



ALLANS CREEK FLOOD STUDY ADDENDUM 2- DARRAGH DRIVE, FIGTREE

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GLOSSARY OF TERMS*

Australian Height Datum (AHD)	A common national surface level datum approximately corresponding to mean sea level.
Cadastre, cadastral base	Information in map or digital form showing the extent and usage of land, including streets, lot boundaries, water courses etc.
Catchment	The area draining to a site. It always relates to a particular location and may include the catchments of tributary streams as well as the main stream.
Design flood	A significant event to be considered in the design process; various works within the floodplain may have different design events, e.g. some roads may be designed to be overtopped in the 1 year ARI flood event.
Discharge	The rate of flow of water measured in terms of volume over time. It is to be distinguished from the speed or velocity of flow, which is a measure of how fast the water is moving, rather than how much it is moving.
Flash flooding	Flooding which is sudden and often unexpected because it is caused by sudden local heavy rainfall or rainfall in another area. Often defined as flooding which occurs within 6 hours of the rain which causes it.
Flood	Relatively high stream flow which overtops the natural or artificial banks in any part of a stream, river, estuary, lake or dam, and/or overland runoff before entering a watercourse and/or coastal inundation resulting from super elevated sea levels and/or waves overtopping coastline defences.
Flood fringe	The remaining area of flood-prone land after floodway and flood storage areas have been defined.
Flood hazard	That which has the potential to cause damage to the community. Provisional flood hazard is categorised in the <i>Floodplain Development Manual</i> (NSW Govt, 2005) as either High or Low Hazard. Provisional hazard categories are defined as a product of flood velocity and depth. The true hazard incorporates the provisional hazard, as well as other factors such as access, type of development, evacuation problems, effective warning time, flood readiness, rate of rise and flood duration.
Flood-prone land	Land susceptible to inundation by the probable maximum flood (PMF) event, i.e. the maximum extent of flood liable land. Floodplain Risk Management Plans encompass all flood-prone land, rather than being restricted to land subject to designated flood events.
Floodplain	Area of land which is subject to inundation by floods up to the probable maximum flood event, i.e. flood prone land.
Floodplain management measures	The full range of techniques available to floodplain managers.

Flood planning levels	Flood levels selected for planning purposes, as determined in floodplain management studies and incorporated in floodplain management plans. Selection should be based on an understanding of the full range of flood behaviour and the associated flood risk. It should also take into account the social, economic and ecological consequences associated with floods of different severities. Different FPLs may be appropriate for different categories of land use and for different floodplains. The concept of FPLs supersedes the "Standard flood event". As FPLs do not necessarily extend to the limits of flood prone land (as defined by the probable maximum flood), floodplain management plans may apply to flood prone land beyond the defined FPLs.
Flood storages	Those parts of the floodplain that are important for the temporary storage of floodwaters during the passage of a flood.
Floodway areas	Those areas of the floodplain where a significant discharge of water occurs during floods. They are often, but not always, aligned with naturally defined channels. Floodways are areas which, even if only partially blocked, would cause a significant redistribution of flood flow, or significant increase in flood levels. Floodways are often, but not necessarily, areas of deeper flow or areas where higher velocities occur. As for flood storage areas, the extent and behaviour of floodways may change with flood severity. Areas that are benign for small floods may cater for much greater and more hazardous flows during larger floods. Hence, it is necessary to investigate a range of flood sizes before adopting a design flood event to define floodway areas.
Geographical information systems (GIS)	A system of software and procedures designed to support the management, manipulation, analysis and display of spatially referenced data.
High hazard	Flood conditions that pose a possible danger to personal safety; evacuation by trucks difficult; able-bodied adults would have difficulty wading to safety; potential for significant structural damage to buildings.
Hydraulics	The term given to the study of water flow in a river, channel or pipe, in particular, the evaluation of flow parameters such as stage and velocity.
Hydrograph	A graph that shows how the discharge changes with time at any particular location.
Hydrology	The term given to the study of the rainfall and runoff process as it relates to the derivation of hydrographs for given floods.
Low hazard	Flood conditions such that should it be necessary, people and their possessions could be evacuated by trucks; able-bodied adults would have little difficulty wading to safety.

