FUTURE DRAINAGE

Guidance for Water and Sewerage Companies and Flood Risk Management Authorities: Recommended uplifts for applying to design storms

Prepared by Murray Dale, JBA Consulting

Reviewed by and with contributions from: Professor Hayley Fowler, Newcastle University; Professor Lizzie Kendon, Met Office; Dr. Steven Chan, Newcastle University

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Introduction

Understanding the impacts of changes to rainfall intensities and seasonal patterns in the future is vital for long-term investment planning in the water industry. It is also important for flood risk management authorities and infrastructure owners interested in how rainfall intensity change could affect fluvial and surface water flood risk.

FUTURE-DRAINAGE[1][2] is a Newcastle University led consortium involving the Met Office, JBA Consulting and Loughborough University, funded by the NERC (UKRI) UK Climate Resilience Programme. It has used the new UKCP high resolution 2.2km data (UKCP Local)[3] to derive more robust rainfall uplift estimates for the high greenhouse gas emissions scenario RCP8.5. Many UK water and sewerage companies (WaSCs), and the Scottish Environment Protection Agency, provided letters of support for this research project. These WaSCs, and other WaSCs, the Environment Agency and Scottish Environment Protection Agency (the 'stakeholder group') were consulted and engaged in a workshop in September 2019 to inform the development of project outputs. The steer this workshop provided for the project was detailed in Dale, 2019[4].

Further consultation occurred with the stakeholder group during May 2021 regarding the regional variation of the uplift amounts (estimated changes to rainfall intensities).

FUTURE-DRAINAGE follows a research project carried out for UK Water Industry Research (UKWIR) in 2017[5]. The 2017 UKWIR project, Rainfall Intensity for Sewer Design, developed guidance for WaSCs for applying rainfall uplifts that were derived in the project using outputs from a 1.5km climate model developed by the Met Office[6]. The uplifts provided within this guidance document supersede those provided in the UKWIR project 2017 guidance. They are based on a revised climate

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[1] http://gotw.nerc.ac.uk/list_full.asp?pcode=NE%2FS017348%2F1&cookieConsent=A
[2] https://www.ukclimateresilience.org/projects/future-drainage-ensemble-climate-change-rainfall-estimates-for-sustainable-drainage/
[3] Kendon, EJ, et al (2021) Update to UKCP Local 2.2km projections, Met Office. Available from https://www.metoffice.gov.uk/research/collaboration/ukcp/guidance-science-reports.
[4] Future Drainage – UKCP18 data for more robust future rainfall change estimates, Proceedings of the CIWEM Urban Drainage Conference November 2019. http://ftp2.ciwem.org/2019/2019-Autumn/
[5] https://ukwir.org/rainfall-intensity-for-sewer-design-stage-2-0
[6] Kendon EJ, Roberts NM, Fowler HJ, Roberts MJ, Chan SC, Senior CA. Heavier summer downpours with climate change revealed by weather forecast resolution model. Nat. Clim. Ch., 4, 570–576, 2014.

model with improved physics and a larger UK-wide domain, as well as a set of twelve realisations (as opposed to the 2017 guidance where only a single smaller-spatial-domain climate change simulation of the 1.5km climate model was available). Beyond enhancements to underlying climate simulations, the underlying statistical method has also been improved[7].

Who is this guidance for?

This guidance is aimed at all persons and organisations who need to allow for an increase to design storm rainfall[8] in sub-daily to daily durations (1 – 24-hour) to account for the impact of climate change projections in the UK. Therefore, this guidance applies to the UK water industry, flood risk management authorities, local authorities, infrastructure owners and operators, and consultants supporting these organisations.

How are the uplift values organised?

GIS shapefiles and comma-separated value ("csv") text files of the uplift values in percentages are provided for the UK. The uplift values are organised in the following way:

1. **Uplift values have been produced in map form with accompanying GIS shapefiles and csv text files, rounded to the nearest 5%.** This choice has been made following consultation with the FUTURE-DRAINAGE stakeholder group, for the following reasons:
    a. Analysis of the uplift variation across the UK showed that in some regions, and for some durations, variation in uplift was regarded as significant within individual WaSC region boundaries. This means that if a single average uplift value was provided per WaSC region this could mask variation that could have significant impact on water company investment plans, or on individual flood scheme design for flood risk authorities. The shapefiles, hence, give options for users to decide on their own regions and boundaries.
    b. There is uncertainty in the projected uplifts, especially at the local scale, due to sampling uncertainty (each climate simulation is only 20 years in length and, even though there are twelve realisations, there is limited sampling of rainfall extremes compared to natural climate variability) and climate model uncertainty (projections from different climate models will vary due to differences in the way atmospheric processes are represented). Therefore, providing uplift values to higher precision than 5% is not scientifically justifiable.
2. **Uplift values vary by rainfall design storm duration**. In the UKWIR 2017 guidance, uplift values were produced that were the same for all durations from 1-hour to 24-hour. This reflected the outputs of the modelling at the time in which there were not substantial differences in uplift across rainfall durations from 1 to 24-hours. In the more detailed FUTURE-DRAINAGE research, uplift values have been shown to differ by duration and our recommendation is to use the appropriate uplift value for the design event duration being considered.

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[7] Youngman BD (2018) Generalized Additive Models for Exceedances of High Thresholds With an Application to Return Level Estimation for U.S. Wind Gusts. Journal of the American Statistical Association 1–19. https://doi.org/10.1080/01621459.2018.1529596

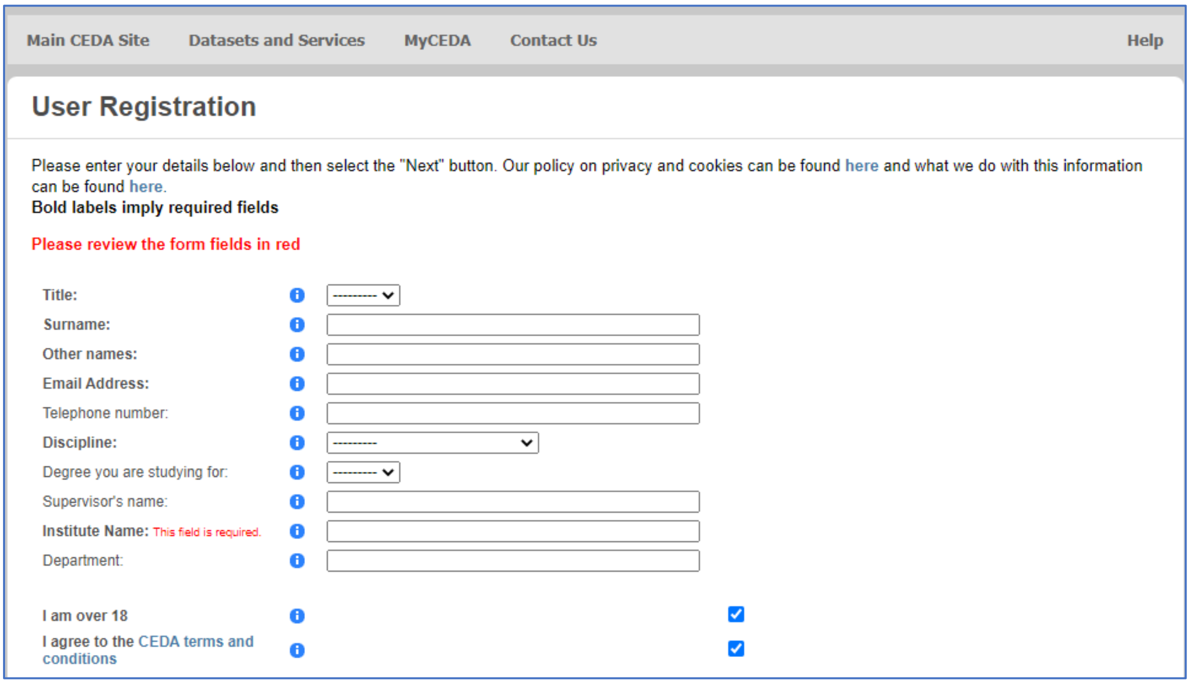
[8] The 'design storm' concept is defined in the Flood Estimation Handbook (https://www.ceh.ac.uk/services/flood-estimation-handbook) and represents the industry standard approach for assessing flood risk

