UNIVERSITY OF BIRMINGHAM

Increasing the resilience of UK water resources using probabilistic climate change information

Christopher Harris, Dr Andrew Quinn and Dr John Bridgeman

Context

Key barriers that prevent successful climate change adaptation in the water industry exist, including:

- **Can the need for adaptation be defined?**
- **Can potential adaptation options be evaluated?**
- **Can an option be selected?**

The uncertainty surrounding what the future climate may be increases the challenge these barriers represent. This project uses Aquator in an approach that aims to make effective decision making possible despite uncertainty using a water shortage risk approach

UNIVERSITY OF BIRMINGHAM

Probabilistic information

- **Using a probabilistic range of climate change information increases accuracy, but is not precise.**

- **Future reality is within the range – it is better to be approximately right than precisely wrong.**

UNIVERSITY OF BIRMINGHAM

Research project

- **The Stoke and Ladderedge drought zones (Staffordshire, UK) are used in a study to:**

1. **Determine the future changes to key variables (precipitation and PET using a modified UKCP09 weather generator**
2. **Determine the range of potential impacts of climate change on hydrology**
3. **Assess the probabilities of risk of water shortage as a result of these changes**
4. **Quantify the most robust policies and adaptations available to water resource managers as a result of their modelled performance across the range of uncertainty.**
5. **Quantify the sources of uncertainty involved with climate change impacts on water resources**

