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DUNGONG FLOOD 20-21 APRIL 2015

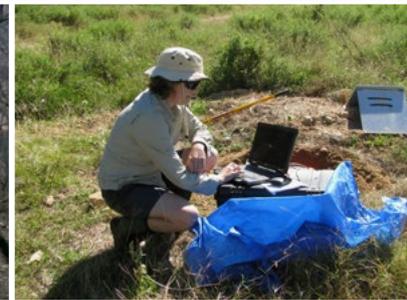
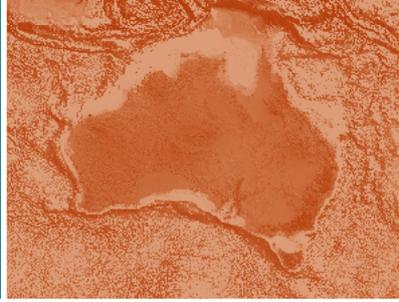
Post-flood damage survey

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Geoscience Australia





Australian Government
Geoscience Australia



Record 2015/21 | GeoCat 83928

Dungog Flood, 20–21 April, 2015

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1 Introduction

Dungog is a country town of approximately 2,100 people (2011 census) located at the junction of Myall Creek and the Williams River in the Hunter Valley, NSW. It was severely impacted on the 20th and 21st of April, 2015 by flooding in both of these watercourses. This report presents the findings of a short post-disaster damage survey undertaken by Geoscience Australia on 13 May, 2015. It includes an analysis of the survey data and makes comparisons with existing models for building damage in high velocity flow regimes. Comparisons were made with the most current flood study for the town, both in depth of inundation and predicted flow velocities.

The town is situated on undulating topography which rises from quite flat countryside close to Myall Creek and the Williams River to become quite steep terrain at the southern end of the town. Like many Australian country towns, Dungog's building stock consists of a core of older buildings, many predating World War 1, surrounded by residential buildings of all ages up to the present day. Most commercial retail buildings are located on Dowling Street, the main north-south thoroughfare, and are of unreinforced masonry construction. Light industrial buildings are generally steel portal frame construction with a variety of cladding materials. Some light industrial buildings are located on low terrain around the north end of town while the more modern light industrial buildings are located in a new part of town at the north-west corner of the urban area. There were 1015 private residential dwellings in Dungog recorded in the 2011 census. Residential buildings range from older, clad timber frame houses on low stumps to more modern construction styles such as brick veneer and cavity brick houses with slab on grade foundations.

The floodwaters damaged approximately 46 houses and directly impacted five businesses. Six of the impacted houses exhibited velocity-related damage for which video footage taken at the time of the flood was available and enabled an estimate of water velocity to be made. Hence, although only a small survey was undertaken, the flood afforded the opportunity to gather some data on velocity related flood damage to Australian house types for use as validation points on velocity-depth fragility curves for one Australian house type. Typically such validation data is difficult to obtain due to paucity of information relating to estimates of water velocity accompanying building loss.

2 The Flood Event

Heavy rainfall over the town of Dungog, NSW, and surrounding areas resulted in flooding of many local creeks and rivers. Twenty-four hour rainfall totals in the vicinity of Dungog on Tuesday 21 April, 2015 ranged from 188 to 250mm with 233mm recorded at Dungog Post Office (BOM, 2015).

Relatively minor twenty-four hour totals (7 to 20mm) were recorded on the preceding Monday and on the following Wednesday (0 to 39mm). Interviews with Dungog residents indicated that the majority of Tuesday's rain fell between midnight and the morning of Tuesday 21 April, 2015.

Water flooded the valley of Myall Creek at the north end of Dungog together with its tributaries (Figure 2.1). Interviews with Dungog residents indicated that water levels rose very quickly, of the order of several metres within a few tens of minutes. Water covered Dowling Street (where it crosses Myall Creek), Hooke Street and Brown Street within Dungog. Flooding also occurred on an unnamed tributary creek at the north-west end of Dungog impacting residences in Hillview Avenue. Interviews with Dungog residents also indicated that water levels fell relatively quickly (Figure 2.2). Furthermore, interviews revealed that water levels were of the order of 2.5m higher than the previous highest flood which occurred on the 9th and 10th of June, 2007. An appreciation for the depth of inundation can be gained from Figure 2.4 and Figure 2.5.

The flood waters washed away four houses at the north end of Dowling Street, close to where it crosses Myall Creek (Figure 2.3). Many other houses were inundated, some to ceiling level. Five businesses were directly impacted by flood waters.

Tragically, three people were killed during the flooding, trapped in their homes (Kirkwood et al, 2015).



Figure 2.1 A view looking north from Hooke Street across the Myall Creek valley at close to peak flood level indicating that the entire valley is flooded. Image courtesy of Mr Tim Irwin.



Figure 2.2 Image of flood water draining from under-floor space in a house in Hooke Street, approximately 45 minutes after peak flood (level arrowed) indicating that water levels fell faster than water could drain from the under-floor space. Image courtesy of Thompsons Mitsubishi.



Figure 2.3 Flood waters at northern end of Dowling Street at close to peak water level. When this image was taken four houses had been washed away. Image courtesy of Mr Neale Currie.

Rapidly flowing water occurred within Dungog itself in minor gullies as evidenced by velocity-related damage at the Dungog tennis courts and debris caught in fences along Common Road at the north-west end of Dungog. Both of these sites have catchments of the order of 40 to 50 hectares in area.



Figure 2.4 High water level in Hooke Street, Dungog, is shown by the blue line, indicating that it was flooded to a depth of several metres during the event.



Figure 2.5 Looking west along Hooke Street with a similar aspect to Figure 2.4. The image was taken as the water level was receding, approximately 0.9m below high water level. Image courtesy of Mr Tim Irwin.

Figure 2.6 and Figure 2.7 show extracts from a flood study undertaken for the Williams River (BMT WBM, 2009) for the 0.5% AEP Flood Event and the Probable Maximum Flood (PMF) Event respectively. The yellow lines superimposed on the images represent the high water level for the 20-21 April, 2015 event derived from field observations, interviews with residents and photos supplied by Dungog residents. They suggest that the 2015 event exceeded a 0.5% AEP event but was significantly below a PMF event.

