6 Assessment of Floodplain Management Measures

6.1 Identifying Floodplain Risk Management Measures

The Floodplain Development Manual (NSW State Government, 2005) states that the purpose of a FRMS&P is to identify, assess and compare various flood risk management options to mitigate flood affectation and as such lower the overall flood damages and/or risk to life in the area considered by the study. This process involves assessing the flood impacts of management options for existing, future and continuing flood risk on flood behaviour and hazard and the social, economic, ecological and cultural costs and benefits of options. Assessment of these factors forms the basis for robust decision making in the management plan. The following sections assess a range of flood mitigation options to mitigate and manage flood risk in Dungog.

6.2 Risk Management Measures Categories

Measures which can be employed to mitigate flooding and reduce flood damages can be separated into three broad categories:

Flood modification measures: modify the flood's physical behaviour (i.e. depth, velocity) and includes flood mitigation dams, retarding basins, on-site detention, channel improvements, levees, floodways or catchment treatments.

Property modification measures: modify property and land use including development controls. This is generally accomplished through such means as flood proofing (house raising or sealing entrances), planning and building regulations (i.e. zoning) or voluntary purchase.

Response modification measures: modify the community's response to flood hazard by informing flood-affected property owners and users about the nature of flooding so that they can make informed decisions. Examples of such measures include provision of flood warning and emergency services, improved information, awareness and education of the community and provision of flood insurance.

6.3 Potential Floodplain Risk Management Measures

The following Sections provide a first pass assessment of options by determining if they would be applicable/suitable to the flooding characteristics of Dungog.

Section 6.3.1 provides a list of options that were considered applicable/suitable, and subjected to a detailed assessment as part of this FRMS.

Section 6.3.2 provides a list of options that were considered not be applicable/suitable, and require no further assessment in this FRMS.

Section 6.3.3 provides a list of options that were considered to be potentially effective flood mitigation options and may warrant further investigation in future studies if funding is available.

6.3.1 List of potential flood mitigation options assessed in this FRMS

The following mitigation options were considered applicable/suitable for reducing flood risk in Dungog, and were therefore the subject of a detailed assessment as part of this FRMS. Please refer to the appropriate report sections for detailed descriptions and assessment outcomes for each option.

Flood modification measures

O1) Major Myall Creek (Road and Rail) Bridge Modifications – Section 6.4.1

O2) Minor Myall Creek (Road and Rail) Bridge Modifications – Section 6.4.2

O3) Myall Creek Levee with Pumps – Section 6.4.3

O4) Myall Creek Levee with Diversion Culverts – Section 6.4.4

O5) Vegetation Removal with Scour Protection – Section 6.4.5

O6) Dungog Showground Detention Basin Augmentation – Section 6.4.6

O7) Dungog North-West Detention Basin – Section 6.4.7

Property modification measures

O8) Voluntary House Raising – Section 6.4.8

O9) Voluntary House Purchase – Section 6.4.9

O10) Flood Resistant Surfacing for Bennett Park Tennis Courts – Section 6.4.10

Response modification measures

O11) Flood Warning System - The development of a flood warning system for Dungog is presented in detail in Section 7.

6.3.2 List of potential flood mitigation options not recommended for further investigation in this FRMS

This section provides a list of options that were considered not be applicable/suitable, and require no further assessment in this FRMS.

NRO1) Myall Creek Levee: A levee protecting Dungog from Myall Creek backwater flooding was investigated. Initial investigations show that pumping or culverted outfalls are required to prevent flooding from the impounded catchment. While a Myall Creek Levee in isolation was not further investigated, a Myall Creek Levee, in conjunction with pumping or a diversion culvert was investigated (refer Section 6.4.3 and 6.4.4).

NRO2) Williams River Levee: A levee protecting a small number of properties from Williams River Flooding (to the east of Windeyer Street) is not considered financially viable due to the low number of properties receiving benefit. Due to the adequate warning time for Williams River events and ease of evacuation in this location, it is considered a relatively low risk flood area.

NRO3) Myall Creek Detention Basins: Due to the size of the Myall Creek catchment and the impact of Williams River backwater, detention basins would not be practical or effective.

NRO4) Williams River Dam Operations: Chichester Dam is operated by Hunter Water for the purposes of water supply. If the Dam was also operated for flood mitigation purposes, the large and branched catchment size means that the flood benefit for Williams River events would only be relatively small. Also this option would have negligible impact on Myall Creek events such that changes to Chichester Dam operations would not be practical or effective.

NRO5) Increased Hooke Street Culvert Capacity: Increasing the capacity of the either set of Hooke Street culverts would have no impact on peak flood levels as the key flood mechanism in this area is not due to the local Dungog catchment, but rather backwater flooding in Myall Creek. Council may wish to examine the influence of the Hooke Street culvert and operation of the gross pollutant trap during more frequent minor local catchment flood events as part of a self-funded drainage improvement programme.

6.3.3 Potential flood mitigation options recommended for future investigations

This section provides a list of flood mitigation options that were considered to be potentially effective and may warrant further investigation in future studies if funding is available.

FRO1) Increased Cross-Road Drainage Capacity: Increasing the capacity of other cross-road drainage infrastructure was investigated in a preliminary desktop assessment. The initial assessment shows that at all locations, the road crest is low enough such that for larger events peak flood levels are governed by the road elevation and not culvert capacity. However, some improvement in local drainage may be realised for lower recurrence interval events should the culverts be upgraded. Because this option would only have a minor benefit for 1-2 properties immediately upstream of the culvert, the benefit/cost was unlikely to be greater than 1. This meant that while the option was not investigated in the FRMS it may be worth considering in future studies by Council.

FRO2) Increased Drain Clearance and Maintenance: Prevention of drain blockage by a more regular drain clearance and maintenance program has also been investigated in a preliminary desktop assessment. Again, the initial assessment shows that at all locations, the road crest is low enough such that for most events, peak flood levels are governed by the road elevation and not drainage capacity and there are sufficient overland flow paths available to supplement the formal drainage network should blockage occur. This meant that while the option was not investigated in the FRMS it may be worth considering in future studies by Council as it may reduce the occurrence of “nuisance” type flooding.

FRO3) Redirect Overflow to protect Bennett Park Tennis Courts: The synthetic grass surface of the Bennett Park Tennis Courts has been damaged by flood waters on at least two occasions. While an option for preventing future damage by upgrading the court surface is presented in **Section 6.4.10** an alternate mitigation measure would raising the bund on the eastern side of Bennett Park. The bund is currently 54.5 m AHD though there are a number of short sections of the bund that ALS data indicates could be 100-150 mm lower. Raising the bund to 55.0 m AHD, to increase the storage volume of the detention basin, would protect the courts by diverting flows to the north. However, as the basin is located near the end of the local catchment there is no significant benefit to above floor inundation by enhancing the Bennett Park detention volume. In order to protect the tennis courts, provision of a 4m wide, 70m long outlet channel at RL 49.2 m AHD around the southern end of the courts linking back in to the existing drainage swale may be adequate for most of the smaller events. This would require a maximum excavation depth of 0.5m so would require the removal of 140m^2 of material, and re-surfacing the gravel road access in to Bennett Park. Costs of the works is likely to be $200,000 to $300,000. This is significantly more than the costs of replacing the existing synthetic grass surface with a flood resistant hardcourt surface such as synpave (see **Section 6.4.10**) so would only be considered if the tennis court substrate required replacing such that it made surface upgrade options prohibitively expensive.

6.4 Description and Assessment of Floodplain Management Measures

Flood modification measures

Flood Modification Measures refer to physical modifications on the floodplain which alter the flood behaviour and ultimately reduce the flood affectation (flood levels or velocities) in particularly vulnerable areas.

6.4.1 O1) Major Myall Creek (Road and Rail) Bridge Modifications

Overview

In order to reduce the afflux of water levels through the road and rail bridge crossings of Myall Creek, significant increases in the available waterway area have been investigated. Increased waterway opening could be achieved through the use of banks of: 3.6m wide x 3m high flood relief culverts (FRC). For the major bridge modifications, 27 FRC culverts would be used at Bennett Bridge and 20 for the Railway Bridge. Ground works (excavation) would be required to improve conveyance and improve channel approach conditions.

Figure 6-1 provides details of key components of the required works. The flood model was updated to include these features and a suite of design runs was simulated to determine the impact of this mitigation option on flood behaviour and property inundation and damages.

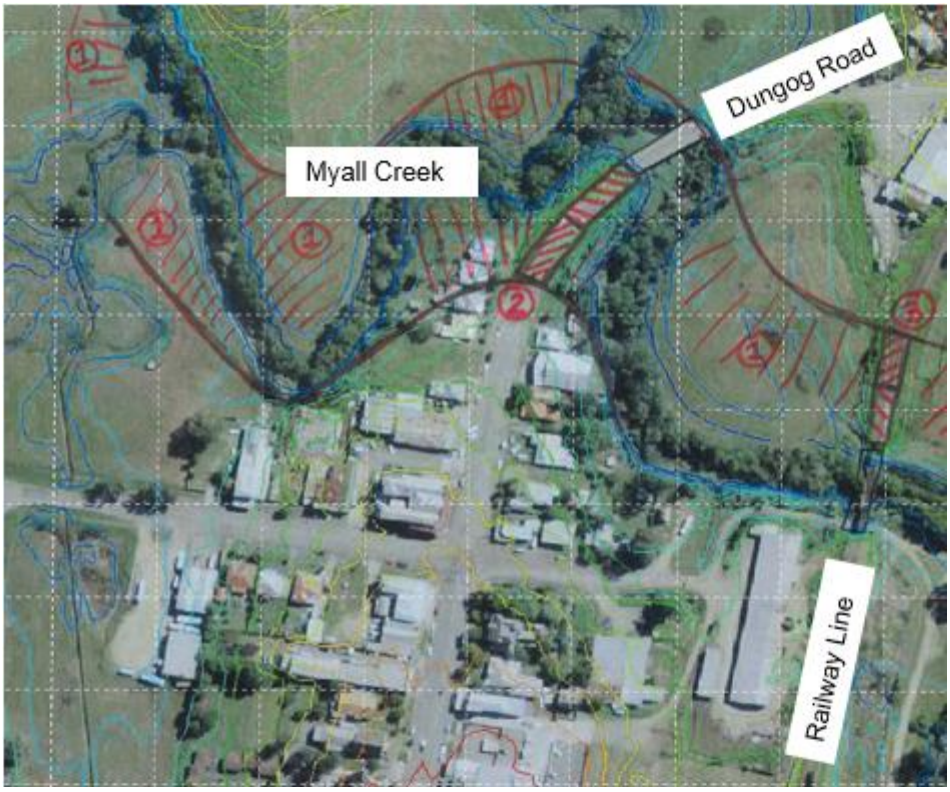

Figure 6-1: Outline Details of O1 - Major Myall Creek (Road and Rail) Bridge Modifications

NB: 1) Ground excavation works to improve conveyance and approach conditions.
2) Two banks (total 27) of flood relief culverts (3.6w x 3.0h) to increase available conveyance at Bennett Bridge crossing.
3) Two banks (total 20) of flood relief culverts (3.6w x 3.0h) to increase available conveyance at the Rail Bridge crossing.

Results

This option results in a significant reduction in peak flood levels in the Dungog tailwater area as presented in **Table 6-1**. For most events, a reduction in peak flood level of 0.3-0.5m is achieved, while during the April 2015 event, a reduction of 1.37m (from 51.98mAHD down to 50.61mAHD) would be expected. Because the PMF event is heavily influenced by the Williams River flood level, this option has a minimal impact on peak flood levels in the PMF.

This option significantly reduces flood affectation in the Dungog tailwater as presented in **Table 6-1.** There is a 54% reduction in AAD, which, over a 50 year period, is expected to reduce flood related damages by $1.8 Million. However, the cost of constructing this mitigation option is $6.8 Million (a cost breakdown for this measure can be found in **Appendix C**). The calculated benefit/cost (B/C) ratio for this option is 0.27. Since the B/C ratio is less than one, this option would not be recommended for implementation or further investigation.

Table 6-1: Change in Flood Levels, Property Affectation and Damages for Mitigation Measure - O1 Major Myall Creek (Road and Rail) Bridge Modifications

Event	Peak Flood Level (m AHD)[1]	Reduction in Peak Flood Levels (m) [2]	No. Properties No Longer Flooded Over Floor[3]	No. Properties No Longer Yard or Under Floor Flooded[3]	Reduction in Damages for Event
PMF	53.18	0.04	0	0	$ 95,696
0.2% / 500yr	50.7	0.41	9	11	$ 1,339,635
0.5% / 200yr	50.25	0.39	8	4	$ 960,463
1% / 100yr	49.84	0.36	6	8	$ 768,018
2% / 50yr	49.31	0.51	5	13	$ 751,061
5% / 20yr	49.03	0.38	6	3	$ 489,121
20% / 5yr	48.51	0.27	3	3	$ 227,673
April 2015	50.61	1.37	31	36	$ 4,900,152
Reduction in Annual Average Damages (AAD)					**$ 123,308**
Reduced Damages (Over 50 years)					**$ 1,825,054**
Cost of Mitigation Option					**$ 6,800,000**
Benefit/Cost					**0.27**
Reduction in Damages (%)					**54%**

Notes: 1) Peak flood levels and reduction in flood levels are for the Dungog tailwater area.
2) Reduction in peak flood levels is compared to the base case in the Dungog tailwater area.
3) Reduction in the number of properties is compared to the base case.

6.4.2 O2) Minor Myall Creek (Road and Rail) Bridge Modifications

Overview

In order to reduce the afflux of water level through the road and rail bridge crossing of Myall Creek, a more economically viable increase in the available waterway area (i.e. span duplication) was investigated. Increased waterway opening could be achieved through the use of banks of, 3.6m wide x 3m high flood relief culverts (FRC). For the minor bridge modifications, 14 FRC would be used at Bennett Bridge and 10 FRC would be used for the Railway Bridge. Again, ground works (excavation) would be required to improve conveyance and improve channel approach conditions. Such a scheme should also be considered if any future upgrade or repair of the road or rail bridge is planned.

Figure 6-2 provides details of key components of the required works. The flood model was updated to include these features and a suite of design runs was simulated to determine the impact of this mitigation option on flood behaviour and property inundation and damages.

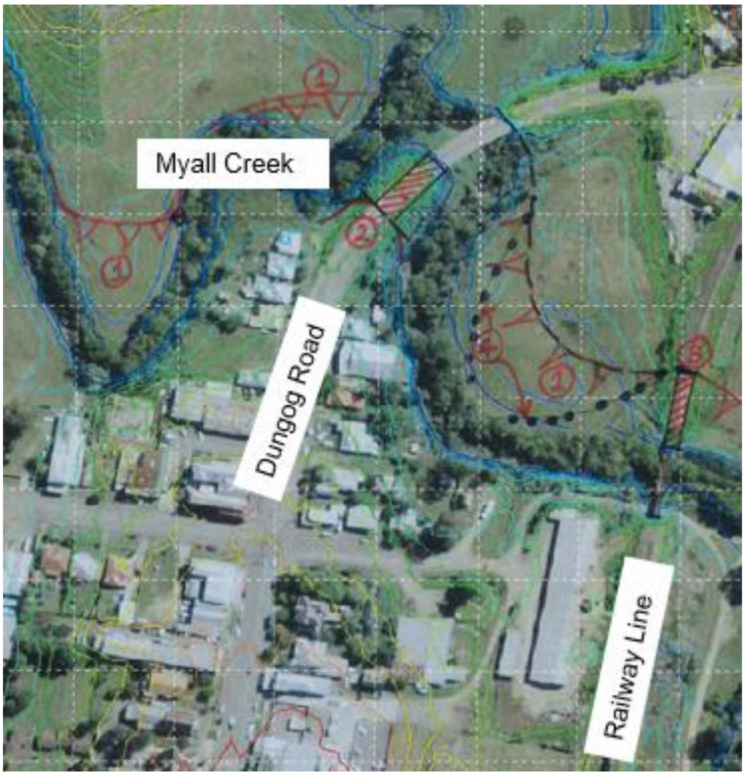

Figure 6-2: Outline Details of O2 - Minor Myall Creek (Road and Rail) Bridge Modifications

Notes: 1) Ground excavation works to improve conveyance and approach conditions.
2) One bank (total 14) of flood relief culverts (3.6w x 3.0h) to increase available conveyance at Bennett Bridge crossing.
3) One bank (total 10) of flood relief culverts (3.6w x 3.0h) to increase available conveyance at the Rail Bridge crossing.