UNIVERSITY OF BIRMINGHAM

Methodology

UKCP09 Weather generator

↓

Sub-sampling of UKCP09 information

↓

Cross-correlation model

↓

Hysim hydrological model

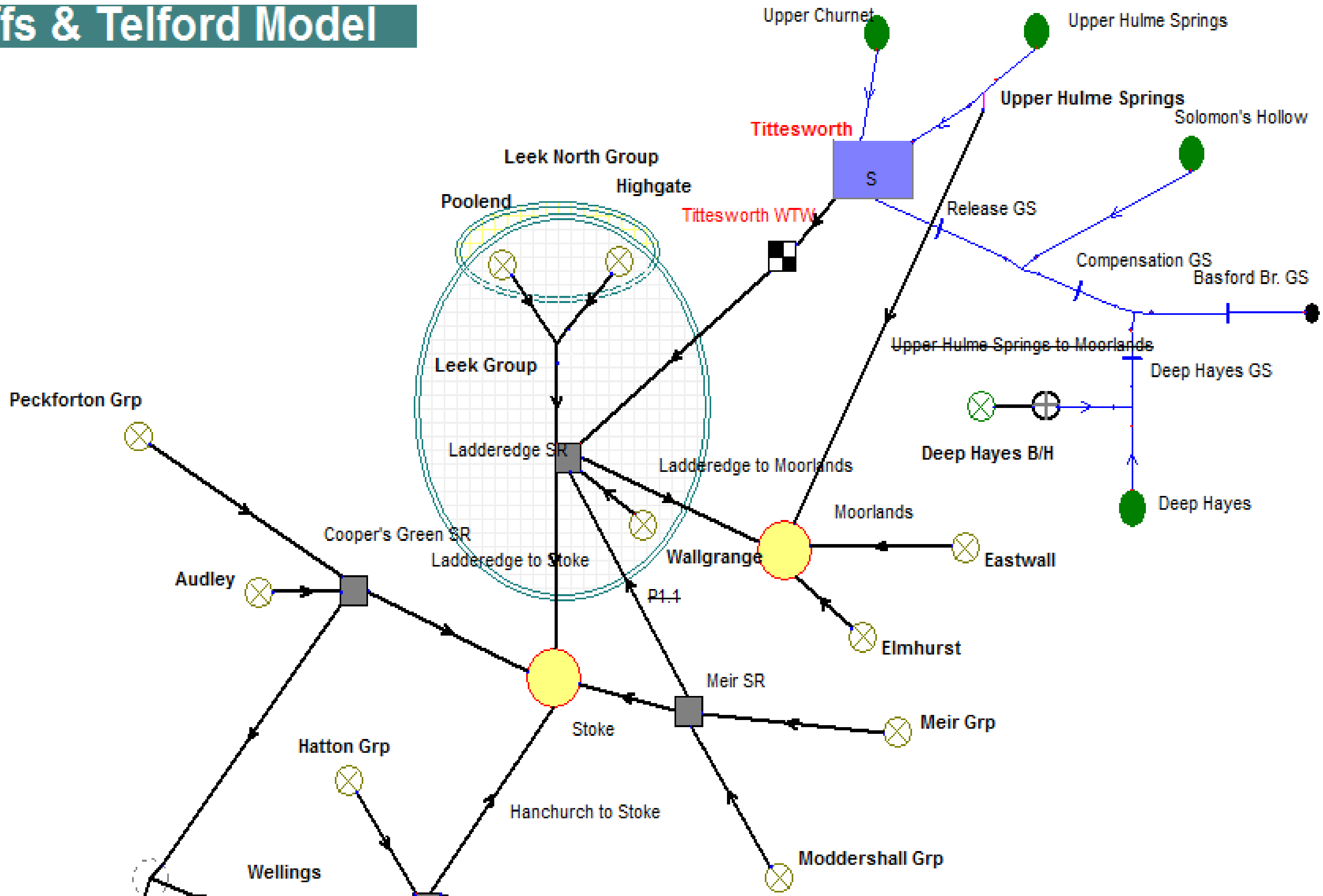
↓

Aquator model

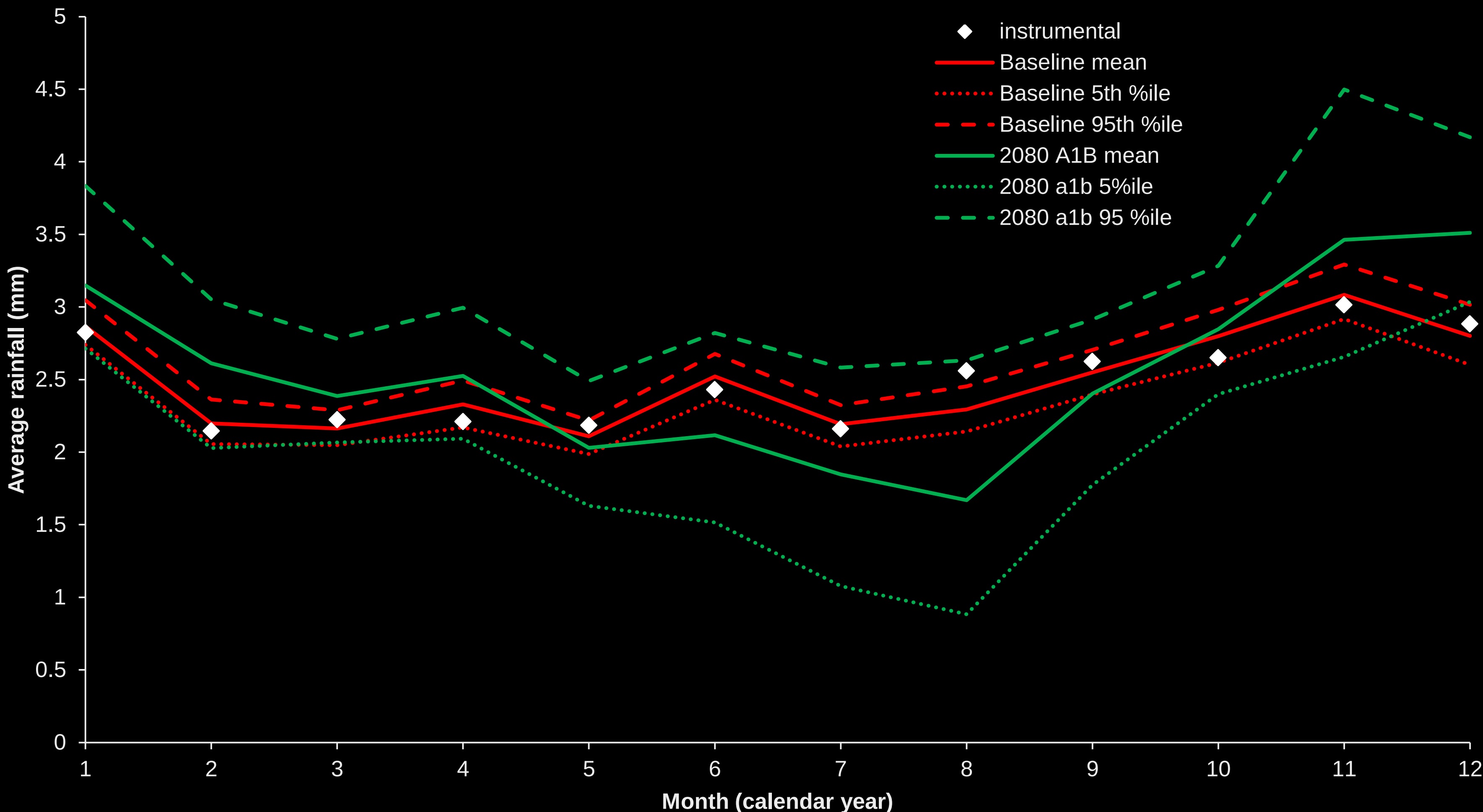
UNIVERSITY OF BIRMINGHAM

Severn Trent Water

Staffs & Telford Model



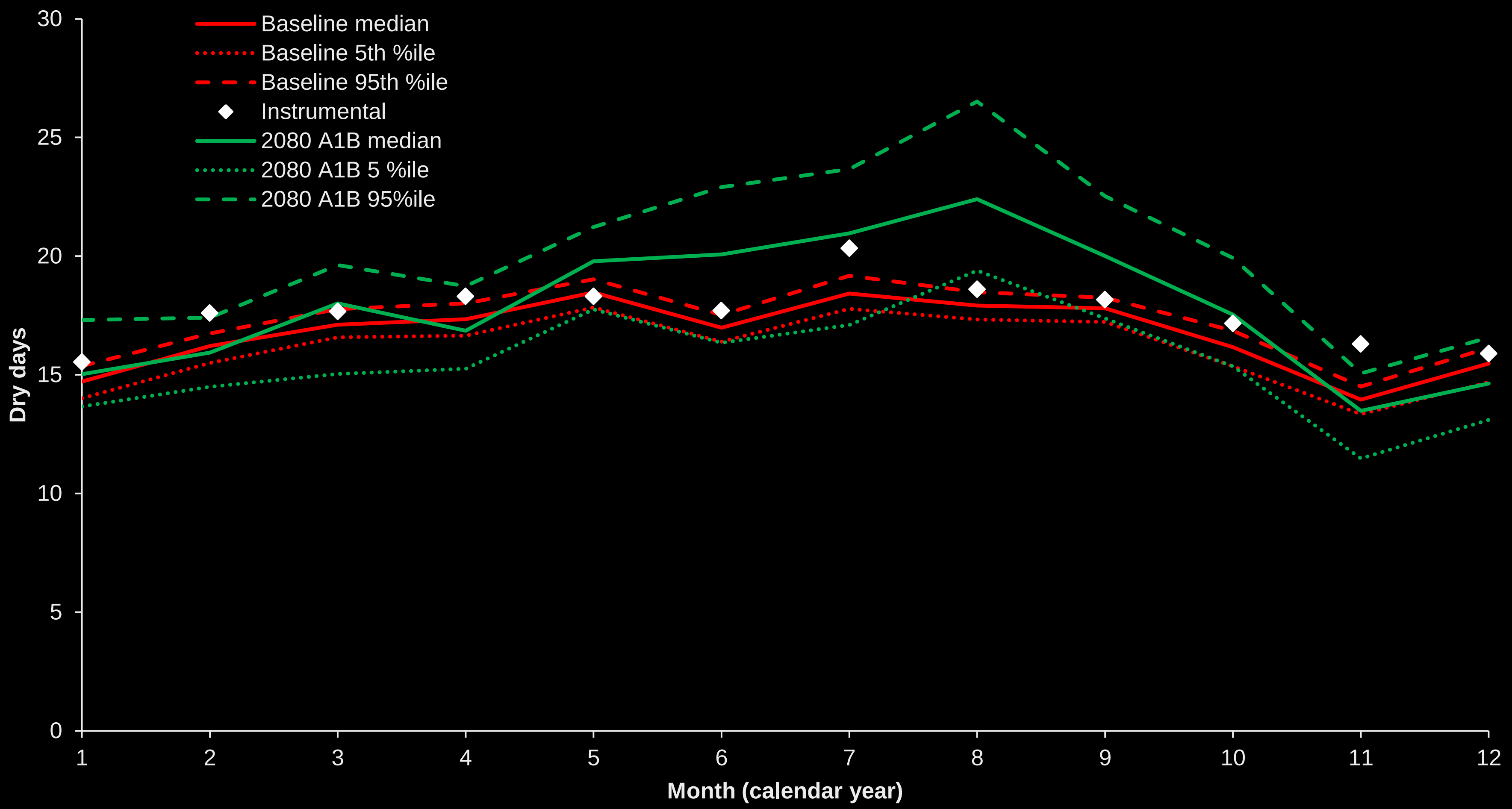
1. Changes to precipitation: average



Simulated precipitation data for Deep Hayes sub-catchment

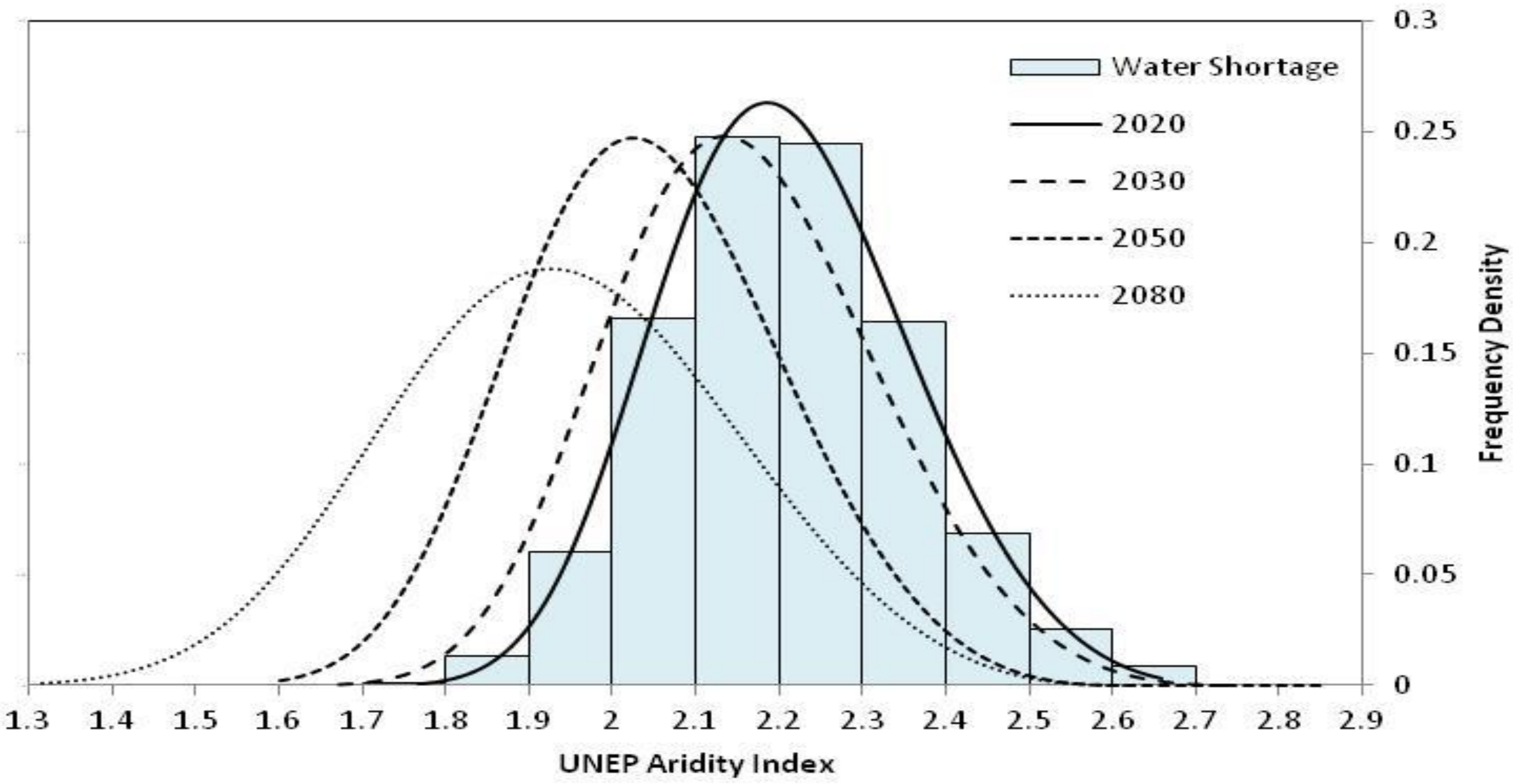
UNIVERSITY OF BIRMINGHAM

