



HR Wallingford
Working with water

Incorporating drought risk modelling as a planning tool for climate change adaptation measures in Saint Kitts and Nevis

Design of the drought prediction tool



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Client representative	Ramiro Salinas
Project manager	Gina Tsarouchi
Project director	Nigel Walmsley

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Prepared Gina Tsarouchi	Approved Azucena Rodriguez Yebra	Authorised Acuzena Rodriguez Yebra
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1 Background

1.1 Project summary

In an effort to address the impacts of climate change and climate variability in a sustainable way, access to critical information within the water sector is vital. Drought prediction models can identify areas most susceptible to water supply variability and shortages, and therefore facilitate early action to manage risks. In doing so, this will increase resilience in the water sector to improve use of water resources and therefore ensure food security and water usage including from the agricultural, domestic and tourism sectors in the two islands of Saint Kitts and Nevis.

The overall objective is to incorporate drought risks modelling as a planning tool for climate change adaptation measures in Saint Kitts and Nevis. The main outputs include:

- Map stakeholders and establish a stakeholder working group;
- Assess drought risk and water resources in Saint Kitts and in Nevis;
- Benchmark, design and implement a drought prediction tool in Saint Kitts and in Nevis;
- Train administrators and users of Saint Kitts and Nevis to use the drought prediction tool.

The Project outcomes respond directly to SDG 13 'Taking early action to combat climate change and its impacts' by providing a system that will support planning and decision-making for the sustainable management and conservation of water resources in Saint Kitts and Nevis. The Project will also contribute to SDG 1 (End poverty), SDG 2 (Food security) and SDG 6 (Availability and sustainable management of water) as the drought prediction tool will improve agricultural practices and use of water resources, improve food security and increase the income of rural communities.

1.2 About this report

This report presents the design of the drought prediction tool, including a suggested implementation plan and operational framework. The report outlines key concepts, the independent systems that are assembled to deliver the St Kitts and Nevis (SKN) drought forecasting system and the relationships between them. The SKN drought forecasting system is a set of independent systems which are brought together to deliver the complete drought forecasting capability.

These systems include a Groundwater and Water Balance Modelling System that provides a forecast of surface water and groundwater availability and a set of satellite-based Drought Indicators that provide information on the current and future state of drought for the two islands.

The Groundwater and Water Balance Modelling System is an implementation of the Variable Infiltration Capacity (VIC) model suite including the groundwater AMBHAS component. The suite is set up using a series of supporting files populated by a set of variables calculated from Earth Observation re-analysis products, survey products and in-situ monitoring.

Section 2 of the report gives an overview of the conceptual framework that underpins the drought forecasting system, presents the high-level structure of the system and provides a more detailed description of the main components of the system. Section 3 of the report focuses on the implementation plan and operational framework of the system. It defines the key roles of organisations that support the implementation of the system, the hosting arrangements, operational functions and recommends communication channels to be used for the dissemination of information generated by the system.

2 Structure and components of the drought forecasting system

2.1 Conceptual framework

The typical components of a drought forecasting system are shown schematically in Figure 2.1 alongside the work flows to generate and deliver drought forecasts.