Mainstream flooding	Inundation of normally dry land occurring when water overflows the natural or artificial banks of the principal watercourses in a catchment. Mainstream flooding generally excludes watercourses constructed with pipes or artificial channels considered as stormwater channels.
Mathematical/computer models	The mathematical representation of the physical processes involved in runoff and stream flow. These models are often run on computers due to the complexity of the mathematical relationships. In this report, the models referred to are mainly involved with rainfall, runoff, pipe and overland stream flow.
NPER	National Professional Engineers Register. Maintained by the Institution of Engineers, Australia.
Peak discharge	The maximum discharge occurring during a flood event.
Probable maximum flood (PMF)	The flood calculated to be the maximum that is likely to occur.
Probability	A statistical measure of the expected frequency or occurrence of flooding. For a fuller explanation see Annual Exceedance Probability.
Risk	Chance of something happening that will have an impact. It is measured in terms of consequences and likelihood. For this study, it is the likelihood of consequences arising from the interaction of floods, communities and the environment.
Runoff	The amount of rainfall that actually ends up as stream or pipe flow, also known as rainfall excess.
Stage	Equivalent to 'water level'. Both are measured with reference to a specified datum.
Stage hydrograph	A graph that shows how the water level changes with time. It must be referenced to a particular location and datum.
Stormwater flooding	Inundation by local runoff. Stormwater flooding can be caused by local runoff exceeding the capacity of an urban stormwater drainage system or by the backwater effects of mainstream flooding causing the urban stormwater drainage system to overflow.
Topography	A surface which defines the ground level of a chosen area.

* Many terms in this Glossary have been derived or adapted from the NSW Government *Floodplain Development Manual*, 2005.

1. INTRODUCTION

Darragh Drive is located in the suburb of Figtree, which includes Allans Creek. Brandy and Water Creek, a tributary of American Creek, runs along the rear of the properties on the western side of Darragh Drive. **Figure 1.1** shows the location of the study area.

The *Allans Creek Flood Study* (Cardno Lawson Treloar, 2006) and the subsequent addendum (Cardno Lawson Treloar, 2008) defined the flood behaviour for the entire Allans Creek floodplain. However, during correspondence with Council and Cardno Lawson Treloar, it has been noted that the Allans Creek Flood model, which utilises the one-dimensional (1D) MIKE11 model, is not capable of explicitly defining the breakout behaviour of the flood flows in the Darragh Drive study area. Council therefore commissioned Cardno Lawson Treloar on the 23 January 2009 to construct a more detailed two-dimensional (2D) model, focusing specifically on the Darragh Drive Study area.

This report provides details on the flood modelling undertaken as a part of this detailed assessment of the Darragh Drive Study Area. Flood modelling has been undertaken for the 100 year, 50 year, 20 year, 10 year and 5 year ARI design events, together with the PMF event.

2. AVAILABLE DATA

2.1 Previous Studies

A number of studies have been undertaken for the study area previously. These include:

- *Allans Creek Flood Study, Allans Creek Floodplain Risk Management Study & Allans Creek Floodplain Risk Management Plan – Addendum 1* (Cardno Lawson Treloar, 2008). This study provided an update to Cardno Lawson Treloar (2006), and incorporated changes to the F6 Freeway median strip.
- *Allans Creek Flood Study* (Cardno Lawson Treloar, 2006). This study utilised a combination of RAFTS for the hydrological component and MIKE11 for the hydraulic component of the study. These results were then updated using new information (Cardno Lawson Treloar, 2008). It is noted that the MIKE11 model in this study extends to approximately 50 metres downstream of the junction of Darragh Drive and Hennessy Lane.
- *Report on Flooding in Brandy and Water Creek for the Darragh Park Development O'Briens Road Figtree* (Forbes Rigby, 1996). This report was prepared as a part of a development application for the Darragh Drive area.

These reports have been considered in the preparation of this study.

2.2 Cross Section Survey

Cross section survey is available for the study area from Cardno Lawson Treloar (2006), which covers the majority of the Allans Creek floodplain. For the study area, these cross sections are approximately 50 to 100 metres apart, and extend to approximately 50 metres downstream of the junction of Darragh Drive and Hennessy Lane (refer **Figure 1.1**).

Cross section data was also available from Forbes Rigby (1996). These cross sections are spaced from 60 to 120 metres, and extend to approximately 60 metres upstream of Hennessy Lane.

2.3 Aerial Survey

ALS data was provided by Wollongong City Council. Generally the reported accuracy of this data is +/- 0.15 m on hard surfaces to one standard deviation.

2.4 GIS data

GIS data was provided by Wollongong City Council, and included:

- Cadastre
- 2m LIC contours
- Aerial photograph

3. HYDROLOGIC MODEL

A hydrological model was constructed as a part of the *Allans Creek Flood Study* (Cardno Lawson Treloar, 2006). This model was indirectly calibrated to flood events including the 1998 and 1999 events. The inflows at the top of Brandy and Water Creek derived in Cardno Lawson Treloar (2006) were applied in this study. Based on the results of Cardno Lawson Treloar (2006), the critical duration for the study area is 2 hours.