1. Changes to precipitation: dry days



UNIVERSITY OF BIRMINGHAM

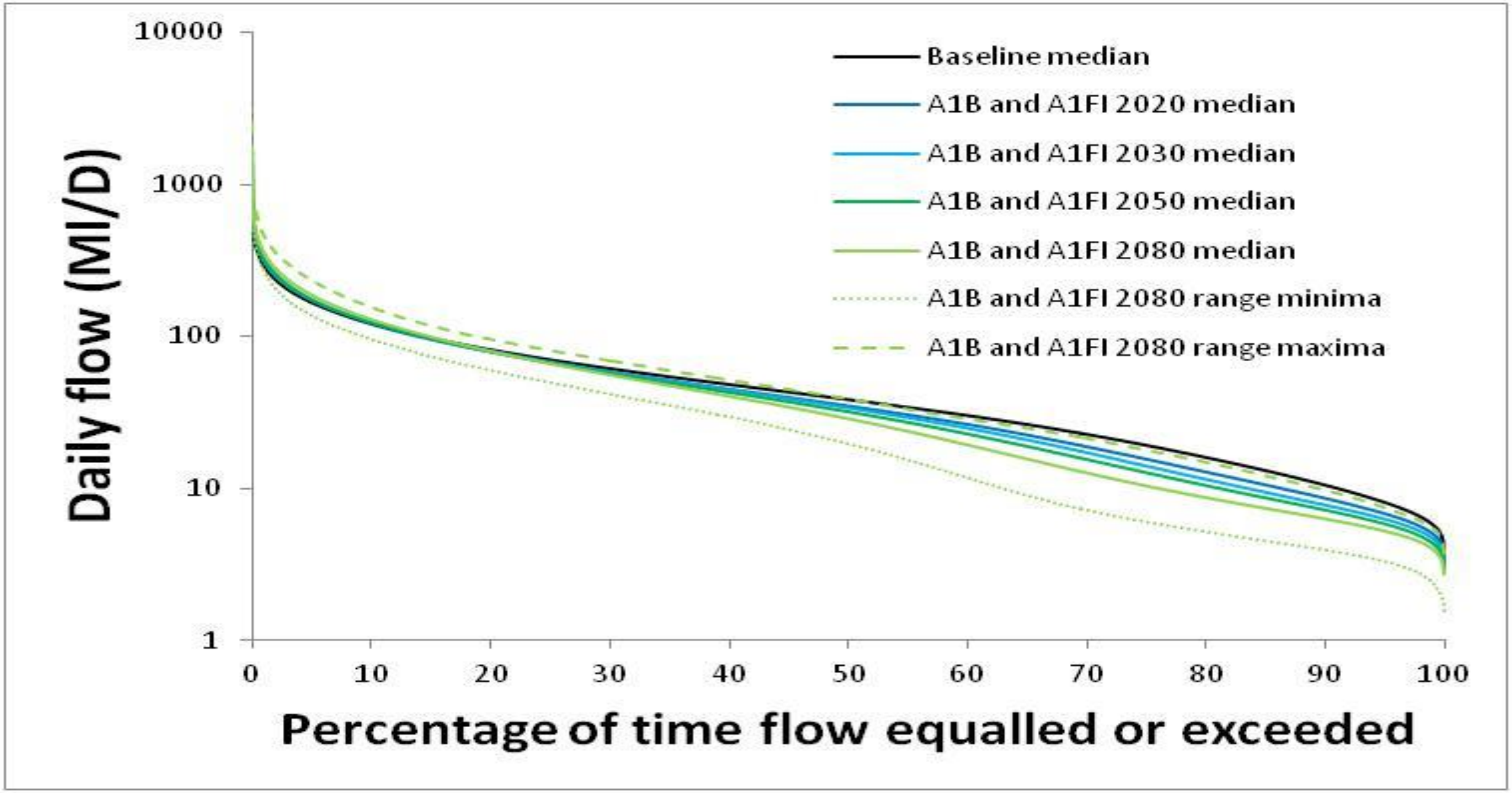
1. Changes to UNEP aridity index



Simulated changes to UNEP aridity index over the 21st century, showing the importance of taking increased PET into account. Baseline (1961-1990) AI median is 2.35

UNIVERSITY OF BIRMINGHAM

2. Changes to flow



Flow duration curves for Upper Churnet sub-catchment at various time horizons. Note substantial range of feasible 2080s futures. Hysim hydrological model used.

