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National Coastal Flood Hazard Mapping 2021

Flood Mapping Methodology Report



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Flood Mapping Methodology Report DOCUMENT CONTROL SHEET

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Appendix A FME Workbench

1.0 Introduction

This report has been prepared by the Office of Public Works (OPW) Coastal and Flood Risk Management Data Management Sections to detail the methodology used in the National Coastal Flood Hazard Mapping 2021 project. The aim of this project is to produce updated national scale coastal flood extent and depth maps for the 50%, 20%, 10%, 5%, 2%, 1%, 0.5% and 0.1% Annual Exceedance Probabilities (AEPs) for the present day scenario and for the Mid-Range Future Scenario (MRFS), High End Future Scenario (HEFS), High+ End Future Scenario (H+EFS) and High++ End Future Scenario (H++EFS) which represent a 0.5m, 1.0m, 1.5m and 2.0m increase in sea level respectively.

2.0 Data Inputs

2.1 Extreme Water Level Data

The estimated extreme water level outputs from Phase 1 of the Irish Coastal Wave and Water Level Modelling Study (ICWWS 2018), relative to OD Malin OSGM02, were used as the input water level data for the project. Refer to the ICWWS 2018 Phase 1 – Extreme Water Levels Technical Report (RPS, 2020) for further details on the estimation of the extreme water levels.

The location of the ICWWS 2018 Phase 1 estimation points are included in Figure 2.1.

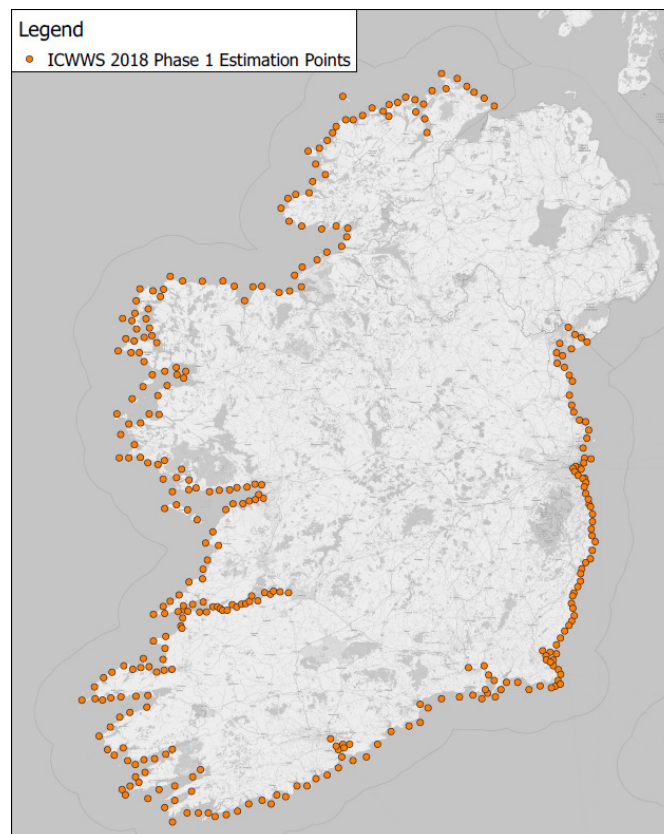


Figure 2.1 – ICWWS 2018 Phase 1 Estimation Points (Background Map data © 2021 OpenStreetMap)

2.2 Digital Terrain Model

A national Digital Terrain Model (DTM), created by merging OPW owned and open licenced elevation data, was used in the production of the flood extent and depth datasets. All elevation data used to produce the national DTM was relative to OD Malin OSGM02. As the elevation data used to create the national dataset was captured at different times using different methodologies, the accuracy of the

national DTM varies depending on the source of the DTM data used. It may be noted that in some areas a “step” in the elevation can be seen at the boundaries between datasets. The decision was taken not to smooth these steps, in order to preserve the underlying legacy data.

The various sources of the elevation data used to create the national DTM is included in Figure 2.2.

