Process for Generating a 'Structures Breached' DEM (SB-DEM) and Statewide Stream Network

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1. Introduction

A statewide 10 m DEM of Tasmania was created from a combination of LiDAR data and other sources, as described in Kain and Mazengarb (2018). This DEM is based on bare earth points and structures such as bridges, road embankments and dams are included as solid surfaces in the model, as points for these surfaces are not usually classified separately in the input data. Consequently, the DEM represents a 'structures blocked' surface and is not suitable for flood modelling in its current form. A second version of the DEM has now been created through automated means, which represents a 'structures breached' surface (SB-DEM) that allows water to flow freely along channels as it does in reality. The term 'hydrologically enforced' DEM has been avoided, as this term implies a greater level of processing and flow checking than was applied to generate this preliminary surface for the Proof of Concept (POC) model.

An accurate stream network is also required as an input to the flood model. The existing statewide hydrography layer was digitised from topographic maps and aerial photographs and is now outdated. When this existing network was used in the pilot flood study for the 2018 Hobart Floods, the streams did not match the channels in the DEM and significant manual work was required to rectify these mismatches. For the case of flood modelling, it is preferable to use a stream network that has been extracted directly from the DEM that will be used in the model. To this end, a stream network was extracted from the SB-DEM and each link assigned a Strahler number.

This document outlines the procedures used to generate the SB-DEM and statewide stream network for the POC model. These outputs have some known errors and inconsistencies, but are deemed adequate for the POC and will be significantly improved for the final model.

2. Methodology

The purpose of this processing was to generate a DEM that was free of obstructions in the stream channels, allowing a sensible flow path of flood waters across the surface.

The first step for creating a hydrologically correct DEM involves identifying and correcting erroneous sinks/depressions in the DEM, such as those created by bridges, embankments or dams. Many hydrological tools manage these through a 'fill sinks' followed by a 'burn streams' approach, but others use a 'breach depressions' method that negates the immediate need to burn the stream channels into the DEM. The latter method is thought to be more accurate and is the option used here. The lack of an accurate pre-existing stream network contributed to this choice. Details of software and workflow are presented in Section 2.2.

Following the creation of the SB-DEM, a stream network was extracted as a statewide process and each stream link was assigned a Strahler number.

2.1. Software choice

A number of tools were considered and trialled before settling on a combination of Whitebox GAT and ArcGIS Pro. Initially, the ArcHydro suite was used on a test area in NE Tasmania, but the results achieved with the fill depressions approach and the stream extraction tool were underwhelming. The

same test area was then analysed using Whitebox GAT tools (breaching depressions rather than filling) and the results were much more reflective of reality.

The state was then processed as a whole using Whitebox GAT. However, due to memory allocation constraints, flow accumulation could not be performed for the entire state in Whitebox, so this was done in ArcGIS Pro, as were some final minor processing steps and file conversions. Technical detail is described in Section 2.2.

2.2. Final workflow

Details of the processing steps and tools is presented in Table 1. The processing involved a number of intermediate steps, each of which resulted in a separate statewide output that can be made available if desired. All processing was done across the entire state in one iteration and processing was largely performed with Whitebox GAT. Whitebox uses its own raster format (.dep and .tas), which necessitated ongoing file conversions between ESRI or ASCII grid rasters and the Whitebox format.

Table 1. List of processing steps and tools used to generate the SB-DEM and stream network.

PROCESS	TOOL
1. Create a 'structures breached' DEM	Whitebox - Breach Depressions (Fast)
2. Generate D8 flow direction raster using output from (1)	Whitebox - D8 Flow Pointer
3. *Export flow direction and SB-DEM to ASCII grid*	Whitebox - Raster Export
4. Generate flow accumulation raster using output from (3)	ArcGIS Pro - ArcHydro Flow Accumulation
5. Extract stream network from outputs of (2) and (4)	Whitebox - Stream Extraction, channelization threshold 1000 (i.e. 1000 cells = 10 000 m^2)
6. Calculate Strahler order using outputs of (2) and (5)	Whitebox - Strahler Order Basins
7. Convert Strahler ordered stream raster (6) to vector format	Whitebox - Raster to Vector Lines
8. Smooth lines of output (7)	ArcGIS Pro – Smooth Line (PAEK algorithm, tolerance = 50)

2.3. Other methods considered

Other methods for removing structures in the DEM were considered and/or trialled. Firstly, the use of culverts to represent bridges in the model was considered; however, the computational overhead of this method was thought to be too great and so it was not pursued further.

Secondly, removal of the bridges from the DEM was trialled, using ArcGIS. This method involved the use of an existing bridges vector layer, which was buffered out to generate a set of 'bridge masks' that were then used to remove the underlying cells of the DEM. The zonal statistics tool (minimum value) was then run to fill in the gaps, with the idea that the minimum value of the surrounding area would represent the channel either side of the bridge. This method was moderately successful for the trial area, but was inferior to the Whitebox breach depressions option as it compromised the integrity of the data around the bridges.

The removal of the bridges at point level (i.e. prior to building the DEM) was also considered. This method was not trialled, as it would have necessitated a rebuild of the entire statewide DEM, but will be considered during the DEM update that will take place later in 2019.

3. Outputs

- Structures Breached DEM – 10 m cell size with tidal waterbodies set to an elevation of -10 m ASL
- Strahler ordered stream network - vector layer, shapefile format,
- Intermediate hydrological outputs: flow direction raster (D8 flow pointer algorithm), flow accumulation raster, stream network raster, Strahler order raster, Stream network vector (without Strahler order)

4. Limitations and implications

These outputs were generated entirely through automated means and have not been quality controlled. The purpose of this process was to generate datasets that are reasonable and will function when used as inputs to the POC flood model, but accurate results are not important at this stage of the project. In particular, errors have been identified in flat areas and areas of complex urban structures (e.g. around Invermay in Launceston and the plains around Longford).

The process of generating a true hydrologically enforced DEM involves significant cross checking and reworking to ensure the flow paths and depressions reflect reality. A new DEM will be created later in 2019 to take advantage of newly acquired LiDAR data, and a hydrologically enforced DEM will be created from the new data for the final flood model.

5. References

Kain, C. L. and Mazengarb, C. 2018. *A Statewide Digital Elevation Model (DEM) for Tasmania*. Mineral Resources Tasmania Unpublished Report UR2018_05, 34 pp.

Lindsay, J. 2019. *Whitebox Tools User Manual*. https://jblindsay.github.io/wbt_book/intro.html