UNIVERSITY OF BIRMINGHAM

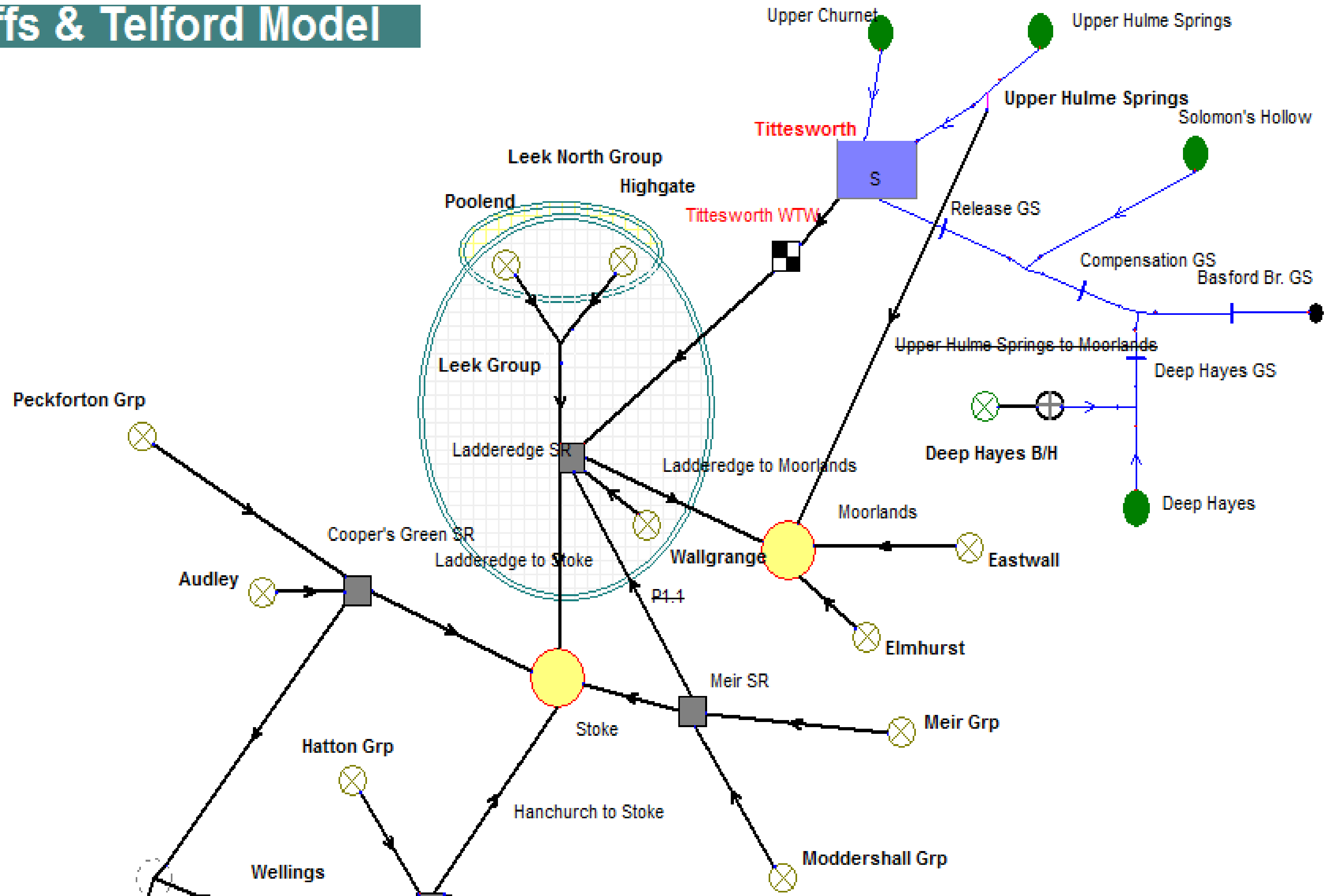
3. Future water resource shortage: Risk-based approach

- **Focus on assessing the probability of an unwanted outcome of a certain severity**
- **Drought warning curves at reservoirs represent ideal water shortage risk metrics**
- **Options and strategies can be found that reduce risk across the range of uncertainty**

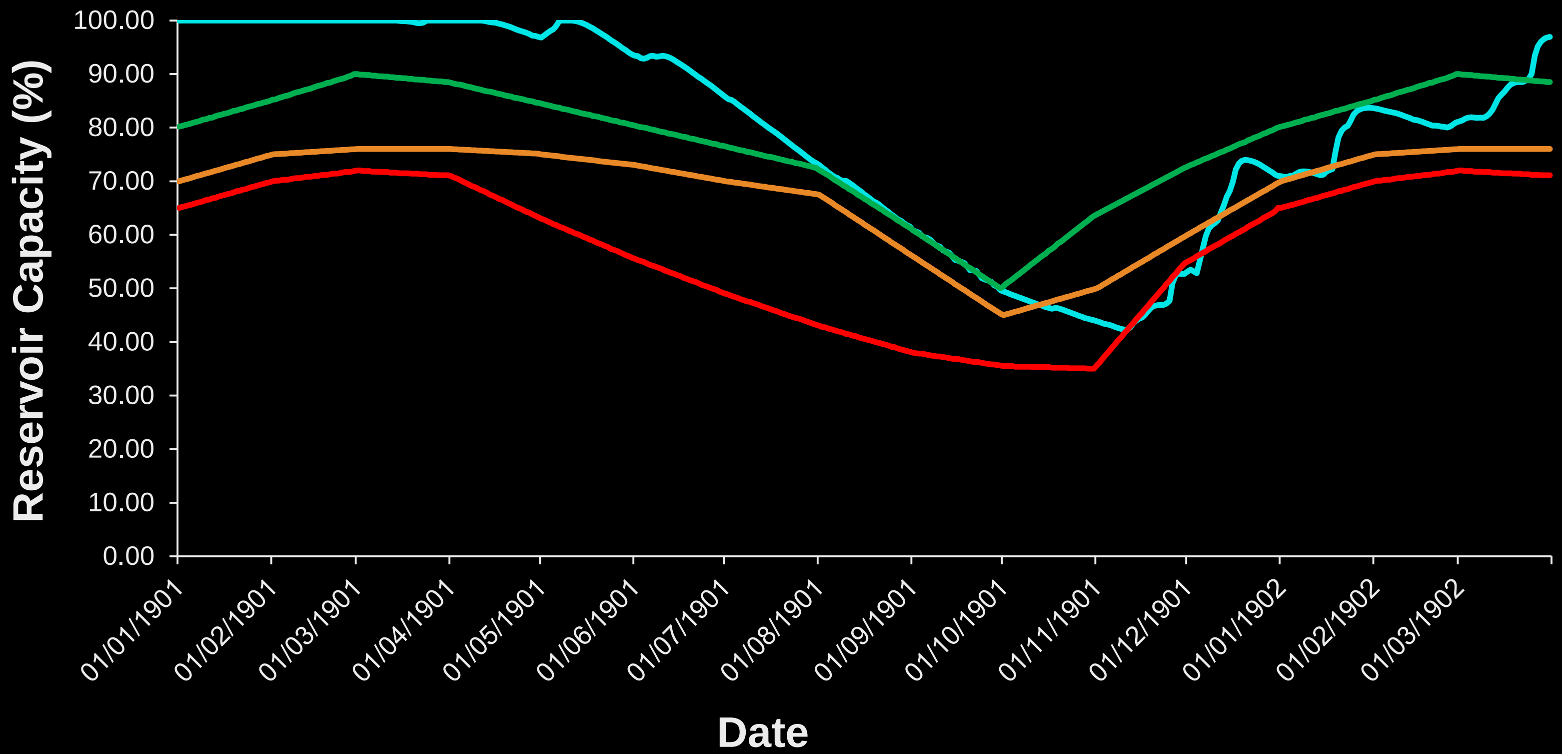
UNIVERSITY OF BIRMINGHAM

Severn Trent Water

Staffs & Telford Model



‘Triggering’ a drought event



Where,
Green = storage alert line
Orange = drought warning curve
Red = hosepipe ban