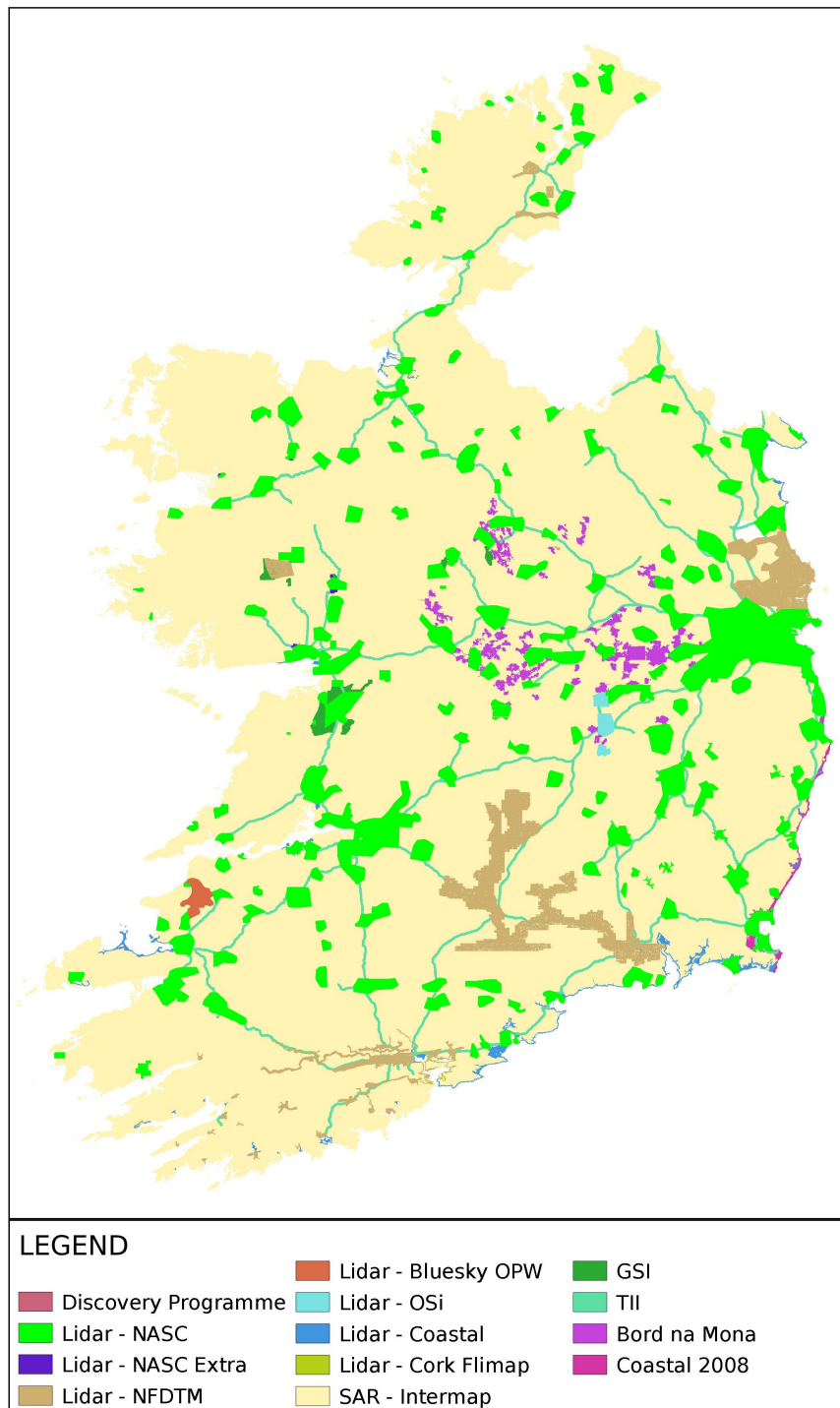


Figure 2.2 – National DTM Index

2.2.1 Glacial Isostatic Adjustment

The datasets produced for the MRFS, HEFS, H+EFS and H++EFS represent a projected future scenario for the end of century (circa 2100) and include an allowance of -0.5mm/year¹ for glacial isostatic adjustment in accordance with the Flood Risk Management Climate Change Sectoral Adaptation Plan (OPW, 2019). For mapping purposes, the glacial isostatic adjustment allowance was applied to the estimated extreme water levels rather than the DTM.

