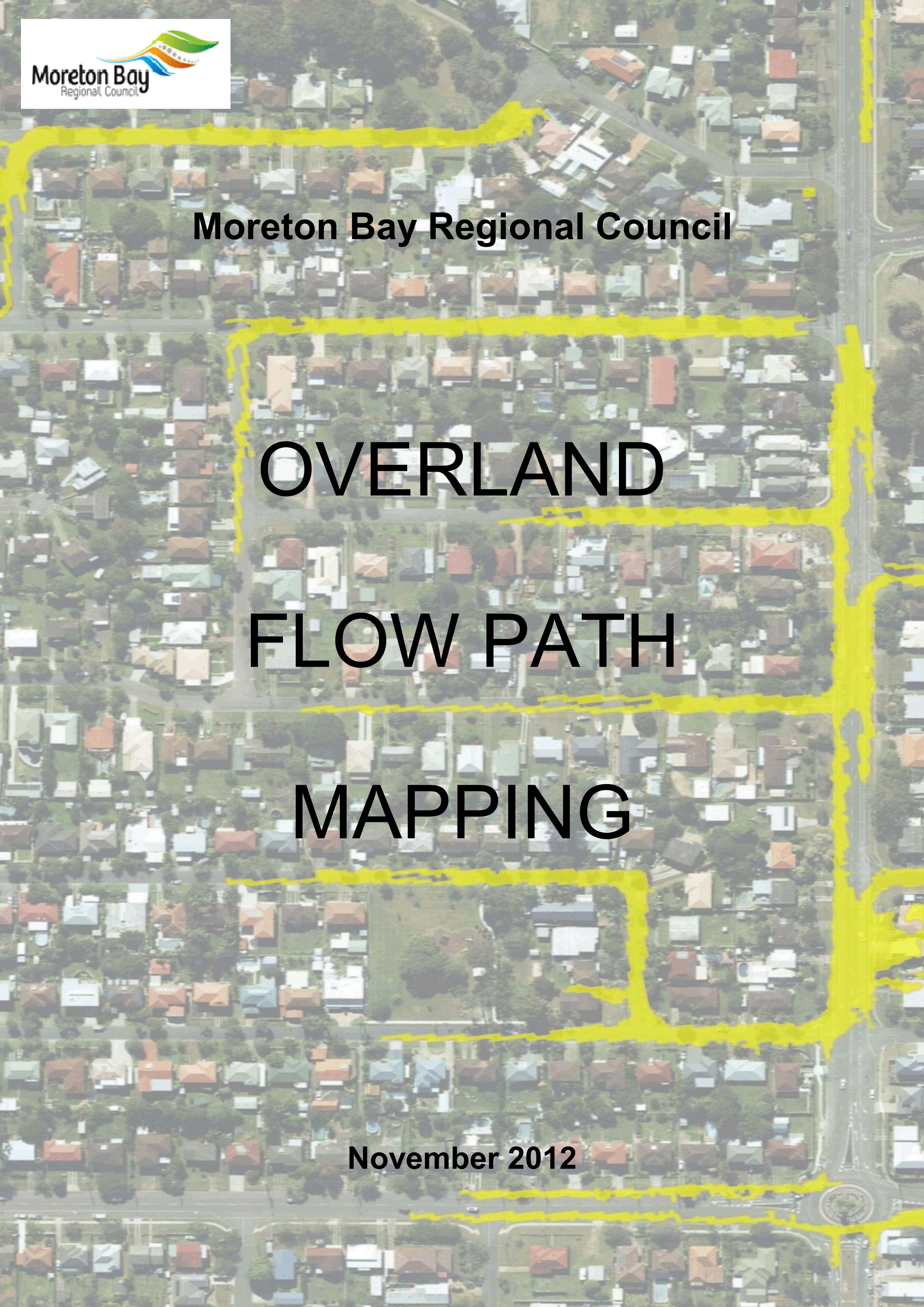

## Moreton Bay Regional Council

# OVERLAND FLOW PATH MAPPING

**November 2012**

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# Executive Summary

Moreton Bay Regional Council (MBRC) commenced a region wide flood investigation in 2009 referred to as the 'Overland Flow Path Mapping Project'.

This project complements the Regional Flood Plain Database River and Creek Flood Mapping Project and the Storm Tide Mapping Project providing Council with a full set of high quality flood information consistent with the 2011 flood commission recommendations.

