New joint probability guidance for England & Wales

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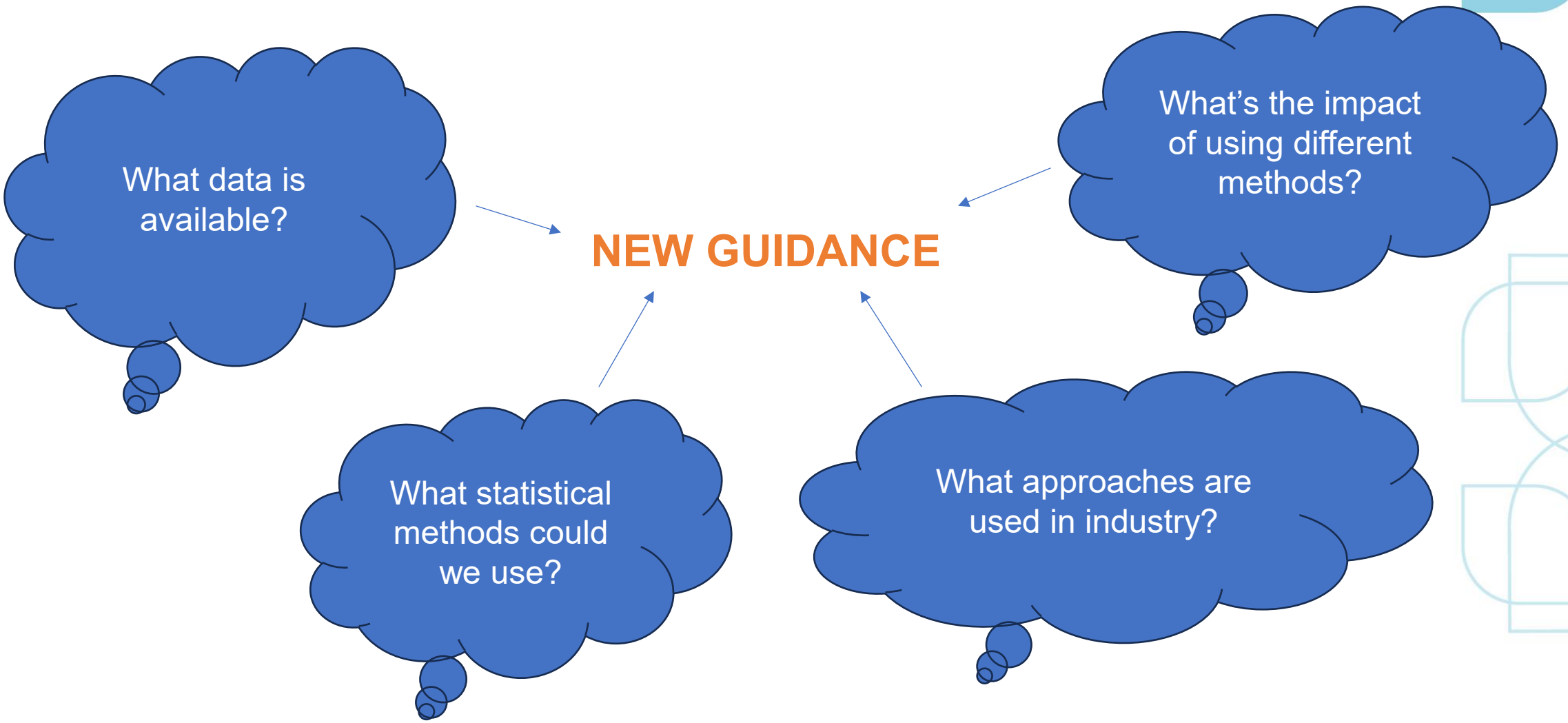
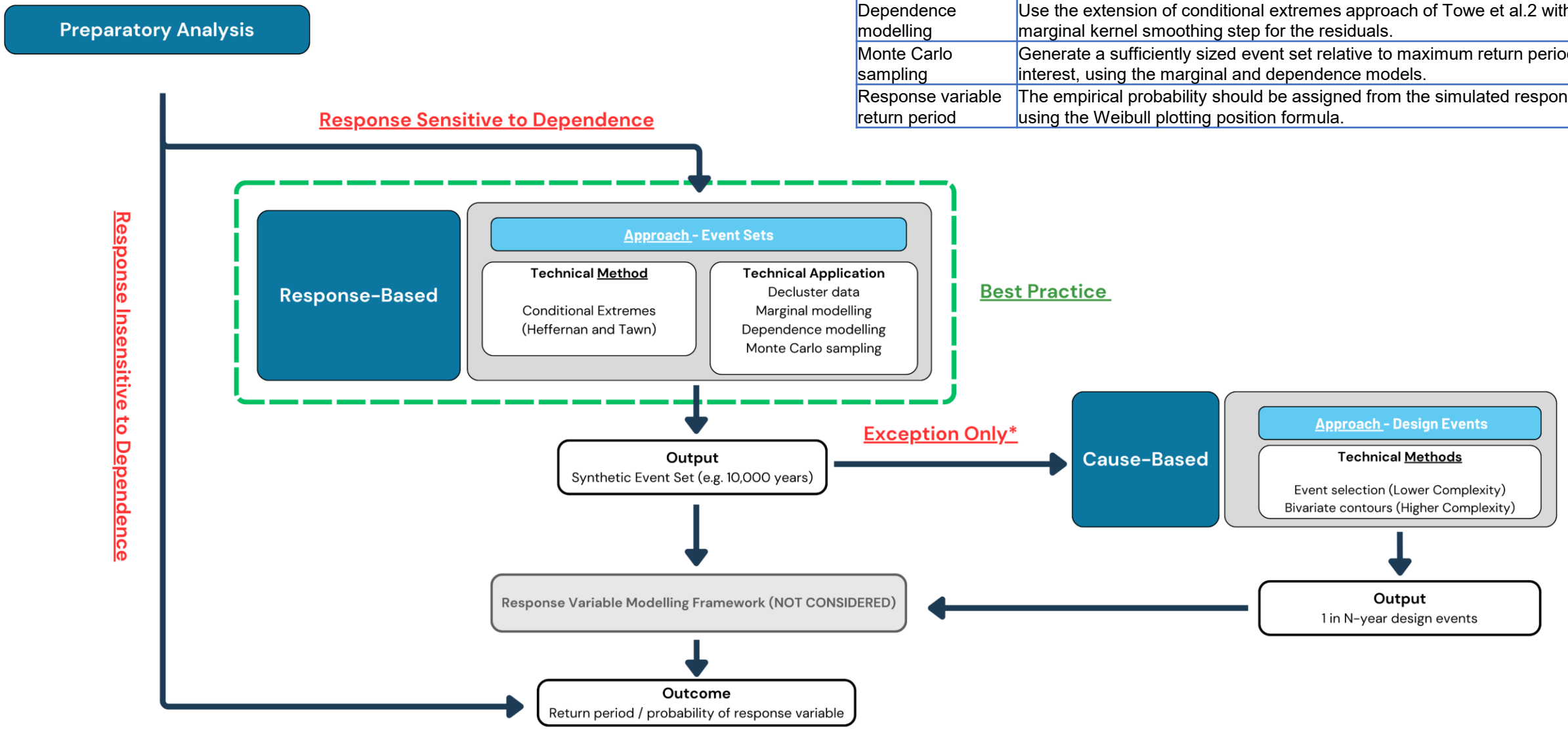
Overview of stage 1