The peak flows for each of the storm events is shown in **Table 3.1**. The inflow discharge time series for each of the design storm events are illustrated in **Figure 3.1**.

Table 3.1 Peak Flows at Upstream of Study Area

Event	Peak Flow (m ³ /s)
PMF	398
100 year	208
50 year	179
20 year	143
10 year	116
5 year	94

4. HYDRAULIC MODEL

A hydraulic model of the subject site and adjoining areas was developed in SOBEK, a linked one- and two-dimensional (2D) modelling system that models flood flow behaviour. For the purposes of this analysis, only the 2D portion of the modelling system was utilised.

4.1 Digital Terrain Model

A digital terrain model (DTM) was established, based on a mixture of the cross section survey data from the *Allans Creek Flood Study* (Cardno Lawson Treloar, 2006) as well as the ALS data from Council. This DTM was then utilised to create the 2D grid for the SOBEK model. The dimensions and details of the 2D grid are provided in **Table 4.1** and the extent of the 2D domain is shown in **Figure 4.1**.

Table 4.1 2D Grid Details

Grid Cell Size	2 metres
Origin (north-western corner) (MGA coordinates)	301500, 6188040
Bottom Corner (south-eastern corner) (MGA coordinates)	302210, 6186960
Total number of Cells (rows, columns)	192,596

Rather than using the 1D portion of the SOBEK modelling system to define the in-bank flows, the 2D grid itself was utilised. A check of the 2D domain showed that the 2 metre grid provided sufficient detail when compared with the 1D cross sections.

Buildings were represented as blocked elements in the 2D portion of the model. This is a conservative assumption, as it assumes that water cannot enter the building. In a steep area such as this, where storage is less of an issue, this assumption is considered reasonable.

4.2 Roughness

Roughness mapping was undertaken based on recent aerial photography supplied by Council, and was double checked with the most recent imagery from Google Maps. Therefore, the roughness is representative of the current floodplain conditions. **Figure 4.2** provides the roughness mapping utilised in the study.

Boundary fences were modelled with a Mannings 'n' of 0.10. This accounts for fences and other obstructions within each property. For small flowpaths between buildings, a higher Mannings 'n' of 0.20 was adopted. This accounts for the higher level of potential obstructions in this area, as observed during site inspections of the area.

4.3 Downstream Boundary

The model extends to the junction of Brandy and Water Creek and American Creek. A constant water level boundary was adopted for the model, utilising the peak water level from the *Allans Creek Flood Study Addendum 1* (Cardno Lawson Treloar, 2008). This approach was adopted for reasons of conservatism and simplicity.

The downstream boundary levels adopted for the study are shown in **Table 4.2**. These were based on the cross section American 3166 (Cardno Lawson Treloar, 2008).

Table 4.2 Adopted Downstream Boundary Levels

Design Event	Adopted Level (m AHD)
PMF	17.10
100 year ARI	16.17
50 year ARI	16.05
20 year ARI	15.89
10 year ARI	15.73
5 year ARI	15.58

A sensitivity analysis was undertaken utilising the 100 year ARI event to test the validity of this adopting a constant water level boundary. The sensitivity analysis involved increasing the downstream boundary level in the 100 year ARI design event by 1 metre to assess the potential impact. The results, shown in **Figure 4.3**, show that there is little impact within the study area.

4.4 Culvert Blockage

A number of culvert blockage scenarios were assessed under Cardno Lawson Treloar (2006). However, there are no culverts within the study area, nor would the study area be influenced by culvert blockages downstream. Therefore, no culvert blockage scenarios were assessed.

4.5 Model Calibration

In order to evaluate the model performance, calibration is usually required to ensure that the hydraulic model is fully represented the catchment conditions. In this study, calibration or verification was conducted by a comparison of the SOBEK model and the MIKE11 model (from Cardno Lawson Treloar, 2008). As the MIKE11 model was calibrated to a number of historical flood events, this provides confidence in the results of the SOBEK model. Detailed discussion on the verification process is provided in Section 5.2.

5. MODEL RESULTS

5.1 Flood Extents, Depths & Velocities

The flood extents determined from the modelling, together with peak water level contours, are provided in **Figures 5.1 to Figure 5.6**.

The peak flood depths for each design event are provided in **Figure 5.7 to Figure 5.12**.