3. **Uplift values vary by return period**. In general, uplifts have been found to increase as return period increases, or stay the same. We recommend that uplift values are used that correspond to the rainfall return period of the design storm being changed.
4. **A central estimate and high estimate of uplift is provided**. Consistent with the UKWIR 2017 project guidance, two uplift values have been provided representing a central estimate from the climate model output and a high estimate (derived from its 12-member ensemble). The central estimate is the middle value across the ensemble, but given the small ensemble size it is not possible to associate this with a given probability or likelihood; the upper estimate is provided for use in precautionary cases and represents a form of 'reasonable worst case', but again is only based on a small ensemble that does not comprehensively sample climate modelling uncertainty. These are derived from the 50th and 95th percentile of the probability distribution, sampling both the ensemble spread and statistical model uncertainty at each grid cell[9]; this is in contrast with the approach used in UKWIR 2017 where the central and high estimates are based on the spatial variability of uplifts within designated regions only. The high estimate results demonstrate that there is considerable uncertainty in the uplift estimates and that users should be aware of this, particularly in considerations of high vulnerability to flooding or high cost implications of proposed solutions.

How to access the uplifts

Uplift values for a location in the UK are available as GIS shapefiles from the CEDA archive. To access the files an account is required: https://help.ceda.ac.uk/article/39-ceda-account.

To register, you need to complete the form shown below. Please note: although set up for academic users, **you do not need to be an academic user to register and can leave the following fields blank: Discipline, Degree you are studying for, Supervisor's name.** For Department, please enter your organisation. This information is required to monitor use of the data.


Main CEDA Site Datasets and Services MyCEDA Contact Us Help

User Registration

Please enter your details below and then select the "Next" button. Our policy on privacy and cookies can be found here and what we do with this information can be found here.
Bold labels imply required fields

Please review the form fields in red

Title:
Surname:
Other names:
Email Address:
Telephone number:
Discipline:
Degree you are studying for:
Supervisor's name:
Institute Name: This field is required.
Department:

I am over 18
I agree to the CEDA terms and conditions

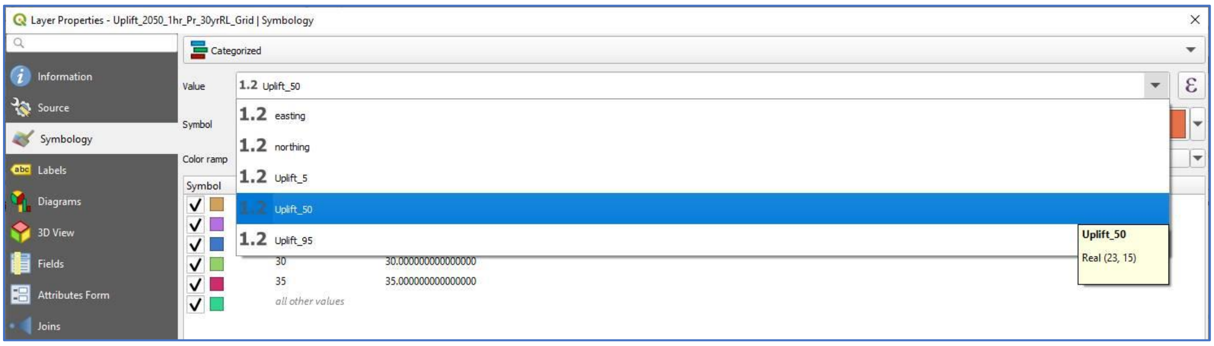
[9] Fosser G, Kendon EJ, Stephenson D, Tucker S (2020) Convection-Permitting Models Offer Promise of More Certain Extreme Rainfall Projections. Geophysical Research Letters 47:e2020GL088151. https://doi.org/10.1029/2020GL088151

Once registered, shapefiles of uplift values are accessible at this link:
https://data.ceda.ac.uk/badc/ukcp18/data/land-cpm/derived/future-extremes

You need to download the shapefiles for the rainfall **duration, return period** and **time horizon** of interest. The format of the files is as shown below. This example is for the 1-hour duration, 2-year return period, 2050 time horizon.

- uplift_land-cpm_uk_5km_2050_01hr_pr_002yrl.dbf
- uplift_land-cpm_uk_5km_2050_01hr_pr_002yrl.prj
- uplift_land-cpm_uk_5km_2050_01hr_pr_002yrl.shp
- uplift_land-cpm_uk_5km_2050_01hr_pr_002yrl.shx

Remember that uplifts can vary by location, rainfall duration (1 – 24-hours), and return period (2 – 100 years). Uplifts are also provided for a central and high estimate of change. The image below shows how to select the uplift value for the central (0.5) and high (0.95) cases.