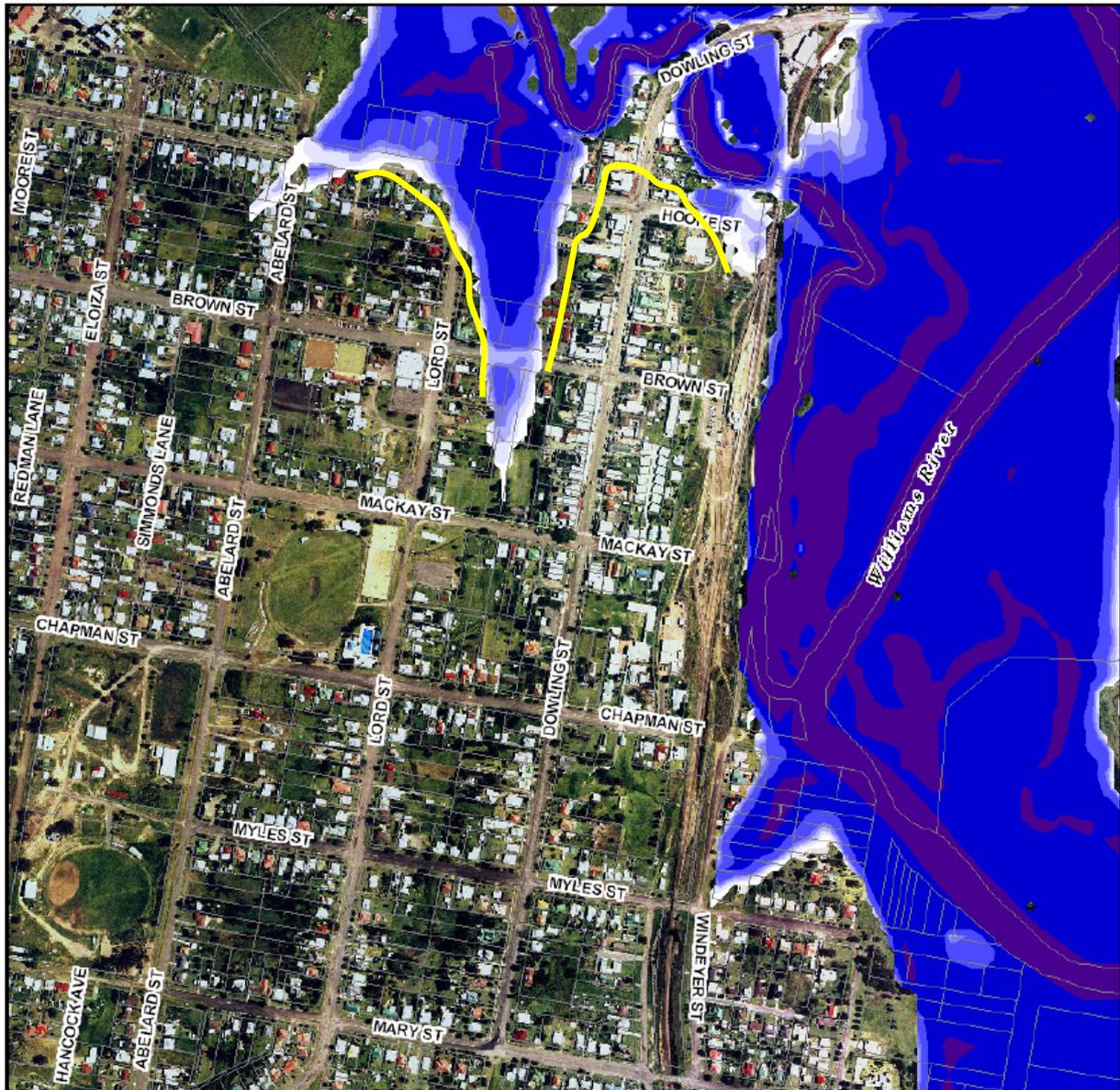


Figure 2.6 Extract from BMT WBM (2009) showing modelled flood extents for the 0.5% AEP Flood Event. The yellow lines superimposed on the images represent the high water level for the 20-21 April, 2015 event derived from field observations, interviews with residents and photos supplied by Dungog residents.