The purpose of this project was to identify and map the overland flow path flood extent. These flow patterns form along the natural gullies, flow paths and depressions that convey or detain water when there is no local drainage or the local drainage is blocked.

Overland flow is generally shallow fast moving stormwater that may be carrying debris during intense rain events. These flows often cause a lot of unnecessary community stress and damage during storm events that can be reduced through improved public awareness of the risk when making land use decisions.

The methodology involves 'rainfall on grid' hydraulic modeling of 895 catchments and post processing the data (depth and velocity) to map areas at risk from overland flows.

The overland flowpath mapping is now available free on the Council's web site www.moretonbay.qld.gov/floodcheck.

This report is to provide users of this data an understanding of how the overland flow path mapping was prepared and the limitations of the data.

# 1. Introduction

The Moreton Bay local government area is located immediately to the north of Brisbane, Queensland.

The Moreton Bay local government area covers a total of 2,070 km² extending between the northern suburbs of Brisbane to the southern edge of the Glass House Mountains.

A total of 14 separate drainage catchments are located within the Moreton Bay region including those of the Pine and Caboolture Rivers, the headwaters of the Mary River, the Stanley River (a major tributary of the Brisbane River) and numerous large creek catchments. Some of these drainage catchments straddle the boundary of the Moreton Bay region. This means there is 630 km² of additional catchment area that is located outside the local government area but contributing to the floodplains located within the region. The catchment area therefore has a total footprint of 2,700 km².

The study area contains a diverse mix of land uses (e.g. rural, semi-rural, urban and forest) and provides a key urban growth corridor for South-East Queensland, expecting to accommodate another 150,000 people over the next 20 years.

In 2009 Moreton Bay Regional Council (MBRC) started on a region wide flood investigation referred to as the Overland Flow Path Mapping Project. The project incorporates a number of innovative features, each contributing to the projects overall success.

This report provides further detail about the project including background and context of the project, an overview of the adopted approach, and the innovative tools used to support the project.

Council became aware of the need for overland flow path mapping across the region in response to a thunderstorm event in November 2008 affecting Council's southern suburbs. The need for mapping has since been supported by the 2011 Queensland Floods Commission of Inquiry Recommendations.

An overland flowpath map identifies the route taken by stormwater as it concentrates during a rainfall event and makes its way downslope. It can vary in width, depth and velocity depending on the shape of the topography. Overland flowpaths can also be affected by blockage, the capacity of underground drainage infrastructure and alteration of the ground surface through natural or man-made influences.

Previously Council had very limited overland flowpath information for internal assessments and dissemination to the public. This sometimes resulted in poor decision making by property owners and developers, resulting in a legacy of inappropriately sited dwellings. In major rainfall events, this can lead to increased property flood damage, nuisance flooding and associated customer complaints.

Council is undertaking a concurrent project known as the Regional Floodplain Database (RFD) which will map the river and creek flood plains. The overland flowpath mapping produced using the approach described in this report is intended to complement the RFD by providing basic flood information in the upper catchment reaches only (i.e. upstream of the major rivers and creeks).


**Figure 1: Study Area**

## 1.1 Objectives

Council's Overland Flow Path mapping project sought to achieve the following objectives:

- Provide detailed mapping of all overland flowpaths across the region, in particular densely populated urban areas;
- Provide consistency of approach across the region;
- Permit the identification of areas that are of high and low risk of overland flooding;
- Develop a model system that would permit selective future upgrade in areas of high risk.

Increase in general public awareness of overland flow flooding allows the public to better manage their flood risk, in particular empowering landowners to modify building and landscaping practices to accommodate overland flow through their property. Increasing public safety and decreasing property damage following heavy rainfall. Providing Council with regionally reliable overland flow path flood data will also help to prioritise a capital program of drainage upgrades.

More recently the Queensland Floods Commission of Inquiry made the following recommendations in its final report which also provides justification for Council.

> *8.1* ***Councils should, resources allowing, maintain flood maps and overland flow path maps*** *for use in development assessment. For urban areas these maps should be based on hydraulic modelling; the model should be designed to allow it to be easily updated as new information (such as information about further development) becomes available.*
>
> *8.2* ***Councils should make their flood and overland flow maps and models available*** *to applicants for development approvals, and to consultants engaged by applicants.*
>
> *(QFCI – Final Report Recommendations, Chapter 8,pg19)*

## 1.2 General Approach

In order to achieve the project objectives in an efficient manner and having regard to the limited time and budget available, Council adopted a semi-automated high level modelling and post-processing approach.