2.3 Coastal Mask

A coastal mask was created by the OPW to remove permanent water bodies from the outputs. The mask was created using the following datasets:

- 2.5km buffer of the Irish Coastal Protection Strategy Study (ICPSS) flood extent dataset (this was rasterised with a value of 1).
- OSI PRIME2 high water mark (HWM). This dataset was edited in a number of locations in order to refine the position of the HWM based on a comparison with aerial imagery (this was then converted to a polygon and rasterised with a value of 1).
- OSI PRIME2 water polygon dataset filtered to show only lakes, canals, rivers, ponds, open reservoirs and the sea polygons (these were then dissolved into a single polygon, which was rasterised and given a value of 0).
- OSI PRIME2 quarry polygon extents dataset filtered to remove any quarries which could flood, leaving only quarries with no direct path to the sea (these were then rasterised and given a value of 0).

These individual raster datasets were then merged into a single national coastal mask with the output extents, resolution and pixel alignment matching the national DTM.

2.4 Summary of Data Inputs

The data inputs are summarised in Table 2.1.

¹ Applicable to the southern part of the national coastline only (Dublin – Galway and south of this).

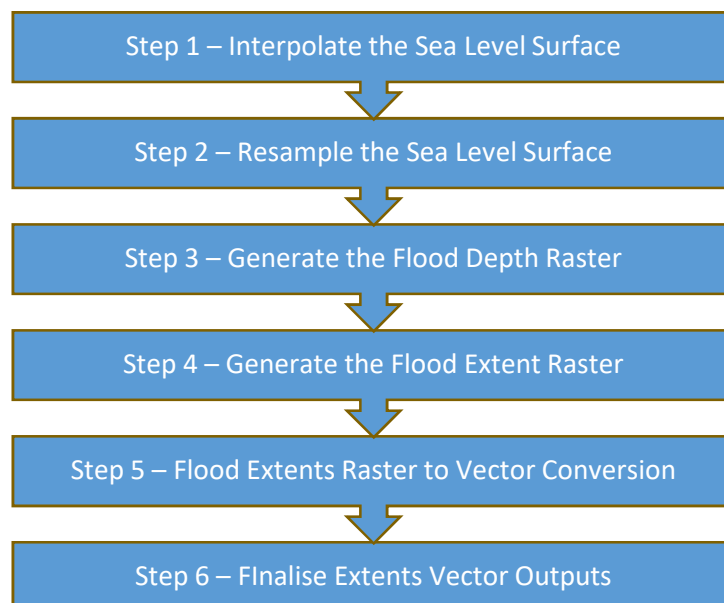
Table 2.1 – Summary of Data Inputs

Dataset	Description	Resolution	Coordinate Reference System	Height Datum	Source
ICWWS 2018 Phase 1 Estimation Points	CSV file including the coordinates and estimated extreme water levels at the ICWWS 2018 estimation points. The MRFS, HEFS, H+EFS and H++EFS water levels were edited to include an allowance for glacial isostatic adjustment as described in Section 2.2.1	n/a	Irish Transverse Mercator (EPSG: 2157)	OD Malin (OSGM02)	OPW
National Digital Terrain Model (DTM)	National DTM created by merging various sources of elevation data available to OPW	5m	Irish Transverse Mercator (EPSG: 2157)	OD Malin (OSGM02)	Various elevation datasets available to OPW
Coastal Mask	Developed from a buffer of the ICPSS flood extents and the OSi PRIME2 datasets	5m	Irish Transverse Mercator (EPSG: 2157)	n/a	Developed by OPW from OPW and OSi datasets

3.0 Methodology

3.1 Overview

The methodology developed by the OPW and used in the preparation of the national coastal flood extent and depth datasets is summarised in Figure 3.1. The methodology utilises, in the main, Geospatial Data Abstraction Library (GDAL)/OGR scripts incorporated into batch scripts which can be run to complete each step. These batch scripts allow for multiple datasets to be generated from a single script, helping to speed up the process.