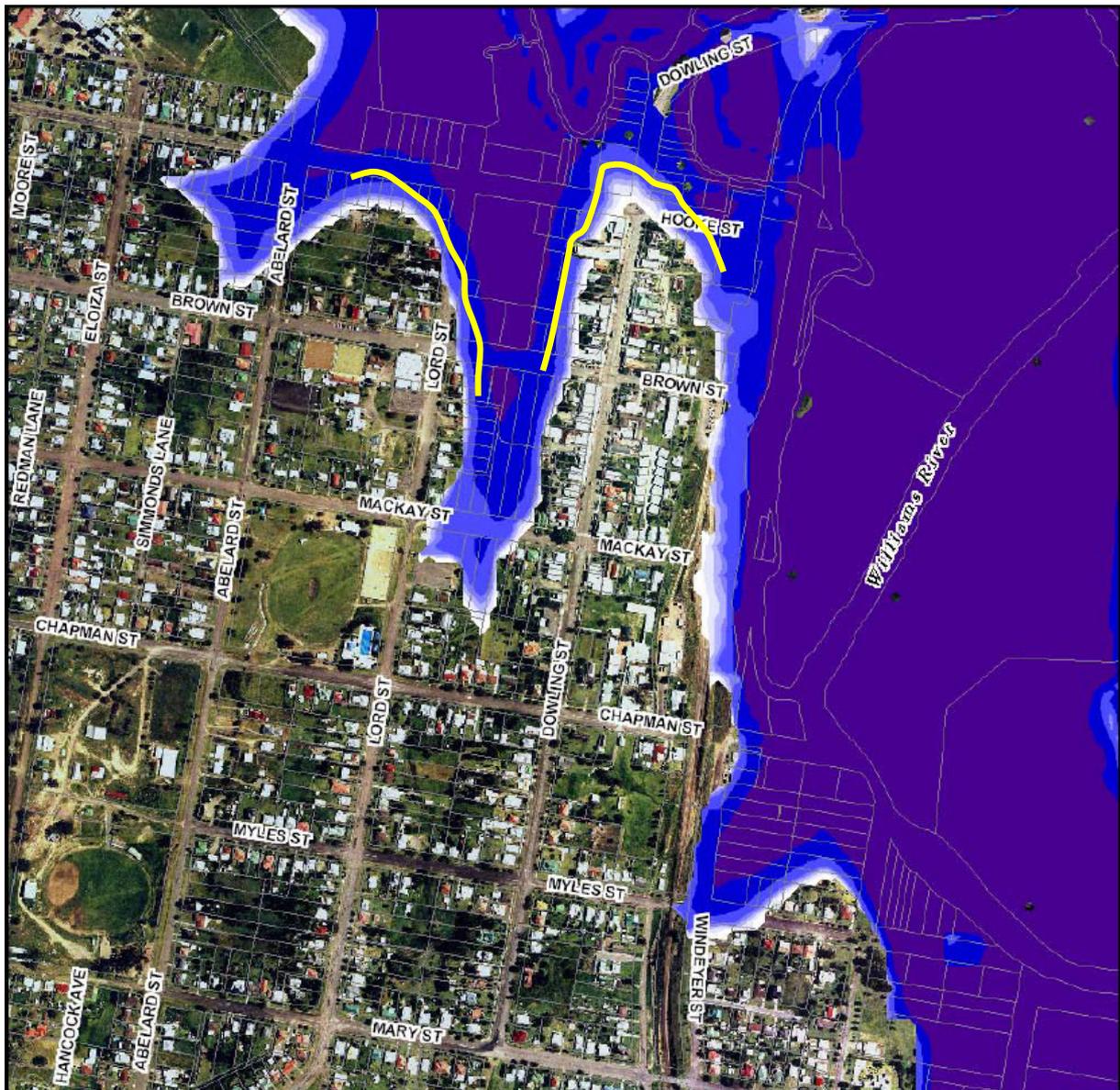


Figure 2.7 Extract from BMT WBM (2009) showing modelled flood extents for the Probable Maximum Flood Event. The yellow lines superimposed on the images represent the high water level for the 20-21 April, 2015 event derived from field observations, interviews with residents and photos supplied by Dungog residents.

3 Post-flood Damage Survey

Prior to the field survey a desk-top rapid damage assessment (RDA) was undertaken. This utilised available public media, social media and SES call-out records in an attempt to establish the extent of flooding and the number of affected properties. This also served as a pilot exercise to examine the effectiveness of such rapid damage assessments for potential use following future disasters.

On Wednesday the 13th May, 2015, two officers from Geoscience Australia undertook a damage survey within the area of Dungog indicated in the box in Figure 3.1. The primary objective was to record sufficient information to enable an estimate of the water velocity at the site of the washed-away houses at the north end of Dowling Street. This involved measuring distances between features visible in videos taken during the flood. The field survey had a secondary objective which was to confirm or correct the results of the desk-top RDA.

In addition, interviews were conducted with business owners who had been directly impacted by flooding.



Figure 3.1 Surveyed area in Dungog, NSW

4 Post-survey Analysis

4.1 Overview

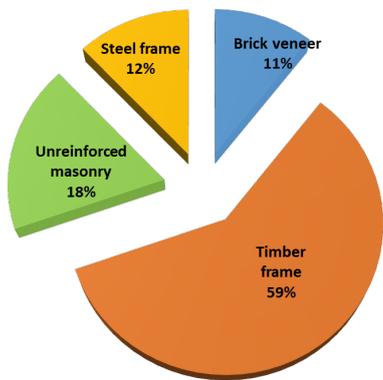
Figure 4.1 shows statistical summaries of the 66 buildings in Dungog recorded in the SES RDA data. The survey was conducted along the impacted streets, namely Dowling Street, Hooke Street, Brown Street and Mackay Street. The majority of the surveyed residential buildings were single storey timber frame structures built on brick piers with metal roof. Almost all commercial buildings were single storey steel portal frame structures with metal sheet roof. A small proportion of the surveyed buildings (8%) were destroyed and washed away by the fast flowing water. A large percentage of surveyed buildings were damaged to varying degrees. The severities ranged from minimal damage, which required cleaning only, to damage requiring major repairs.

4.2 Residential Buildings

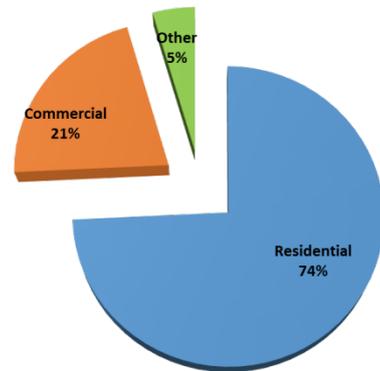
The fast flowing floodwaters impacted six houses at the north end of Dowling Street. These houses are indicated in Figure 4.2. All the houses appear to have had similar superstructure characteristics; comprising metal sheet roofing, hardwood timber framing, weatherboard external wall cladding and hardwood timber framed floors. The substructure of Houses 1, 2, 3 and 6 appears to have been brick piers, the substructure of House 4 was low level timber stumps and that of House 5 was tall timber stumps or piers. Images of the surviving parts of the houses are provided in Figure 4.3 to Figure 4.9 and the flood impacts summarised in Table 4.1. In addition, four other houses at the north end of Dowling Street were affected by inundation, apparently without velocity-related damage. Floodwaters also impacted houses in Hooke Street and Brown Street where approximately 30 other houses incurred inundation damage from comparatively slow moving water.

Table 4.1 Summary of flood impacts to houses at north end of Dowling Street, Dungog. Locations identified in Figure 4.2.