UNIVERSITY OF BIRMINGHAM

3. Changes to future water shortage risk

2020s

	0	<0.02	>0.02, <0.05	>0.05,<0.2	>0.2
s1	30%	15	25	30	0
s2	10	15	15	45	15
s3	0	0	5	30	65
s4	0	0	0	15	85

Baseline

	0	<0.02	>0.02, <0.05	>0.05,<0.2	>0.2
s1	65%	25	10	0	0
s2	30	45	20	5	0
s3	0	0	0	100	0
s4	0	0	0	15	85

2030s

2050s

	0	<0.02	>0.02, <0.05	>0.05,<0.2	>0.2
s1	10	5	30	45	10
s2	5	0	0	50	45
s3	0	0	5	5	90
s4	0	0	0	5	95

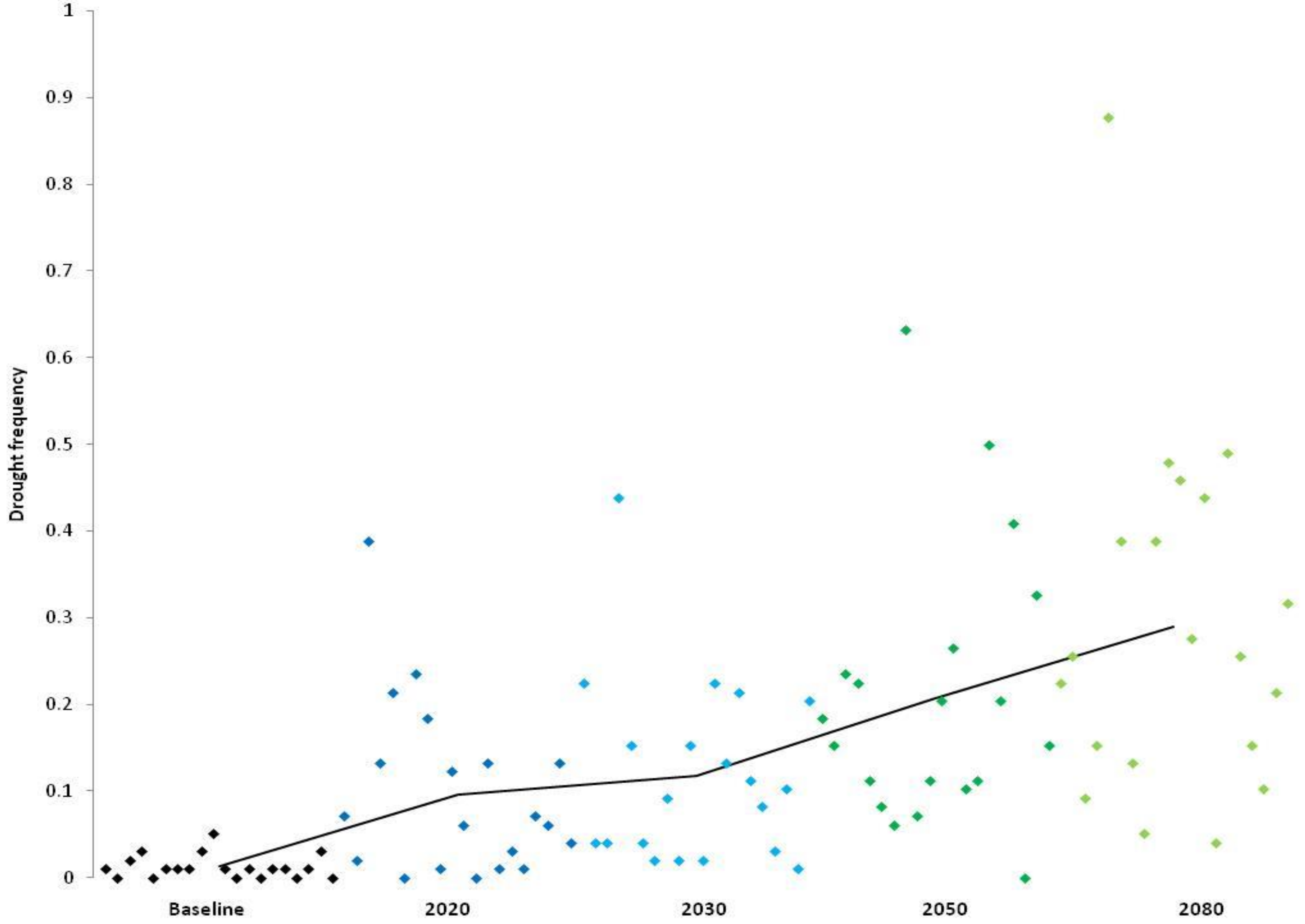
2080s

	0	<0.02	>0.02, <0.05	>0.05,<0.2	>0.2
s1	10	10	10	55	15
s2	0	0	5	30	65
s3	0	0	0	5	95
s4	0	0	0	0	100

Where, s1 = hosepipe ban, s2 = drought warning trigger, s3 = reservoir level alert, s4 = control curve.