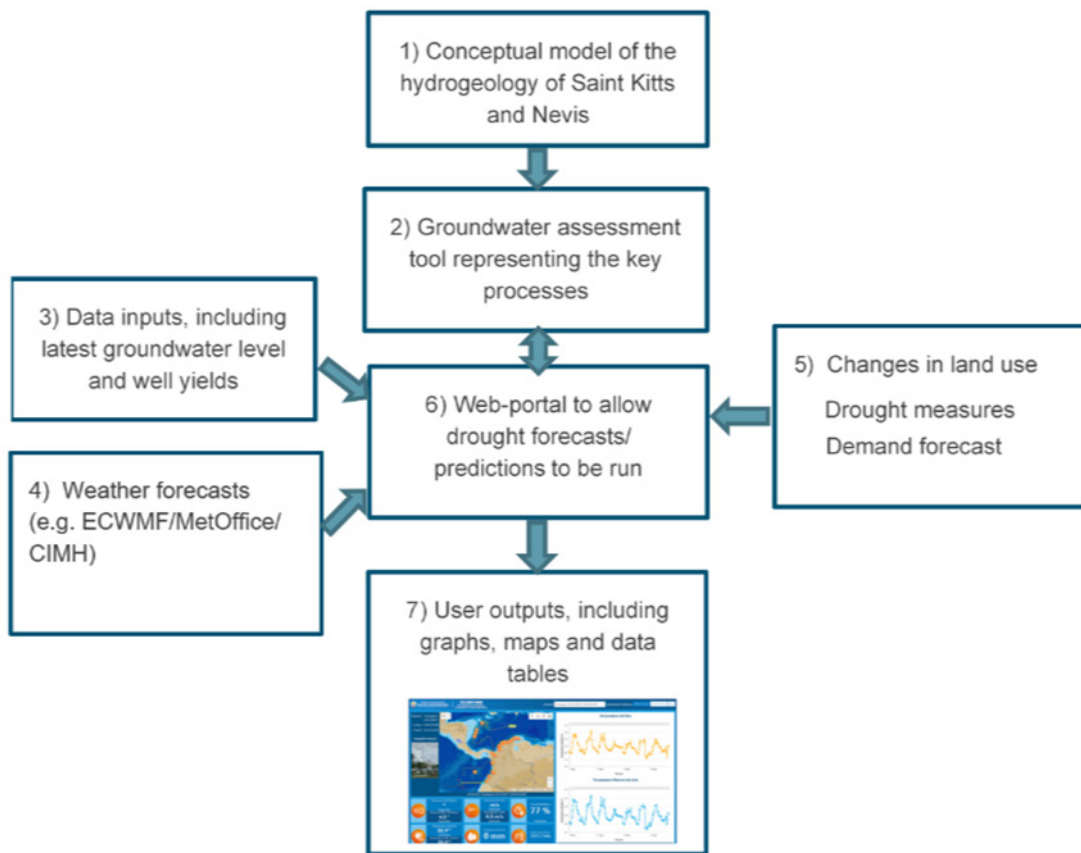


Figure 2.1: Typical components of the forecasting system

Source: HR Wallingford, 2022

2.2 High-level structure

The Drought Forecasting System for Saint Kitts and Nevis comprises a set of independent systems and datasets which are connected together via data flows and formatting functions.

The systems are as follows:

1. Data Management System:

- The Data Management System harvests data from multiple Earth Observation and in-situ observation sources as well as data from forecasting models. It post-processes this data, formatting, scaling and standardising it and stores it in various data stores. The data management system

transforms and delivers these complex climate datasets to the web application for visualisation and display.