Proposed best practice

Step	Description
Decluster data	A specific methodology is not currently proposed.
Marginal modelling	Whole-sample model with Generalised Pareto Distribution tail. Below the threshold, use of the empirical distribution to characterise events.
Transform variables to standard form	Use marginal distribution to transform variables to standard form, before studying the dependence structure.
Dependence modelling	Use the conditional extremes approach of Heffernan & Tawn1 for dependence. Use the extension of conditional extremes approach of Towe et al.2 with the marginal kernel smoothing step for the residuals.
Monte Carlo sampling	Generate a sufficiently sized event set relative to maximum return period of interest, using the marginal and dependence models.
Response variable return period	The empirical probability should be assigned from the simulated response using the Weibull plotting position formula.

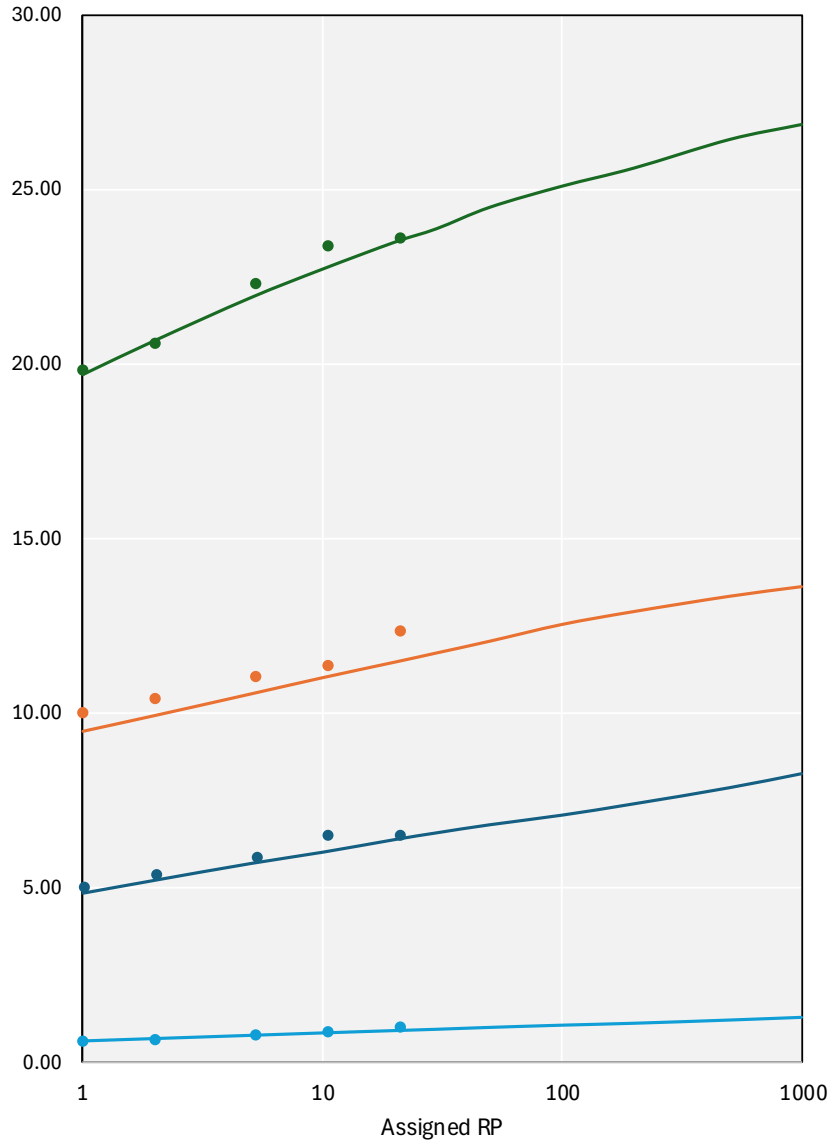


Reporting

During Stage 1 we have identified a strong need to improve joint probability reporting. In line with this ambition, we recommend the new guidance is accompanied by report requirements e.g. report template that clearly defines what needs to be demonstrated to show best practice.

Aim

- Provide sufficient detail for analysis to be repeatable.
- Provide diagnostic figures for example showing that fitted tail distributions are a good fit to the data.
- Provide critical checks of the results: e.g. compare marginal return periods from event set and observations.
- Promote QA, transparency and consistency



New joint probability guidance for England & Wales

Fay Luxford, JBA Consulting

Lancaster University | Horritt Consulting | JBA consulting | Department for Environment Food & Rural Affairs | Environment Agency | Cyfoeth Naturiol Cymru Natural Resources Wales | Llywodraeth Cymru Welsh Government

Background

Quantifying coastal risk requires assessing hazards from multiple extreme environmental drivers, such as extreme sea levels, waves, fluvial flows, and local winds. In England, joint probability guidance was released by the Environment Agency in 2005, with design contours widely used since. In the past decade event set methodologies have been commonly adopted across the UK but lack any guidance on how these should be developed or verified. JBA Consulting, Lancaster University and Horritt Consulting are currently undertaking a project to review and update joint probability guidance on behalf of the Flood and Coastal Erosion Risk Management Research programme, managed by the Environment Agency. We have recently completed stage 1 of 4:

Stage 1: Review of data, identification of methods and approaches and their limitations.
Stage 2: Development of the decision making tool and testing of this.
Stage 3: Development of the guidance documentation
Stage 4: Final reporting and dissemination.

Verification and reporting

A strong need to improve joint probability reporting has been identified. To support this ambition, it is recommended that the new guidance is accompanied by report requirements (e.g. a report template) that clearly defines what needs to be demonstrated to show best practice.

Aim

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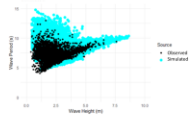
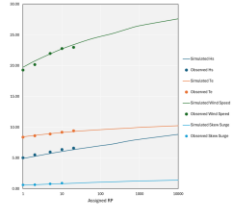