UNIVERSITY OF BIRMINGHAM

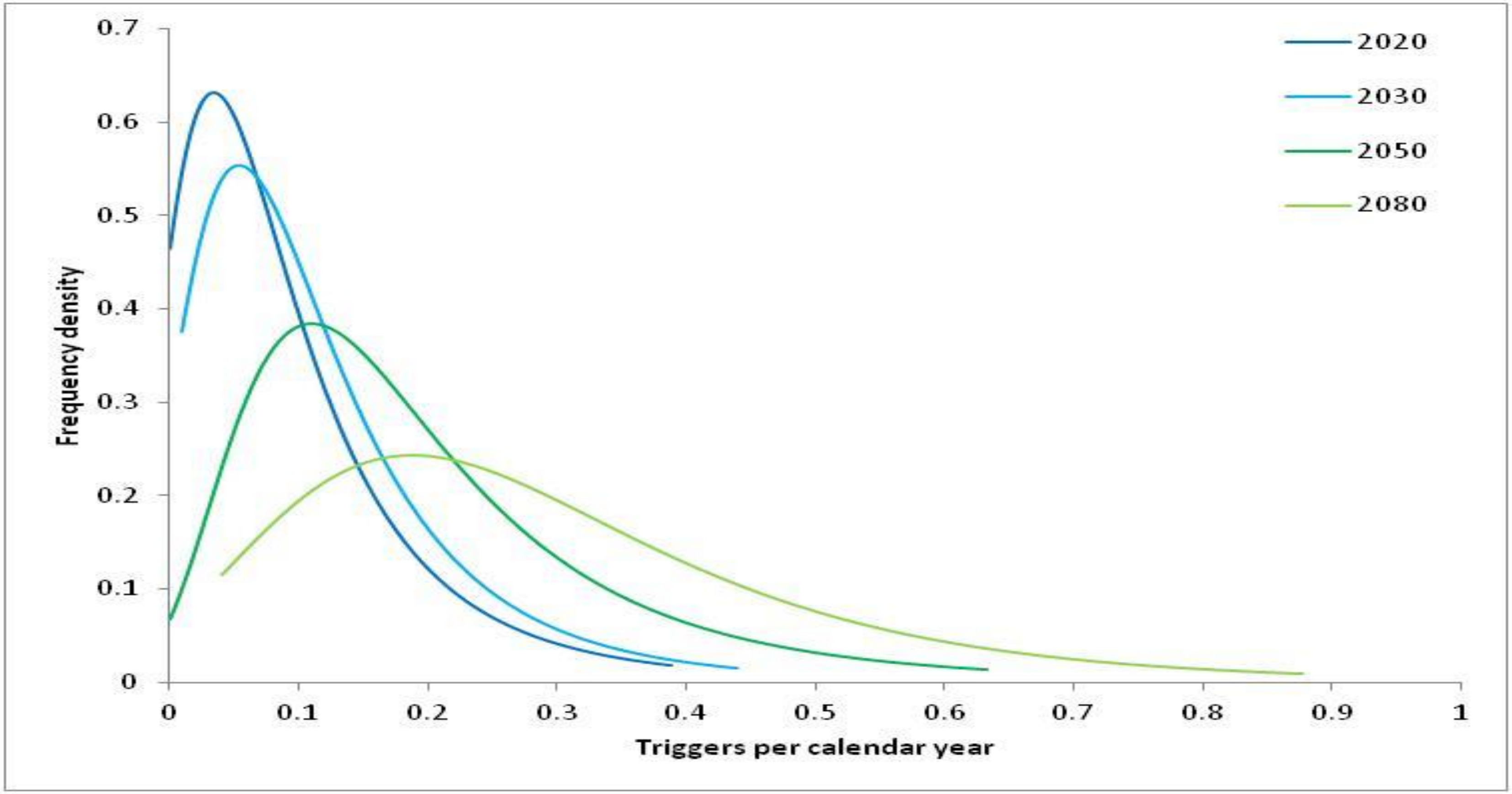
3. Future water resource shortage



scatterplot for water shortage severity 2 over the course of the 21st century

UNIVERSITY OF BIRMINGHAM

3. Future water resource shortage



GEV plots for water shortage severity 2. Note the increased uncertainty and worsening 'most-likely' scenario as time progresses.

UNIVERSITY OF BIRMINGHAM

4. Using probabilistic water shortage assessments (current research)

- **Applying strategies and options to the Aquator model can enable an assessment of system resilience to the range of possible futures**
- **Strategies and options that reduce water shortage across the range of uncertainty can be found**
- **Financial considerations can be built into decision-making**

UNIVERSITY OF BIRMINGHAM

4. Using probabilistic water shortage assessments (current research)

- **Building in future projections of demand**
- **Future adaptation strategies:**
  - **Leakage reduction**
  - **Water transfers**
  - **Non-essential use reduction in times of drought**
- **Further stresses on water resource supply: changes to groundwater licenses, population changes etc.**

UNIVERSITY OF BIRMINGHAM

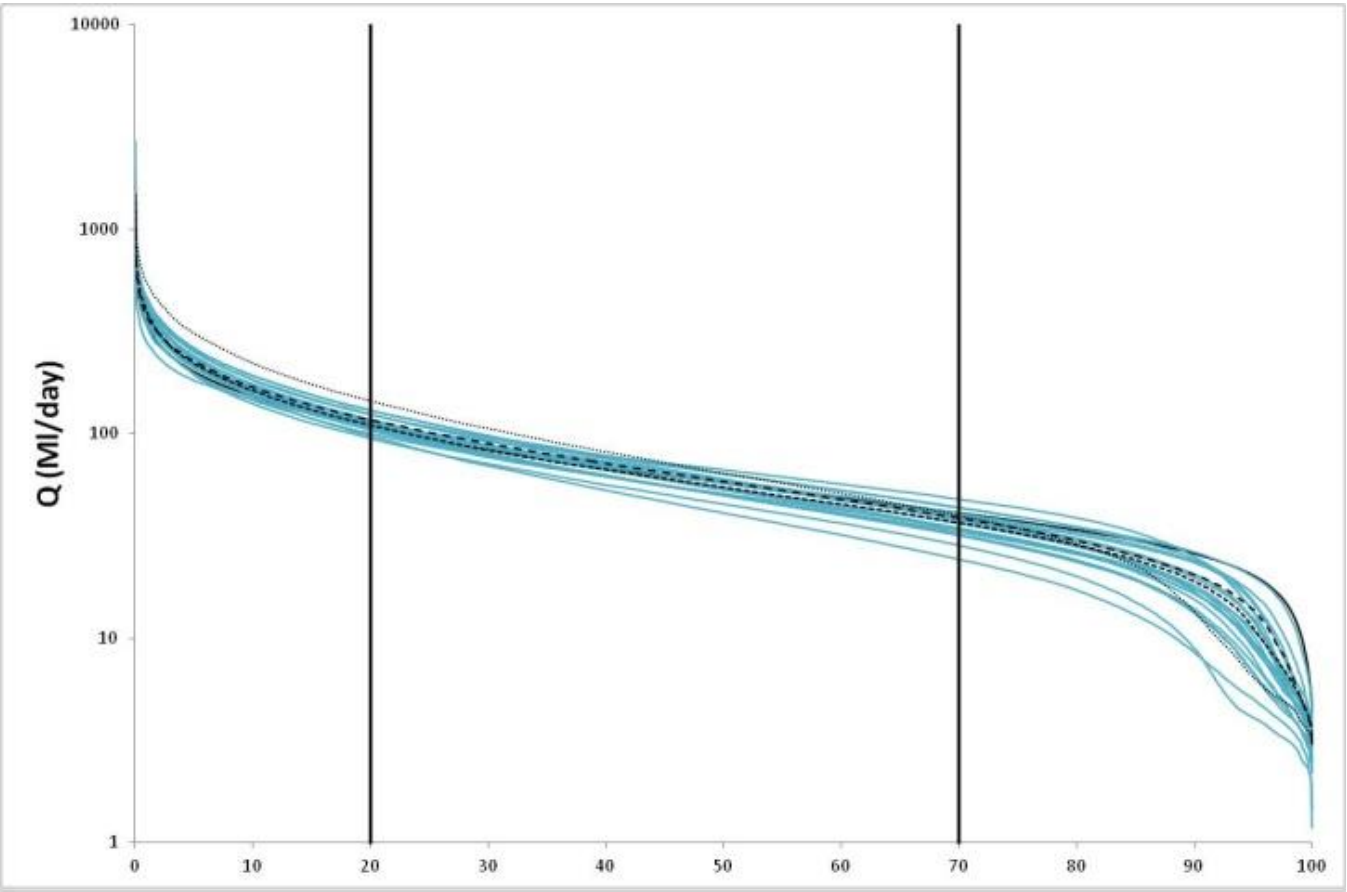
5. Causes of future water resource shortage uncertainty:

- **Quantify the relative effects of climate model uncertainty and emissions scenario uncertainty on estimates of water shortage risk in the 2080s**

- **Describe the potential for maladaptation when using means from climate model ensembles or assuming one projection is correct**

UNIVERSITY OF BIRMINGHAM

5. Climate model and emissions scenario uncertainty: flows

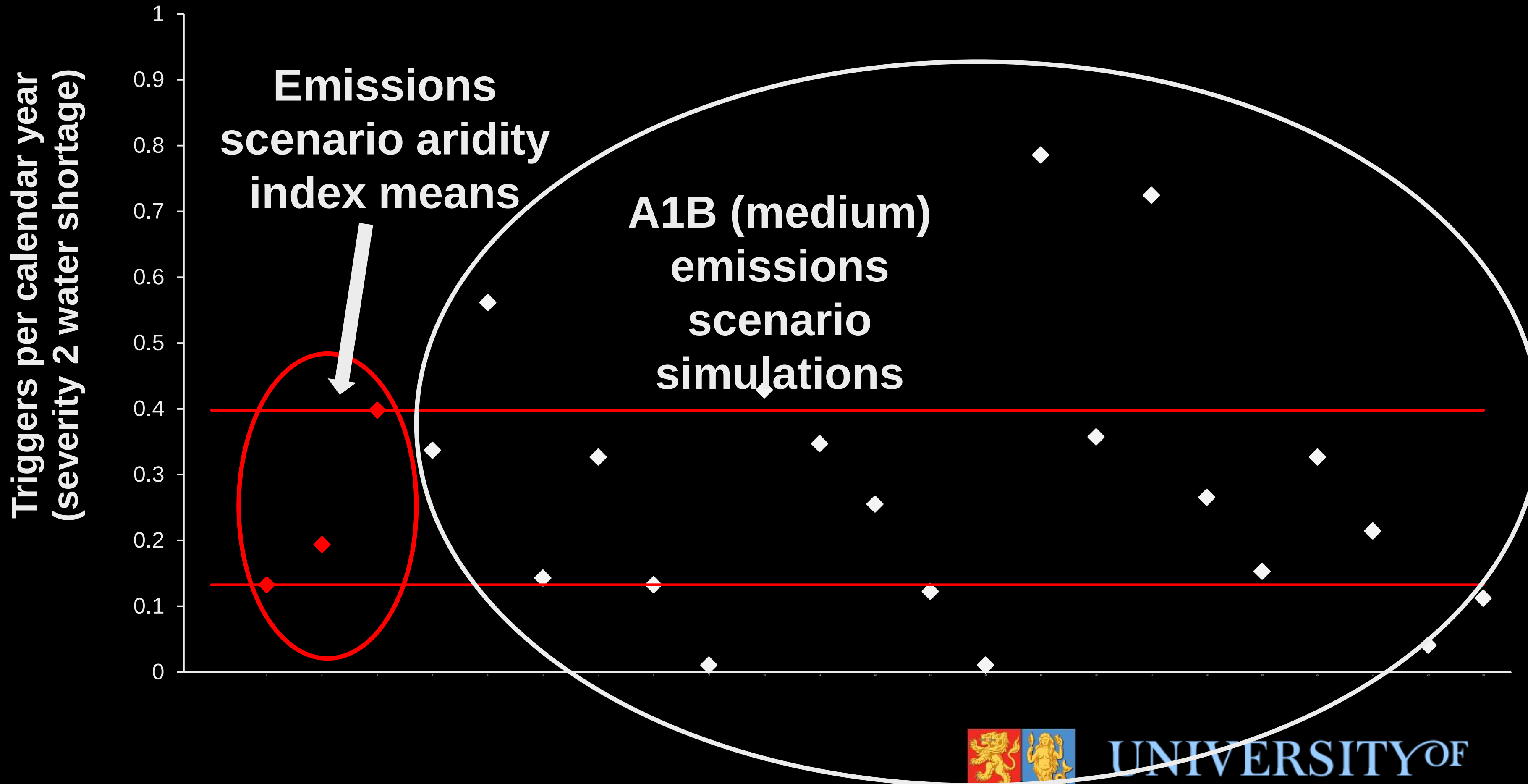


Flow duration curves at Upper Churnet.