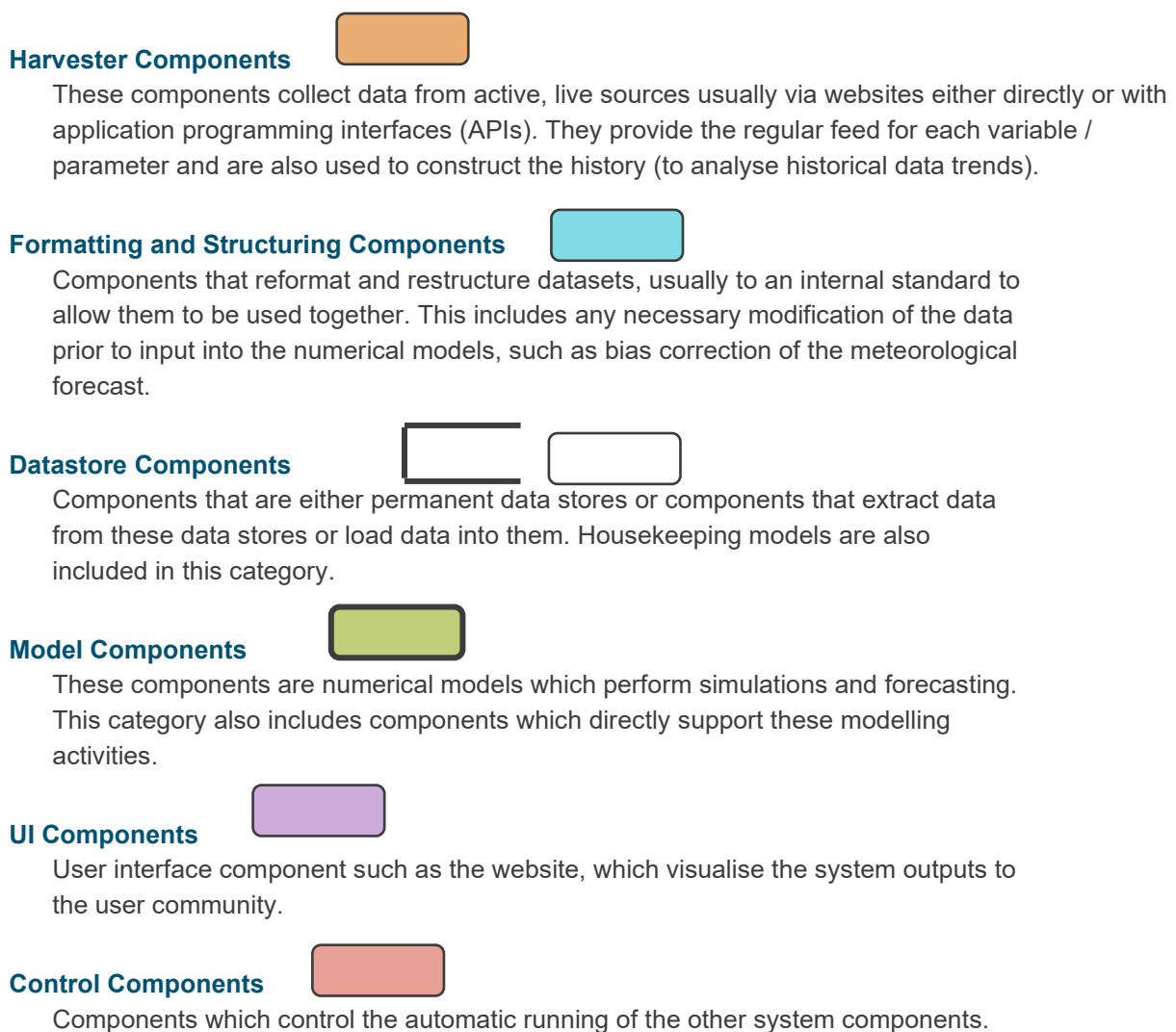
2. Water Availability Modelling System:

- The Water Availability Modelling System is a hydrological modelling suite which produces a forecast for a set of parameters which, together, describe water availability. It is driven by a seasonal meteorological forecast.

3. Data Visualisation System:

- This is a website which displays an ensemble drought forecast, the drought indicators and information from static layers (e.g. landcover, population density) together with associated information pages.

Technically, each of these systems consists of services, processing components and datastore components divided into the following categories, which are shown in [Figure 2.2](#):



The generic information flow between these various systems and component types is given in the figure below.