**Figure 3.1 – Methodology Overview**

3.2 Step 1 – Interpolate the Sea Level Surface

The ICWWS 2018 estimation points, including an allowance for glacial isostatic adjustment for the MRFS, HEFS, H+EFS and H++EFS, were used to interpolate a sea level surface for each AEP event analysed. The GDAL Inverse Distance Weighted (IDW) interpolation method with nearest neighbour searching was used to ensure that the closest points will have more influence on their surrounding areas, resulting in a smooth surface. To optimise the processing time for this national scale assessment, the resolution of the interpolated sea level surface was set to 100m.

There were two areas where additional points were included in the derivation of the sea level surface: Lough Corrib and Lough Foyle and upstream of these areas. These points were added to ensure the sea level surface generated was representative of the nearest hydraulically linked estimation point. The estimated extreme water levels from ICWWS 2018 estimation points W6 and NW52 were assigned to the additional points at Lough Corrib and Lough Foyle respectively. To limit the influence of these additional points to the area of interest, the extent of the surface generated from each point was limited to 8km. This required a number of points to be added to each area to provide sufficient coverage for the sea level surface.

These points were then processed separately and the resulting outputs merged with the national sea level surface outputs. Some examples of the outputs can be seen below in Figure 3.2.

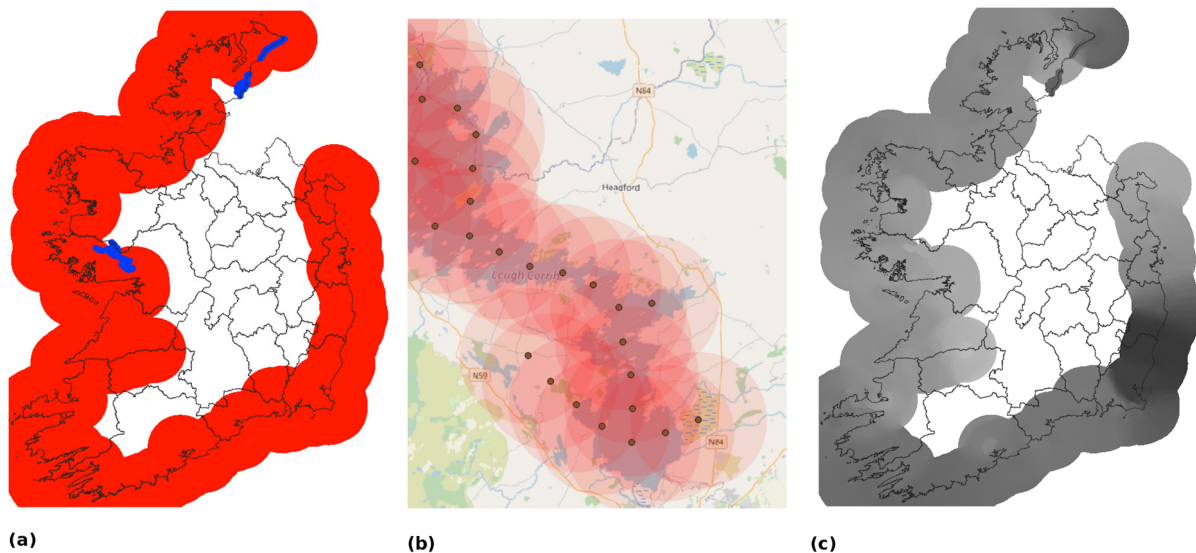


Figure 3.2 – (a) Extent of Sea Surface (Red – 30km radius, Blue – 8km radius in Lough Corrib and Lough Foyle) (b) Example of additional estimation points and extent of influence, Lough Corrib, Co. Galway. (c) Example of National Sea Surface

The sea level surface interpolation was carried out using a GDAL script similar to that outlined below. All variables are shown in red with the values used shown in bold. Refer to Table 3.1 for details.

```
gdal_grid -l ncfhm_water_levels_itm_osgm02 -zfield h++_0100 -a invdistnn: power= 3.0: radius= 30000.0:  
max_points= 6: min_points= 0 -ot Float32 -of GTiff -co "NUM_THREADS=ALL_CPUS" -co "BIGTIFF=YES" -co  
"TILED=YES" -co "COMPRESS=DEFLATE" -tse 415000 767300 -tse 515000 970000 -outsize 4551 3524 -a_srs  
EPSG:2157 "ncfhm_water_levels_itm_osgm02.shp" "30km_sur_h++_0100.tif"
```