UNIVERSITY OF BIRMINGHAM

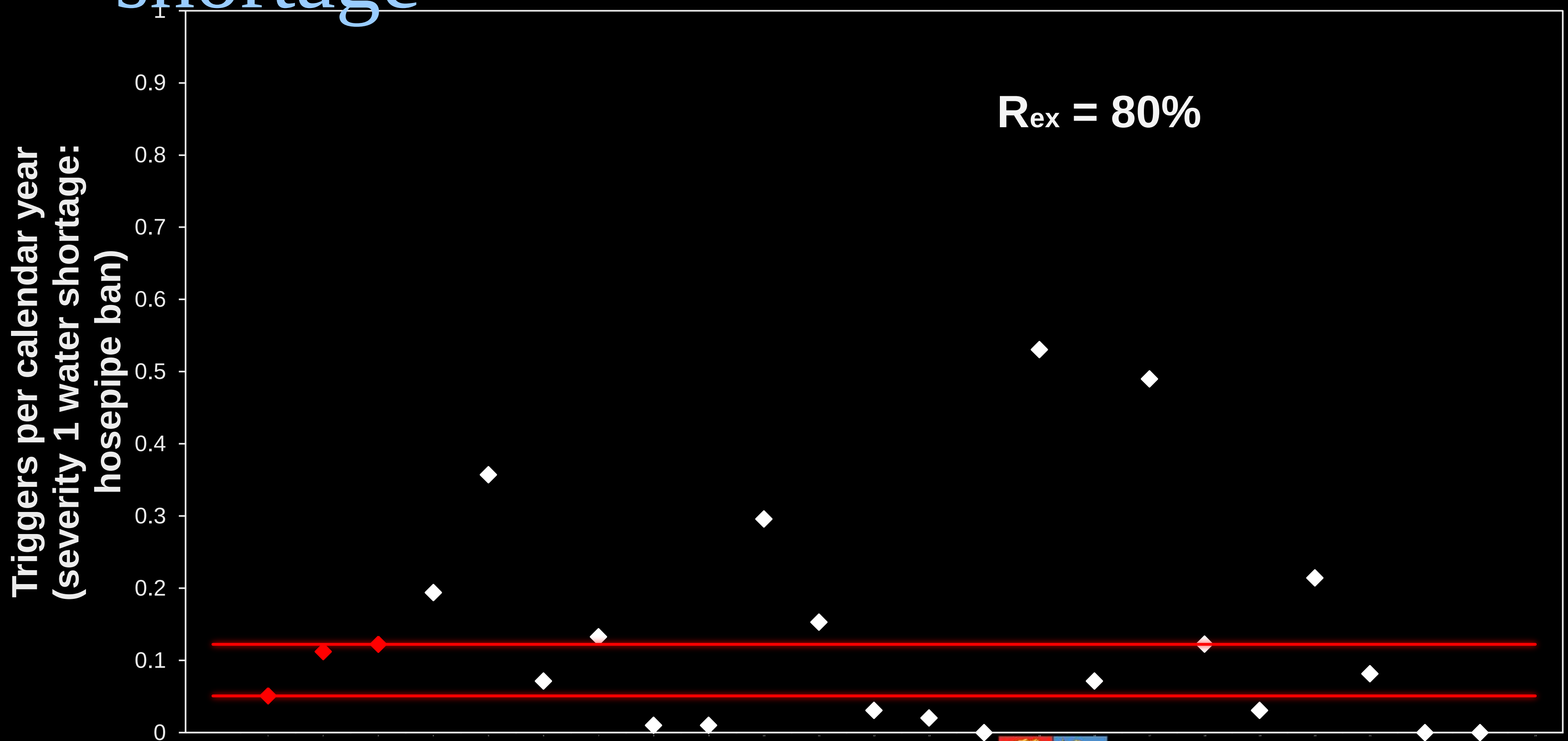
5. Uncertainty analysis: water shortage

R_{ex} = 50%

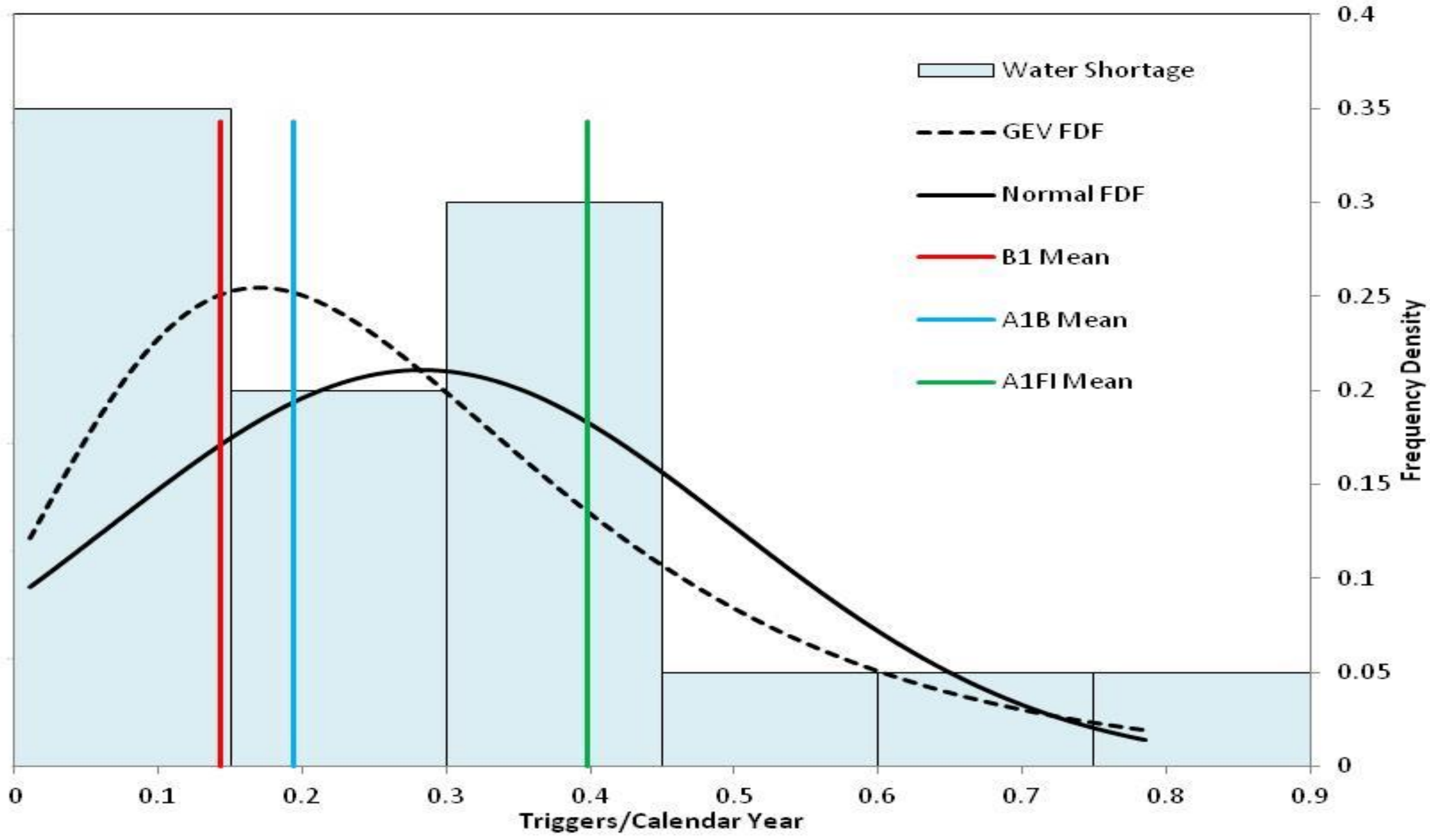


UNIVERSITY OF BIRMINGHAM

5. Uncertainty analysis: water shortage



5. Uncertainty analysis: water shortage



UNIVERSITY OF BIRMINGHAM

5. Uncertainty analysis: outcomes

- **Maximum difference between simulations of summer flow at Upper Churnet from across the A1B range is 97.3%, whilst maximum difference between the emssion scenario medians is 31.8%.**

- **Climate model uncertainty far exceeds emission scenario uncertainty in its affect on flow in the 2080s.**

UNIVERSITY OF BIRMINGHAM

5. Uncertainty analysis: outcomes

- **Differences between climate models is a greater source of uncertainty than choosing different emissions scenarios**

- **Using individual projections of the future can lead to significant maladaptation to climate change**

- **Using the mean value from a distribution does not represent the most likely outcome from the probabilistic data**

UNIVERSITY OF BIRMINGHAM

Conclusions

- Multi-model approach used here enables reliable projections of the range of feasible climate futures on a sub-catchment scale – Aquator key part
- Summer flows are reduced in nearly all future projections, with winter flows increased.
- Climate change substantially increases risk of summer water shortage in the Stoke and Ladderedge drought zones
- Water resource management decisions can be found that are beneficial to the sustainable use of resources across the range of uncertainty
- Disagreements between climate models (or more accurately, the range of the perturbed physics ensemble used in UKCP09) far exceeds emissions scenario selection as an uncertainty source

UNIVERSITY OF BIRMINGHAM

Publications

- **CNP Harris, AD Quinn, J Bridgeman (2012): "The use of probabilistic weather generator information for climate change adaptation in the UK water sector".** ***Meteorological Applications,*** **DOI 10.1002/met.1335 (currently in preview, fully available online in the coming days/weeks).**

- **Forthcoming publication: CNP Harris, AD Quinn, J Bridgeman (2012/3): "Sources of uncertainty in a hydroclimatological assessment of future water shortage in the UK"**

UNIVERSITY OF BIRMINGHAM

Questions?