Results

This option produces a slightly smaller flood level reduction compared to O1 (major bridge modifications) and results in a significant reduction in peak flood levels in the Dungog tailwater as presented in **Table 6-2**. For most events a reduction in peak flood level of 0.2-0.5m is achieved, while during the April 2015 event, a reduction of 1.16m (from 51.98mAHD down to 50.82mAHD) would be expected. Because the PMF event is heavily influenced by the Williams River flood level, this option has a minimal impact on peak flood levels in the PMF.

This option significantly reduces flood affectation in the Dungog tailwater as presented in **Table 6-2**. There is a 45% reduction in AAD, which, over a 50 year period, is expected to reduce flood related damages by $1.5 Million. However, the cost of constructing this mitigation option is $4.4 Million (a cost breakdown for this measure can be found in **Appendix C**).

The calculated benefit/cost (B/C) ratio for this option is 0.35. Since the B/C ratio is less than one, this option would not be recommended for implementation on purely economic grounds. However, considering the high reduction in damages and water levels in an extreme Myall River event (such as the April 2015 superstorm), such a mitigation option could be considered as it would reduce the potential risk to life. Also as the scheme significantly reduces flood damages for such an extreme event (by $4.15 Million), the B/C for an extreme event is close to one. If future studies reveal that climate change has significantly altered the severity and intensity of storms in the Dungog region, such a scheme may be considered to reduce the impact of severe events. Also, such as scheme should also be considered if any future upgrade or repair of the road bridge or rail bridge is planned.

Table 6-2: Change in Flood Levels, Property Affectation and Damages for Mitigation Measure – O2
Minor Myall Creek (Road and Rail) Bridge Modifications

Event	Peak Flood Level (m AHD)[1]	Reduction in Peak Flood Levels (m)[2]	No. Properties No Longer Flooded Over Floor[3]	No. Properties No Longer Yard or Under Floor Flooded[3]	Reduction in Damages for Event
PMF	53.18	0.04	0	0	$ 116,322
0.2% / 500yr	50.72	0.39	9	11	$ 1,254,106
0.5% / 200yr	50.3	0.34	8	4	$ 888,497
1% / 100yr	49.89	0.31	6	6	$ 641,517
2% / 50yr	49.34	0.48	5	13	$ 711,915
5% / 20yr	49.07	0.34	6	3	$ 489,121
20% / 5yr	48.57	0.21	2	2	$ 145,571
April 2015	50.82	1.16	24	30	$ 4,149,403
Reduction in Annual Average Damages (AAD)					**$ 102,623**
Reduced Damages (Over 50 years)					**$ 1,518,896**
Cost of Mitigation Option					**$ 4,400,000**
Benefit/Cost					**0.35**
Reduction in Damages (%)					**45%**

Notes: 1) Peak flood levels and reduction in flood levels are for the Dungog tailwater area.
2) Reduction in peak flood levels is compared to the base case in the Dungog tailwater area.
3) Reduction in the number of properties is compared to the base case.

6.4.3 O3) Myall Creek Levee with Pumps

Overview

A levee protecting Dungog from Myall Creek backwater flooding has been investigated. In order to prevent catchment flooding from behind the levee, one option is to provide a large pump to pump stormwater runoff out against the backwater flood level outside the Levee. A number of pump sizes were investigated with a 5 m^3/s capacity pump being selected as an appropriate compromise between cost and performance. A flood levee crest level of 52.0 m AHD was selected so that it was capable of protecting Dungog from an extreme event such as the April 2015 “superstorm”.

Figure 6-3 provides details of key components of the required works. The flood model was updated to include these features and a suite of design runs was simulated to determine the impact of this mitigation option on flood behaviour and property inundation and damages.

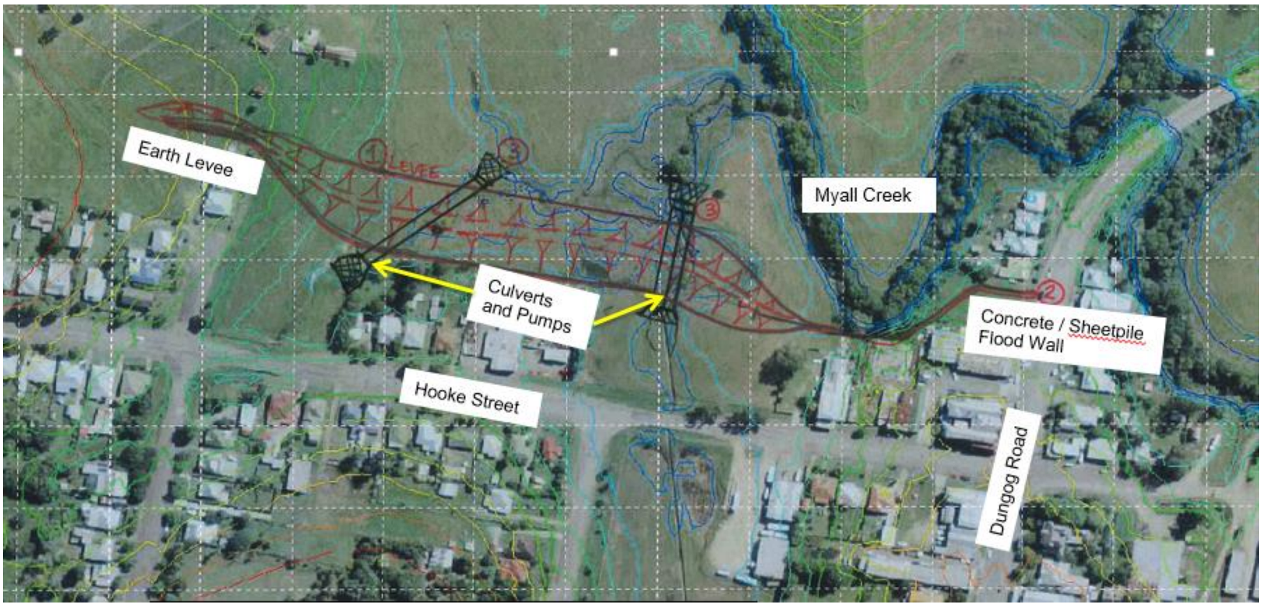

Figure 6-3: Outline Details of O3 - Myall Creek Levee with Pumps

Notes: 1) A ~400m long flood defence earth levee with crest at 52.0 m AHD (up to 5 m high) with 1V:3H batters
2) A 150m long concrete or Sheetpile flood wall near Dungog Road
3) Local drainage flow relief culvert with non-return “Flap” valve. Pumps with 5m^3/s capacity.

Results

This option produces a very significant reduction in peak flood levels in the Dungog tailwater area as presented in **Table 6-3**. For most events, a reduction in peak flood level of greater than 1m is achieved. However, for the April 2015 event, a reduction of only 0.5m (from 51.98mAHD down to 50.48mAHD) occurs due to the high volume of local catchment runoff in this extreme event. Because the PMF event overtops the levee, there is no reduction in peak flood levels in the PMF, however, it would increase the available evacuation timeframe.

This option significantly reduces flood affectation in the Dungog tailwater as presented in **Table 6-3.** There is a 71% reduction in AAD, which, over a 50 year period, is expected to reduce flood related damages by $2.4 Million. However, the cost of constructing this mitigation option is $8.0 Million (a cost breakdown for this measure can be found in **Appendix C**). The calculated benefit/cost (B/C) ratio for this option is 0.3. Despite the ability for this option to nearly completely eliminate flooding in the Dungog tailwater for all but the severest of events, as the B/C ratio is less than one, this option would not be recommended for implementation or further investigation. This option also has significant ongoing operational cost and may cause additional local catchment flooding if pumps were to fail during a storm event.

Table 6-3: Change in Flood Levels, Property Affectation and Damages for Mitigation Measure – O3
Myall Creek Levee with Pumps

Event	Peak Flood Level (m AHD)[1]	Reduction in Peak Flood Levels (m)[2]	No. Properties No Longer Flooded Over Floor[3]	No. Properties No Longer Yard or Under Floor Flooded[3]	Reduction in Damages for Event
PMF	53.22	0.00	0	0	$ 0
0.2% / 500yr	50.12	0.99	18	19	$ 2,508,775
0.5% / 200yr	49.59	1.05	18	16	$ 2,030,388
1% / 100yr	49.16	1.04	13	18	$ 1,525,932
2% / 50yr	48.79	1.03	9	17	$ 1,079,171
5% / 20yr	48.31	1.10	8	9	$ 710,648
20% / 5yr	47.13	1.65	3	3	$ 227,673
April 2015	51.48	0.50	9	14	$ 1,688,104
Reduction in Annual Average Damages (AAD)					**$ 162,589**
Reduced Damages (Over 50 years)					**$ 2,406,433**
Cost of Mitigation Option					**$ 8,000,000**
Benefit/Cost					**0.30**
Reduction in Damages (%)					**71%**

Notes: 1) Peak flood levels and reduction in flood levels are for the Dungog tailwater area.
2) Reduction in peak flood levels is compared to the base case in the Dungog tailwater area.
3) Reduction in the number of properties is compared to the base case.

6.4.4 O4) Myall Creek Levee with Diversion Culverts

Overview

A levee protecting Dungog from Myall Creek backwater flooding has been investigated. In order to prevent catchment flooding from behind the levee, a diversion culvert conveying water downstream of Bennett Bridge would be required. This option would be cheaper than the pumping option and does not have the maintenance or operational issues associated with pumping. An option where the diversion culvert discharged downstream of the Rail Bridge was also investigated, however, the increase in cost was not justified by the slight reduction in flood levels. A levee crest level of 52.0 m AHD was selected so that it was capable of protecting Dungog from an extreme event such as the April 2015 "superstorm".

Figure 6-4 provides details of key components of the required works. The flood model was updated to include these features and a suite of design runs was simulated to determine the impact of this mitigation option on flood behaviour, property inundation and damages.

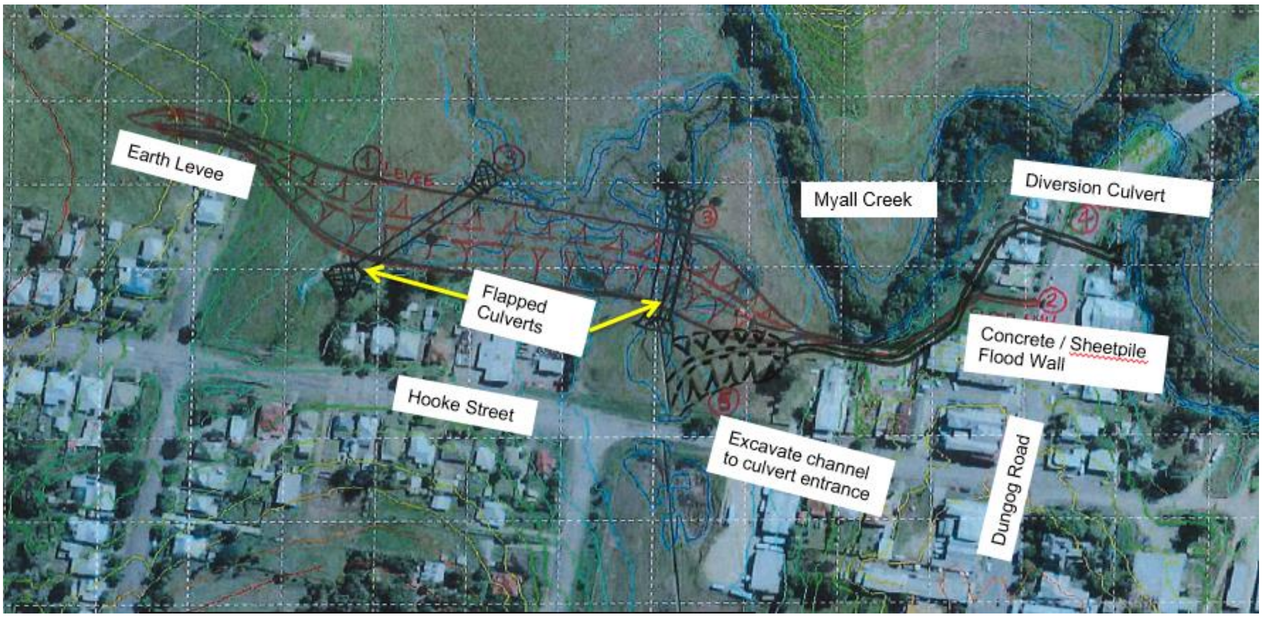

Figure 6-4: Outline Details of O4 - Myall Creek Levee with Diversion Culvert

Notes:
1) A ~400m long flood defence earth levee with crest at 52.0 m AHD (up to 5 m high) with 1V:3H batters
2) A 150m long concrete or Sheetpile flood wall near Dungog Road
3) Local drainage flow relief culvert with non-return "Flap" valve.
4) 200m long diversion culvert 3.6W x 3.0H would convey flow downstream of Bennett Bridge
5) To reduce the culvert length a channel would be excavated to the culvert entrance.

Results

This option produces a very significant reduction in peak flood levels in the Dungog tailwater as presented in **Table 6-4**. For most events a reduction in peak flood level of 0.3-0.7m is achieved, while during the April 2015 event a reduction of 0.78m (from 51.98mAHD down to 51.2mAHD) is expected. Because the PMF event overtops the levee, this option has no impact on peak flood levels in the PMF, however, it would increase the available evacuation timeframe.

This option significantly reduces flood affectation in the Dungog tailwater as presented in **Table 6-4.** There is a 56% reduction in AAD, which, over a 50 year period, is expected to reduce flood related damages by $1.9 Million. However, the cost of constructing this mitigation option is $7.0 Million (a cost breakdown for this measure can be found in **Appendix C**). The calculated benefit/cost (B/C) ratio for this option is 0.27. Despite the ability for this option to significantly reduce flooding in the Dungog tailwater for all but the PMF event, as the B/C ratio is less than one, this option would not be recommended for implementation or further investigation.

Table 6-4: Change in Flood Levels, Property Affectation and Damages for Mitigation Measure – O4
Myall Creek Levee with Diversion Culvert

Event	Peak Flood Level (m AHD)[1]	Reduction in Peak Flood Levels (m) [2]	No. Properties No Longer Flooded Over Floor[3]	No. Properties No Longer Yard or Under Floor Flooded[3]	Reduction in Damages for Event
PMF	53.22	0.00	0	0	$ 5,655
0.2% / 500yr	50.4	0.71	16	16	$ 1,976,962
0.5% / 200yr	50.05	0.59	9	8	$ 1,313,909
1% / 100yr	49.84	0.36	5	6	$ 676,713
2% / 50yr	49.23	0.59	6	12	$ 838,142
5% / 20yr	49.05	0.36	6	3	$ 489,121
20% / 5yr	48.46	0.32	3	3	$ 227,673
April 2015	51.2	0.78	16	18	$ 2,661,019
				Reduction in Annual Average Damages (AAD)	**$ 127,274**
				Reduced Damages (Over 50 years)	**$ 1,883,747**
				Cost of Mitigation Option	**$ 7,000,000**
				Benefit/Cost	**0.27**
				Reduction in Damages (%)	**56%**

Notes: 1) Peak flood levels and reduction in flood levels are for the Dungog tailwater area.
2) Reduction in peak flood levels is compared to the base case in the Dungog tailwater area.
3) Reduction in the number of properties is compared to the base case.

6.4.5 O5) Vegetation Removal with Scour Protection

Overview

Community consultation indicated that several residents believe that flooding is exacerbated by instream vegetation along Myall Creek. Investigations into vegetation removal, combined with adequate scour protection were undertaken. Without adequate scour protection, vegetation removal would result in severe channel erosion which could ultimately reduce the stability of Bennett and/or the Railway Bridge.

Figure 6-5 provides details of key components of the required works. The flood model was updated to include these features and a suite of design runs was simulated to determine the impact of this mitigation option on flood behaviour, property inundation and damages.