How to apply the uplifts

Identifying the location for which uplifts are required, the appropriate uplift value can be extracted from the relevant map option (dependent on duration, return period and output timeframe – 2050 or 2070). These uplifts correspond to the high greenhouse emissions scenario (RCP8.5).

We do not recommend using results from individual grid cells, but to take results from a region (e.g. consider the Lake District as a whole, and consider what the range of values are across the region). There are geographic features that give rise to local differences, but otherwise we do not expect results to differ significantly from one adjacent grid cell to the next.

If a location of interest is on the border of two uplift zones, we propose using either an uplift value that is an average of the two uplift amounts (e.g. if on the border between an uplift of 25% and 30%, use a value of 27.5%), or, if taking a more precautionary approach, use the higher of the two values. In either case, we recommend that you document the option that has been taken so that there is a record justifying the value used.

We note that Shetland is too close to the boundary of the 2.2km model domain for the UKCP Local 2.2km projections to be reliable over Shetland. Thus, uplifts from FUTURE-DRAINAGE are not available for Shetland itself. Results from the Orkney Islands can be used as indicative of values over Shetland. Alternative sources of data for Shetland include 2.2km climate simulations recently carried out over Europe as part of the EUCP project[10], alongside the UKCP Regional 12km ensemble projections.

Case example – uplifting a 30-Year design storm for a sewer catchment in Glasgow.

A critical duration for this catchment is 1-hour. The output shows (Figure 2) that the 1-hour uplift for Glasgow is 25% for 2050 under RCP8.5. Sensitivity analyses could be run by using the high estimate which is 40% in 2050.

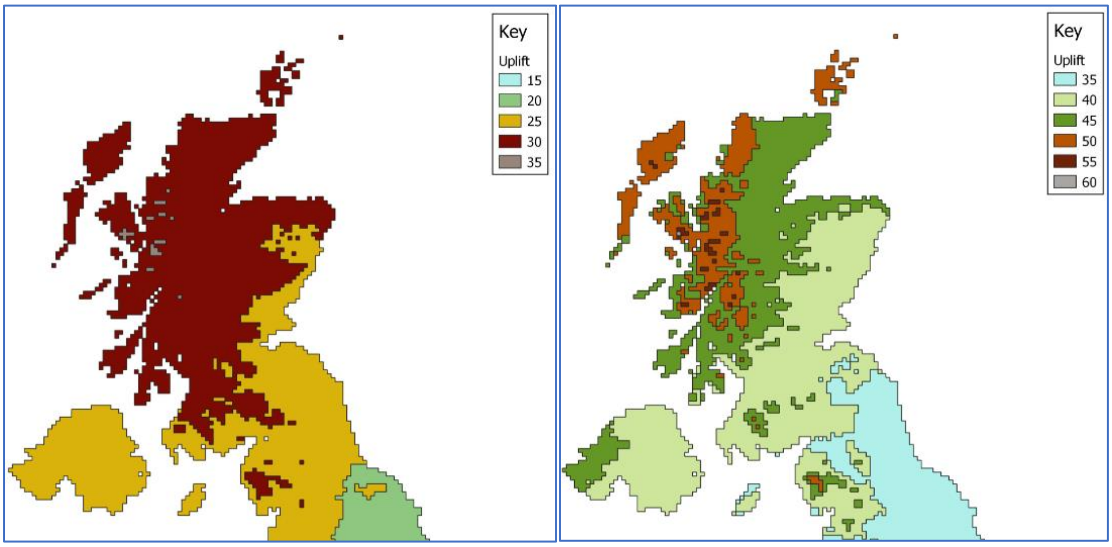


Figure 2 - 1-hour, 30-year uplifts for Scotland for the central estimate (left) and high estimate (right)

Application with baseline rainfall data

The uplifts have been developed against a baseline period of 1981 – 2000. They are appropriate for use with FEH13 depth-duration-frequency (DDF) data. We are aware that a new version of the FEH DDF model will be released in the next year or so, currently referred to as FEH22. As the baseline data that are used to derive the FEH22 DDF model will change (i.e. become later in time), it may be appropriate to scale back the uplifts based on the change in the baseline data period, if the centre point of the data period differs substantially from the UKCP Local baseline centre point (1990).