The peak flood velocities for each design event are provided in **Figure 5.13 to Figure 5.18**.

The peak flood levels from the SOBEK model are also provided in **Table 5.1**, at the same locations as the MIKE11 cross sections, **as well as the locations along Darragh Drive These locations are shown in Figure 1.1**.

Table 5.1 Peak Flood Levels from SOBEK

Cross Sections	Peak Water Levels (m AHD)					
	PMF	100 year	50 year	20 year	10 year	5 year
BRANDY&WATER 2202.00	24.05	22.73	22.46	22.09	21.78	21.50
BRANDY&WATER 2268.00	23.25	22.14	21.92	21.60	21.34	21.11
BRANDY&WATER 2348.00	21.68	20.67	20.48	20.23	19.99	19.79
BRANDY&WATER 2474.00	21.42	20.41	20.18	19.85	19.58	19.34
BRANDY&WATER 2722.00	17.71	17.64	17.61	17.56	17.52	17.48
DARRAGH DRIVE 1	22.97	N/A	N/A	N/A	N/A	N/A
DARRAGH DRIVE 2	21.46	20.81	20.68	N/A	N/A	N/A
DARRAGH DRIVE 3	20.78	20.03	19.93	N/A	N/A	N/A
DARRAGH DRIVE 4	20.37	19.48	19.41	N/A	N/A	N/A

Note: N/A indicates no inundation

5.2 Model Verification

It would be expected that the results of the 2D model developed for this study would differ to that of the MIKE11 model results reported in Cardno Lawson Treloar (2008). The primary reasons for these differences include:

- The SOBEK model is a local model developed specifically for the Darragh Drive study area, while the MIKE11 model was developed for the entire Allans Creek catchment.
- The SOBEK model extends upstream of the MIKE11 model limit.
- The SOBEK model is a 2D model, and is therefore more appropriate in modelling overbank flows, flows through properties as well as shortcutting flow around creek bends, which can only be schematised in a quasi-2D manner in MIKE11.

While differences are expected between the two modelling systems, a verification of the two separate results was undertaken to ensure that the SOBEK model developed was not substantially different to the MIKE11 model. **Table 5.2** provides a comparison of the MIKE11 results and the SOBEK results for the 100 year ARI event, comparing the levels at the MIKE11 cross sections within the study area.

Table 5.2 Comparison of MIKE11 and SOBEK Results (100 year ARI event)

Cross Section	MIKE11 (m AHD)	SOBEK (m AHD)	Difference (m)
BRANDY&WATER 2202.00	23.17	22.73	-0.44
BRANDY&WATER 2268.00	22.20	22.14	-0.06
BRANDY&WATER 2348.00	20.65	20.67	+0.02
BRANDY&WATER 2474.00	19.97	20.41	+0.44
BRANDY&WATER 2722.00	17.51	17.64	+0.13

It is important to note that the water level of a cross section in **Table 5.2** represents the peak water level along the cross section.

From **Table 5.2**, it is noted that the results of the verification provide a good match at three of the cross sections. At cross section Brandy&Water 2202, larger differences occur. However, this can be attributed to the cross section Brandy&Water 2202 being at the upstream boundary of the MIKE11 model.

At cross section Brandy&Water 2474, a difference of 0.44 metres is observed. It is expected that this is a result of the bend in the creek at this location. While the majority of the flow follows the bend around the creek, a substantial portion of the flow is shown in the 2D model to shortcut the bend. This flow behaviour is not incorporated into the 1D MIKE11 model, and therefore differences would be expected in this area.

5.3 Discussion of Results

The results show that a number of properties on the south western side of Darragh Drive are affected by the 100 year ARI design event (**Figure 5.2**). For some of the properties on the low point on Darragh Drive, floodwaters enter the property and proceed through the gaps between the buildings to flow onto Darragh Drive itself for events greater than 20 year ARI. This flow behaviour has been identified through the use of the 2D SOBEK model, and would be difficult to re-create in a pure 1D model.

Darragh Drive is also inundated by backwater from Brandy and Water Creek which proceeds up a low point to enter the cul-de-sac on the southern end of Darragh Drive, in events greater than 20 year ARI. This backwater meets with the flows entering Darragh Drive through the properties, discussed above.

The velocity results (**Figure 5.13** to **Figure 5.18**) indicate high velocities along the main creekline, with velocities ranging from approximately 3 to 3.5m/s near the junction of Hennessy Lane and Darragh Drive, and approximately 3.5 to 4m/s at the southern boundaries of the most downstream properties on Darragh Drive for the 100 year ARI design event.