Table 3.1 – Sea Level Surface Interpolation Parameters

Variable	Value	Description
-l	ncfhm_water_levels_itm_osgm02	Layer name
-zfield	h++_0100	The attribute/field containing the Z value (sea levels)
-a	Invdistnn	The algorithm used for the interpolation (inverse distance to a power with nearest neighbour searching)
power	3.0	Weighting power
radius	30000.0 or 8000.0 (<i>units are meters</i>)	The radius of the search circle, 30km or 8km
max_points	6	Maximum number of data points the algorithm will use
min_points	0	Minimum number of data points the algorithm will use
-ot	Float32	Force the output image bands to have a specific data type
-of	GTiff	Specify output format GeoTiff
-co NUM_THREADS	ALL_CPUS	Creation option, utilises all available threads in CPU for multi-threaded compression
-co BIGTIFF	YES	BigTIFF is a TIFF variant which can contain more than 4GiB of data
-co TILED	YES	Creates internal tiling for more efficient rendering
-co COMPRESS	DEFLATE	Sets the method of compression
-txe	415000 767300	Sets georeferenced X extents of output file to be created
-tye	515000 970000	Sets georeferenced Y extents of output file to be created
-outsize	4551 3524	Sets the size of the output file in number pixels, or number of rows and columns.
-a_srs	EPSG:2157	The coordinate reference system to be assigned to the raster (no re-projection)
	ncfhm_water_levels_itm_osgm02.shp	Input dataset name
	30km_sur_h++_0100.tif	Output dataset name

The 30km and 8km resolution sea level surfaces were then merged into a single raster, with the values in the 8km dataset overwriting the values in the 30km dataset. This was achieved using a GDAL script similar to the one outlined below. All variables are shown in red with the values used shown in bold. Refer to Table 3.2 for details.

```
gdalbuildvrt -srcnodata 0 -vrtnodata -9999 "warped_30km_sur_h++_0100"
"warped_add_8km_sur_h++_0100" "sur_h++_0100.vrt"
```

Table 3.2 – Sea Level Surface Merging Parameters

Variable	Value	Description
<i>-srcnodata</i>	0	Layer name
<i>-vrtnodata</i>	-9999	The attribute/field containing the Z value
	"warped_30km_sur_h++_0100"	Input dataset name
	"warped_add_8km_sur_h++_0100"	Input dataset name
	"sur_h++_0100.tif"	Output dataset name

3.3 Step 2 – Resample the Sea Level Surface

The sea level surface was interpolated to a 100m resolution in Step 1. In order to match the extent, resolution and pixel alignments of the national DTM, the sea level surface was resampled down to 5m resolution.

This process was carried out using a GDAL script similar to that outlined below. All variables are shown in red with the values used shown in bold. Refer to Table 3.3 for details.

```
gdalwarp -of GTiff -te 415000 515000 767300 970000 -te_srs EPSG:2157 -tr 5 5 -tap -co
"NUM_THREADS=ALL_CPUS" -co "BIGTIFF=YES" -co "TILED=YES" -co "COMPRESS=DEFLATE"
"sur_h++_0100.vrt" "nifm_itm_sur_h++_0100_f_00.tif"
```

Table 3.3 – Sea Level Surface Resampling Parameters

Variable	Value	Description
<i>-of</i>	GTiff	Specify output format GeoTiff
<i>-te</i>	415000 515000 767300 970000	Sets georeferenced extents of output file to be created
<i>-te_srs</i>	EPSG:2157	Specifies the coordinate reference system for the extents
<i>-tr</i>	5 5	Target resolution (meters)
<i>-tap</i>		Target aligned pixels
<i>-co</i>	"NUM_THREADS=ALL_CPUS"	Creation option, utilises all available threads in CPU for multi-threaded compression
	"BIGTIFF=YES"	BigTIFF is a TIFF variant which can contain more than 4GiB of data
	"TILED=YES"	Creates internal tiling for more efficient rendering
	"COMPRESS=DEFLATE"	Sets the method of compression
	"sur_h++_0100.tif"	Input dataset name
	"ncfhm_itm_sur_c_h++_0100_f_00.tif"	Output dataset name