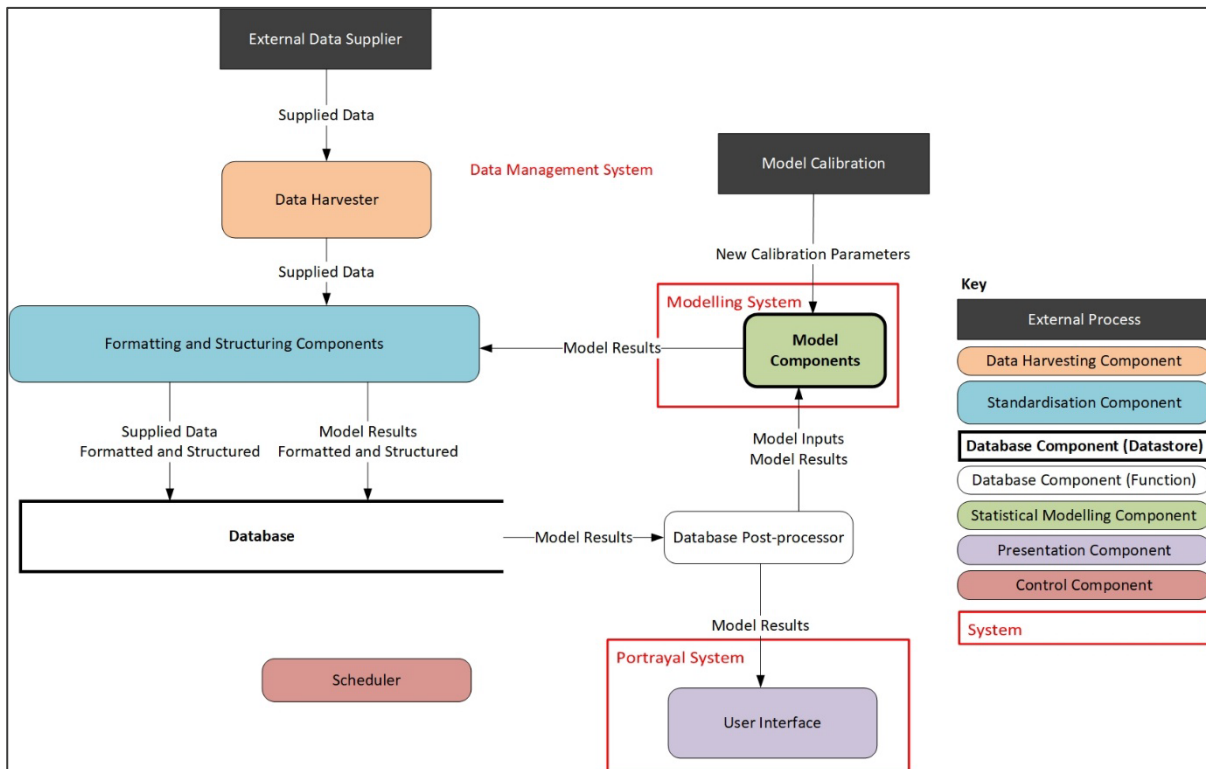


Figure 2.2: Drought Forecasting System process data flow diagram

2.3 Details of main components

2.3.1 Data harvester components (live)

A suite of harvesting modules collect regular feeds of data from the three different types of input:

- The ECMWF seasonal meteorological forecast;
- A set of Earth Observation sources providing inputs of various kinds, usually hydrometeorological;
- The latest data from ground-based monitoring stations (this is aspirational and could be included in a future version of the tool, especially once ground-based monitoring stations are automated and standardized).

Data is harvested regularly for the following co-variables:

- A subset of the large amount of meteorological variables included in the ECMWF forecast product. It is used by the Water Availability Model and also to calculate the forecasts of some drought indicators (SPI, SPEI);
- NDVI provided by Google Earth Engine;
- Precipitation provided by CHIRPS. It is used to calculate SPI, PET and SPEI;
- Temperature provided by ECMWF, interpolated to the chirps grid resolution. It is used to calculate SPI, PET and SPEI.

2.3.2 Formatting and structuring components

A comprehensive set of modules which change the format and structure of data files to deliver standardised outputs for digestion by the web application. These functions include:

- format and structure each independent input ready for further processing;

- translation into the internal standard NetCDF file for the water availability modeling; translating downloaded climate and earth observation data into geotiff and json for web consumption, charting and graphing;
- Spatial interpolation of data into other gridded datasets and locally relevant governance boundaries (e.g. parishes of St Kitts and Nevis).

Wherever possible, file structures and formatting is standardised to a local standard devised to be optimal for the system operation.

2.3.3 Datastore components

Many temporary files are created and deleted when components are run. However, permanent data stores are also required to support the system. Some of these are also used to build up data archives detailing a complete history of system activity. These datastores are supported by components to synchronise data between them and load standardised data into them.

The following datastores / datastores are required:

Observation and Forecasting Datastore:

- A datastore which contains all of the data collected by the harvesters. This datastore is divided into two:
 - 'Live', which contains all data files currently required for running the next forecast; and
 - 'Historical', which stores the main data files from previous runs.

Ground station Datastore:

- A folder structure containing all of the latest data on observations from ground stations in St Kitts and Nevis.

Drought Forecasting Datastore:

- A relational datastore, which supports the Water Availability Models by storing all of the associated inputs and outputs required by the model. It is designed around MultiPolygon structures which are used to reflect all geographical administrative levels.

2.3.4 Model components

As discussed above, the system contains two modelling systems, the **Groundwater and Water Balance Modelling System** that provides a forecast of surface water and groundwater availability and a set of satellite-based **Drought Indicators**. These model components are each supported by a set of small components which pre-process input data, manage the model runs and post-process output data.