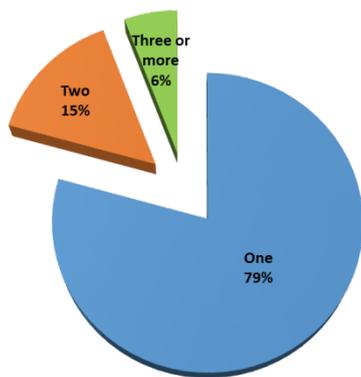
House	State after flood	Discussion
1	Intact, however suffered inundation damage to a depth of about 0.7m above floor level.	House was possibly floated as evidenced by displaced antcaps that would have been located between pier tops and underside of bearers.
2	Destroyed.	Debris observed moving downstream in Youtube, 2015
3	Floated and washed away.	House observed being washed away in Youtube, 2015
4	House severely damaged and moved off supporting stumps.	
5	House destroyed.	Evidently taller timber stumps failed under lateral loading from moving water.
6	House destroyed.	



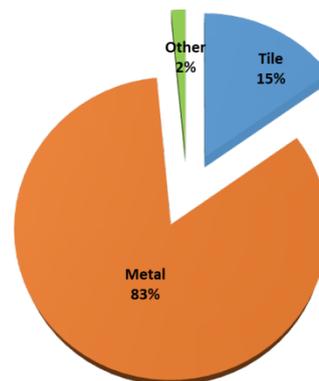
(A) Building structure



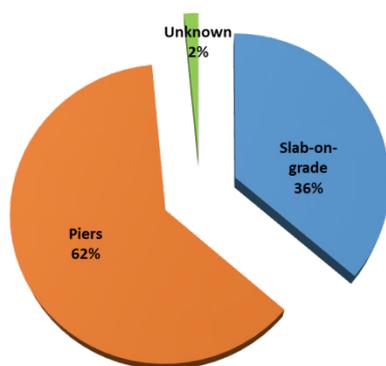
(B) Building usage



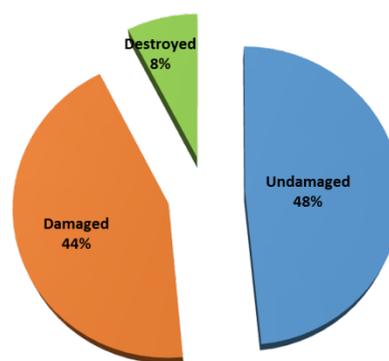
(C) Number of storeys



(D) Roof material



(E) Foundation type



(F) Building damage

Figure 4.1 Statistics of surveyed buildings

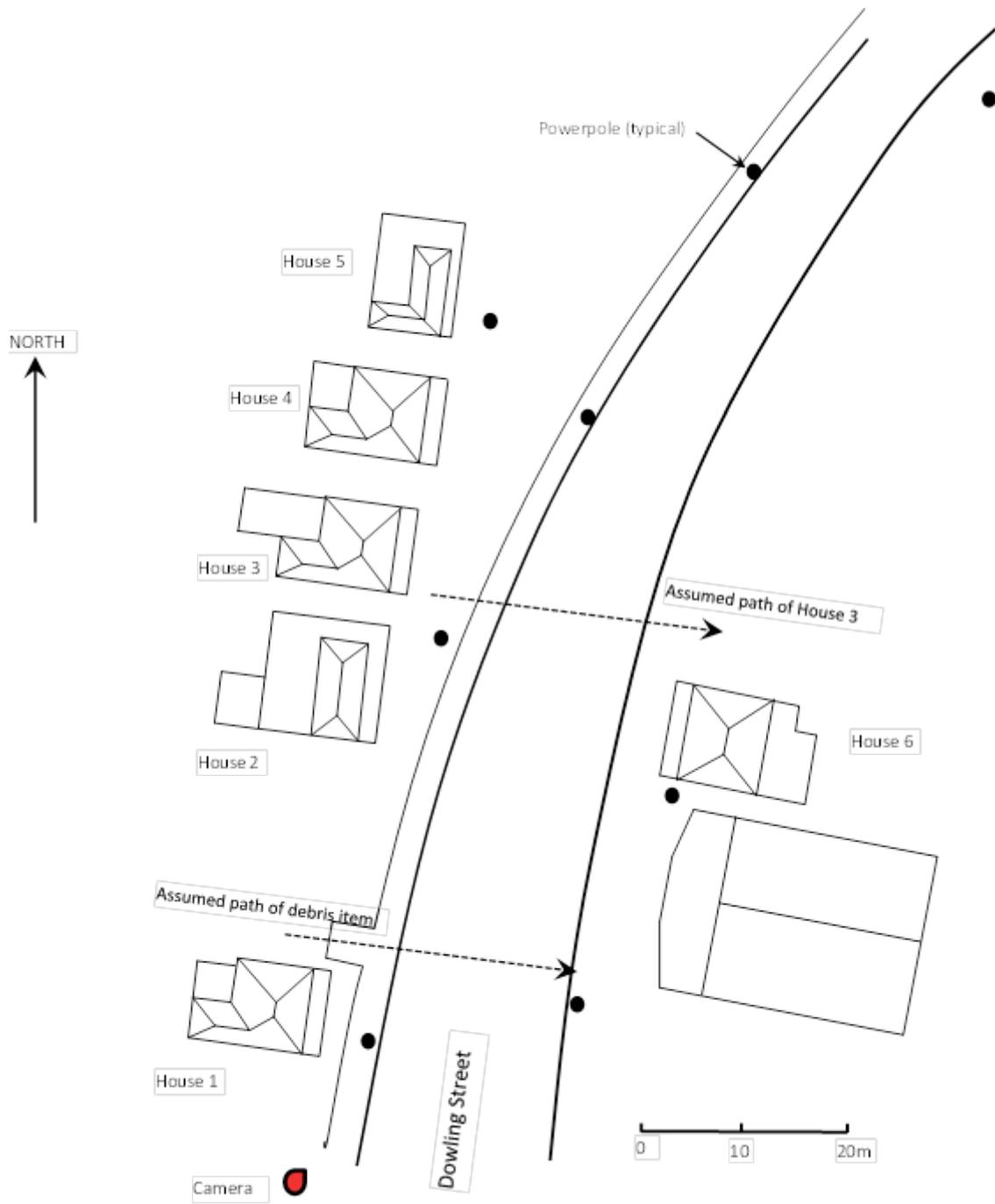


Figure 4.2 Sketch map of north end of Dowling Street, Dungog, showing estimated location of camera (red dot) used to record Youtube (2015) and relevant features visible in the video.