Because of the size of the study area and the large number of flood models used (895), standardised and automated methodologies were applied allowing the production of a library of model outputs. Batch processing was used to prepare the input data and run the 895 TUFLOW two-dimensional flood models providing depth, velocity and flow outputs.

The models were deployed using a 'rainfall on grid' approach to define the approximate extent of the overland flowpaths arising from a 1% 'annual chance' storm event.Simplified model input were used, for example, excluding existing underground infrastructure and averaged floodplain roughness values. The model surface level data is based on a 2 metre grid calculated from the 2009 LiDAR aerial survey data using an automated GIS tool developed by Worley Parsons.

The model depth and velocity outputs were then processed using GIS tools to clean the model data and develop an overland flow extent for display. The output was then compared with observations to confirm its accuracy.

### 1.3 Related Projects

The following RFDsub-projects provide input data and/or methodologies that support the Overland Flow Path Mapping Project.

**1E – Floodplain Topography (2009 LiDAR) including 1F, 2E, 2I,** sub-project 1E provided the topographic information, such as model z-points layer and Digital Elevation Models (DEM). This was achieved using a bespoke DEM tool developed for the RFD (Worley Parsons, 2010a);

**2J – Floodplain Landuse (historic and future),** sub-project 2J provided landuse data for use in hydraulic modelling (SKM, 2010).

These reports are available for free and can be downloaded from Council’s website.

# 2. Available Data

The following provides a list of the data available for this study:

- **Floodplain Topography -** DEM and z-point tools were generated using the Worley Parson tool. The DEM resolution was 1m. The topography is based on LiDARaerial survey data collected in 2009 and provided by the Department of Environment and Resource Management (DERM).
- **Hydrography -** Catchment delineation was developed by MBRC.
- **Design Rainfall -** Design rainfall is based on Australian Rainfall and Runoff (IE Aust, 1987).

# 3. Methodology

### 3.1 Sub-catchment delineation

The input catchment data was reviewed and split into 895 sub-catchments based on a nominal average area of 250 ha. The 2009 LiDAR aerial survey data was reviewed and post processed to create a suitable terrain for TUFLOWmodelling for each of these sub-catchments. Each sub-catchment was used as a basis for a separate overland flow path model.

## 3.2 Underground Infrastructure

No underground infrastructure was used in the modelling. This simplification has allowed semi-automation, however the hydrologic approach was adjusted to account for some underground capacity (refer to Section 3.3).

## 3.3 Hydrologic Approach

Overland flow paths were calculated separately for each sub-catchment. The overland flow modelling for each sub-catchment excludes flows from neighbouring upstream catchments. In large streams and watercourses where flows pass from one sub-catchment to the next, the overland flow data is superseded by the RFD River and Creek Flood Modelling Project data.

In order to minimise the number of rainfall scenarios that Council was required to run, a nested burst design rainfall approach was used. This involved a synthetic storm burst comprising of all AR&R standard duration bursts between 5 and 120 minutes. By using this approach the full range of catchment sizes are expected to achieve peak flow when compared against a traditional critical duration analysis. A single average rainfall IFD was assumed for the whole region.

In order to define the 1% 'annual chance' overland flowpaths while at the same time indirectly accounting for the capacity of the underground drainage system, Council scaled the storm down to a 2% 'annual chance' rainfall burst. The difference in flowrate between the 2% storm and the 1% storm was assumed to be approximately equivalent to the underground pipe system capacity.

## 3.4 Hydraulic Model

### 3.4.1 Model Software

The construction of 895 similar sub-models is a highly repetitive and time consuming task. Council sought to develop tools to assist with the rapid construction of these models and manage model quality.

Two separate model construction tools have been developed:

1) <u>MBRC DEM Tool (developed by Worley Parsons):</u>

MBRC DEM Tool - TUFLOW requires a spatial file often referred to as a 'z-point file' to define the model topography. A Digital Elevation Model (DEM) Tool was developed to automate the process for creating these input files. Each z-point feature in the z-point file is assigned an elevation using a DEM derived from Council's library of LiDAR and bathymetry data. This tool was specifically developed for MBRC by Worley Parsons. The tool can operate using a batch process initiated using a spatial file containing each of the hydraulic model sub-catchment boundaries.