How do the new uplifts compare with the old (2017 values)?

A direct comparison of the uplift values from this (FUTURE-DRAINAGE) research and those produced by the UKWIR 2017 project is not possible since the regions over which the uplifts apply are different. However, an approximate comparison is provided in Table 1 and Figure 3. This compares UKWIR 2017 guidance uplift values for the 30-year return period, 2050 case with the range of values from FUTURE-DRAINAGE for the 30-year return period, 2050 case. The regions referred to in this table are those used in the 2017 UKWIR project. In general, the lower values in the FUTURE-

[10] Hewitt C.D. and J.A. Lowe (2018) Toward a European Climate Prediction System, BAMS, doi: 10.1175/BAMS-D-18-0022.1

DRAINAGE range are from the 24-hour duration and the higher values in the range are from the 1-hour and 3-hour duration. For the high estimate, it can be seen that FUTURE-DRAINAGE results are lower than UKWIR 2017 values in all regions except South UK. For the central estimate, FUTURE-DRAINAGE results are lower in the North-West and higher in the South UK.

Uplifts from FUTURE-DRAINAGE are based on a revised climate model with improved physics and a larger UK-wide domain, as well as a set of twelve realisations giving an indication of uncertainty in future changes at local scales. Thus the FUTURE-DRAINAGE uplifts are considered more reliable and supersede the UKWIR 2017 values. However, it should be noted that the UKCP Local (2.2km) projections likely underestimate uncertainty in future climate change since they are only using variants of the Met Office Hadley Centre climate model, with no multi-model information. Furthermore, all uplift values are conditioned on the chosen scenario of future greenhouse gas emissions (RCP8.5; the most aggressive "business-as-usual" RCP scenario) and the particular methodologies we employ.

Table 1 – Approximate comparison of uplifts to the UKWIR 2017 values for 2050, 30-year return period.

UKWIR 2017 values			**FUTURE-DRAINAGE Range**	
			From	**To**
North West UK	Central estimate	35%	15%	30%
	High estimate	*65%*	*35%*	*45%*
North East UK	Central estimate	20%	10%	30%
	High estimate	*50%*	*25%*	*45%*
South UK	Central estimate	15%	20%	25%
	High estimate	*35%*	*25%*	*35%*

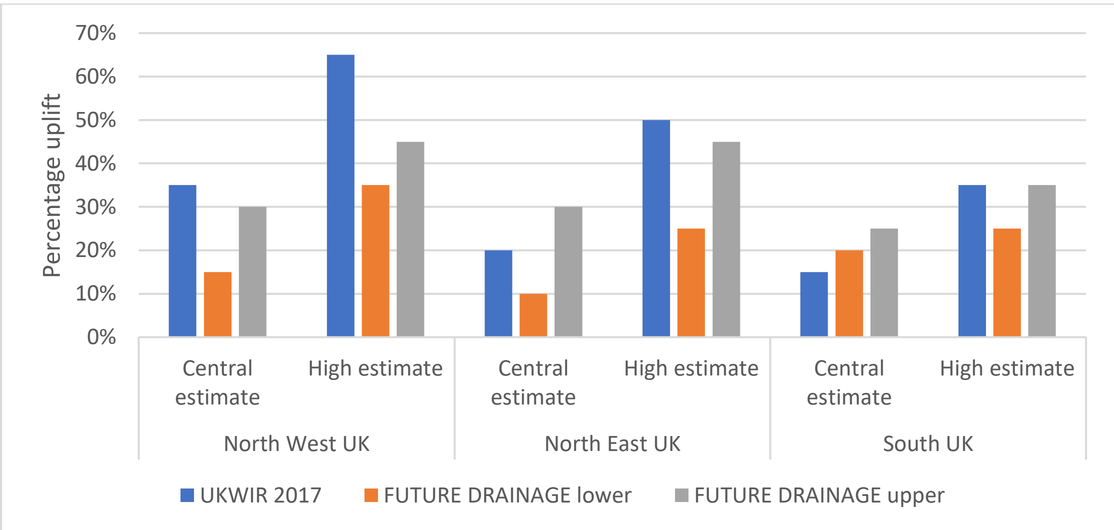


Figure 3 - Approximate comparison of uplifts to the UKWIR 2017 values for 2050, 30-year return period.