Figure 4.3 House 1, east elevation.



Figure 4.4 House 1, north elevation. Note ant-caps in foreground and displaced brick piers at right hand side of veranda and at rear corner of house.



Figure 4.5 Site of House 2. Evidently a timber framed house on brick piers.



Figure 4.6 Site of House 3. Evidently a timber framed house on brick piers.



Figure 4.7 House 4. Note that house has been moved off its supporting timber stumps. The peak water level is estimated to have been 3.5m above ground level at this location (approximately gutter level on the house).



Figure 4.8 Site of House 5. Evidently a timber framed house on timber stumps. Piers are estimated to be 250mm diameter with 600 mm embedment and approximately 1.5 m projection above ground.



Figure 4.9 Site of House 6 with very little remaining. Evidently a timber framed house on brick piers. Note scour on downstream side of Dowling Street exposing in-ground services. Tyre business premises in background.



Figure 4.10 Two stills taken from Youtube (2015) at 26 seconds and 35 seconds after commencement of video. The two stills show where the near rear corner of House 3 crosses sight lines between the camera and power poles.



Figure 4.11 Two stills taken from Youtube (2015) at 31 seconds and 34 seconds after commencement of the video. The two stills show where the debris item, arrowed, crosses sight lines between the camera and power poles.

Using the two pairs of images in Figure 4.10 and Figure 4.11 estimates of water velocity were obtained. House 3 in Figure 4.10 was estimated to have travelled 19.7m in 9s yielding a velocity of 2.2m/s. The debris item in Figure 4.11 was estimated to have travelled 5.6m in 3s yielding a velocity of 1.9m/s. Qualitatively, in the video the water appears to be travelling faster at the house than closer to the camera which matches these numerical results. The chief uncertainty in calculating the water velocity by this method is with estimating the distance that a floating item has travelled in the time period. Although times are known for objects crossing sight lines from the camera the distance of objects from the camera are not known precisely and hence need to be estimated. In this instance the house was assumed to have travelled parallel to its long axis (roughly at right angles to Dowling Street). The debris item was assumed to be traveling parallel to House 3 but immediately north of House 1 as shown in Figure 4.2.

The calculated flow velocities were also compared to the current flood study for the Williams River (BMT WBM, 2009). The values above were consistent with modelled main stream velocities in Myall Creek shown in Figure 4.12 although they exceed the modelled velocities over Dowling Street. It is important to note that each flood is different at local scales and hence it is unlikely that the flood of 20-21 April, 2015 exactly matched the flood event modelled to produce the results in Figure 4.12. Furthermore, there are uncertainties associated with all flood modelling.

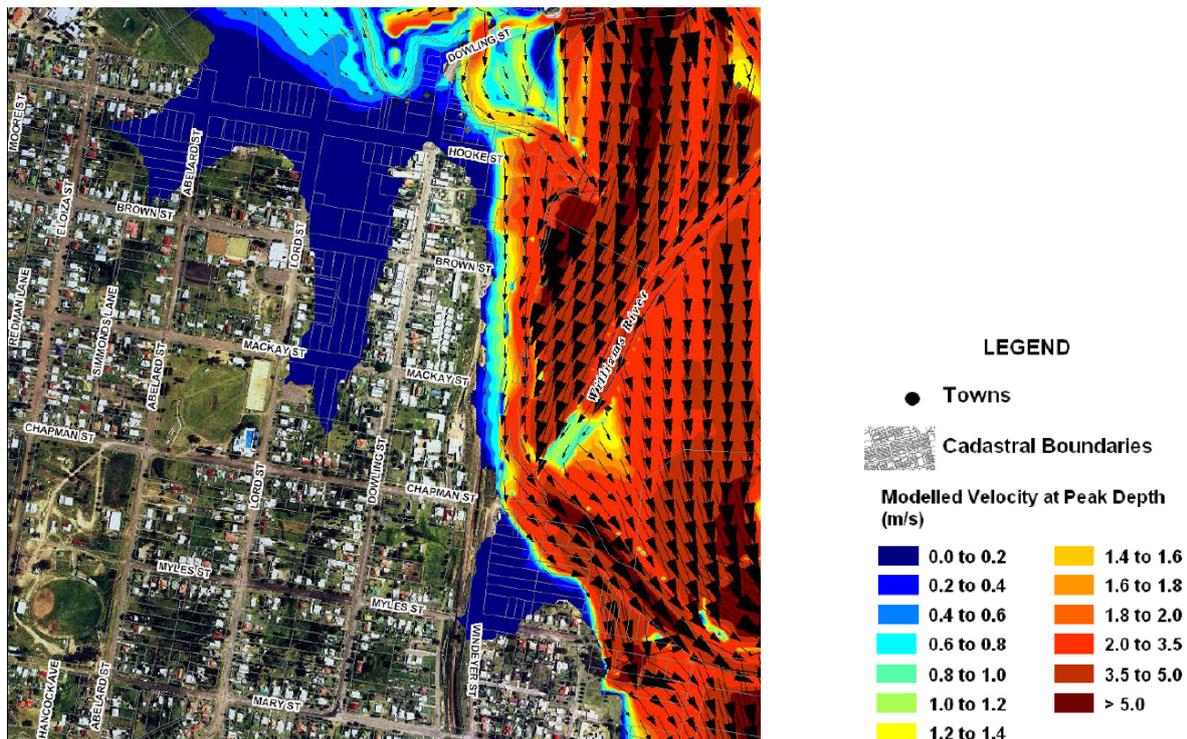


Figure 4.12 Extract from BMT WBM (2009) showing modelled velocities for a PMF Event.

