Overview of the fact sheets and briefing note

The **fact sheets** are designed to provide a **brief overview** on the ability of the river flow or groundwater models to reproduce (simulate) some of the most important components of the water cycle when using observed and modelled climate. This overview is given by sets of **statistics** (measuring the differences between two time series) and **graphs** (providing a visual comparison). Detailed information on the meaning of the statistics and graphs is provided in the **Modelling protocol** report (Crooks et al., 2012, SC090016/PN4) accessible from the FF web pages (www.ceh.ac.uk). This briefing note summarises the **meaning** and **relative importance** of the statistics and graphs. It **does not** provide any **interpretation** for specific catchments/model.

One **fact sheet** is delivered **for each site and river flow / groundwater level model combination.** If two hydrological models are used to simulate flow at the same site, two catchment fact sheets are provided for this site. Note that different models use different methods of **calibration** ranging from **catchment specific** to **regionalised parameters**. The advantage of a regionalised parameter model is to extend the climate range under which the model parameters are evaluated; this is particularly important in a warming climate for catchments where evaporation processes may change from a surplus of summer precipitation over evaporation to a deficit. The advantage of catchment calibrated models is that they are designed to reproduce well the local hydrological processes. The calibration method may affect the statistical measures of model performance.

A fact sheet is divided into three parts. **Top front page**: general information section with the main physical characteristics of the borehole, its location and the availability of observed level data. **Front**: how well level time series are reproduced by the models when using **observed climate**; or a measure of the confidence in the hydrological model. **Back**: how well level time series are reproduced by the models when using **modelled climate**; or a measure of the confidence in the climate/hydrological model combination. **Both front and back** must be looked at to fully understand the factors affecting the Future Flows Hydrology (FFH) time series. This is very important when the FFH time series are used to assess climate change impact on a catchment ecosystem. The FFH level time series are in m.

Front page: Simulation from observed climate

Table

Summary of differences in modelling groundwater levels with observed climate. Differences (except Nash Sutcliffe) are given in metres between statistics calculated from simulated and observed level time series.

Names represent the considered statistics; Lx = difference in level percentile value (i.e. in level exceeded x% of the time); Nash Sutcliffe measures if the modelled time series describes the observed time series better than the long term average. A value of 1 shows a perfect match.

Three parts of the hydrological regime are of interest: (i) Water balance and seasonality, (upper part of table); (ii) Low and high levels (level percentiles L90 to L10), (lower left); (iii) Difference in range in level (%), (lower right).

Differences include measurement errors but generally **the smaller the difference the better the model simulation**.

Graphs

The graphs illustrate how well the model simulates the level time series by plotting together observed and simulated levels.

Two types of graphs are shown:

Hydrographs of groundwater levels for the whole observed period and for two periods representative of contrasting climatic conditions: (i) The 1975-1977 period illustrative of a dry episode and subsequent re-wetting; (ii) The 2000-2001 period illustrative of a wet episode.

They give a visual assessment of the reproduction of different hydrological processes under contrasting conditions (e.g. drying during the recession phase);

Mean monthly levels and **level duration curves**. These graphs provide a visual assessment of how well the long-term variability and seasonality is reproduced by the simulation.

Model performance

Assessment of model performance is given for each of the statistics for the period of groundwater level observations using three Bands as defined in the Modelling Protocol. Interpretation of the performance Bands; (i) Define the purpose for which the Future Flows level time series are being used; (ii) Select the statistics most relevant to the purpose; (iii) Assess the performance bands for these statistics. Where several statistics have performance Band 2 or 3 then particular care should be taken in use of the FFH data.

Because of the year-to-year variability of the climate of the UK (also called climate variability) it is possible that several climate time series differ while representing different plausible realisations of the climate. In addition, because knowledge of the physics of the atmosphere is limited and it is not yet feasible to accurately model small-scale climate features, it is now recommended that several climate models projections are considered together when assessing future projections in hydrology. For both reasons, an ensemble of climate models has been used to drive the FF hydrological models and generate an ensemble of FFH time series for each of the sites. The FFH ensemble is derived from the ensemble of Future Flows Climate (FFC) which contains information on both climate variability and climate modelling uncertainty; **no single projection should be considered in isolation of the others as this might mask some important information given by the other ensemble members**. Note that as FFC is derived from a climate model, the day-to-day sequencing of the climate and resulting levels is **not the same as that of observed levels when directly comparing time series**. Long-term statistics, such as the level duration curves, should match more closely those derived from simulations using the observed climate.

Table

Summary of the differences in metres in modelling groundwater levels with observed and modelled climate (FFC time series; note that FFC is a version of HadRM3-PPE where systematic biases in precipitation and temperature have been corrected, a snowmelt module applied and which has been downscaled at a hydrologically-relevant scale). Naming convention and units are as on the Front page.

Comparisons are made for a 30-year period representative of 1962-1991, called control. This gives an assessment of the difference introduced by the use of modelled rather than observed climate when simulating levels. This is important because FF time series, as they project into the future, can only be derived from modelled climate. These differences help identify two possible features:

Systematic differences in the climate-hydrological chain for a **specific part of the regime**; e.g. if all summer levels show a large difference, this might suggest that modelled summer climate (rainfall and/or potential evaporation (PE)) is different from observed;

Systematic differences in the climate-hydrological chain for **specific ensemble member**; e.g. if all statistics associated with afixa show a large difference, this might suggest that afixa climate (rainfall and/or PE) has different characteristics from the observed climate;

In both cases, the statistics should only suggest caution when interpreting the results of the whole FF ensemble, in particular if runs/periods with large differences in the control period are associated with a future signal different from the rest of the FF ensemble. **Large differences in some statistics of the control runs should not be used to automatically reject one of the ensemble members**.

Graphs

Three pairs of graphs are shown.

Groundwater level surplus and deficit statistics (observed climate)

The top pair shows two additional statistics for groundwater levels, referred to as *surplus* and *deficit*. These are measures of the severity of an extreme event above and below a threshold level. The surplus and deficit are expressed in units of m.days and calculated as:

$$S = \int_{t_1}^{t_2} [h(t) - \tau] dt , \qquad D = \int_{t_1}^{t_2} [\tau - h(t)] dt$$

where, τ is the threshold groundwater level, and t_1 and t_2 are the start and end time of the period of extreme groundwater levels, h(t), above or below the threshold. This results in a number of S and D values for a given time-series, and upper and lower threshold values. The distributions of these values, expressed as an empirical cumulative distribution function, calculated from the observed and simulated groundwater level time-series are compared. The threshold values are defined as the 10^{th} and 90^{th} percentile value of the observed groundwater level time-series (shown on the front page).

Mean monthly flows and flow duration curves (modelled climate)

The middle pair shows simulated levels using the observed and modelled climate time series (1962-1991).

Change in mean monthly flow and flow duration curve

The bottom pair of graphs shows the change in metres in mean monthly levels and levels exceeded x% of the time between two 30 year periods - the 1970s (1961-1990) and 2050s (2041 – 2070) for the 11 modelled climate series. The range of change is indicative of uncertainty in the climate modelling.