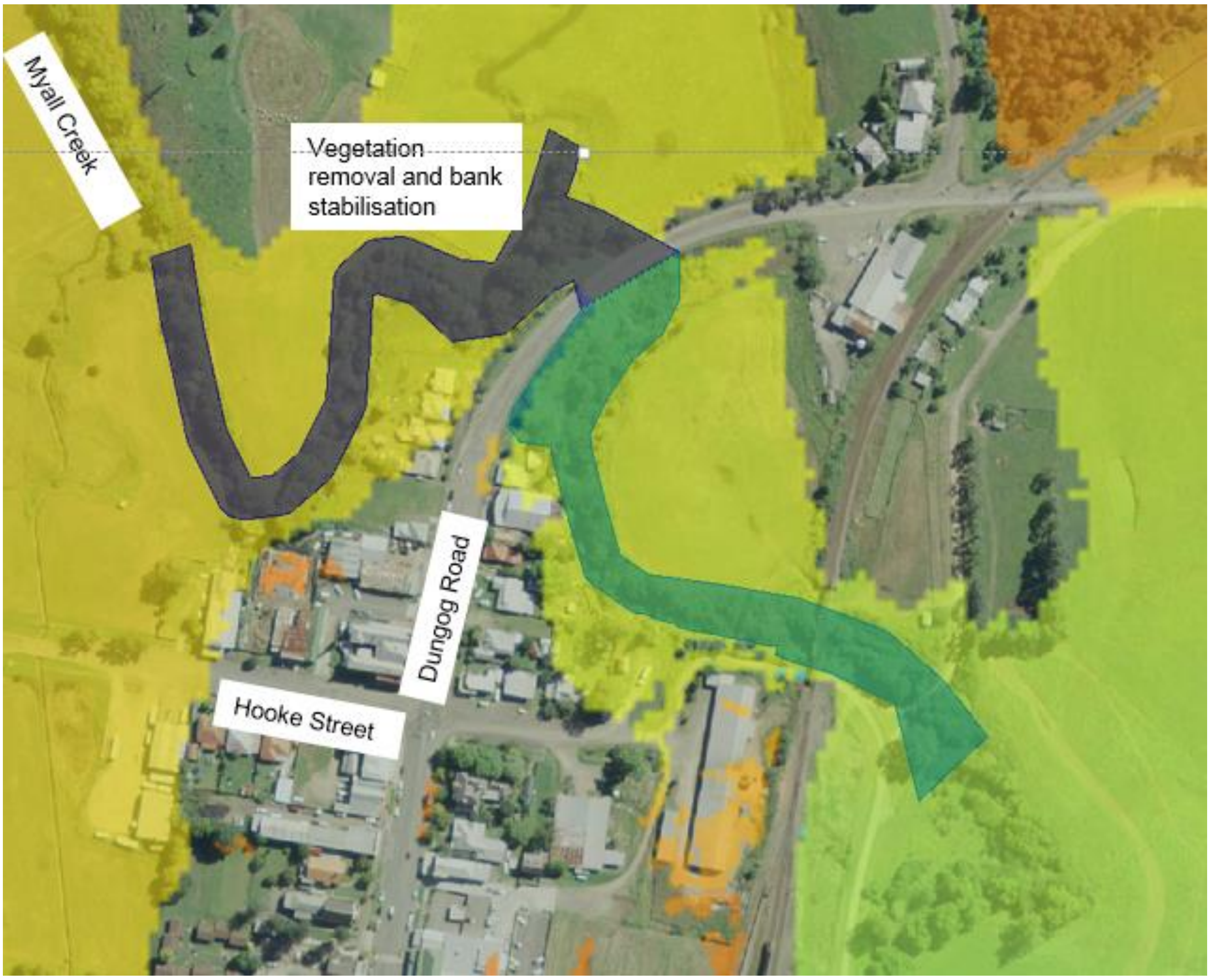

Figure 6-5: Outline Details of O5 - Myall Creek Vegetation Removal and Scour Protection

Notes: 1) Vegetation clearance and channel stabilisation works along an 800m length of Myall Creek

Results

This option produces a reasonable reduction in peak flood levels in the Dungog tailwater area as presented in **Table 6-5**. For most events a reduction in peak flood level of 0.2-0.4m is achieved, while during the April 2015 event a reduction of 0.37m (from 51.98mAHD down to 51.61mAHD) would be expected. Because the PMF event is heavily influenced by the Williams River flood level, this option has a minimal impact on peak flood levels in the PMF.

This option reduces flood affectation in the Dungog tailwater as presented in **Table 6-5.** There is a 40% reduction in AAD, which, over a 50 year period, is expected to reduce flood related damages by $1.33 Million. The costs of constructing this mitigation option is $3.5 Million (a cost breakdown for this measure can be found in **Appendix C**). The calculated benefit/cost (B/C) ratio for this option is 0.38. Despite the ability for this option to reduce flooding in the Dungog tailwater for all but the PMF event, as the B/C ratio is less than one, this option would not be recommended for implementation or further investigation.

Table 6-5: Change in Flood Levels, Property Affectation and Damages for Mitigation Measure – O5
Myall Creek Vegetation Removal and Scour Protection

Event	Peak Flood Level (m AHD)[1]	Reduction in Peak Flood Levels (m) [2]	No. Properties No Longer Flooded Over Floor[3]	No. Properties No Longer Yard or Under Floor Flooded[3]	Reduction in Damages for Event
PMF	53.21	0.01	0	0	$ 5,655
0.2% / 500yr	50.9	0.21	1	6	$ 504,940
0.5% / 200yr	50.43	0.21	3	3	$ 496,935
1% / 100yr	49.99	0.21	5	3	$ 364,756
2% / 50yr	49.45	0.37	4	11	$ 581,513
5% / 20yr	49.1	0.31	6	3	$ 443,060
20% / 5yr	48.56	0.22	2	2	$ 145,571
April 2015	51.61	0.37	7	13	$ 1,456,008
Reduction in Annual Average Damages (AAD)					**$ 90,248**
Reduced Damages (Over 50 years)					**$ 1,335,738**
Cost of Mitigation Option					**$ 3,500,000**
Benefit/Cost					**0.38**
Reduction in Damages (%)					**39%**

Notes: 1) Peak flood levels and reduction in flood levels are for the Dungog tailwater area.
2) Reduction in peak flood levels is compared to the base case in the Dungog tailwater area.
3) Reduction in the number of properties is compared to the base case.

6.4.6 O6) Dungog Showground Detention Basin Augmentation

Overview

The benefit of augmenting the existing detention basins at the Dungog Showground to reduce the impact of downstream overland flooding has been investigated. Additional flood detention storage within the Dungog Showgrounds could be provided by increasing the height of the existing bund wall from 63 to 64.5m AHD as presented in **Figure 6-6**. This option was schematised into the local Dungog Catchment model and a number of design runs were used to investigate the performance of this mitigation measure.

Figure 6-6: Outline Details of O6 - Dungog Showground Detention Basin Augmentation

Notes: 1) extend basin embankment and increase embankment crest level from 63 to 64.5 mAHD
2) existing detention basin
3) existing drainage network.

Results

This option produces a 10cm reduction in peak water levels (and hence depths) along the overland flow path and channel between Abelard and Chapman Street. However, as this option will not influence the level of flooding in the Dungog tailwater (which is caused by Myall Creek flooding) and the majority of damages are caused by tailwater flooding, there is not sufficient economic justification for this measure and it has not been investigated further in this study. Again, Council may wish to further investigate this option as part of a local drainage improvement study.

6.4.7 O7) Dungog North-West Detention Basin

Overview

The benefit of constructing detention basins in the upstream catchment areas north of Mackay Street and west of Abbott Lane has been investigated. The proposed detention basin would be formed by constructing an earth embankment with a crest level of 65 mAHD (i.e. 2-2.5 high embankment) along Abbot Lane and excavating the upstream land to 63 m AHD (i.e. up to 4m depth). A 0.5 m diameter outlet pipe would be used to drain the basin. Details of the basin are presented in **Figure 6-7**. This option was schematised into the local Dungog Catchment model and a number of design runs were used to investigate the performance of this mitigation measure.

Figure 6-7: Outline Details of O7 - Dungog North-West Detention Basin

Notes: 1) earth embankment with a crest level of 65 mAHD
2) excavate land to a 63 m AHD
3) 0.5 m diameter pipe with inlet structure.
4) existing drainage network.

Results

This option produces a 5-10cm reduction in peak water levels (and hence depths) along the overland flow path and channel between Abbot Lane and Eloiza Street. However, as this option will not influence the level of flooding in the Dungog tailwater area (which is caused by Myall Creek flooding) and the majority of damages are caused by tailwater flooding, there is not sufficient economic justification for this measure and it has not been investigated further in this study. Again, Council may wish to further investigate this option as part of a local drainage improvement study.

Property modification measures

6.4.8 O8) Voluntary House Raising

Description

Voluntary House Raising (VHR) has been widely used in NSW as a means of reducing above floor flood inundation. The application of VHR is limited since it is not suitable for all building types (primarily only for single storey non-brick buildings on piers). VHR, where suitable, is cost effective because it does not require significant quantities of new material and does not "sterilise" land. It should be noted that VHR is unlikely to be approved in high hazard areas and can cause evacuation problems.

Overview

A key advantage of VHR is the potential to eliminate above floor inundation and the resulting flood damages. An analysis of at-risk properties potentially eligible for VHR in the study found 7 properties that would be suitable for VHR. One property was located in the local (overland flow) catchment, 5 properties were located in the Dungog tailwater area and one property was located on the Williams River floodplain. Included in the analysis of VHR, is the demolition (DEMO) of 6 Council owned Alison Court properties that have been considered for demolition as it was deemed that the independent senior living units should not be allowed in the newly designated FPA (flood planning area). It should be noted that the demolition of the six Council owned properties may be eligible for funding under the NSW OEH Voluntary Purchase scheme. VHR was represented in the damage analysis by raising the floor level of the property to the 1% AEP (100yr ARI) + 0.5m level. For the 6 Alison Court properties, both the floor level and the ground level was raised to 55mAHD to prevent any damages being calculated for the 6 properties that are to be demolished.

Results

This option will have a negligible effect on flood levels. However, by targeting the properties that are frequently flooded (and hence result in a high contribution to AAD), a significant reduction in flood damages is achieved as presented in **Table 6-6.** There is a 31% reduction in AAD, which, over a 50 year period, is expected to reduce flood related damages by $1.03 Million. The cost of this mitigation option is $0.47 Million (assuming 7 x $50,000 for VHR and 6 x $20,000 for demolition). The calculated benefit/cost (B/C) ratio for this option is 2.2. **Given that the B/C ratio is considerably higher than one, this option would be recommended for implementation or further investigation.**

Table 6-6: Change in Property Affectation and Damages for Mitigation Measure – O8
Voluntary House Raising and Demolish 6 Alison Court Units

Event	Peak Flood Level (m AHD)	Reduction in Peak Flood Levels (m) [2]	No. Properties No Longer Flooded Over Floor[1]	No. Properties No Longer Yard or Under Floor Flooded[1]	Reduction in Damages for Event
PMF	53.22	n/a	6	6	$ 106,611
0.2% / 500yr	51.11	n/a	7	6	$ 1,136,715
0.5% / 200yr	50.64	n/a	13	7	$ 1,213,776
1% / 100yr	50.2	n/a	12	5	$ 990,774

2% / 50yr	49.82	n/a	11	6	$ 810,501
5% / 20yr	49.41	n/a	6	2	$ 357,171
20% / 5yr	48.78	n/a	1	1	$ 27,454
April 2015	51.98	n/a	7	7	$ 1,145,814
Reduction in Annual Average Damages (AAD)					**$ 69,548**
Reduced Damages (Over 50 years)					**$ 1,029,369**
Cost of Mitigation Option					**$ 470,000**
Benefit/Cost					**2.19**
Reduction in Damages (%)					**30%**

Notes: 1) Reduction in the number of properties is compared to the base case.
2) This option will not change peak flood levels.

6.4.9 O9) Voluntary House Purchase

Description

Voluntary Purchase (VP) refers to the acquisition and demolition of severely flood affected residential properties which pose a significant risk to life during flood events. Typically, these properties are frequently inundated by high hazard flows. These properties are generally removed from the floodplain and rezoned to a high hazard flood compatible use, such as open public space. The removal of these properties may also restore the hydraulic capacity of the floodplain if the properties are located in a “floodway”.

Overview

An advantage of VP is that it eliminates flood damages and also risk to life. An analysis of at-risk properties potentially eligible for VP in the study found 3 properties (out of the 7 considered for VHR) that may be suitable for VP. The 3 properties are all located in the Dungog tailwater area and though they can experience high hazard from depth, the low velocities experienced in this location means that they are not considered to be in a floodway (refer Map Compendium Figure “Hyd Cat 1%” of Royal HaskoningDHV (2017)). While the properties are considered (for the 1% AEP (100yr ARI)) to be in a high hazard area using the NSW FDM definitions, they are only considered to be H4 using the newer AEM guidelines. To be eligible for VP, properties normally must be in an H5 or H6 area, though may be considered in an H4 area. In larger events such as the 200yr ARI, an H5 hazard would occur, so VP should still be considered for these 3 properties.

Included in the analysis of VP is the 4 remaining properties considered for VHR and the 6 Council owned Alison Court properties that have been considered for demolition, (as it was deemed that independent senior living units should not be allowed in the newly designated FPA). VHR was represented in the damage analysis by raising the floor level of the property to the 1% AEP (100yr ARI) + 0.5m level. For the 3 VP properties and 6 Alison Court properties, both the floor level and the ground level were raised to 55mAHD to prevent any damages being calculated for the 9 properties.

Results

This option will have a negligible effect on flood levels. However, by targeting the properties that are frequently flooded (and hence result in a high contribution to AAD) a significant reduction in flood damages is achieved as presented in **Table 6-7.** There is a 36% reduction in AAD, which, over a 50 year period, is expected to reduce flood related damages by $1.22 Million. However, the cost of this mitigation option is $1.22 Million (assuming: 3 x $300,000 for VP, 4 x $50,000 for VHR and 6 x $20,000 for demolition). The calculated benefit/cost (B/C) ratio for this option is 1.00. **Given that the B/C ratio is unity, this option could be recommended for implementation or further investigation on economic grounds.** It should be noted that consideration for VP is not solely based on economic grounds and that VP schemes may be approved based on consideration of risk to life. Because VHR may increase the likelihood of residents sheltering in place during large events, there is the potential for increased risk to life during a severe event if residents can no longer be safely evacuated. **In order to reduce risk to life this option should be considered in preference to O8.**

Table 6-7: Change in Property Affectation and Damages for Mitigation Measure – O9

Voluntary Purchase, Voluntary House Raising and Demolish 6 Alison Court Units

Event	Peak Flood Level (m AHD)	Reduction in Peak Flood Levels (m) [2]	No. Properties No Longer Flooded Over Floor[1]	No. Properties No Longer Yard or Under Floor Flooded[1]	Reduction in Damages for Event
PMF	53.22	n/a	9	9	$ 526,936
0.2% / 500yr	51.11	n/a	10	9	$ 1,462,547
0.5% / 200yr	50.64	n/a	13	10	$ 1,380,550
1% / 100yr	50.2	n/a	12	8	$ 1,129,038
2% / 50yr	49.82	n/a	11	9	$ 920,255
5% / 20yr	49.41	n/a	6	5	$ 438,416
20% / 5yr	48.78	n/a	1	1	$ 27,454
April 2015	51.98	n/a	10	10	$ 1,604,643
Reduction in Annual Average Damages (AAD)					**$ 82,203**
Reduced Damages (Over 50 years)					**$ 1,216,665**
Cost of Mitigation Option					**$ 1,220,000**
Benefit/Cost					**1.00**
Reduction in Damages (%)					**36%**

Notes: 1) Reduction in the number of properties is compared to the base case.
2) This option will not change peak flood levels

6.4.10 O10) Flood Resistant Surfacing for Bennett Park Tennis Courts

Description

The synthetic grass surface of the Bennett Park Tennis Courts has been damaged by flood waters on at least two occasions. Yeo (2015a) found that the tennis courts were damaged by a storm that occurred on the 13th October, 1985. The courts were again damaged in the April 2015 superstorm. An ABC news article (http://www.abc.net.au/news/2016-04-20/dungog-tennis-court-april-2016/7336974) shows that the courts were repaired within a year with synthetic grass. Given that the courts have been damaged twice by floods and once by cockatoos (as reported in the Dungog Chronicle in 18 September 2012 (http://www.dungogchronicle.com.au/story/342033/courts-back-to-new-again/)), it is suggested that the costs of replacing the synthetic grass surface with a more durable and flood resilient hard court surface (such as synpave or a bonded short-pile synthetic grass) be investigated.

Overview

The synthetic grass surface of the Bennett Park Tennis Courts is damaged during flood events when the sand covering the courts is washed away by flood waters. Once the sand is washed away the synthetic grass surface is easily washed away, as the weight of the sand is the mechanism that holds the court down. It is understood that the costs of replacing the synthetic grass courts are in the order of $20,000 per court (i.e. $120,000 for the six courts).