Groundwater and Water Balance Model:

- As discussed above, the Groundwater and Water Balance Modelling System uses an implementation of the Variable Infiltration Capacity (VIC)¹ model at its core. A set of accompanying utilities and control scripts manage the creation and update of the required files. The water availability forecast produced consists of values for groundwater levels, soil moisture, runoff and evapotranspiration.

Drought Indicators:

- As discussed above, the system uses satellite data to calculate a series of drought indicators. This is done by creating an understanding of the relationship between occurrence of droughts and certain

¹ <https://vic.readthedocs.io/en/master/>

hydrometeorological variables and then using forecasts of these variables to drive the forecasts of drought indicators.

2.3.5 User Interface (UI) components

The user interface (UI) component is the only component visible to the user community. The main user interface component is the Data Visualisation System.

Data Visualisation System:

- A secure website – the Drought Forecasting Website – which displays the results of the system components in a variety of ways alongside some of the historical data which has been input into the models. This component actively displays the drought indicators, the VIC model results and other supporting data. Three visualisation methods are used: maps, charts and tables;
- The website also includes supporting contextual information in static web pages.

2.3.6 Control components

The system's control components are a set of 'cronjobs' (scheduled tasks) which run the components in a set of schedules as follows:

- The harvesting components run regularly, according to the schedules of production of data from the suppliers. They collect the most recent data to add to the history of data held in the datastore components;
- The formatting and structuring components run whenever they are required as part of the other processes;
- The model components run once every month to provide new forecasts;
- Some of the UI components run every month following the run of the model components. These UI components arrange the outputs from the model run so that these outputs are available to portray;
- The Data Visualisation System is run continually. It is always available to the user community.

3 Implementing plan and operational framework

3.1 Roles and responsibilities

The two organisations who, together, are responsible for the running of the drought forecasting system are:

1. The **owner**, that is, DoE;
2. The **system supplier**, that is HR Wallingford.

The CTCN project ends at the end of December 2022. From this point onwards, DoE will be the owning user of the drought forecasting system in St Kitts and Nevis.

3.1.1 Owning user: DoE

As the **owner** of the system, DoE has the following roles and responsibilities in the operation of the drought forecast, as summarised in Table 3.1.

Table 3.1: DoE roles and responsibilities in the operation of the drought forecasting system

Role / Responsibility	Description
Governance of use of the system in St Kitts and Nevis	Decides which organisations have access to the forecasts. Communicates this information to the system supplier (HR Wallingford).
Communication with the system supplier on behalf of the user community	Coordinates and undertakes the main official and strategic communications with the system supplier. This does not include day-to-day user queries which users may undertake directly with the system supplier. Service interruptions are to be reported to the system supplier via email.
Day-to-day communication with end users	Undertakes day-to-day communications with users concerning the operation of the system and general feedback and clarification.
Building capacity amongst end users	Facilitates ad-hoc training with new end users on system features and with existing end users when / if new features are added.

3.1.2 System supplier: HR Wallingford

As the **system supplier**, HR Wallingford, has the following roles and responsibilities in the operation of the drought forecasting system, as summarised in Table 3.2.

Table 3.2: HR Wallingford roles and responsibilities in the operation of the drought forecasting system

Role / Responsibility	Description
Provision of drought forecasts	Provides the drought forecasts to the user community in St Kitts and Nevis in the form of a private website: The service levels for support of this system are detailed in Appendix A.
Communication with the owning user	Undertakes the main official and strategic communications with the owning user. This does not include day-to-day user queries which users may undertake directly with the system supplier.
Day-to-day provision of technical assistance to fix any system errors	Undertakes day-to-day communications with the owner concerning the operation of the system and general feedback and clarification.

3.1.3 Other key stakeholders

There is a wide variety of users of the drought forecasting system in St. Kitts and Nevis as summarized in Table 3.3. Some of these end users have the added responsibility of data collection and / or communication with the public based on the outputs of the system.

Table 3.3: End users for the drought forecasting system

Stakeholder	Role / Responsibility
Department of Economic Affairs and Public Sector Investment Planning (PSIP) Ministry of Sustainable Development	End user.
Water Services Department, Ministry of Public Infrastructure, Utilities, Posts and Urban Development	End user. Provision of data from ground-based monitoring stations periodically and as system is further enhanced and developed. Issuance of communication bulletins to the public based on the outputs of the system.
Public Works Department, Ministry of Public Infrastructure, Utilities, Posts and Urban Development	End user.