The behaviour of Houses 1 and 3 under the action of flood waters permitted some deductions to be made about the effect of buoyancy forces on clad timber framed housing. Both houses were assumed to have been of similar construction, namely, corrugated metal roof sheeting on hardwood roof framing; hardwood timber framed walls with weatherboard exterior cladding and hardboard or similar interior cladding; hardwood timber flooring on hardwood bearers and joists. Substructure consisted of low brick piers, presumably founded on small mass concrete pad footings. It is normal in this style of construction for there to be no tie connection between the bearers and the supporting piers or foundations. House 1 experienced inundation to approximately 0.7m above floor level and at this depth must have at least partially floated to permit the current to remove the ant-caps from between the piers and bearers as seen in Figure 4.4. House 3 can be seen in Youtube (2015) and Figure 4.11 floating downstream with a similar draft.

The total mass of such a house (excluding contents) was estimated to be approximately 10.5t. Allowing for fully permeable surfaces, i.e. floodwater penetrates all cavities within the building fabric essentially instantaneously, a depth of inundation equal to 3.6m would be required for buoyancy to overcome the gravity load of the house. Clearly, from the experience in Dungog, this type of house floats at considerably less inundation depth; closer to about 1m above underside of bearers. This points to air trapped within the building fabric being a contributing factor in assisting with floating a house.

If a house has insufficient structural strength to resist the hydrodynamic forces imposed by flowing water, it may fail prior to floating such as happened to House 2 in Figure 4.13. It is difficult to determine the hazard magnitude (depth and velocity) at House 2 when it began to disintegrate. Presumably the velocity may have been about 2m/s (as derived from the stills in Figure 4.10 and Figure 4.11), however the depth is not known precisely. It is estimated at 2.2m above floor level based on the high water mark at House 4, which was approximately 2.7m above floor level, and the water level in Figure 4.13 being approximately 0.5m below maximum depth at the time it was taken.



Figure 4.13 A still from Youtube (2015) showing parts of destroyed House 2 (brown roof to right of nearest powerpole) travelling downstream. House 3 is floating and mounting the embankment up to Dowling Street (note canted attitude). The water level at House 1 in the foreground is about 0.5m below high water mark.

The only remains of House 5 were the failed timber stumps visible in Figure 4.8. An attempt was made to estimate the likely depth and velocity of water that destroyed this house. In making this estimate the failure mode of the timber stumps needs to be determined. In this case, the absence of disturbance of the soil around the stumps, such as may have resulted from a short laterally loaded pile type failure, suggested a simple overturning failure mechanism. Drag from the flowing water was calculated as per AS 5100.2-2004 (Standards Australia, 2004) and allowance made for buoyancy effects. The resulting velocity versus depth required for failure of the supporting stumps is shown in Figure 4.14.

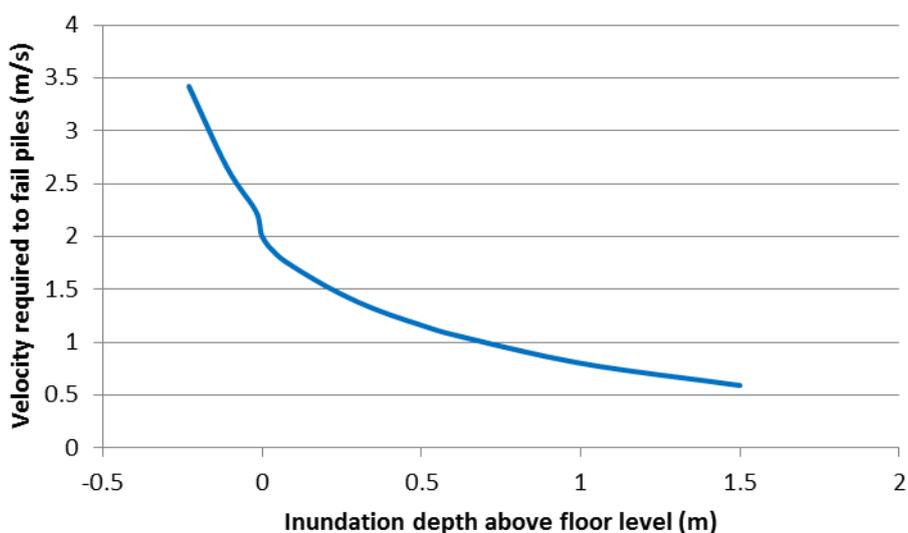


Figure 4.14 Graph of velocity versus depth of inundation above floor level required to fail the supporting stumps of House 5. The deviation from a smooth curve at inundation depths just below floor level is due to a rapid increase in buoyancy force as the floor framing becomes immersed.

A photograph in Sansom (2015) taken looking southwest across the Myall Creek bridge at about the time flood waters reached maximum depth, shows House 4 in place but House 3 and House 5 missing, suggesting that House 5 was washed away before flood waters reached their maximum depth. Assuming that House 5 had already been destroyed by the time House 3 was washed away as shown in Youtube (2015) the water velocity would have been lower than the 2.2m/s value derived from Youtube (2015). This suggests that House 5 failed when the water was about 0.3m above floor level (about 2m above ground level) and flowing at about 1.5m/s. It appears that in this case the presence of tall stumps has negatively influenced the strength of the house to resist water induced loads.

The velocity and depth estimates for Houses 1, 2, 3 and 5 are plotted against published failure thresholds in Figure 4.15 and Figure 4.16. The curves in Figure 4.15 include those developed by Black (1975) for light timber framed residential construction. The work by Black was later refined and applied to Australian construction (Dale et al, 2004) which is also presented in the figure. The more generalised relationships developed by Smith et al (2014) and McLuckie et al (2014) are presented in Figure 4.16. The estimates indicate that the published threshold curves are reasonable for low-set timber framed houses on low stumps or piers and suggest that houses of similar construction on tall piers or stumps may be more vulnerable than indicated by the published threshold curves.

