipes, will be reduced.
- Areas more prone to flooding may need to have backwater protection devices retro-fitted to prevent internal flooding with sewage.
- Overflows becoming submerged more frequently.

In general, drainage is designed using extreme short event rainfall. This is rarely experienced when rivers are in flood and therefore the implications of this issue for drainage design into rivers is likely to be limited. The study will carry out a review of the likely degree of impact of climate change on the rise of receiving water levels.

7. Objective 5

Objective 5 looks wider than objective 4 by visiting the framework of standards and principles of drainage currently applied in the UK. It is important to consider the use of new approaches and techniques to cater for changing climate, changing expectations of society and make use of the increase in knowledge and technology.

Objective 5 – task 1

Produce a summary of drainage design practice elsewhere in the world with particular emphasis on trends in the developed world and where rainfall is of a similar nature to that likely to be found in UK in the future.

The drainage standards of nations are often quite different although there is now a degree of convergence do to the natural effects of globalisation and international spread of knowledge as to best practice. However, different climactic conditions will always create differences in approach to drainage design and operation. The Met Office will produce an overview of where rainfall is currently experienced elsewhere in the world is similar to that which might be expected in the UK.

With the expectation of increasing levels of service by the community and the increasing technical capability of technology and engineering skills, this subject area is never static.

This subject for investigation must therefore draw on the standards applied by communities who currently have climactic conditions which might be experienced by Britain over the coming century. However it is also important to take account of the direction in which drainage standards are moving, specifically in those countries with expectations of a high levels of service, particularly those with a climate which is of relevance to this study. This needs to take into account both the increased severity of rainfall, but also any seasonal implications for drainage design.

A further report can be produced to show the impact of weather experienced by countries currently experiencing conditions which may be experienced in UK in the future. This is not strictly required by the brief, but would graphically illustrate the problems that can be anticipated.

Objective 5 – task 2

The use of major / minor systems for extreme event drainage.

Countries in which extreme rainfall events occur have accepted the concept of overland flooding and flows. There are relatively few countries who specifically cater for this issue by designing for these events by specific consideration of the hydraulic processes. Generally there is an expectation of a lower level of service and the capability for dealing with the results of flooding. However, the tools now exist to enable planning to control surface flooding caused by extreme events and it will be useful for the water industry in UK to take advantage of the benefits of existing approaches now being pursued by these countries.
The study will summarise the approach taken, the criteria applied and the planning issues relating to it.

Objective 5 – task 3
The use of DTM models for modelling overland flows

A related issue to task 5.2 is the technology that is needed to enable the planning and design of controlling overland flooding caused by extreme events and also the prediction of flooding impact on an area. An outline of the tools which are now available and are likely to be available in the near future will be made. The study will summarise the uses and benefits of applying these technologies.

Objective 5 – task 4
The trend in litigation relating to flooding

The modern world is becoming more litigious, particularly in the area of community services. With the increasing risk of flooding caused by climate change, it is thought appropriate to report on the trends in litigation, especially looking to other countries to establish the key drivers which cause litigation and the methods being used to minimise its impact on service providers.

Objective 5 – task 5
The influence of sustainability on the design and performance of drainage networks

Drainage design has recently been involved in a debate on the use of other methods of dealing with rainfall runoff which have a umber of environmental benefits. The use of many of these options is limited and experience in their robustness is still being established. However it must be recognised that these drainage methods are going to become more commonly used. It is therefore proposed to briefly evaluate the implications of using these methods in the light of the expected effects of climate change.

Objective 5 – task 6
The choice between separate or combined systems with respect to climate change

An area of investigation which is probably not of direct interest of Undertakers for this study is the debate over the use of combined sewers compared to separate systems. For example, research over the last 5 years has shown that trying to pass all flows through treatment is not necessarily best practice, and that surface water systems are not "clean" and have a significant pollution impact. The implications of this, together with the cost of building and operating twin sewer systems, and the difficulty of preventing cross connections, will be examined with a brief summary of the advantages and disadvantages of using combined sewers. This will be supported by using a real model of a combined system and predicting pollution loads for the two scenarios of combined and separate systems.

8. Other Tasks

The objectives of the study have been detailed in the previous sections. There is at least one further task which needs to be addressed and that is the promotion of the results of the research.

Launch seminar
A launch seminar is planned to take place at HR Wallingford. If it is thought appropriate this will be repeated in Scotland at a suitable venue provided by one of the Scottish Water Authorities.

This will be a one day seminar for which promotion flyers will be produced. Speakers will include members of the research team and the steering group. The latter speakers will ensure that the perspective of the Water Industry on this subject is properly presented.
It is suggested that there should also be an interim seminar made mid-way through the project. It is felt that once the analysis and tools on rainfall enhancement are available for the industry, that these should be announced and made available, before the completion of other tasks. Although this might seem a little unusual, the industry needs to have this information at the earliest opportunity.

Take-up of the research
Take up of the research is essential and therefore it must be rapid and easy to obtain. The phased approach of the research must allow the results to be presented and used before the project is completed. A communications plan is therefore shown to allow the take up of the results to be facilitated.

Outputs & Communication Plan

HR Wallingford will produce all reports, CDs maps and any other interim or final output of the study. The format will conform to UKWIR requirements.

The impact of this project on the construction industry would be immediate and therefore dissemination of the results must be rapid and widespread. Project outputs will take the following forms:
Technical reports on the work and findings of the project. These will be:

- The Climate change study
- The set of reference hydrological maps and supporting user summary report
- The tools and research analysis for modifying TSR and design events
- The cost implications of climate change to the water industry
- Related hydrological phenomena and their impact on drainage
- Standards of design revisited in the light of climate change

This information will be made available in stages through the project to ensure maximum benefit is obtained by the industry, subject to approval by the Steering group.

Press releases to industry bulletins with wide circulation such as Research Focus, Construction News and Water bulletin will be made at the start and at regular intervals as and when the steering group feels that they are appropriate.

An Industry seminar will be held to promote the findings of the project. It is proposed that the launch seminar is repeated in Scotland. An interim seminar is also proposed to facilitate the early use of the rainfall data and tools before the end of the project.