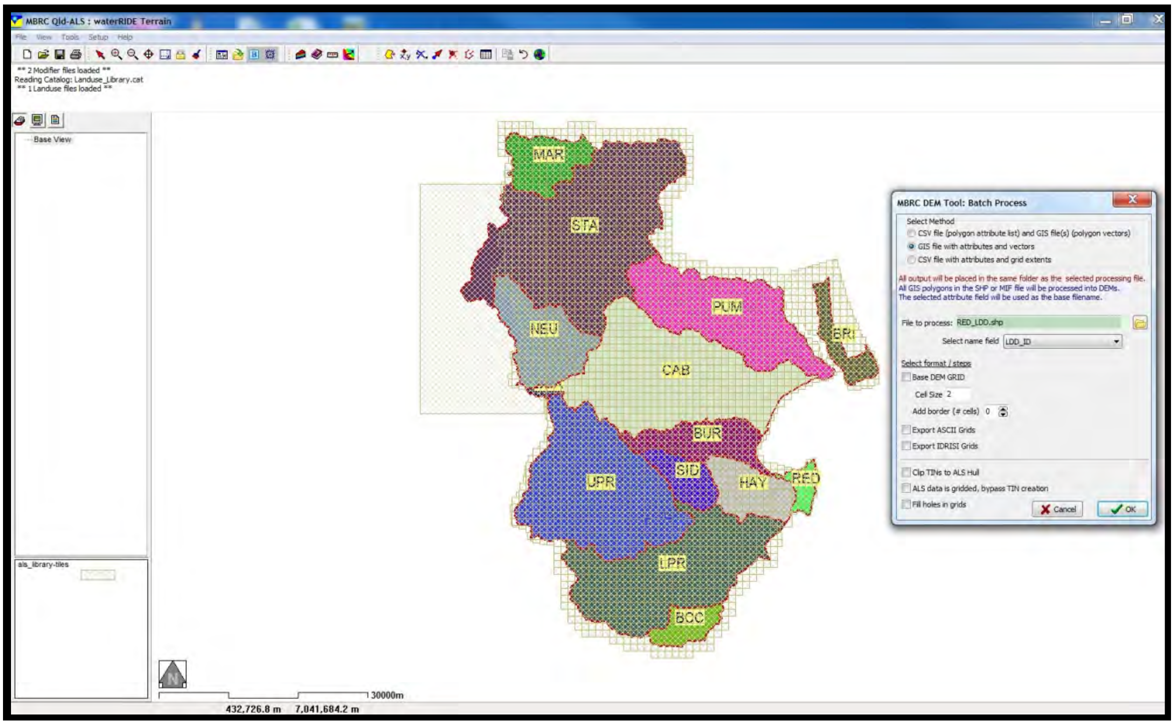


**Figure 2: Screen shot extracted from automated z-point file creation tool**

In order to operate the z-point tool the user is required to:

- Select a z-point creation method (typically batch mode);
- If using a batch process select the spatial file to be processed (typically an ESRI shapefile);
- Select an identifier field to be used for file naming;
- Select the required hydraulic model cell size (in metres);
- Select the desired output types (if more than z-points required).

2) <u>ArcGIS TUFLOW Model Build Tool (developed by MBRC):</u>

ArcGIS TUFLOW Model Build Tool - This tool was developed in house by MBRC staff. The tool automatically creates TUFLOW hydraulic model sub-folders and input files necessary for model execution (excluding z-point files). The tool only creates those files specific to the modelling methods adopted for simulating overland flow within each of the sub-catchments. In order to manage the large number of individual sub-models and their component model files, a carefully designed folder structure was developed.

Creating the TUFLOW model inputs is a three (3) step process as follows:

*Step 1:* Create the model shell and spatial files using the ArcGIS TUFLOW model build tool.

*Step 2:* Convert the shape file outputs to mid/mif format using a specially created cut down version of Universal Translator in MapInfo.

*Step 3:* Transfer the terrain inputs (z-point files created using the MBRC DEM tool) to the model shell.

### 3.4.2 Model Geometry

Due to the size of the study area and Council's aspiration to prepare overland flowpath mapping having a high degree of detail, it was necessary to further split the 14 separate drainage catchments, as indicated in Figure 1, into a series of 895 sub-catchments.