3.4 Step 3 – Generate the Flood Depth Raster

To generate the flood depth raster datasets, the following steps were carried out:

1. The DTM was subtracted from the sea level surface and a temporary mask created for pixel values less than zero.
2. The DTM was subtracted from the sea level surface and multiplied by the temporary mask generated in step 1 to remove all pixels with a value less than zero.
3. The output of step 2 was multiplied by the coastal mask to remove all permanent water bodies.

A GDAL script similar to that outlined below was used. All variables are shown in red with the values used shown in bold. Refer to Table 3.4 for details.

```
gdal_calc -A "ncfhm_itm_sur_c_h++_0100_f_00.tif" -B "all_island_combined_dtm.tif" -C
"ncfhm_coastal_mask_itm.tif" --outfile= "ncfhm_itm_dep_c_h++_0100_f_00.tif" --calc= "round((((A-B) >
0.00) * (A-B)) * C),4)" --NoDataValue= 0 --co "NUM_THREADS=ALL_CPUS" --co "BIGTIFF=YES" --co
"TILED=YES" --co "COMPRESS=DEFLATE"
```

Table 3.4 – Flood Depth Raster Parameters

Variable	Value	Description
-A	"ncfhm_itm_sur_c_h++_0100_f_00.tif"	Input dataset name "A" (sea level surface)
-B	"all_island_combined_dtm.tif"	Input dataset name "B" (national DTM)
-C	"ncfhm_coastal_mask_itm.tif"	Input dataset name "C" (coastal mask)
--outfile	"ncfhm_itm_dep_c_h++_0100_f_00.tif"	Output dataset name (depth raster)
--calc	"round((((A-B) > 0.00) * (A-B)) * C),4)"	Raster calculation which subtracts the DTM from the sea level surface and applies the coastal mask, resulting in outputs depths greater than Zero with all values rounded to four decimal places
--NoDataValue	0	Sets the NoData value of the raster to zero
--co	"NUM_THREADS=ALL_CPUS"	Creation option, utilises all available threads in CPU for multi-threaded compression
	"BIGTIFF=YES"	BigTIFF is a TIFF variant which can contain more than 4GiB of data
	"TILED=YES"	Creates internal tiling for more efficient rendering
	"COMPRESS=DEFLATE"	Sets the method of compression

3.5 Step 4 – Generate the Flood Extent Raster

The flood extent raster dataset was generated to make the creation of vector (polygon) datasets easier to process. The script uses two specific variables to achieve this:

1. **type= Byte**
2. **--co "SPARSE_OK=TRUE"**

These variables, combined with compression, can reduce the size of the resulting raster dataset considerably.

A GDAL script similar to that outlined below was used. All variables are shown in red with the values used shown in bold. Refer to Table 3.5 for details.

```
gdal_calc -A "ncfhm_itm_ext_c_h++_0100_f_00.tif" --outfile= "ncfhm_itm_ext_c_h++_0100_f_00.tif" --
type= Byte --calc= "1*(A>0)" --NoDataValue= 0 --co "NUM_THREADS=ALL_CPUS" --co "TILED=YES" --co
"COMPRESS=DEFLATE" --co "SPARSE_OK=TRUE"
```

Table 3.5 – Flood Extent Raster Generation Parameters

Variable	Value	Description
-A	"ncfhm_itm_sur_c_h++_0100_f_00.tif "	Input dataset Name "A" (sea level surface)
--outfile	"ncfhm_itm_dep_c_h++_0100_f_00.tif"	Output dataset name (depth raster)
--type	Byte	Sets the raster output type to byte
--calc	"1*(A>0)"	Raster calculation which outputs depths greater than zero giving all pixels a value of 1
--NoDataValue	0	Sets the NoData value of the raster to zero
--co	"NUM_THREADS=ALL_CPUS"	Creation option, utilises all available threads in CPU for multi-threaded compression
	"BIGTIFF=YES"	BigTIFF is a TIFF variant which can contain more than 4GiB of data
	"TILED=YES"	Creates internal tiling for more efficient rendering
	"COMPRESS=DEFLATE"	Sets the method of compression
	"SPARSE_OK=TRUE"	Omits empty blocks, blocks with a value of zero or NoData

3.6 Step 5 – Flood Extents Raster to Vector Conversion

The flood extent raster dataset was transformed into a vector layer to facilitate further processing and analysis using the data.