The velocities along Darragh Drive reach approximately 1.5m/s in the 100 year ARI design event in some localised areas, although the majority of Darragh Drive is typically in the range of 0 to 1m/s. Velocities through the properties where the breakout flow enters Darragh Drive are lower, typically 0.1 to 0.3m/s. This is due to the number of obstructions and obstacles to flow through these properties.

The low point on Darragh Drive experiences depths of up to 0.5 metres and the cul-de-sac of Darragh Drive also experiences up to 0.4 metres of depth in the 100 year ARI event. However, for the majority of Darragh Drive the depths are generally around 0.2 metres or less. The depths through the properties where the break-out occurs from the creek can experience up to 0.5 metres depth where the flowpaths are constrained between the houses.

Depths on the properties along the southern side of Darragh Drive, which back on to the creek, experience depths ranging from 1.5 to 2.5 metres in the 100 year ARI. This is primarily due to the proximity of their cadastral block to the creek line, where their backyards slope down to the creek. Peak depths at the building line for some of the properties approaches 1.5 metres depth in the 100 year ARI.

The depths noted here are for descriptive purposes. However, it is recommended that peak water levels should be utilised in defining controls or determining affectation of individual properties.

5.4 Flood Risk Precincts

Wollongong City Council utilises flood risk precincts as a part of their planning (*Development Control Plan No. 54 ; Managing our Flood Risks*). There are three precincts, defined below:

- **High Flood Risk Precinct** – This has been defined as the area within the envelope of land subject to a high hydraulic hazard (in accordance with the provisional criteria outline in the *Development Control Plan No.54; Managing our Flood Risks*) in a 100 year flood event together with all the land within a corridor 10 metres horizontally from the top of the creek bank. The high flood risk precinct is where high flood damages, potential risk to life, evacuation problems would be anticipated or development would be significantly and adversely affect flood behaviour. Most development should be restricted in this precinct. In this precinct, there would be a significant risk of flood damages without compliance with flood-related building and planning controls.

- **Medium Flood Risk Precinct** – This has been defined as land below the 100 year flood level (plus 0.5 metres freeboard) that is not within the High Flood Risk Precinct. It is land subject to low hydraulic hazard (in accordance with the provisional criteria outlined the *Development Control Plan No.54*). In this precinct there would still be a significant risk of flood damages, but these damages can be minimised by the application of appropriate development controls.

- **Low Flood Risk Precinct** – This has been defined as all other land within the floodplain (i.e. within the extent of the PMF) but not identified within either the High Flood Risk Precinct or the Medium Flood Risk Precinct. The Low Flood Risk Precinct is that area above the 100 year flood (plus 0.5 metre freeboard) and most landuses would be permitted within this precinct.

The risk precinct mapping based on the 2D results is provided in **Figure 5.19**.

The risk precinct mapping shows that the majority of properties on the south western side of Darragh Drive lie within the high/medium flood risk precinct. The properties on the north eastern side of Darragh Drive are generally located within the medium and low flood risk precincts, primarily on the frontages of the properties.

6. CONCLUSION

A detailed 2D hydraulic model has been prepared for the Darragh Drive study area, using hydrological results from Cardno Lawson Treloar (2006). Modelling has been undertaken for the 100 year, 50 year, 20 year, 10 year, 5 year ARI design events, together with the PMF event.

The modelling has provided information on flood extents, water levels, velocities and depths throughout the study area. Using this information, flood risk precinct mapping has been prepared in the Darragh Drive study area.

7. QUALIFICATIONS

This report is based on the following assumptions:

- Flow behaviour of the local runoff within the site has not been incorporated or analysed in this study.
- Wollongong City Council has provided permission for Cardno Lawson Treloar to utilise their ALS and GIS data for undertaking this flood study. This data is not permitted for any other use.
- The accuracy of the model is dependent on the accuracy of the inputs. This includes the ALS data and the hydrology.

8. REFERENCES

Cardno Lawson Treloar (2006). *Allans Creek Flood Study*, September, Version 6, prepared for Wollongong City Council.

Cardno Lawson Treloar (2008). *Allans Creek Flood Study, Allans Creek Floodplain Risk Management Study & Allans Creek Floodplain Risk Management Plan – Addendum 1*, September, Version 3, prepared for Wollongong City Council.

Forbes Rigby Pty Ltd (1996). *Report on Flooding in Brandy and Water Creek for the Darragh Park Development O'Briens Road Figtree*, January, prepared for R W Sheargold Pty Ltd.

FIGURES















