It was anticipated that the optimal model grid size for each sub-catchment would be of the order of 2 to 4m in order to adequately represent the smaller dimensioned overland flowpaths. Using a selection of pilot sub-catchments for testing purposes, Council tested the performance of a rainfall on grid modelling approach using different grid sizes and determined that a 2m grid with an average sub-catchment size of approximately 250 hayielded the most effective configuration for the model library. Using this configuration testing indicated that each model would have a typical run-time of approximately 4 to 6 hours for the selected storm and time step.

Accordingly a hydraulic model was established for each of the 895 discrete sub-catchments in the study area. In order to allow for the efficient preparation of such a large number of models a number of simplifications were necessary.

For example, an averaged manning's 'n' roughness value of 0.06 was used for the general catchment surface, with the exception of buildings (0.3) and roads (0.02). To understand the sensitivity of the results to this assumption, testing of general roughness values was conducted. Alternative roughness values of 0.035, 0.04, 0.05 and 0.06 were tested for the general catchment surface. It was found that there were some localised impacts as a result of these changes, but overall a relatively minimal change in overland flowpath extent.

Other examples of necessary simplifications include:

- No underground structures (refer to Section 3.4.3);
- Simplified boundary conditions;
- A simplified rainfall scenario (refer to Section3.3).

These simplifications did not substantially compromise the project objectives.

### 3.4.3 Model Structures

Structures have not been included in this modelling as the objective is to identify where water will flow when there is limited local drainage infrastructure or if there is a blockage of inlets. The adopted hydrologic approach does indirectly allow for some underground capacity.

### 3.4.4 Model Processing

Following completion of the model build process described in Section 3.4.1 the model library was ready for processing.

Funding was sought to purchase a 64 bit server with 5Tb Storage Area Network (SAN) and 64GB RAM. As well as a 16 core TUFLOW iDP w64 dongle licence which allows up to

15models to be run simultaneously (1 core was preserved for the operating system). This combination of hardware and software licensing afforded Council a powerful model processing environment in order to run the large overland flowpath model library. Using a 16 core licence the total run time is between 4 to 6 weeks.

Model stability issues, though not difficult to resolve, provided a challenge given the large number of models. Such errors included negative depth warnings and model instability due to steep model topography. There were also some model issues due to the intricate Manning's roughness polygons used and the model boundary approach. These issues were resolved through refinements to the modelling methodology.

### 3.4.5 Post-processing

A third tool was created for post-processing. This ArcGIS Post-Processing Tool is utilised following completion of model runs and was implemented to convert the raw model output into a 'clean' overland flowpath extent. This automated process was also developed in-house by MBRC staff. Part of the user-interface is depicted in Figure 3 below.


**Figure 3: Screen shot extracted from the Post-Processing tool**

Once the models were successfully completed using TUFLOW, and relevant outputs created, the post-process tool was applied. Broadly the tool carries out five post-processing tasks as follows:

i)Selection of a sub-set of the raw model output – v, d & q: The TUFLOW output included velocity (v), depth (d) and unit flow (q). Suitable threshold values were established and used to create a sub-set of the raw model outputs. The sub-sets included only those parts of the overland flowpaths where the following thresholds were exceeded:

- v threshold ≥ 0.6m/s
- d threshold ≥ 0.25m
- q threshold ≥ 0.15m3/s

ii.) Merging of the sub-sets: For each sub-catchment the three model output sub-sets (i.e. with the above described thresholds applied), were merged into a single polygon extent.

iii.) Removal of 'Puddles': The polygon resulting from merging of the sub-sets included 'puddles' comprising of isolated pools of water on the modelled terrain. These are a typical product of the 'rainfall on grid' approach. These were eliminated where the size of the 'puddle' was below a threshold value of 600m².

iv.) Removal of 'Islands': The polygon resulting from merging of the sub-sets also included 'islands' which are holes within the overland flowpath polygon features. These are also a typical product of the 'rainfall on grid' approach. These were eliminated where the size of the 'island' was below a threshold value of 600m².

v.) Merging of sub-model outputs into a single seamless spatial layer: The four preceding tasks resulted in a vector polygon for each sub-catchment. The final task involved merging of these into a seamless spatial layer which included all 895 post-processed sub-model outputs.