A single house on Hooke Street was able to be inspected internally during the survey. It was of similar construction to the houses on Dowling Street (i.e. timber framed and clad, roofed with metal sheeting and supported on low stumps) and had been inundated to a depth of 2.73m above floor level. The owner reported that the water initially entered the house by “bubbling up through the floorboards”. There was no evidence of flotation having occurred nor high velocity flow either through damage to the house or in the surrounding gardens. The data point for this house is plotted in Figure 4.15 and Figure 4.16 for the relevant inundation depth with a very low velocity of 0.1m/s. The house could have been expected to fail as it plotted above both the Black (1975) and relevant Dale et al (2004) curves. The behaviour of this house supports the earlier conclusion that permeability of the house fabric influences flotation.

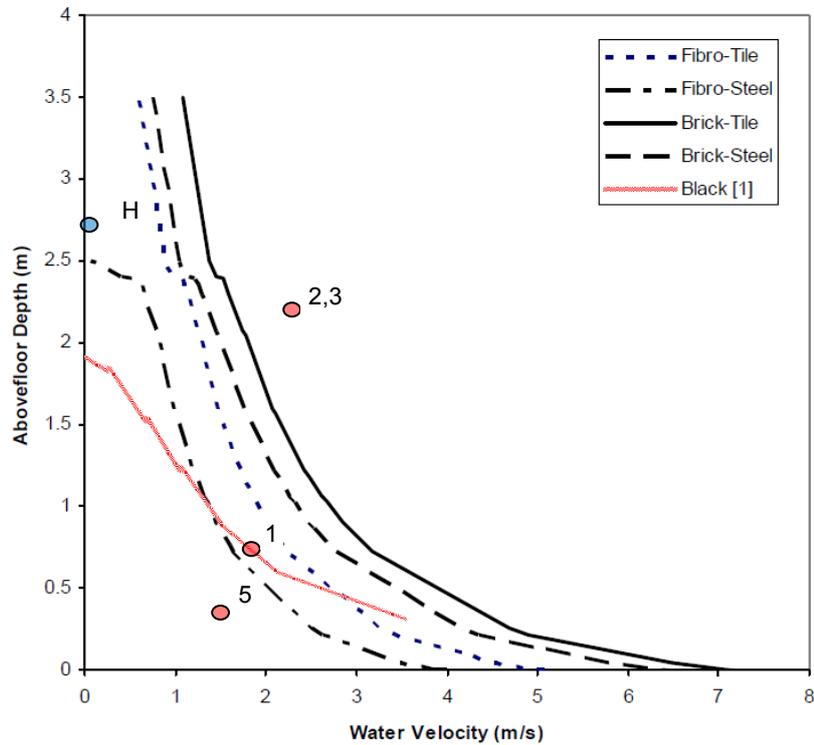


Figure 4.15 Extract from Dale et al (2004) showing thresholds for building stability for Australian house types. Results from this study are shown as red dots with identifying house numbers. Note that House 5 was a high-set house compared to Houses 1, 2, 3. The blue dot labelled 'H' is the data point for the house on Hooke Street that was not floated.

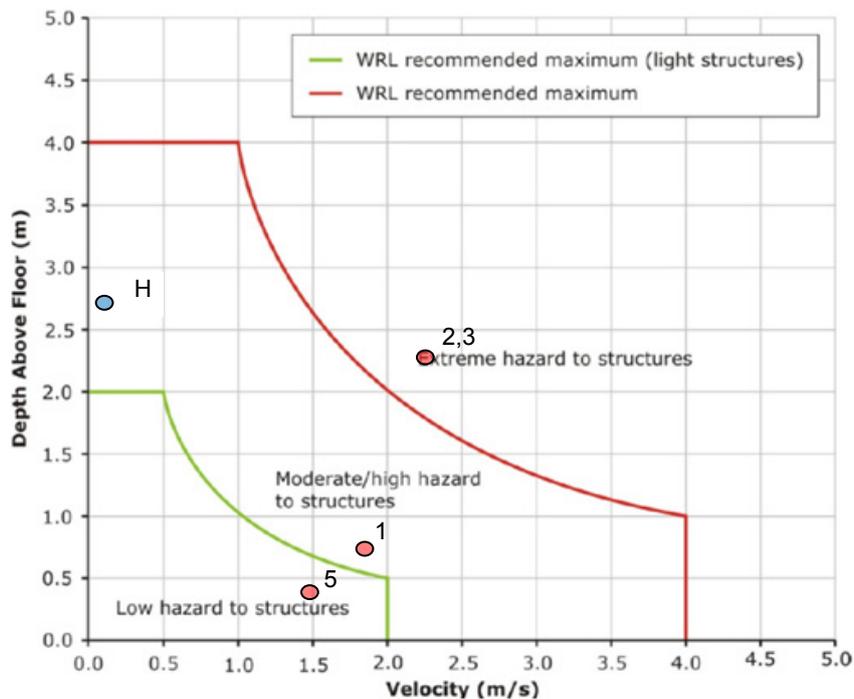


Figure 4.16 Extract from Smith et al (2014) and McLuckie et al (2014) depicting thresholds for building stability in floods for Australian residential structures. Results from this study are shown as red dots with identifying house numbers. Note that House 5 was a poorly braced high-set house compared to Houses 1, 2, and 3 giving it greater vulnerability. The blue dot labelled 'H' is the data point for the house on Hooke Street that was not floated.

4.3 Commercial Buildings

The flood directly impacted five businesses in Dungog. The field survey team interviewed staff at each business.

Tyre Business

This business was located at the northern end of Dowling Street, Dungog (Figure 4.9). At the time of the survey, the business was operating out of alternative accommodation elsewhere in Dungog. The maximum water depth in the premises was reported as 1.8m and flowing “very fast”. The premises are a steel portal frame building clad with fibre-cement sheeting fixed to timber sub-framing and a metal roof. Anecdotally, it was reported that the building is supported on reinforced concrete piers founded on rock. The structure of the main part of the building suffered little or no damage. The structure of the veranda had been heavily damaged, reportedly by the impact from a floating vehicle, with the northernmost column removed and consequential roof collapse. Sheet cladding had been removed along the northern elevation. The staff indicated that the intention was to rebuild the premises and move back into the original location.