A GDAL script similar to that outlined below was used. All variables are shown in red with the values used shown in bold. Refer to Table 3.6 for details.

```
gdal_polygonize "ncfhm_itm_ext_c_h++_0100_f_00.tif" -f "ESRI Shapefile" "ncfhm_itm_ext_c_h++_0100_f_00.shp"
```

Table 3.6 – Flood Extent Vectorisation Parameters

Variable	Value	Description
	"ncfhm_itm_ext_c_h++_0100_f_00.tif "	Input raster dataset name
-f	"ESRI Shapefile"	OGR format for output dataset
	"ncfhm_itm_ext_c_h++_0100_f_00.shp"	Output dataset name (depth raster)

3.7 Step 6 – Finalise Extents Vector Outputs

This step was carried out to produce geometries which are optimised for use in future analysis and to generate the required attribution.

This process was carried out in SAFE Software's FME. The process is as follows:

1. Ensure all geometries are 2D.
2. Convert multipart geometries to single part geometries.
3. Buffer all geometries by 0.001m and dissolved results. This removes any common geometry issues which can occur after vectorization, such as self-intersections.
4. Validate geometry based on OGC compliance.
5. Creation of attribution in line with the Flood Relief Scheme Engineering Spatial Data Specification (OPW, 2020).

6. Write out final shapefiles.

An example of the FME Workbench is included in Appendix A.

4.0 Flood Mapping Outputs

National coastal flood extent and depth maps have been produced for the 50%, 20%, 10%, 5%, 2%, 1%, 0.5% and 0.1% Annual Exceedance Probabilities (AEPs) for the present day scenario, and for the MRFS, HEFS, H+EFS and H++EFS. The flood extent and depth maps were prepared using elevation datasets relative to OD Malin OSGM02.

The maps prepared are predictive, as they provide predicted flood extent and depth information for a 'design' flood event that has an estimated probability of occurrence (e.g. the 0.5% AEP event), rather than information for floods that have occurred in the past.

The maps have been produced at a strategic level to provide an overview of coastal flood hazard in Ireland, and minor or local features may not have been included in their preparation. A Digital Terrain Model (DTM) is used to generate the maps, which is a 'bare-earth' model of the ground surface with the digital removal of man-made and natural landscape features such as vegetation, buildings and bridges. This methodology can result in some of these man-made features, such as bridges and embankments, being shown within a flood extent, when in reality they do not flood.

It should be noted that the flood extent maps indicate the predicted maximum extent of flooding, and flooding in some areas, such as near the edge of the floodplain area, might be very shallow. The predicted depth of flooding at a given location is indicated on the flood depth maps. The flood depth is displayed as a constant depth over grid squares with a 5m resolution, whereas in reality depths may vary within a given square.

No post-processing of the flood extent and depth map datasets has been undertaken to remove small areas of flooding that are remote and isolated, small islands within the flooded area, etc. Local factors such as flood defence schemes, structures in or around river channels (e.g. bridges), buildings and other local influences, which might affect coastal flooding, have not been accounted for.

4.1 Uncertainties

Although widely accepted methods have been used to prepare the maps, there is a range of inherent uncertainties within the process of preparing the flood extent and depth maps. These include:

- Uncertainties in the estimated extreme water levels: This can arise due to uncertainties in topographic and other survey data, meteorological data, assumptions and / or approximations in the hydraulic / hydrodynamic models in representing physical reality, assumptions in the hydraulic / hydrodynamic modelling, datum conversions, etc.
- Uncertainties in the flood extents and depths: This can arise due to uncertainties in the estimated extreme water levels, topographic and other survey data, assumptions and / or approximations in the way that flooding spreads over a floodplain, etc.