Stakeholder	Role / Responsibility
Department of Physical Planning, Ministry of Sustainable Development	End user. Provision of GIS base layer updates.
Department of Agriculture, Ministry of Agriculture, Fisheries and Marine Resources	End user. Issuance of communication bulletins to farmers based on the outputs of the system.
Environmental Health Unit, Ministry of Health	End user.
National Emergency Management Agency	End user. Issuance of communication bulletins to the public based on the outputs of the system.
St. Kitts Meteorological Services St. Christopher Air and Sea Ports Authority (SCASPA)	End user. Provision of data from ground-based monitoring stations as needed. Issuance of communication bulletins to the public based on the outputs of the system.
Farmers' cooperatives (several groups in SKN)	End user.
Department of Economic Planning Ministry of Finance	End user.
Nevis Water Department Ministry of Communications	End user. Provision of data from ground-based monitoring stations periodically and as system is further enhanced and developed. Issuance of communication bulletins to the public based on the outputs of the system.
Integrated Water Resources Management Unit Ministry of Communications	End user. Provision of data from ground-based monitoring stations periodically and as system is further enhanced and developed. Issuance of communication bulletins to the public based on the outputs of the system.
Projects Unit Ministry of Communications	End user.
Department of Public Works Ministry of Communications	End user.
Department of Physical Planning and Environment Ministry of Communications	End user. Provision of GIS base layer updates.
Department of Agriculture, Ministry of Agriculture	End user. Issuance of communication bulletins to farmers based on the outputs of the system.
Environmental Health Unit, Ministry of Health	End user.
Nevis Department of Disaster Management, Ministry of Agriculture	End user. Provision of data from ground-based monitoring stations as needed. Issuance of communication bulletins to the public based on the outputs of the system.
Nevis Meteorological Services Nevis Air and Sea Ports Authority	End user. Provision of data from ground-based monitoring stations as needed. Issuance of communication bulletins to the public based on the outputs of the system.

3.2 Operating costs

Table 3.4 below provides the indicative operating costs of the drought forecasting system.

HR Wallingford will not be able to cover the operating costs beyond the end of December 2022. The long-term plan, starting from January 2023, is for the system be funded through the DoE budget.

Table 3.4: Indicative annual operating costs for the drought forecasting system

Item	Cost (US\$)	Notes	Expected source
Cloud hosting	\$230	The entire system is deployed on the Amazon Web Services (AWS) cloud-based server. This is used for data storage, running models, and hosting the website.	DoE budget.
Operational and maintenance support	\$2,000	Costs for HR Wallingford staff to ensure that D-MOSS runs smoothly and effectively.	DoE budget.
Updating of water availability model	\$5,000	The updating of the water availability model allows incremental gains in accuracy owing to new data that continually becomes available. This activity is recommended every one-to-five years, but is not essential for operation.	DoE budget.
Totals (US\$):	\$2,230		

3.3 Generation of regular forecast bulletins and implementation of early drought warnings

A drought forecast looking forwards six months into the future is issued every month.

3.4 Communication channels (how would the information be released, who will access it)

A drought forecast looking forwards six months into the future is automatically issued every month by the system. These will be categorized by the various types of drought whether meteorological, hydrological and / or agricultural along with an alert level. Effective drought communication should be easy to understand and focus on solutions. The bulletins should include details as to the type of drought, the anticipated impacts and include parish-specific information. They should also focus on solutions and refer to the water conservation methods described in Output 2.

These bulletins are available for download by all end users. However, in the event an alert level is triggered, the DoE will email the bulletin directly to the key agencies charged with communicating with the public (Emergency Management Agencies, Met Office, Departments of Agriculture and Water Utilities).



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We design smarter, more resilient solutions across both the natural and built environment to help everyone live and work more sustainably with water.

HR Wallingford Ltd, Howbery Park, Wallingford, Oxfordshire OX10 8BA, United Kingdom
Tel +44 (0)1491 835381, email info@hrwallingford.com
www.hrwallingford.com