Discussions with tennis court installers show two potentially more flood resistant alternatives are available. Synthetic short pile (low sand) courts can be adhered (using a glue like substance) to the substrate. Costs are typically $22,000/court, though this assumes a suitable substrate is already in place. Assuming only minor repairs to the substrate are required, an allowance of $150,000 to $180,000 for this option is reasonable. A cheaper option would be to convert the courts to a hard court surface such as synpave. Costs are typically $10,000/court, though this assumes a suitable substrate is already in place. Assuming only minor repairs to the substrate are required, an allowance of $80,000 to $100,000 for this option is reasonable.

Results

To prevent ongoing costs from the repair of flood damaged synthetic grass tennis courts, more flood resistant surfaces should be investigated. Cost for replacing the courts with a hardcourt synpave surface are likely to cost $80,000 to $100,000 assuming only minor repairs to the substrate are required. However, if the tennis court owners are unwilling to change to a hardcourt surface, a short pile synthetic grass surface that is glued to the substrate is likely to cost $150,000 to $180,000, assuming only minor repairs to the substrate are required.

These changes should only be considered if/when the existing court surface is damaged. The replacement of damaged assets with more flood resilient options, as opposed to a like for like replacement, is preferred by the Insurance Australia Group (IAG) who represents major insurance agencies in Australia.

6.4.11 Summary of Peak Flood Levels and Damages for Mitigation Measures

A summary of peak flood levels for the 5 mitigation options that will reduce flood levels in the Myall Creek Backwater (i.e. Hooke Street) are shown in **Table 6-8.**

Table 6-8: Design Peak Water Levels (m AHD) in Dungog Tailwater (Hooke Street) for a Range of Mitigation Measures

Design Conditions AEP / ARI	BC Existing / Base Case	O1 Major Bridge Upgrade	O2 Minor Bridge Upgrade	O3 Levee with Pumping	O4 Levee with Diversion Culvert	O5 Channel Vegetation Clearance
20% / 5yr	48.78	48.51	48.57	47.13	48.46	48.56
5% / 20yr	49.41	49.03	49.07	48.31	49.05	49.10
2% / 50yr	49.82	49.31	49.34	48.79	49.23	49.45
1% / 100yr	**50.2**	**49.84**	**49.89**	**49.16**	**49.84**	**49.99**
0.5% / 200yr	50.64	50.25	50.30	49.59	50.05	50.43
0.2% / 500yr	51.11	50.70	50.72	50.12	50.40	50.90
PMF*	53.22	53.18	53.18	53.22	53.22	53.21
April 2015	51.98	50.61	50.82	51.48	51.20	51.61

Notes: Williams River PMF for scenario events is limited to 10,000 m^3/s. The PMF estimate for the Flood Study was 11,361m^3/s which produces an equivalent flood level of 53.65m AHD. The adopted lower flow for the PMF allows the model to be run at a more reasonable time step and is suitable for the comparison of mitigation options. This slightly lower PMF rate was used for all damage calculations in the Section and is why the AAD is slightly (<1%) lower than that presented in Section 4.

A summary of flood damages and benefit / cost (B/C) ratios for the base case (do nothing) and 7 mitigation options is presented in **Table 6-9.** Because mitigation options O6 and O7 (local catchment detention basins) do not influence peak flood levels in the Dungog tailwater area and only produce a localised minor reduction in flood level, no cost / benefit analysis was undertaken for these options.

Table 6-9: Summary of Damages and B/C Ratios for a Range of Mitigation Measures

Option	AAD	NPV of Damage	Cost Of Option	Option Benefit Relative to Base Case	Benefit/Cost Relative to Base Case	Reduction in Damages (%)
Base Case for Comparison	$228,998	$3,389,341	n/a	n/a	n/a	n/a
O1 - Major Bridge Upgrade	$105,690	$1,564,287	$6,800,000	$1,825,054	0.27	54%
O2 - Minor Bridge Upgrade	$126,375	$1,870,445	$4,400,000	$1,518,896	0.35	45%
O3 - Levee with Pumping (5m^3/s)	$66,409	$982,908	$8,000,000	$2,406,433	0.30	71%
O4 - Levee with Diversion Culvert	$101,724	$1,505,594	$7,000,000	$1,883,747	0.27	56%
O5 - Channel Vegetation Clearance	$138,750	$2,053,602	$3,500,000	$1,335,738	0.32	39%
08 - VHR 7 properties, DEMO 6 Properties	$159,449	$2,359,971	$470,000	$1,029,369	**2.19**	30%
09 - VP 3 properties, VHR 4 properties, DEMO 6 Properties	$146,795	$2,172,676	$1,220,000	$1,216,665	**1.00**	36%

Key points regarding the options assessment include:

- O3 (Levee with pumping) produces the highest flood damages saving of $2.4 Million (a 71% reduction in damages compared to the Base Case). However, due to the high cost of implementing this option ($9.0 Million) the resulting benefit/cost (B/C) ratio is only 0.3.
- An analysis of mitigation options O1-O5 shows that they result in a significant reduction in flood damages (between $1.33 and $2.4 Million). However, due to the high cost of implementing such measures, all B/C ratios are significantly below 1 and hence would not be considered for implementation on an a solely economic basis.
- For the O2 (Minor Bridge Upgrade) mitigation option, using the AAD approach, the calculated benefit/cost (B/C) ratio for this option is only 0.35 (due to the high cost of the scheme ($4.4 Million)). However, this mitigation measure is able to provide a 1.16 m reduction in peak flood levels for an extreme event such as the April 2015 superstorm. This reduction in peak flood level produces a $4.15 Million reduction in flood damages and hence, the B/C for this extreme event is close to one. If future studies reveal that climate change has significantly altered the severity and intensity of storms in the Dungog region, such a scheme may be considered to reduce the impact of severe events.
- Mitigation option O8 (VHR for 7 properties, demolition of 6 properties) produces the highest B/C ratio (2.2) but the lowest overall reduction in damages of just over $1.0

Million (a 30% reduction in flood damages). Given that the B/C ratio is considerably higher than one, this option would be recommended for implementation or further investigation.

- Mitigation option O9 (VP of 3 properties, VHR for 4 properties, demolition of 6 properties) produces a B/C ratio of 1.0 and hence this option could be recommended for implementation or further investigation on economic grounds. It should be noted that consideration for VP is not solely based on economic grounds and that VP schemes may be approved based on consideration of risk to life. Because VHR may increase the likelihood of residents sheltering in place during large events, there is the potential for increased risk to life during a severe event if residents can no longer be safely evacuated. **In order to reduce risk to life this option should be considered in preference to O8.**
- Because none of the “flood modification measures” (O1-O7) are recommended for implementation, Dungog will still experience flood related risk to life and property issues during severe flood events. In order to mitigate against this risk to life, a flood warning system (as presented in **Section 7**) is recommended.
- Mitigation O10 (Flood Resistant Surfacing for Bennett Park Tennis Courts) should only be considered if/when the existing court surface is next damaged.

6.4.12 Summary of Potential Mitigation Measures

A summary of all the mitigation measures considered in the FRMS is presented in **Table 6-10.**

Table 6-10: Risk Management Option – Assessment Summary and Analysis

Measure	Description	Priority	Benefit	Comments & Concerns	Responsibility for Implementation, Costs and Funding
FLOOD MODIFICATION MEASURES					
O1 - Major Bridge Upgrade (Section 6.4.1)	Option 1 investigated a major increase (i.e. approximate tripling) in floodplain width at Bennett Bridge and the Myall Creek Rail Bridge.	**Very Low** Effective but too costly	B/C = 0.27 Option 1 reduces flood damages by 54% and would have reduced peak flood levels in the April 2015 event by 1.4m.	Option 1 is estimated to cost $6.8 Million and would require significant ground works and excavation which would have a negative environmental effect.	Council and/or NSW RMS would be responsible for costs and implementation of Option 1. Limited funding may be available through the NSW Floodplain Management Program or other Federal Grants Programs.
O2 - Minor Bridge Upgrade (Section 6.4.2)	Option 2 investigated a minor increase (i.e. approximate doubling) in floodplain width at Bennett Bridge and the Myall Creek Rail Bridge.	**Low** Effective but costly	B/C = 0.35 Option 2 reduces flood damages by 45% and would have reduced peak flood levels in the April 2015 event by 1.2m.	Option 2 is estimated to cost $4.4 Million and would require significant ground works and excavation which would have a negative environmental benefit. If future studies reveal that climate change has significantly altered the severity and intensity of storms in the Dungog region, such a scheme may be considered to reduce the impact of severe events	Council and/or NSW RMS would be responsible for costs and implementation of Option 2. Limited funding may be available through the NSW Floodplain Management Program or other Federal Grants Programs.
O3 - Myall Creek Levee with Pumps (Section 6.4.3)	Option 3 investigated a levee protecting Dungog from Myall Creek. Pumps with a $5m^3/s$ capacity would be required to reduce the impact of local catchment flooding behind the levee.	**Very Low** Effective but too costly	B/C = 0.3 Option 3 reduces flood damages by 71% and would have reduced peak flood levels in the April 2015 event by 0.5m.	Option 3 is estimated to cost $8.0 Million and would require significant ongoing maintenance and testing to ensure effectiveness during flood events. Significant ground works and excavation which would have a negative environmental effect	Council would be responsible for costs and implementation of Option 3. Limited funding may be available through the NSW Floodplain Management Program or other Federal Grants Programs.
O4 - Myall Creek Levee with Diversion Culvert (Section 6.4.4)	Option 4 investigated a levee protecting Dungog from Myall Creek. In order to prevent catchment flooding from behind the levee, a diversion culvert conveying water downstream of Bennett Bridge would be required.	**Very Low** Effective but too costly	B/C = 0.3 Option 4 reduces flood damages by 56% and would have reduced peak flood levels in the April 2015 event by 0.8m.	Option 4 is estimated to cost $7.0 Million. Significant ground works and excavation which would have a negative environmental effect	Council would be responsible for costs and implementation of Option 4. Limited funding may be available through the NSW Floodplain Management Program or other Federal Grants Programs.
O5 - Myall Creek Channel Vegetation	Option 5 investigated clearing the vegetation from the Myall Creek Channel. In order to	**Very Low** Only moderately	B/C = 0.3 Option 5 reduces flood damages by	Option 5 is estimated to cost $3.5 Million. Significant vegetation removal and ground works which would have a negative environmental effect	Council would be responsible for costs and implementation of Option 5. Limited funding may be available through the NSW

Measure	Description	Priority	Benefit	Comments & Concerns	Responsibility for Implementation, Costs and Funding
Clearance (Section 6.4.5)	prevent adverse channel erosion and morphologic change, bank stabilisation would be required.	effective and costly	39% and would have reduced peak flood levels in the April 2015 event by 0.4m.		Floodplain Management Program.
O6 - Dungog Showground Detention Basin Augmentation (Section 6.4.6)	Option 6 investigated additional flood detention storage within the Dungog Showgrounds by increasing the height of the existing bund wall	**Low** No influence on Dungog tailwater flood levels	Option 6 was able to reduce peak flood levels along the drainage path d/s of the showgrounds by ~10cm. However, this option would not influence over floor flood damages.	This option could reduce flood levels and the magnitude of "nuisance flooding" to a number of properties along Abelard Street. Council may wish to further investigate this option as part of a local drainage improvement study.	Council staff time or budget would be required to further investigate this option.
O7 - Dungog North-West Detention Basin (Section 6.4.7)	Option 7 investigated constructing a detention basin in the upstream catchment area north of Mackay Street and west of Abbott Lane.	**Low** No influence on Dungog tailwater flood levels	Option 7 was able to reduce peak flood levels along the drainage path d/s of the basin by 5-10cm. However, this option would not influence over floor flood damages.	This option could reduce flood levels and the magnitude of "nuisance flooding" to a number of properties. Council may wish to further investigate this option as part of a local drainage improvement study.	Council staff time or budget would be required to further investigate this option.
PROPERTY MODIFICATION MEASURES					
O8 – Voluntary House Raising (Section 6.4.8)	Option 8 investigated VHR for 7 properties and the demolition of 6 Alison Court properties.	**Medium-High**	B/C = 2.2 Potential to significantly reduce damage costs to properties that are most frequently flooded.	The VHR of 7 properties and demolition of 6 properties is estimated to cost $470,000 and is the most cost effective flood risk management option available in Dungog. However, as three properties are in a high risk area, VP should be considered for these properties unless the residents are unwilling to move. Council has already agreed to demolish the 6 Alison Court properties as they acknowledge that the land use is not compatible with the flood risk.	Recommendation for a Voluntary House Raising Feasibility Assessment to be conducted. 2:1 Funding may be available through the NSW Floodplain Management Program, with the resident liable for paying 1/3 the cost of raising.
O9 – Voluntary House Purchase (Section 6.4.9)	Option 9 investigated VP for 3 properties, VHR for 4 properties and the demolition of 6 Alison Court properties.	**High**	B/C = 1.0 VP would remove residents from an area which is subject to hazardous flood conditions in rare events. VHR would significantly reduce damage costs to properties that are most frequently flooded.	The Voluntary Purchase Scheme is a costly measure (estimated at $1.2 Million), however, due to the high flood risk and willingness of property owners for VP, this option is highly recommended. Council has already agreed to demolish the 6 Alison Court properties as they acknowledge that the land use is not compatible with the flood risk. This option would significantly reduce flood damages in Dungog.	Recommendation for a Voluntary Purchase Feasibility Assessment to be conducted. 2:1 funding may be available through the NSW Floodplain Management Program, with Council liable for paying 1/3 the cost of the purchased property.
O10 – Bennett Park Tennis Court Surface	Option 10 investigated future replacement of the synthetic grass tennis court surface with a	**Medium**	Future re-surfacing costs could be avoided by changing the surface to a more flood resilient material. This	Provided the existing substrate is suitable upgrading the 6 courts to a synpave hard court surface is likely to cost $100,000. This is cheaper than the typical replacement cost of $120,000	Courts are owned by Dungog Tennis Association though it is understood that Council has previously loaned them the

Measure	Description	Priority	Benefit	Comments & Concerns	Responsibility for Implementation, Costs and Funding
Protection (Section 6.4.10)	more flood resilient surface.		would only need to be done next time the courts are damaged.	for the existing synthetic grass surface. If a change of surface is not acceptable, than a flood resilient, bonded short-pile grass surface would cost ~$180,000.	money for court repairs. The insurance status of the Courts should be investigated.
			RESPONSE MODIFICATION MEASURES		
O11 - Flood Warning System (see Section 7)	Option 11 investigated the development of a flood warning system for Myall Creek.	**Very High**	A flood warning system is strongly recommended to reduce risk to life from rapidly rising floodwaters that are capable of inundating a number of low lying properties to above ceiling level in severe events.	A suitable flood warning system for Dungog is estimated to cost $50,000 to $100,000. Ongoing annual monitoring costs of ~$5,000 are likely to be required. A significant benefit of flood warning system is in intangibles including reduced fear in the community and also reduced likelihood of flood related loss of life. The method of warning delivery would have to be tailored to the range of residents living on the floodplain.	Council submitted an application in April 2017 for OEH Floodplain Grants for a flood warning system for Dungog. 2:1 funding is likely to be available through the NSW Floodplain Management Program, with Council liable for paying 1/3 the cost of the system.
EM1 - Emergency Management Planning	Effective emergency management planning involves the collaboration of emergency services including the SES and other rescue services to develop a Local Flood Plan.	**High**	An update to the Local Flood Plan will ensure that informed decisions can be made during a flood event and allow for flood preparedness to increase efficiency and reduce risk to residents and emergency services.	Requires effective communication with the community and stakeholders.	The NSW SES are responsible for developing and maintaining a Local Flood Plan for the study area.
EM2 - Community Flood Education	A community flood education program would maintain flood awareness.	**Medium**	Increasing flood preparedness and maintain awareness in the community would ensure that communities are informed and ultimately reduce the damages during a flood event.	Community members are likely to ignore flood information if too much is given. Communication needs to be direct and concise.	Council in partnership with the SES are responsible for community education. To reduce costs, this information can be incorporated with other information such as in the local paper or with Council Rates.
			PLANNING and FPL CONSIDERATIONS		
P1 - Adopt non-standard FPL for Dungog tailwater	Recent flood history shows that adoption of the standard FPL is not appropriate in the Dungog tailwater area.	**Very High**	An FPL based on the 500yr ARI with 0.5m freeboard, could prevent tragedy should another large flood occur in Dungog.	Adoption of a high FPL would only benefit new developments and does not reduce the risk to existing properties. Adopting the higher FPL could also inhibit the adoption of VHR.	Council staff time would be required to negotiate the higher than standard FPL with DoP.
P2 - Update LEP for purchased properties near Bennett Bridge	Update the LEP where Council purchased the five properties (destroyed during the April 2015 superstorm) adjacent to Bennett Bridge,	**High**	Council will need to update the LEP to ensure that future develop considers the high flood risk at this locations.	If an appropriate land use zoning is not adopted in this area, risk to life and increases in flood damages could result.	Council staff time would be required to implement and update to the LEP.