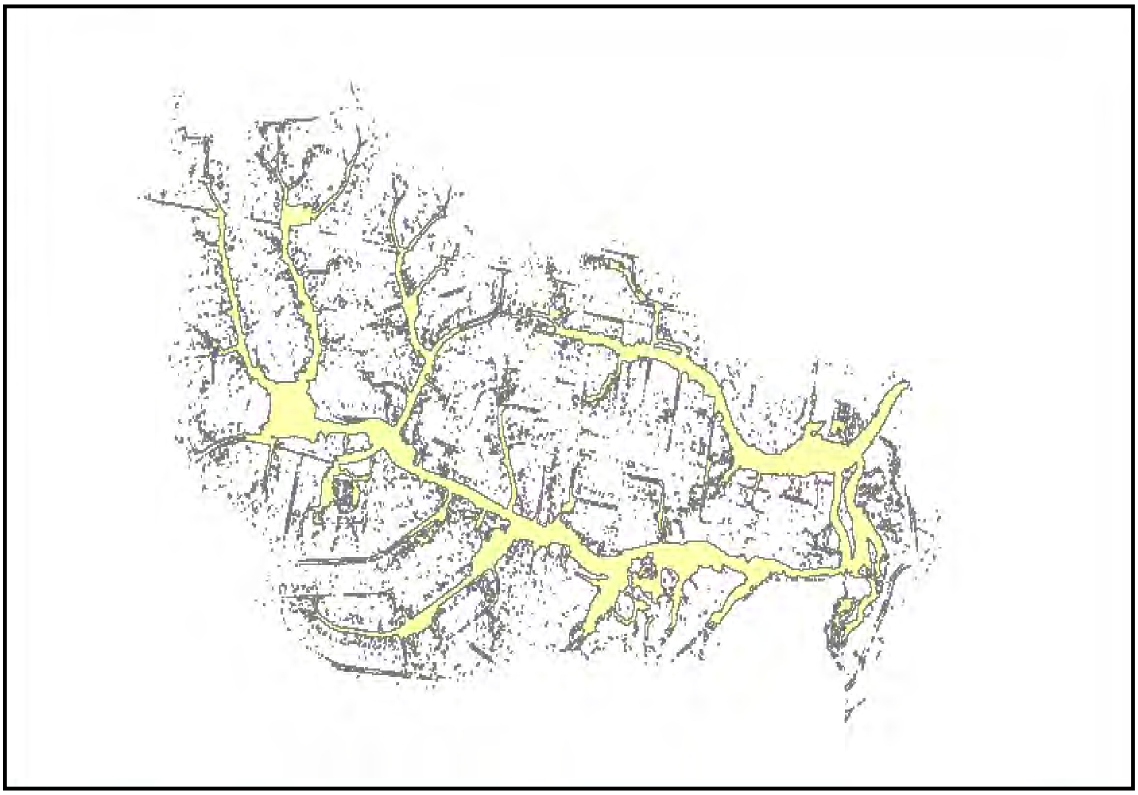

**Figure 4: Merged raw model output (v, d & q) before 'Puddles'&'Islands' removed**

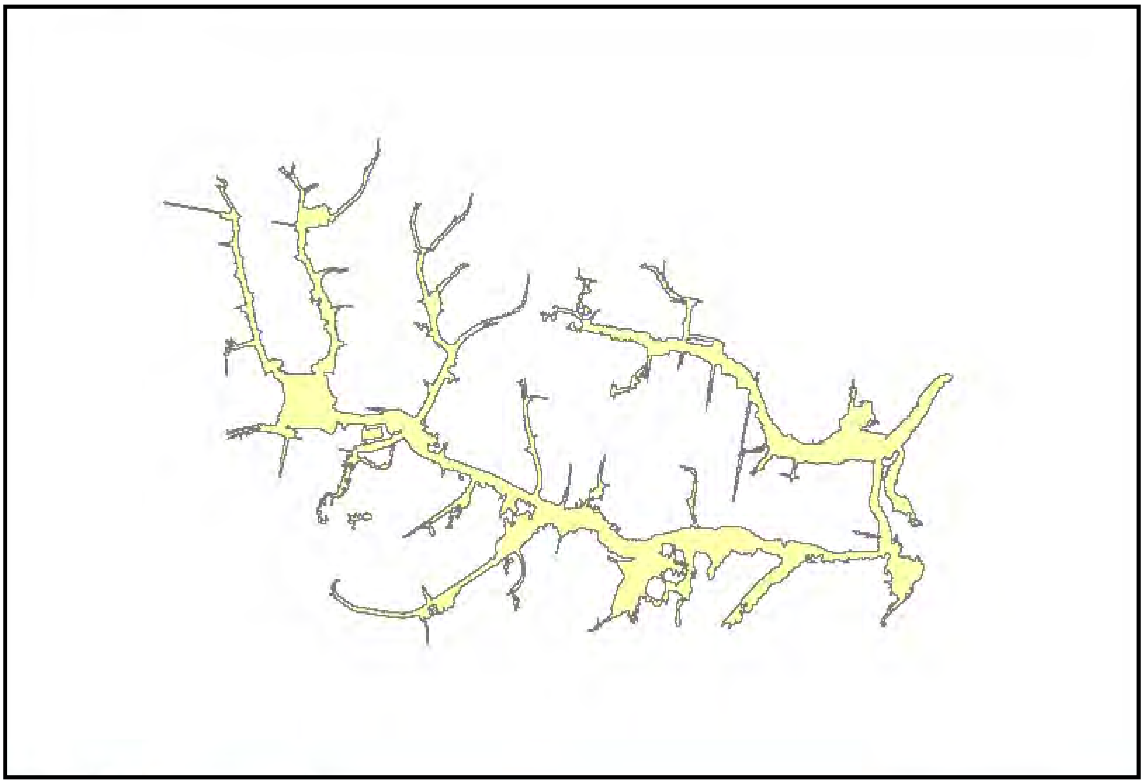

**Figure 5: Removal of 'Puddles'& 'Islands'**

The various threshold values that are described above were established using an iterative testing approach that gave results consistent with real world observations. This suite of values provided the most representative and contiguous overland flowpath extent possible using the model output obtained.

## 3.5 Model Calibration and Verification

Given the simplified hydraulic modelling approach that has been adopted it was not considered appropriate to apply a formal model calibration and validation approach as would normally be applied to a flood or drainage model.

However, historical flood observations were gathered from the November 2008, May 2009, January2011 and other storms. This was used to compare the overland flow mapping extent to real events. These observations were made at a number of locations around the region sourced from residents and staff. Council has found excellent agreement between the modelled and observed overland flowpath extent.

# 4. Results

## 4.1 Model Results

The TUFLOW model methodology has produced consistent reliable output forvelocity, depth and flows within each of the 895 catchments. This has been a suitable basis for post processing to determine the overland flow path extent. This extent highlights areas where there is a risk of overland flow occurring.

**Figure 6: Example of MBRC Overland Flow Path Map for part of the study area**

## 4.2 Model Limitations

The overland flow flood mapping has been prepared using a model representation of the ground surface and assumed rainfall characteristics. Accordingly the flood mapping has inherent uncertainty.

Whilst the data has been prepared using a reliable methodology, there are some key limitations that need to be highlighted:

- The mapping does not include very small flowpaths at the very top of catchments. These are beyond the resolution of the terrain data used.