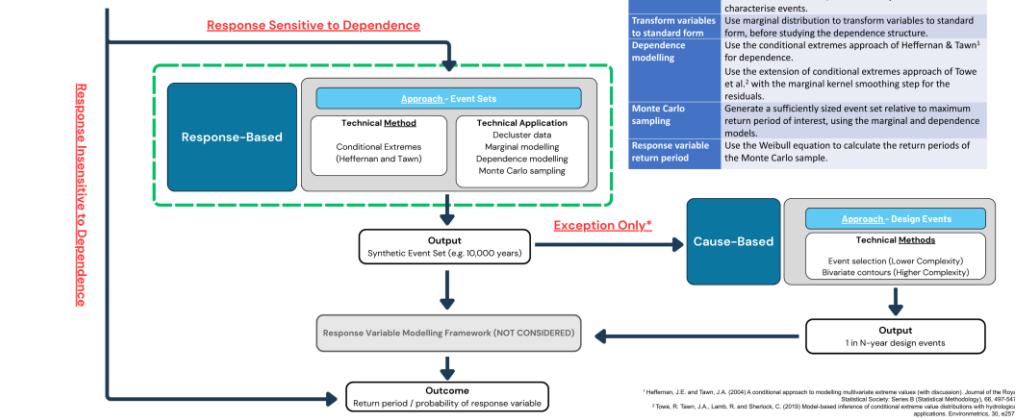
Example plot: comparison of event set (blue) wave heights and period to observations (black)



Example plot: comparison of marginal return periods from event set (line) and observations (points)

Preparatory Analysis

Proposed new guidance



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Transform variables to standard form	Use marginal distribution to transform variables to standard form, before studying the dependence structure.
Dependence modelling	Use the conditional extremes approach of Heffernan & Tawn[1] for dependence. Use the extension of conditional extremes approach of Towe et al.[2] with the marginal kernel smoothing step for the residuals.
Monte Carlo sampling	Generate a sufficiently sized event set relative to maximum return period of interest, using the marginal and dependence models.
Response variable return period	Use the Weibull equation to calculate the return periods of the Monte Carlo sample.

[1] Heffernan, J.E. and Tawn, J.A. (2004) A conditional approach to modelling multivariate extreme values (with discussion). Journal of the Royal Statistical Society: Series B (Statistical Methodology), 66, 497-541

[2] Towe, R. Tawn, J.A., Lamb, R. and Sherlock, C. (2019) Model-based inference of conditional extreme value distributions with hydrological applications. Environmetrics, 30, e2577

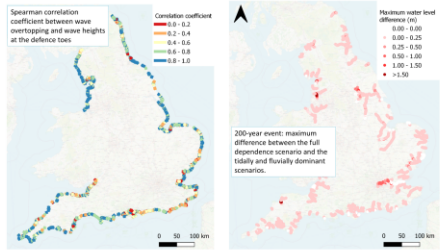
Impact of joint probability choice

To inform the draft guidance, the impact of using different joint probability choices was explored. A key decision was if the guidance would suggest a cause or response-based approach.

Cause based approach (e.g. design contours): assumes that X-year return period wave overtopping is caused by X-year return period storm conditions
Response based approach (e.g. event set): where many synthetic storms are simulated and the response calculated then the probability is assigned based on a uni-variate sample of the response variable.

Open coast
Existing literature shows that there are large and variable differences between cause and response based methods for processes where wind waves are a driver (e.g. wave overtopping, wave forces on a structure): estimated overtopping return periods sometimes differ by an order of magnitude. New analysis has been performed using data from the Environment Agency's updated National Flood Risk Assessment. The spatial pattern was investigated looking at the correlation between wave overtopping and environmental drivers. The new analysis shows no consistent relationship between the extremity of wave overtopping (response) and the extremity of offshore storm variables such as wave height, wave period, wind speed and sea level (cause). The strongest correlation between environmental drivers and wave overtopping is with wave height at the defence toe; however, this correlation is still not consistently strong along any length of coastline, as shown opposite. Based on the results of this analysis, it is recommended that cause based approaches are not used to assess wave overtopping or other parameters on the open coast, such as wave forces on structures. In exceptional cases where a response based approach isn't feasible, these results highlight that the offshore drivers need to be defined as close as possible to the response i.e. wave conditions at the toe of the defence rather than offshore.

Estuaries
The impact of joint probability choice on estuary water levels was explored by comparing three joint probability scenarios (full dependence, tidally dominant, and fluvially dominant) across 120 estuaries, six return periods and three epochs. The analysis found that differences between results are typically constrained to mid-estuary zones, although some exceptions exist. For many estuaries, the difference in water levels between methods is less than 0.5m (for all return periods and epochs). Based on this analysis, it is recommended that estuary models are run under full dependence, tidally dominant, and fluvially dominant scenarios to understand how sensitive results are in the area of interest. Comparison of these simulations could be used to justify simpler joint probability methods (e.g. assume full dependence) or to justify not using joint probability at all.



For more info, contact Fay Luxford – fay.luxford@jbaconsulting.com