7 Detailed Assessment of a Flood Warning System for Dungog

7.1 Response Modification Measures

Flood response measures encompass various means of modifying the response of the population to the flood threat. These measures aim to reduce risk to life and property during a flood event by improving factors such as flood warning and prediction, emergency management planning and community flood education.

7.1.1 Flood Warning Systems

Overview

A flood warning system provides advice on imminent flood events allowing residents to take action to minimise the flood impacts. Typically, flood warning systems integrate factors such as rainfall, river flows and weather forecasts to predict the severity and timing of flooding, then distribute warning messages to agencies such as the SES and to community members where necessary.

Flood warning systems are most effective on large river systems where there is significant warning time providing residents and emergency services with ample time to prepare. There is currently a formal flood warning service for the Williams River provided by the Bureau of Meteorology (BoM) as discussed below.

On smaller systems such as the Myall Creek, flood warning systems are typically harder to implement and unless they are based on forecast data, result in less warning time than large systems. However, given the relatively small number of properties and short evacuation distances, a warning system for the Myall Creek could still be effective in reducing risk to life. Information regarding development of a suitable warning system for Myall Creek flooding is provided below.

Smaller overland flow catchments, such as the local township catchment study area, are typically subject to flash flooding from short intense bursts of rainfall and tend to be difficult to provide effective warning time because of their rapid onset. The implementation of a specific flood warning system for the local township catchment is considered unnecessary given the low risk to life from this flood mechanism. Details of the existing BoM thunderstorm warnings are provided below.

Description of Available BoM Flood Warnings

The Bureau's Flood Warning Service provides:

- Early advice of possible flooding if flood producing rain is expected in the near future.
- A generalised flood warning that flooding is occurring or is expected to occur in a particular region. No information on the severity of flooding or the particular location of the flooding is provided in this instance. These warnings are issued for areas where no specialised warnings systems have been installed. As part of its Severe Weather Warning Service, the Bureau also provides warnings for severe storms that may cause flash flooding. In some areas the Bureau has implemented local monitoring systems (in collaboration with local councils) to assist with flash flood warning.
- Warnings of minor, moderate or major flooding in areas where specialised warning systems have been installed. In these areas, the flood warning message will identify the river valley,

the locations expected to be flooded, the likely severity of the flooding and when it is likely to occur.

- Predictions of expected river height at a town or other important locations and the time that this height will be reached. This particular service is the most useful because it allows local emergency authorities and people in the flood threatened zone to determine the area and likely depth of flooding. This type of warning can only be provided for locations with specialised flood warning systems and for which flood forecasting models are available.

The specialised flood warning system on the Williams River is described below. While a flash flood warning for the local township catchment is considered unnecessary, a warning system for Myall Creek is strongly recommended to reduce risk to life from rapidly rising floodwaters that are capable of inundating a number of low lying properties to above ceiling level in severe events (such as the April 2015 superstorm).

Existing BoM Williams River Flood Warnings

The Bureau of Meteorology (BoM) currently provides a formal flood warning service for the Williams River and provides an estimate of peak flood levels. An example of a BoM flood warning for the Williams River is presented in **Figure 7-1**.

Flood classifications in the form of locally defined flood levels are used in flood warnings to give an indication of the severity of flooding (minor, moderate or major) expected. These levels are used by the NSW State Emergency Service (SES) and the Bureau of Meteorology (BoM) in flood bulletins and flood warnings.

The BoM/SES classifies major, moderate and minor flooding according to the gauge height values at Williams River (Dungog) (Station Number: 061267) as detailed below. The flood classification levels are described by:

Minor flooding (4.9 m, ~46.2mAHD): flooding which causes inconvenience such as closing of minor roads and the submergence of low-level bridges. The lower limit of this class of flooding, on the reference gauge, is the initial flood level at which landholders and/or townspeople begin to be affected in a significant manner that necessitates the issuing of a public flood warning by the BoM.

Moderate flooding (7.6 m, ~48.9mAHD): flooding which inundates low-lying areas, requiring removal of stock and/or evacuation of some houses. Main traffic routes may be flooded.

Major flooding (8.5 m, ~49.8mAHD): flooding which causes inundation of extensive rural areas, with properties, villages and towns isolated and/or appreciable urban areas flooded.

A comparison of the Major flood level classification to the flood model results (Royal HaskoningDHV, 2017) indicates that a Major flood level would have a design magnitude (frequency) of between a 5yr ARI (20% AEP) and 10yr ARI (10% AEP) event. An examination of the floor level database indicates that no properties (on the Williams River floodplain) are flooded from a Williams River event below a 20yr ARI (5% AEP) event in the Dungog . This indicates that the existing BoM flood warnings for the Williams River provide a suitable warning system for this flood mechanism within the Dungog township.

Australian Government Bureau of Meteorology, New South Wales

Final Flood Warning for the Williams River

At Dungog

Issued at 1:55 pm EDT on Saturday 18 March 2017
Flood Warning Number: 3

Rainfall has eased since 11:00 am Saturday morning over the Williams river valley, however further rainfall is forecast for the next 24 hours.
The Williams River at Dungog is expected to peak below the minor flood level.
The situation is being closely monitored and warnings and predictions will be issued if necessary.

Williams River:
The Williams River at Dungog is approaching a peak below the minor flood level

Flood Safety Advice:
FloodSafe advice is available at www.ses.nsw.gov.au

For emergency assistance call the SES on telephone number 132 500.
For life threatening emergencies, call 000 immediately.

Next issue:
This is a final warning, no further warnings will be issued for this event.

Latest River Heights:
Williams River at Dungog, 3.77, Steady, 12:45 PM SAT 18/03/17
Williams River at Mill Dam Falls, 1.48, Rising, 01:00 PM SAT 18/03/17
Allyn River at Halton, 2.01, Rising, 01:00 PM SAT 18/03/17
Paterson River at Gostwyck Bridge, 1.65, Rising, 01:00 PM SAT 18/03/17

This advice is also available by dialling 1300 659 218. Warning, rainfall and river information are available at www.bom.gov.au/nsw/flood. The latest weather forecast is available at www.bom.gov.au/nsw/forecasts.

Figure 7-1: Example BoM Flood Warning for the Williams River

From http://weather.news.com.au/warning/?id=IDN36639

Recommended Development of Myall Creek Flood Warning System

Development of a flood warning system for Myall Creek is strongly recommended to reduce risk to life from rapidly rising floodwaters that are capable of inundating a number of low lying properties to above ceiling level in severe events (such as the April 2015 superstorm). A graph comparing the number of floor levels at a given elevation, compared to a range of historic and design flood levels is presented in **Figure 7-2**. The figure shows that while there are less than 20 properties (in the Dungog tailwater area) that would experience over floor flooding in the 100yr ARI (1% AEP) design flood (50.2 m AHD), in the April 2015 flood, these properties would have been flooded to above or near ceiling level and a total of 50 properties would experience above floor flooding.

The topography of Dungog means that evacuation paths (to safe higher ground) are less than 250m long. In general, evacuation routes to high ground are straight forward (i.e. walk uphill to high ground); however, there are two locations where evacuation should proceed with caution:

- Properties between 44 and 62 Hooke Street may need to evacuate up the driveway of 60 Hooke Street (towards the grounds of the St Joseph Catholic School), as the crest of the roadway along Abelard Street is 49.2 m AHD, while the Lord Street intersection is significantly lower.
- While floor levels for the units at 30 Brown Street are above 50.0 m AHD, the driveway at the front of the properties is only 49.0 m AHD, which means these units should be evacuated early. Local catchment flooding may cause minor (up to ~0.3m) inundation of this area prior to the development of tailwater flooding from the Myall Creek. Because these units are typically occupied by retirees (i.e. residents are mostly aged over 55), evacuation assistance may be required for occupants.

Options for Rainfall based Flood Warning System

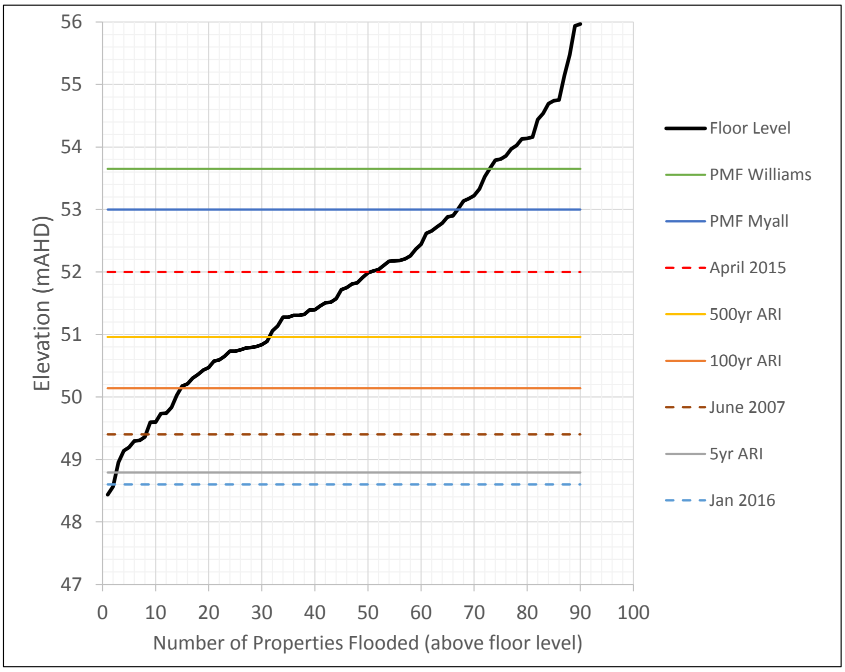

Figure 7-2: Flood Stage vs Property Floor Levels (Dungog Tailwater)

The absence of an accurate, telemetered water level gauge in the Myall Creek tailwater means that unless a suitable water level gauge is installed, flood warnings would need to be based on observed or predicted rainfall.

BoM operates two rainfall gauges in the Myall Creek catchment at: Dungog Post Office (61017) and Upper Myall Creek (61415). Warnings based on a specified rainfall depth in a given time could be defined to generate a number of warning levels. An example of this rainfall depth, warning type is presented in **Table 7-1.** It should be noted that the below table would need to be checked and refined prior to adoption. Due to the potential for high spatial variation in the catchment and the availability of only two rainfall gauges, the installation of additional gauges or the use of synthetic gauges based on interrogation of rainfall radar data would be recommended. However, as described below, the development of a water level based warning system is recommended over a rainfall based system, so additional rainfall gauges are low priority, though would enhance the forecast accuracy and may increase available warning times of a flood level based system.

Table 7-1: Example of Rainfall Depth (mm) vs Warning Type for Myall Creek Catchment

Rain Duration	Warning to Council and NSW SES	Warning for Evacuation	Immediate Evacuation
Short duration intense rain events (assumes wet catchment (i.e. >50mm in previous 24 hours))			
1 hour	40	50	60-70
2 hour	60	80	90-100
Longer duration events (warnings should consider likelihood of future rainfall (i.e. radar or meteye))			
9 hour	100	120	140-160
24 hour	150	200	250-300

Recommendations for Water Level based Flood Warning System

Due to the spatial variability in rainfall and influence of initial and continuing losses on flood levels, a water level based flood warning system is likely to be more reliable than one based on rainfall alone. A list of relevant feature elevations and suggested flood warning levels is presented in **Table 7-2**. It should be noted that these suggested levels are preliminary in nature and should be refined by a more detailed study prior to adoption. A water level gauge located near the Hooke Street drain would be required to raise the earlier (lower) warning levels.

Table 7-2: Feature Elevations and Flood Level Warning Types

Feature	Level (mAHD)
Hooke St Channel Invert	45.2
Hooke St Top of bank	46.0
Hooke Street road crest	46.5
Warning to Council & SES	**46.5**
Alert to residents	**46.5**
Alert to residents – Evacuate now	**48.0**
2 Commercial Properties on Hooke St Flooded	48.5
Alert to Council and NSW SES – properties are being inundated	**48.5**
First above floor property flooding (Hooke St)	49.0
Evacuation of 7 units at 31 Brown St becomes difficult	49.0
2 lowest Alison Court floor levels	49.6
Alert to Council and NSW SES – flood level has dropped below Hooke St	**46.5**

Water level (i.e. rates of rise) for the April 2015 and the design 1% AEP (100yr ARI) flood events are presented in **Figure 7-3** and **Figure 7-4.** In the April 2015 event, flood levels increased by 3.0m in 2.5 hours, with a peak rate of rise of nearly 1m in 30 minutes being observed. In the 1% AEP (critical 9 hour duration) event, flood levels are predicted to increase by 3.0m in 3.5 hours, with a peak rate of rise of 1m in 45 minutes at the start of the event.

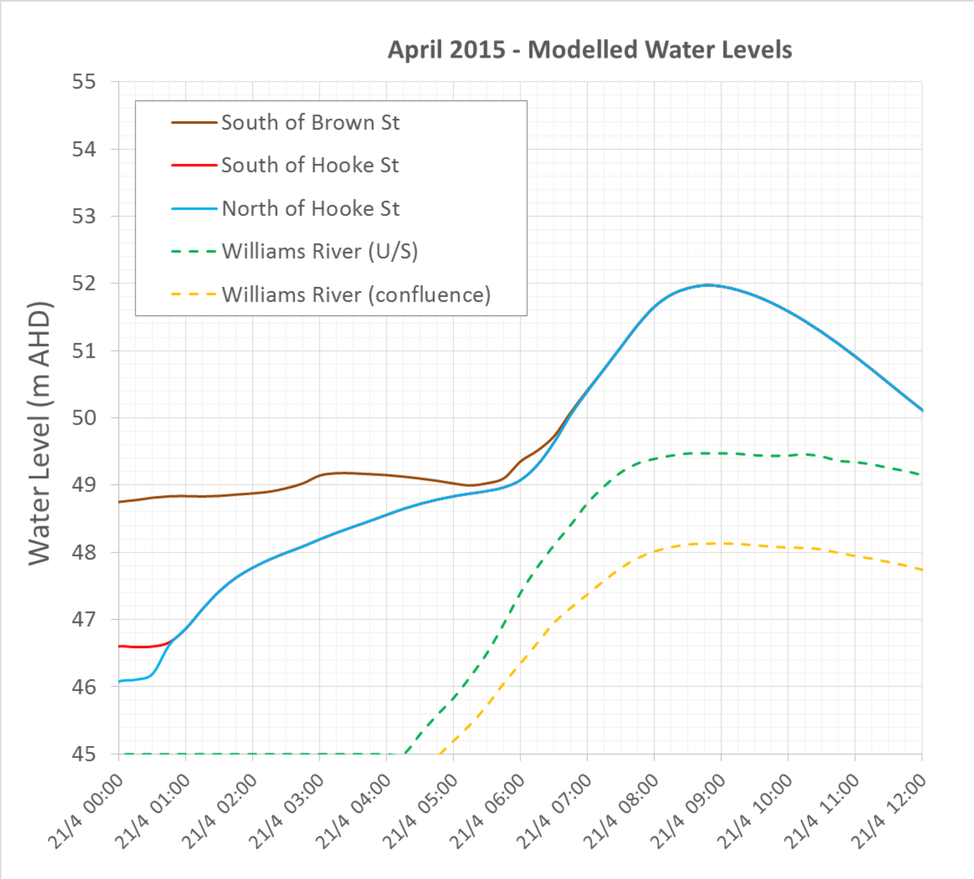

Figure 7-3: Modelled Water Levels – April 2015 Flood Events

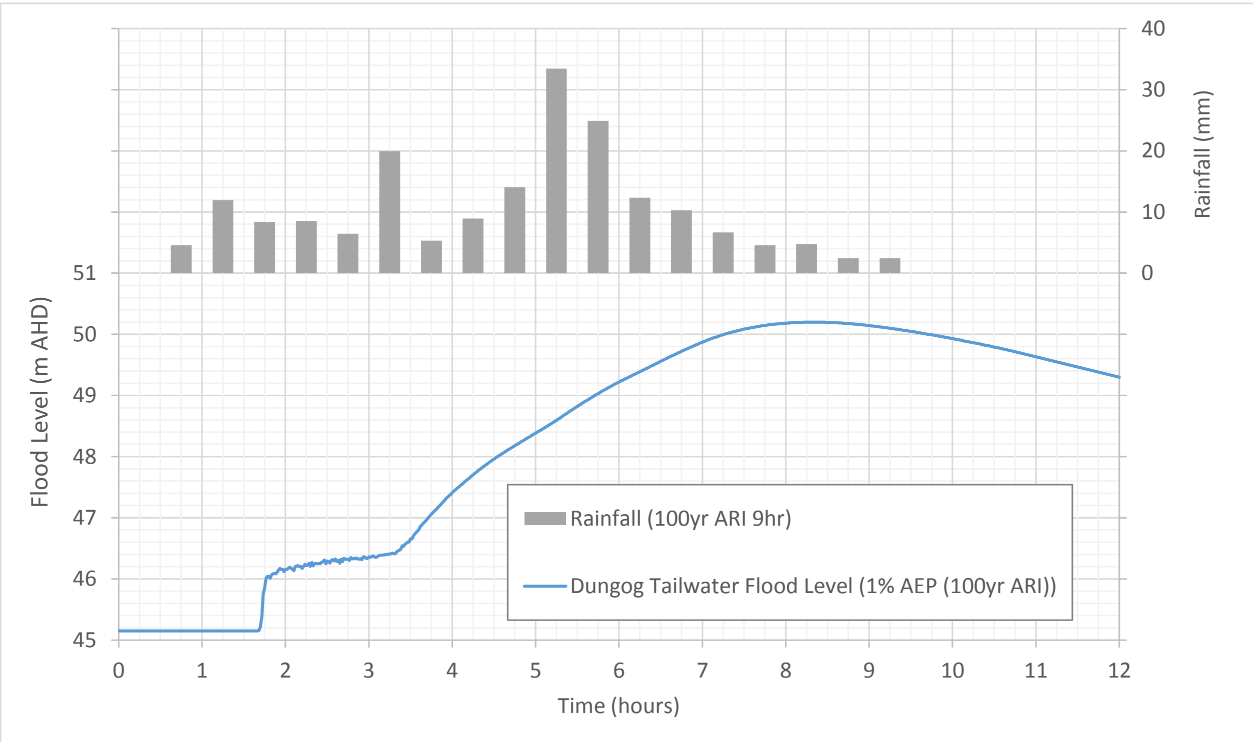

Figure 7-4: Design Rainfall and Modelled Water Levels – 1% AEP (100yr ARI)