- Flow paths disregard building footprints and hence pass right through them.In these situations a more detailed local assessment is recommended to assess actual building susceptibility to overland flow. In many cases overland flow may not actually enter the building.
- Some over-estimation is present at the outlets of the 895 catchments. This is generally covered by the existing interim 100 year river and creek flood surface or has been manually corrected.
- The mapping is not able to identify local affects created by impermeable fences or fences that become impermeable through the accumulation of debris etc. In these circumstances, the actual flood extent could be greater than predicted.
- The data shows an extent of potential inundation only. It is not appropriate to provide levels as typically the overland flowpaths identify shallow inundation that is running along the ground contours and therefore any flood level provided will be subject to surface conditions and localised modifications.

# 5. Conclusion

Overland flowpaths and local drainage network vulnerability have not been well recognised in traditional flood studies.The purpose of this project was to fill this gap and develop overland flowpathmaps for the region.

Council has identified a low cost methodology for the efficient preparation of overland flowpath mapping across a large region. This report has described this methodology and may provide other local governments, which have similar aspirations, some possible ideas to pursue. In particular the use of automated tools for the preparation and post-processing of model files has allowed council to achieve the project objectives in a timely and cost efficient manner.

The mapping is useful for:

- Understanding local drainage flood characteristics;
- Identifying hot spots of high flood damage and nuisance;
- Describing local drainage flood behaviour to residents and stakeholders making land use decisions;
- Providing development services and building services overland flow flood behaviour information to assist with determining appropriate building and development controls;
- Prioritise a program of drainage upgrades.