Glulam Factory

This business is located at the eastern end of Hooke Street, Dungog (Figure 4.17). The maximum water depth in the premises was measured at 1.48m above floor level. The premises are a steel portal frame building clad in sheet metal. Internally the building is divided by timber framed partitions. The structure of the building had suffered little damage, however wall cladding had been lost from the downstream elevation, girts damaged (presumably by floating debris) and internal partitions saturated. The business had lost 70% of its raw production material (swept downstream) and all machinery was rendered unusable due to inundation. The salvaged 30% of raw material required milling to smaller dimensions making it unusable for the manufacture of standard products. At the time of the field survey the business was attempting to source suitable replacement machinery. Typically it was easier for the business to buy replacement machinery than repair inundated equipment due to long and costly repair work being required to rectify elements such as motors, hydraulics and bearings. Replacement machinery was sourced either as second hand items from within Australia or new items ordered from overseas. The business reported that it would take 3 months to recommence manufacturing following the flood.



Figure 4.17 Internal view of Glulam Factory with clean-up operations in progress.

Motor Vehicle Repair Business 1

This business is located at the northern end of Dowling Street, Dungog (Figure 4.18). The maximum water depth at the street frontage was approximately 0.3m although the rear part of the premises suffered deeper inundation as the floor there is at a lower level. The building is a steel portal frame building with a mixture of masonry and timber clad walls and a metal roof. Although the building structure was undamaged apart from necessary cleaning, the business lost all stock and machinery located below the level of inundation.



Figure 4.18 Image showing flood waters at the street entrance to Motor Vehicle Repair Business 1 about 0.1m below high water. Image courtesy of Mr Neale Currie.

Motor Vehicle Repair Business 2

This business is located at the eastern end of Hooke Street, Dungog (Figure 4.19). The maximum water depth within the premises was approximately 1.0m. The business is housed in a brick workshop with a timber framed annex. The impact on the main building structure was minimal apart from necessary cleaning, but the timber framed annex would require re-lining after a drying out period. All stock, equipment and furnishings located below water level was lost.



Figure 4.19 Image showing the high water level in the office area of Motor Vehicle Repair Business 2. Image courtesy of Thompsons Mitsubishi.

Farm Machinery Business

This business is located on Hooke Street, Dungog (Figure 4.20). The maximum water depth in the workshop was 3.6m above floor level, compared to a previous flood level approximately 1.0m above floor level recorded on the weekend of the 9th -10th June, 2007. The business is housed in a variety of steel framed buildings with various wall cladding materials. Other than cleaning, the structure of the buildings appeared unaffected by inundation. However, internal timber partitions require relining following drying out. Much of the stock, equipment and furnishings were lost as the water level reached almost to ceiling level.



Figure 4.20 Drying out operations in the Farm Machinery Repair business. The owner stated that one of the greater losses was irreplaceable machinery catalogues seen here whilst attempts are made to dry them.

4.4 Infrastructure

The RDA had indicated that the flood had severely affected railway embankments, roads and road bridges. Although washed-out railway embankments could not be located in the field, the survey visited a bridge over Myall Creek on the Chichester Dam road north of Dungog which had been flood affected.

The bridge is situated at a sharp bend in Myall Creek with the southern abutment on the outside of the bend. It is a 2-span structure approximately 30m in total length and opened in 1971. Its structure consists of a reinforced concrete pier and abutments with the abutments supported on precast concrete driven square piles. The nature of the foundation to the intermediate pier is unknown. The deck is formed by prestressed concrete beams and an in-situ reinforced concrete slab. Scour protection consisting of sand-cement filled bags had been provided to each abutment.

The flood water had overtopped the bridge deck as evidenced by flattened grass on the northern approach embankment and severe scouring on the downstream side of the northern embankment (Figure 4.21). Damage to the bridge consisted of:

- complete erosion of scour protection and backfill at the northern abutment (Figure 4.22) resulting in a void behind the abutment,
- erosion of scour protection at the southern abutment (Figure 4.24),
- severe scouring on the downstream side of the northern approach embankment (Figure 4.21).



Figure 4.21 Myall Creek bridge, northern approach embankment. Flattened grass and severe scour on downstream side of embankment indicative of over-topping. Southern end of bridge visible in top right of image.



Figure 4.22 Myall Creek bridge. Repaired northern abutment.



Figure 4.23 Myall Creek bridge. Eroded debris from northern abutment deposited immediately downstream. The northern approach embankment is behind shrubbery at left of image.



Figure 4.24 Myall Creek bridge. Scour damage to southern abutment.



Figure 4.25 Myall Creek bridge. Eroded debris from southern abutment deposited immediately downstream of bridge.

Eroded material had been deposited immediately downstream of the bridge (Figure 4.23 and Figure 4.25) which is suggestive of significantly increased water velocity at the constriction caused by the bridge and its approach embankments.

At the time of survey, the northern abutment had been repaired by filling the void behind the abutment with rock and granular material. Road pavement, erosion to the northern approach embankment and removed scour protection had not yet been repaired.

5 Conclusions

The reported field survey has yielded data that has enabled the estimation of validation points for velocity-depth fragility curves for one type of residential building (single storey with clad timber frame and elevated timber floor). The points typically matched previously published fragility curves. The work has highlighted the difficulties in obtaining accurate data to estimate velocity-depth data points to validate existing models and serve as empirical data for regressing new models.

The interviews with businesses conducted during the field survey provided insights into the vulnerability of light industrial buildings and the resilience of businesses. This included the approaches taken by businesses to recover following flooding and likely recovery timeframes.

Two lessons were learnt from a comparison of the field survey data with the earlier desk-top rapid damage analysis. Firstly, the media will not necessarily capture the maximum extent and severity of impact. Following the flood in Dungog, descriptions and images published in the media led to an underestimate of maximum water level by approximately 2.5m and a consequent underestimation of the number of affected buildings.

Secondly, SES call-out databases will not necessarily capture all affected properties. The database compiled following the Dungog flood did not capture several properties in Hooke Street that had been inundated. However, plotting inundated properties recorded in an SES database on a topographic map and then interpolating water levels as a flood extent would give a good estimate of the total number of affected properties.

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