Existing DipStick Gauge

It should be noted that a trial water level gauge was installed in early 2017 immediately upstream of the Hooke Street culvert. The "dipstick gauge" provides information on water depth (the level of the gauge does not appear to have been surveyed) and uses a camera system to verify the data. Images and water levels are uploaded to a website. It is understood that the "dipstick gauge" was provided as Dungog is one of 6 Councils to be included in a trial organised by NRMA insurance in partnership with the SES (https://www.nrma.com.au/dipstik-flood-trial).

The use of this gauge in a more formal flood warning system should be further investigated. However, it is important to note that the manufacturers state that the gauge is designed more for the provision of flood information, and that the accuracy of the water level sensor was not designed for data collection purposes (pers.comm. Peter Stone (CEO Tuftec Solutions), 21/3/2017). Unless the accuracy of the gauge can be confirmed as appropriate, it is likely that an alternate water level monitoring system (as discussed below) will be required. However, while the "dipstick gauge" may not be appropriate as a primary gauge, if the feed can be integrated into the warning system, it would be appropriate to use as a backup or source of confirmation data. The second "dipstick gauge" located on the Williams River at Bendolba is unlikely to provide any useful information for a flood warning system for Dungog, though does provide useful information for the Fosterton Road causeway.

Options for Advanced Hybrid Data / Model based Flood Warning System

An advanced hybrid flood warning system that integrates rainfall and water level data, rainfall radar and forecast rain could further increase available warning times and increase the accuracy of peak water level predictions. Such a system would use observed and forecast rainfall data to run flood models to predict future water levels. This type of system not only provides increased warning time and accuracy it also reduces the likelihood of false warnings being delivered. However, these systems are significantly more expensive to develop and maintain.

Communication

Effective communication of flood warnings is required to reduce the negative impacts of floods. Warning systems should be accurate, timely, reliable and be delivered through appropriate mechanisms. The advantages of a broad range of delivery mechanisms are presented in **Figure 7-5.** It is likely that a mixture of text messages (SMS), automated telephone messages (required for older residents), sirens, flashing lights and door knocking would be required.

Prior community awareness of flood risk tends to make warning more effective. While the April 2015 extreme flood event means that there is currently a very high level of awareness of flood risk in Dungog, it will be important to implement ongoing education programs to ensure new residents are informed of flood risk and to ensure complacency doesn't develop over time.

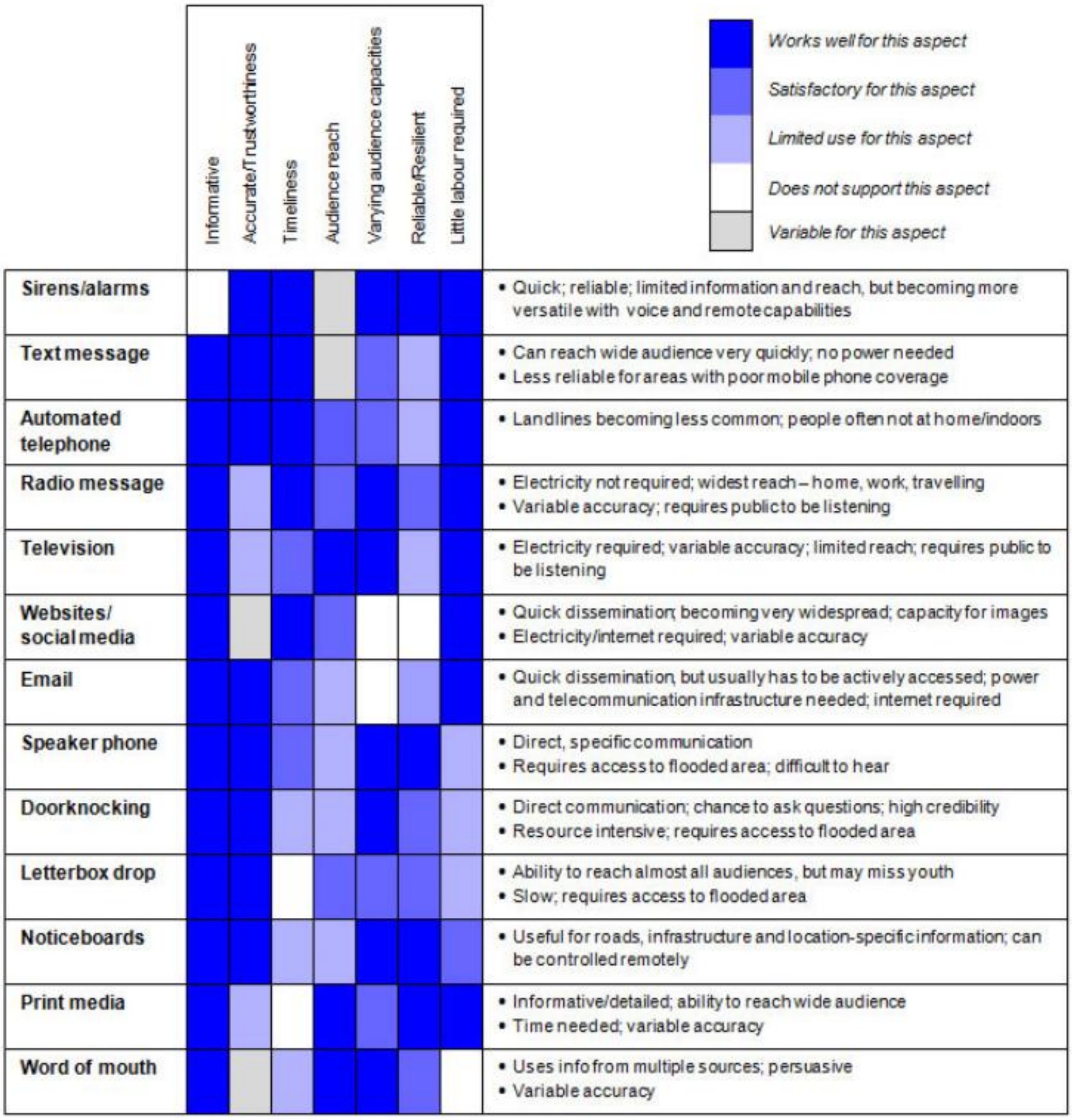

Figure 7-5: Pros and cons of different flood warning communication methods

From http://chiefscientist.qld.gov.au/publications/understanding-floods/flood-warnings (accessed 5th April 2017)

Outline of Costs for Flood Warning System Options

Approximate costs for various flood warning system configurations and options are outlined below.

A rainfall based option using the existing BoM rainfall gauges would be the cheapest option. The Australian Early Warning Network company (EWN) delivers a range of warning services to Councils and Commercial organisation throughout Australia. EWN provided the below pricing information for a rainfall based system in Dungog, that would send SMS or phone messages to registered users. EWN operate a 24hr/7day a week staffed operations room and manually check all alerts before generating warnings.

- setup costs (i.e. user registration and implementation of triggers): $2000-4000
- Monthly monitoring cost $50/gauge
- $50 / event + costs of SMS / calls

An allowance for consultancy costs to undertake a desktop or model based assessment of trigger warnings (i.e. refine **Table 7-1**) of $5,000 to $15,000 should also be included. Given that two rainfall gauges would be monitored, an allowance of $1200/yr for monitoring costs would be required. Assuming 4 warnings are generated each year, with warnings distributed to 100 residents or emergency workers (@50c / txt or call), an allowance for $1600/yr is required.

Installation of an automated water level gauge is likely to cost $7,000[1] to $30,000[2]. EWN is able to provide water level based monitoring in addition to rainfall based systems so pricing would be as per above. A siren and/or strobe warning is likely to add $5,000 to $10,000 to such a system. A high powered, fully featured and tested, mass alert flood warning system for a large area could cost approximately $70,000[3].

Given the harsh operating conditions that flood warning systems are subjected to, there is usually a typical 30% failure rate of gauges and it is important to include a degree of redundancy in flood warning systems. This means it is advisable to either have dual gauges in the tailwater area or to deploy a water level gauge further up the catchment. A water level gauge higher in the catchment would increase available warning times; however, due to the branched catchment shape, two additional gauges would be desirable. The cost for each additional water level gauges is $7,000[1] to $15,000[2]. The use of manually read flood gauges may be a valid alternative for Dungog and could be a suitable redundancy measure. It is recommended that two gauge boards are installed in Hooke Street and one installed in Lord St, Mackay St and Brown St as presented in **Figure 7-6**. These five gauge/information boards should provide historic and design flood level information and would be useful for ongoing flood education. An allowance of $7,500[5] for the five signs (including supply, survey and install) is appropriate.

An advanced hybrid flood warning system that integrates rainfall and water level data, rainfall radar and/or forecast rain to drive a fast solving flood model would cost $120,000 to $170,000[4] to setup and commission. Annual software and licence costs are likely to be $10,000 to $50,000[4].

A summary of costs for the three options is provided in **Table 7-3**.

It is recommended that after a number of years (say 5) of operation, the system is reviewed and refined. An allowance of $10,000 - $15,000 is likely to be sufficient for an external consultant to undertake a full review.

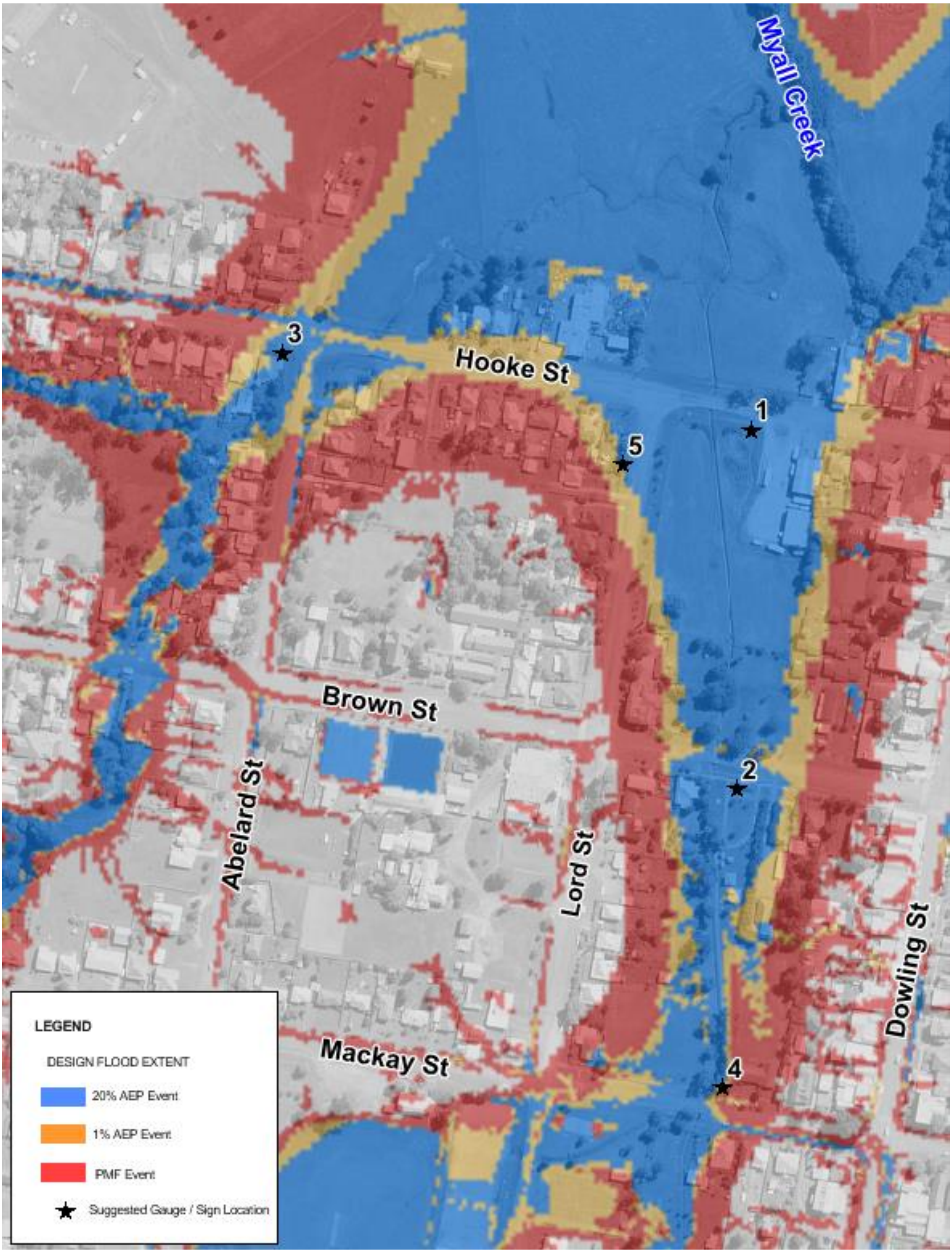

Figure 7-6: Suggested Location of Water Level Gauges and Gauge Boards / Flood Information Signs

Suggested location for water level gauge is location 1 (existing power pole on Hooke St, ground elevation is ~46.3mAHD)

Table 7-3: Summary of Approximate Costs for Flood Warning System Options

Item	Cost
Rainfall based system using existing BoM gauges	
Consultancy costs to refine trigger warnings and assist system development	$5,000-$15,000
System setup (user registration and implementation of triggers)	$2,000-$4,000[6]
Monthly monitoring cost ($50/gauge)	$1200/year[6]
Cost to check and disseminate warnings ($50/event + SMS and calls costs) Assume 100 warnings delivered at 50c per call or SMS and 4 warnings per year.	$200/year[6]
Water Level based system using existing BoM gauges	
Consultancy cost to refine trigger warnings and assist system development	$5,000-$15,000
Supply of water level gauge (most system include a camera feature)	$7,000[1]- $30,000[2]
Additional water level gauge (most system include a camera feature)	$7,000[1]- $15,000[2]
optional siren and/or flashing lights (estimated)	$5,000- $10,000
Integrated mass warning system (Whelen WPS2903)	$70,000[3]
optional supply and install of 5 gauge boards / signs (including survey)	$7,500[5]
EWN system setup (user registration and implementation of triggers) may be included in some WL warning systems, this option could allow the use of both water level and rain based triggers	$2,000-$4,000[6]
Monthly monitoring cost ($50/gauge) single water level gauge only	$600/year[6]
Monthly monitoring cost ($50/gauge) water level only and 2 rain gauges	$1800/year[6]
Cost to check and disseminate warnings ($50/event + SMS and calls costs) Assume 100 warnings delivered at 50c per call or SMS and 4 warnings per year.	$200/year[6]
Advanced hybrid flood warning system (including flood model based forecasts)	
Development and commissioning of system	$120,000 - $170,000[4]
Annual software and licence costs are likely to be $10,000 to $50,000	$10,000 - $50,000[4]

Notes: 1) cost for dipstik system (low accuracy system with basic image output, though SMS is also available)

2) cost for Digilant system (radar based WL gauge with high functioning interface including software and SMS alerts)

3) proposed cost for Wallsend Flood Warning System using a Whelen WPS2903 based system (Prospect Environmental)

4) based on proposed cost for Parramatta CBD Flood Warning System using Lizard Portal interface and a cloud based 3Di flood model.