Due to the various sources of potential inaccuracies in the flood extent and depth maps, a quantitative assessment of their accuracy has not been carried out. A qualitative assessment of the maps was carried out as part of the quality control process. The flood extent and depth maps are therefore suitable for the assessment of flood risk at a strategic scale only, and should not be used to assess the flood hazard and risk associated with individual properties or point locations, or to replace a detailed flood risk assessment. The potential for inaccuracy should be recognised if these flood maps are to be

used for any purpose. Users of this data should refer to the associated Disclaimer, Guidance Notes and Licence.

Appendix A

FME Workbench

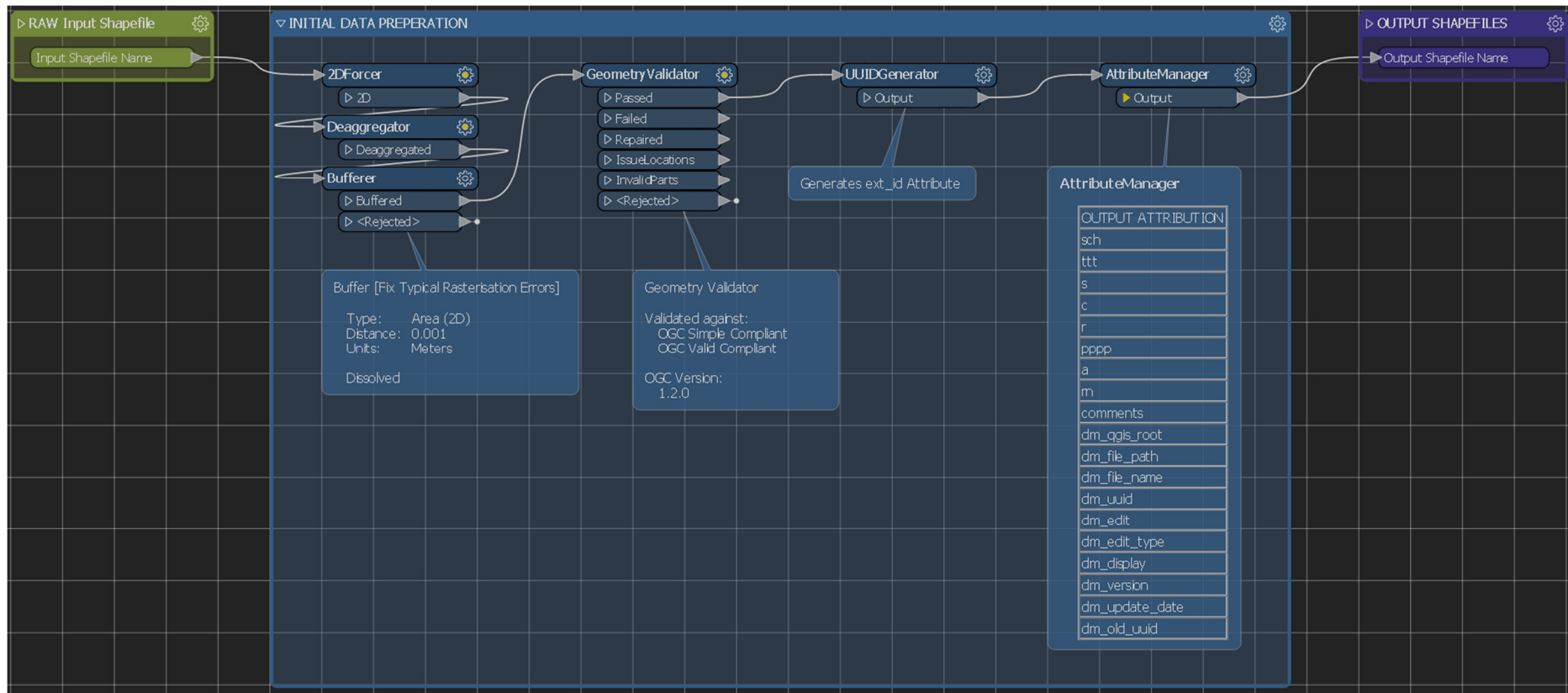


Figure A.1 – Example of the FME Workbench