5) based on proposed cost for Wallsend Flood Signage study (RHDHV, 2016)

6) based discussions with EWN (The Australian Early Warning Network company)

Costs Benefit Considerations for Flood Warning Systems

The benefit of such a system is difficult to quantify. While the limited warning time is likely to allow for residents to raise some items (and therefore reducing flood damages), this cannot be relied upon to reduce damages. The main benefit of such a system is in intangibles including reduced fear in the community and also reduced likelihood of flood related loss of life.

Summary & Recommendation

Based on the information presented above, the implementation of flood warning systems is recommended for the Dungog tailwater area. Community consultation undertaken during the FRMS indicates that many residents in low lying areas are still dealing with the psychological stress of the severe flooding that resulted in significant property destruction and caused three fatalities. These residents fear that a similar event could occur again and believe that a suitable flood warning system would reduce the potential for similar tragedy to occur again.

The higher degree of uncertainty associated with a solely rainfall based system is unlikely to fit in with community expectations of a flood warning system. A water level based flood warning system would provide a higher degree of certainty in the warning and can be more easily related to the degree of flood risk (i.e. number of properties inundated) that exists in the Dungog tailwater. While a hybrid (model based) flood warning system may be able to produce more accurate estimates of peak water level and would provide an increase in the available warning time, given the relative ease of evacuation for properties in Dungog it would be difficult to justify the higher cost of such a system.

Based on the above, it is recommended that a water level based flood warning system is implemented in Dungog to reduce fear in the community and potentially protect against further tragedy. The initial cost for such a system could cost up to $55,000 (for a single water level gauge (including camera feed)), including low powered sirens or flashing light and $15,000 for consultancy, design and installation) and an annual allowance of $1600 for ongoing costs is required. It is also recommended that flood gauge boards be installed at key locations (cost ~$7,500). These signs provide an alternate manual system should the water level gauge fail during an event. The signs would also be useful for ongoing community flood education and engagement.

The suitability of the existing “dipstick gauge” should be investigated for inclusion in the proposed flood warning system either as a primary or secondary water level gauge. If the gauge is considered appropriate as a primary gauge, the cost of implementing a flood warning system in Dungog could be considerably reduced.

In order to increase available warning times, the addition of rainfall based triggers is recommended. The addition of the two available BoM rainfall gauges to the flood warning system would cost $1200/yr and allowance of up to $15,000 may be required to refine alert triggers. The use of predicted (i.e. forecast) rainfall products should also be considered to provide even greater flood warning times. These increased flood warning times would assist emergency services such as the SES coordinate resources during severe flood events. When developing the flood warning service, it is recommended that input from the new national Flash Flood Advisory Resource (FLARE) is sought. FLARE is an authoritative resource created to assist responsible agencies to design, implement and manage fit-for-purpose flash flood warning systems. FLARE is coordinated by the BoM and aims to help agencies, and through them the community, to increase their resilience to flash floods through better preparation and more effective response.

PART B – FLOODPLAIN RISK MANAGEMENT PLAN

8 Draft Dungog Floodplain Risk Management Plan

8.1 Introduction

The following section forms the draft Dungog Floodplain Risk Management Plan (the FRM Plan) and provides a framework by which the plan will be implemented. The objective of this Plan is to recommend a range of property, response and flood modification measures to mitigate the existing and future flood affectation in the study area. This plan has been completed in accordance with the Floodplain Development Manual (NSW State Government, 2005).

8.2 Floodplain Risk Management Measures

The implementation program essentially forms the action list for this Plan and is shown in **Table 8-1**. The benefit of following this sequence is that gradual improvement of the floodplain occurs, as the funds become available for implementation of these options. Further steps in the floodplain management process include:

- Draft Plan to be exhibited for public comment
- Plan to be finalised incorporating public comments
- Floodplain Management Committee to consider and adopt recommendations of this Plan;
- Council to consider the Floodplain Management Committee's recommendations;
- Council to adopt the Plan and submit an application for funding assistance to OEH and other agencies as appropriate; and
- As funds become available from Council's own resources, OEH and/or other state government agencies, implement the measures in accordance with the established priorities.

Table 6-10, provides a summary and brief analysis of the all the Floodplain Risk Management options including further details of what each option entails. Full details of the options are provided in the Dungog Floodplain Risk Management Study (i.e. Part A of this document (mostly in **Section 6.4**)).

The FRM Plan as detailed in **Table 8-1**, should be regarded as a dynamic instrument requiring review and modification over time. The catalyst for change could include new flood events and experiences, legislative change, alterations in the availability of funding or changes to the area's planning strategies. In any event, a thorough review every five years is warranted to ensure the ongoing relevance of the FRM Plan.

Table 8-1: Mitigation Measures Recommended for Implementation

Measure*	Description	Estimated Capital Costs and (Ongoing Costs)	Responsibility and Funding	Priority / Time frame
O11	Flood Warning System	$50,000 to $100,000 ($5,000 / yr)	Council and OEH	**Very High** 1-2 years[1]
P1	Adopt non-standard FPL for Dungog tailwater	Council staff time of ~$5,000	Council	**Very High** <1 years
EM1	Emergency Management Planning (develop a Local Flood Plan)	SES and Council staff time of ~$10,000	SES.	**High** <1 years
P2	Update LEP for purchased properties near Bennett Bridge	Council staff time of $5,000	Council	**High** <1 years
O9	VP for 3 properties, VHR for 4 properties demolition of 6 Alison Court properties.	VP = $900,000 VHR = $200,000 Demolition = $120,000	VP – Council and OEH VHR - Property owner and OEH Demolition – Council[2]	**High** 1-5 years[2]
O10	Bennett Park Tennis Court Surface Protection	Synpave - $100,000 Bonded grass - $180,000.	Club and/or Council and/or Insurance Agency.	**Medium** After flood damage
EM2	Community Flood Education	Council / SES staff time ~$10,000	Council / SES.	**Medium** 2-5 years
O2	Minor Bridge Upgrade	$4.4 Million	Council and/or NSW RMS and OEH	**Low** 5-50 years[3]

Notes: * details of the mitigation measures are provided in **Table 6-10**, and **Section 6.4**

VP = Voluntary Purchase, VHR = Voluntary House Raising

1) a NSW Floodplain Management Application for the Flood Warning System was submitted in April 2017.

2) the demolition of 6 Alison Court properties was approved by Council in April 2017. VP and VHR options are subject to the availability of Council and OEH funding and negotiations with property owners. Funding for the demolition of the 6 properties through Federal Government Disaster Recovery Funds has been approved in principle but has not been forthcoming at this time.

3) This option should be considered if bridge upgrades are being considered due to maintenance or capacity requirements or if increases in storm intensity produce more regular flooding in Dungog.

8.3 Funding, Implementation and Actions

8.3.1 Funding and Implementation

The timing of the implementation of recommended measures will depend on the available resources, overall budgetary commitments of Council and the availability of funds and support from other sources. It is envisaged that the FRM Plan would be implemented progressively over a 5 year time frame.

There are a variety of sources of potential funding that could be considered to implement the FRM Plan. These include:

- Council funds and staff resources;
- Section 94 contributions;
- State funding for flood risk management measures through the Office of Environment and Heritage; and
- State Emergency Service, either through volunteered time or funding assistance for emergency management measures.

State funds are available to implement measures that contribute to reducing existing flood problems. Funding assistance is likely to be available on a 2:1 (State:Council) basis. Although much of the FRM Plan may be eligible for Government assistance, funding cannot be guaranteed. Government funds are allocated on an annual basis to competing projects throughout the State. Measures that receive Government funding must be of significant benefit to the community. Funding is usually available for the investigation, design and construction of flood mitigation works included in the floodplain management plan.

8.3.2 Flood Risk Management Plan Actions

In September 2016, Dungog Shire Council (with 2:1 funding from NSW OEH) purchased the five properties on Dowling Street adjacent to Bennett Bridge that were washed away during the April 2015 super storm. The removal of these high risk lands from private ownership ensures that the overall level of flood risk in Dungog has been reduced. Council will need to update the LEP to ensure that future development in this location considers the high flood risk at these locations.

The demolition of 6 Council owned Alison Court properties was supported by Dungog Council in April 2017, as it was deemed that independent senior living units should not be allowed in the newly designated FPA (flood planning area). The demolition of these units is likely to occur in 2018, however this is dependent on funding. Funding was originally promised from a Federal Government disaster recovery source, however, the actual funds are yet to be paid. The demolition of these 6 properties will reduce the risk to life and also future flood damages and was included in both the VHR and VP options assessed in mitigation options O8 and O9.

In April 2017, Dungog Council submitted a floodplain management grant application to obtain 2/3 funding from the NSW Government Office of Environment and Heritage (OEH) for the design, installation and operation of a flood warning system for Dungog. If the grant application is successful the flood warning system should be operational by 2019. A flood warning system that improves the time available for evacuation of all properties that are potentially flood affected (including those deemed suitable for VHR) should reduce risk to life in Dungog.

The voluntary purchase (VP) of 3 properties is recommended in the plan and is subject to Council's resolution to acquire the property and the property owners concurrence to participate.

This measure can be the subject of an OEH grant application (due for lodgement in March each year) at Councils discretion and if successful Council would be required to fund 1/3 of the costs of purchase while OEH would fund 2/3 costs. Similarly, the Voluntary House Raising (VHR) of 4 properties is recommended in the plan and is subject to Council's resolution and the property owners concurrence to participate. Whilst Council may lodge a grant application for VHR at its discretion, if successful property owners would likely be required to pay 1/3 of the costs while OEH would fund 2/3 of the costs.

Emergency management in Dungog is also being improved with SES updating currently in the process of updating their Flood Plan using information produced during this FRMS&P study. The updated Flood Plan was released in July 2017 and will assist the SES improve the efficiency and effectiveness of evacuating at risk properties in Dungog.

9 References

1. AEMI (2013), **Managing the floodplain: a guide to best practice in flood risk management in Australia,** Edited and published by the Australian Emergency Management Institute (AEMI), part of the Australian Government Attorney-General's Department.
2. Bewsher Consulting (2001), **Paterson River Floodplain Management Study and Plan,** Final Report, November 2001, For Port Stephens Council and Dungog Council. http://www.portstephens.nsw.gov.au/grow/land-environment-and-heritage/flooding/floodplain-management-program
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Appendix A – Mitigation Option Cost Calculations

Appendix A presents detailed cost estimations which been undertaken for the five mitigation options listed below:

O1) Major Myall Creek (Road and Rail) Bridge Modifications
O2) Minor Myall Creek (Road and Rail) Bridge Modifications
O3) Myall Creek Levee with Pumps
O4) Myall Creek Levee with Diversion Culverts
O5) Vegetation Removal with Scour Protection

These cost estimates are indicative and are based on our experience from a number of projects at a range of sites and conditions. This estimates are provided for broad guidance only and are NOT guaranteed by Royal HaskoningDHV as we have no control over contractor's prices, market forces and competitive bids from tenderers. Any construction cost estimates provided may exclude items which should be considered in a cost plan. Examples of such items are design fees, project management fees, authority approval fees, contractors risk, preliminaries and project contingencies (e.g. to account for construction and site conditions, weather conditions, ground conditions and unknown services). If a reliable cost estimate is required, an appropriately qualified Quantity Surveyor should be engaged and market feedback sought.

It should be noted that the cost estimates are suitable for the comparison and assessment of the mitigation options for the Dungog Floodplain Risk Management Study.

Budget Cost Estimate

Haskoning Australia Pty Ltd

Date: 5-Dec-16

Client: Dungog Shire Council

RHDHV Job No. PA1316

Project Name: Dungog Floodplain Risk Management Study & Plan

OPTION O1 - Major Modifications of the Myall Creek Road and Rail Bridg

Item #	Description	Rate	Unit	Qty	Total
1	**General**				
1.1	Site establishment	$ 20,000	item	1	$ 20,000
1.2	Supervision, management, amenities	$ 2,500	Weeks	12	$ 30,000
1.3	Survey, Service Location and setout of works by surveyor	$ 5,000	Days	3	$ 15,000
1.4	Geotechnical testing and certification of pavements	$ 150	Tests	10	$ 1,500
1.5	Relocation and protection of Services	$ 80,000	item	1	$ 80,000
1.6	Traffic control	$ 20,000	item	1	$ 20,000
1.7	Preparation and implementation of Works EMP	$ 20,000	item	1	$ 20,000
				Subtotal	**$ 186,500**
2	**Clearing**				
2.1	Clear trees mulch and stockpile on site	$ 10.00	sqm	2,500	$ 25,000
				Subtotal	**$ 25,000**
3	**Topsoil & Mulch**				
3.1	Strip and Stockpile 150mm of topsoil from construction areas	$ 4.50	cum	5,625	$ 25,313
3.2	Replace 150mm topsoil on construction areas	$ 5.60	cum	5,625	$ 31,500
				Subtotal	**$ 56,813**
4	**Bulk Earthworks**				
4.1	Bulk Excavation to form lowered overbank areas	$ 4.50	cum	36,000	$ 162,000
4.2	Imported Fill for Abutments, Bedding and Surrounds	$ 25.00	cum	1,748	$ 43,700
				Subtotal	**$ 205,700**
5	**Roadworks**				
5.1	30mm AC Concrete	$ 16.50	sqm	1,300	$ 21,450
5.2	7mm Primer Seal	$ 5.70	sqm	1,300	$ 7,410
5.3	150mm Basecourse	$ 15.00	sqm	1,300	$ 19,500
5.4	380mm Sub-base	$ 60.00	sqm	1,300	$ 78,000
5.5	Allowance to make smooth connection with existing road	$ 200.00	lin.m	20	o1
				Subtotal	**$ 126,360**
6	**Concrete Works**				
6.1	Upright Kerb and Gutter (road bridge and approaches)	$ 240	lin.m	240	$ 57,600
6.2	Concrete Footpath (on one side of the bridge)	$ 35	sqm	300	$ 10,500
6.3	Road Box Culvert Headwall	$ 1,100	cum	52	$ 57,640
6.4	Road Box Culvert Base and Apron Slabs	$ 600	cum	540	$ 324,000
6.5	Road Box Culvert Wingwalls	$ 1,100	cum	26	$ 28,160
6.6	*Rail* Box Culvert Headwall	$ 1,100	cum	41	$ 45,320
6.7	*Rail* Box Culvert Base and Apron Slabs	$ 600	cum	312	$ 187,200
6.8	*Rail* Box Culvert Wingwalls	$ 1,100	cum	13	$ 14,080
				Subtotal	**$ 724,500**
7	**Culverts Units**				
7.1	Road Culvert - Standard 3.6 x 3.0 Box Culvert Crown Units delivered to site	$ 7,500	item	135	$ 1,012,500
7.2	Rail Culvert - Bespoke 3.6m wide x 3.0m high RC Culvert Units delivered to site	$ 10,000	item	60	$ 600,000
7.3	Road Culvert Construction	$ 400,000	item	1	$ 400,000
7.4	Rail Culvert Construction	$ 800,000	item	1	$ 800,000
				Subtotal	**$ 2,812,500**
8	**Allowance for Timber Piling under base slab units (say 20m length of base slab closest to creekline)**				
8.1	Road - 300 Diameter F17 Grade hardwood timber piles to H5 treatment class driven to 500kN load capacity (assumed 10m pile lenths) - assumes 4No. Piles per Culvert Unit	$ 290	m	1,111	$ 322,222
8.2	Road - Allowance to Cut Timber Piles to Length	$ 60	item	111	$ 6,660
8.3	Road - Allowance for M24 Coach Screws galv embedded 250mm into timber piles	$ 150	item	111	$ 16,650
8.4	Rail - 300 Diameter F17 Grade hardwood timber piles to H5 treatment class driven to 500kN load capacity (assumed 10m pile lenths) - assumes 4No. Piles per Culvert Unit	$ 290	m	667	$ 193,333
8.5	Rail - Allowance to Cut Timber Piles to Length	$ 60	item	66	$ 3,960
8.6	Rail - Allowance for M24 Coach Screws galv embedded 250mm into timber piles	$ 150	item	66	$ 9,900
				Subtotal	**$ 552,726**
9	**Scour Protection**				
9.1	Road - Geotextile Fabric	$ 7	sqm	600	$ 3,900
9.2	Road - Allow for 800mm thick Rock Rip-Rap Armour	$ 150	sqm	600	$ 90,000
9.3	Road - Allow for 400mm underlayer	$ 65	sqm	600	$ 39,000
9.4	Rail - Geotextile Fabric	$ 7	sqm	480	$ 3,120
9.5	Rail - Allow for 800mm thick Rock Rip-Rap Armour	$ 150	sqm	480	$ 72,000
9.6	Rail - Allow for 400mm underlayer	$ 65	sqm	480	$ 31,200
				Subtotal	**$ 239,220**

SUBTOTAL (excl. GST)	**$ 4,929,318**
Engineering Design (4%)	$ 197,172.72
Environmental Assessment and Approvals	$ 50,000
Tender Preparation (0.6%)	$ 29,576
Supervision and Contract Administration (2%)	$ 98,586.36
Contingency (30%)	$ 1,478,795
TOTAL (excl. GST)	**$ 6,783,448**

Budget Cost Estimate

Haskoning Australia Pty Ltd

Date: 5-Dec-16

Client: Dungog Shire Council **RHDHV Job No.** PA1316

Project Name: Dungog Floodplain Risk Management Study & Plan

OPTION O2 - Minor Modifications of the Myall Creek Road and Rail Bridg

Item #	Description	Rate	Unit	Qty	Total
1	**General**				
1.1	Site establishment	$ 20,000	item	1	$ 20,000
1.2	Supervision, management, amenities	$ 2,500	Weeks	12	$ 30,000
1.3	Survey, Service Location and setout of works by surveyor	$ 5,000	Days	3	$ 15,000
1.4	Geotechnical testing and certification of pavements	$ 150	Tests	10	$ 1,500
1.5	Relocation and protection of Services	$ 80,000	item	1	$ 80,000
1.6	Traffic control	$ 20,000	item	1	$ 20,000
1.7	Preparation and implementation of Works EMP	$ 20,000	item	1	$ 20,000
				Subtotal	**$ 186,500**
2	**Clearing**				
2.1	Clear trees mulch and stockpile on site	$ 10.00	sqm	1,800	$ 18,000
				Subtotal	**$ 18,000**
3	**Topsoil & Mulch**				
3.1	Strip and Stockpile 150mm of topsoil from construction areas	$ 4.50	cum	4,200	$ 18,900
3.2	Replace 150mm topsoil on construction areas	$ 5.60	cum	4,200	$ 23,520
				Subtotal	**$ 42,420**
4	**Bulk Earthworks**				
4.1	Bulk Excavation to form lowered overbank areas	$ 4.50	cum	25,000	$ 112,500
4.2	Imported Fill for Abutments, Bedding and Surrounds	$ 25.00	cum	1,273	$ 31,825
				Subtotal	**$ 144,325**
5	**Roadworks**				
5.1	30mm AC Concrete	$ 16.50	sqm	650	$ 10,725
5.2	7mm Primer Seal	$ 5.70	sqm	650	$ 3,705
5.3	150mm Basecourse	$ 15.00	sqm	650	$ 9,750
5.4	380mm Sub-base	$ 60.00	sqm	650	$ 39,000
5.5	Allowance to make smooth connection with existing road	$ 200.00	lin.m	20	$ 4,000
				Subtotal	**$ 67,180**
6	**Concrete Works**				
6.1	Upright Kerb and Gutter (road bridge and approaches)	$ 240	lin.m	120	$ 28,800
6.2	Concrete Footpath (on one side of the bridge)	$ 35	sqm	150	$ 5,250
6.3	Road Box Culvert Headwall	$ 1,100	cum	27	$ 30,140
6.4	Road Box Culvert Base and Apron Slabs	$ 600	cum	270	$ 162,000
6.5	Road Box Culvert Wingwalls	$ 1,100	cum	26	$ 28,160
6.6	*Rail* Box Culvert Headwall	$ 1,100	cum	24	$ 26,070
6.7	*Rail* Box Culvert Base and Apron Slabs	$ 600	cum	176	$ 105,300
6.8	*Rail* Box Culvert Wingwalls	$ 1,100	cum	13	$ 14,080
				Subtotal	**$ 399,800**
7	**Culverts Units**				
7.1	Road Culvert - Standard 3.6m wide x 3.0m high Box Culvert Crown Units delivered to site	$ 7,500	item	70	$ 525,000
7.2	Rail Culvert - Bespoke 3.6m wide x 3.0m high RC Culvert Units delivered to site	$ 10,000	item	42	$ 420,000
7.3	Road Culvert Construction	$ 200,000	item	1	$ 200,000
7.4	Rail Culvert Construction	$ 500,000	item	1	$ 500,000
				Subtotal	**$ 1,645,000**
8	**Allowance for Timber Piling under base slab units (say 20m length of base slab closest to creekline)**				
8.1	Road - 300 Diameter F17 Grade hardwood timber piles to H5 treatment class driven to 500kN load capacity (assumed 10m pile lenths) - assumes 4No. Piles per Culvert Unit	$ 290	m	1,111	$ 322,222
8.2	Road - Allowance to Cut Timber Piles to Length	$ 60	item	111	$ 6,660
8.3	Road - Allowance for M24 Coach Screws galv embedded 250mm into timber piles	$ 150	item	111	$ 16,650
8.4	Rail - 300 Diameter F17 Grade hardwood timber piles to H5 treatment class driven to 500kN load capacity (assumed 10m pile lenths) - assumes 4No. Piles per Culvert Unit	$ 290	m	667	$ 193,333
8.5	Rail - Allowance to Cut Timber Piles to Length	$ 60	item	66	$ 3,960
8.6	Rail - Allowance for M24 Coach Screws galv embedded 250mm into timber piles	$ 150	item	66	$ 9,900
				Subtotal	**$ 552,726**
9	**Scour Protection**				
9.1	Road - Geotextile Fabric	$ 7	sqm	300	$ 1,950
9.2	Road - Allow for 800mm thick Rock Rip-Rap Armour	$ 150	sqm	300	$ 45,000
9.3	Road - Allow for 400mm underlayer	$ 65	sqm	300	$ 19,500
9.4	Rail - Geotextile Fabric	$ 7	sqm	270	$ 1,755
9.5	Rail - Allow for 800mm thick Rock Rip-Rap Armour	$ 150	sqm	270	$ 40,500
9.6	Rail - Allow for 400mm underlayer	$ 65	sqm	270	$ 17,550
				Subtotal	**$ 126,255**
				SUBTOTAL (excl. GST)	**$ 3,182,206**
				Engineering Design (4%)	$ 127,288.22
				Environmental Assessment and Approvals	$ 50,000
				Tender Preparation (0.6%)	$ 19,093
				Supervision and Contract Administration (2%)	$ 63,644.11
				Contingency (30%)	$ 954,662
				TOTAL (excl. GST)	**$ 4,396,893**

Budget Cost Estimate

Haskoning Australia Pty Ltd **Date:** 5-Dec-16

Client: Dungog Shire Council **RHDHV Job No.** PA1316
Project Name: Dungog Floodplain Risk Management Study & Plan

OPTION O3 - Levee with 5 cumec pump capacity

Item #	Description	Rate	Unit	Qty	Total
1	**General**				
1.1	Site establishment	$ 20,000	item	1	$ 20,000
1.2	Supervision, management, amenities	$ 2,500	Weeks	12	$ 30,000
1.3	Survey, Service Location and setout of works by surveyor	$ 5,000	Days	3	$ 15,000
1.4	Geotechnical testing and certification of pavements	$ 150	Tests	10	$ 1,500
1.5	Relocation and protection of Services	$ 80,000	item	1	$ 80,000
1.6	Traffic control	$ 20,000	item	1	$ 20,000
1.7	Preparation and implementation of Works EMP	$ 20,000	item	1	$ 20,000
				Subtotal	**$ 186,500**
2	**Clearing**				
2.1	Clear trees mulch and stockpile on site	$ 10.00	sqm	300	$ 3,000
				Subtotal	**$ 3,000**
3	**Topsoil, Mulch and Turf**				
3.1	Strip and Stockpile 150mm of topsoil from construction areas	$ 4.50	cum	2,738	$ 12,319
3.2	Replace 150mm topsoil on construction areas	$ 5.60	cum	3,518	$ 19,698
3.3	Turf to Embankment	$ 5.60	cum	3,518	$ 19,698
				Subtotal	**$ 32,017**
4	**Bulk Earthworks for Levee**				
4.1	Bulk Excavation to form cut- off trench (1.5m deep)	$ 4.50	cum	4,050	$ 18,225
4.2	Bulk Excavation to Detention Storages	$ 4.50	cum	4,000	$ 18,000
4.3	Imported Fill for Embankment and cut off trench	$ 25.00	cum	47,250	$ 1,181,250
				Subtotal	**$ 1,217,475**
5	**Blockwork Levee Wall**				
5.1	Reinforced Concrete Footing Including Excavation	$ 564	cum	95	$ 53,298
5.2	Blockwork Wall	$ 233	sqm	768	$ 178,944
5.3	Sheetpile Wall Footing (assume 60m length adjacent to Creek, 12m width)	$ 650	sqm	720	$ 468,000
				Subtotal	**$ 700,242**
6	**Roadworks**				
6.1	30mm AC Concrete	$ 16.50	sqm		$ -
6.2	7mm Primer Seal	$ 5.70	sqm		$ -
6.3	150mm Basecourse	$ 15.00	sqm		$ -
6.4	380mm Sub- base	$ 60.00	sqm		$ -
6.5	Allowance to make smooth connection with existing road	$ 200.00	lin.m		$ -
				Subtotal	**$ -**
7	**Concrete Works**				
7.1	Upright Kerb and Gutter (road bridge and approaches)	$ 240	lin.m	20	$ 4,800
7.2	Concrete Lined Spillway	$ 600	cum	720	$ 432,000
7.3	Box Culvert Headwall	$ 1,100	cum	25	$ 27,500
7.4	Box Culvert Base and Apron Slabs	$ 600	cum	96	$ 57,600
7.5	Box Culvert Wingwalls	$ 1,100	cum	13	$ 14,080
				Subtotal	**$ 535,980**
8	**Culverts Units**				
8.1	Levee Culverts - Standard 3.6 x 3.6 Box Culvert Crown Units delivered to site	$ 8,500	item	33.00	$ 280,500
8.2	Levee Culvert Construction	$ 300,000	item	1	$ 300,000
				Subtotal	**$ 580,500**
9	**Stormwater Pump Stations**				
9.1	Excavation for Wet Well on each outlet	$ 10	item	500	$ 5,000
9.2	Pump Well and Intake Works	$ 430,000	item	1	$ 430,000
9.3	Outlet Pipes and Structures	$ 725,000	item	1	$ 725,000
9.4	Supply and Installation of 1000 l/s (55 KW) pumps and galvanised steel disharge column	$ 150,000	item	5	$ 750,000
9.5	Electrical Connection	$ 250,000	item	1	$ 250,000
9.6	Pump Control System	$ 250,000	item	1	$ 250,000
9.7	Make Good Surface Features	$ 60,000	item	1	$ 60,000
				Subtotal	**$ 2,470,000**
9	**Allowance for Timber Piling under base slab units (say 6 culvert lengths of base slab in low lying areas)**				
9.1	300 Diameter F17 Grade hardwood timber piles to H5 treatment class driven to 500kN load capacity (assumed 10m pile lenths) - assumes 4No. Piles per Culvert Unit	$ 290	m	240	$ 69,600
9.2	Allowance to Cut Timber Piles to Length	$ 60	item	24	$ 1,440
9.3	Allowance for M24 Coach Screws galv embedded 250mm into timber piles	$ 150	item	24	$ 3,600
				Subtotal	**$ 74,640**
10	**Scour Protection**				
10.1	Geotextile Fabric	$ 7	sqm	100	$ 650
10.2	Allow for 800mm thick Rock Rip- Rap Armour	$ 150	sqm	100	$ 15,000
10.3	Allow for 400mm underlayer	$ 65	sqm	100	$ 6,500
				Subtotal	**$ 22,150**
				SUBTOTAL (excl. GST)	**$ 5,822,504**
				Engineering Design (4%)	$ 232,900.15
				Environmental Assessment and Approvals	$ 50,000
				Tender Preparation (0.6%)	$ 34,935
				Supervision and Contract Administration (2%)	$ 116,450.08
				Contingency (30%)	$ 1,746,751
				TOTAL (excl. GST)	**$ 8,003,540**

Budget Cost Estimate

Haskoning Australia Pty Ltd

Date: 5-Dec-16

Client: Dungog Shire Council

RHDHV Job No. PA1316

Project Name: Dungog Floodplain Risk Management Study & Plan

OPTION O4 - Levee with Diversion Culvert

Item #	Description	Rate	Unit	Qty	Total
1	**General**				
1.1	Site establishment	$ 20,000	item	1	$ 20,000
1.2	Supervision, management, amenities	$ 2,500	Weeks	12	$ 30,000
1.3	Survey, Service Location and setout of works by surveyor	$ 5,000	Days	3	$ 15,000
1.4	Geotechnical testing and certification of pavements	$ 150	Tests	10	$ 1,500
1.5	Relocation and protection of Services	$ 80,000	item	1	$ 80,000
1.6	Traffic control	$ 20,000	item	1	$ 20,000
1.7	Preparation and implementation of Works EMP	$ 20,000	item	1	$ 20,000
				Subtotal	**$ 186,500**
2	**Clearing**				
2.1	Clear trees mulch and stockpile on site	$ 10.00	sqm	300	$ 3,000
				Subtotal	**$ 3,000**
3	**Topsoil, Mulch and Turf**				
3.1	Strip and Stockpile 150mm of topsoil from construction areas	$ 4.50	cum	2,738	$ 12,319
3.2	Replace 150mm topsoil on construction areas	$ 5.60	cum	3,518	$ 19,698
3.3	Turf to Embankment	$ 5.60	cum	3,518	$ 19,698
				Subtotal	**$ 32,017**
4	**Bulk Earthworks for Levee**				
4.1	Bulk Excavation to form cut-off trench (1.5m deep)	$ 4.50	cum	4,050	$ 18,225
4.2	Bulk Excavation to Detention Storages	$ 4.50	cum	4,000	$ 18,000
4.3	Imported Fill for Embankment and cut off trench	$ 25.00	cum	47,250	$ 1,181,250
				Subtotal	**$ 1,217,475**
5	**Blockwork Levee Wall**				
5.1	Reinforced Concrete Footing Including Excavation	$ 564	cum	95	$ 53,298
5.2	Blockwork Wall	$ 233	sqm	768	$ 178,944
5.3	Sheetpile Wall Footing (assume 60m length adjacent to Creek, 12m length)	$ 650	sqm	720	$ 468,000
				Subtotal	**$ 700,242**
6	**Roadworks**				
6.1	30mm AC Concrete	$ 16.50	sqm	200	$ 3,300
6.2	7mm Primer Seal	$ 5.70	sqm	200	$ 1,140
6.3	150mm Basecourse	$ 15.00	sqm	200	$ 3,000
6.4	380mm Sub-base	$ 60.00	sqm	200	$ 12,000
6.5	Allowance to make smooth connection with existing road	$ 200.00	lin.m	20	$ 4,000
				Subtotal	**$ 23,440**
7	**Concrete Works**				
7.1	Upright Kerb and Gutter (road bridge and approaches)	$ 240	lin.m	20	$ 4,800
7.2	Concrete Lined Spillway	$ 600	cum	720	$ 432,000
7.3	Box Culvert Headwall	$ 1,100	cum	25	$ 27,500
7.4	Box Culvert Base and Apron Slabs	$ 600	cum	96	$ 57,600
7.5	Box Culvert Wingwalls	$ 1,100	cum	13	$ 14,080
				Subtotal	**$ 535,980**
8	**Culverts Units (through levee)**				
8.1	Levee Culverts - Standard 3.6 x 3.6 Box Culvert Crown Units delivered to site	$ 8,500	item	33.00	$ 280,500
8.2	Levee Culvert Construction	$ 300,000	item	1	$ 300,000
				Subtotal	**$ 580,500**
9	**Culverts Units (to d/s Bennett Bridge)**				
9.1	250m Culverts - Standard 3.6 x 3.6 Box Culvert Crown Units delivered to site	$ 8,500	item	104	$ 884,000
9.2	Levee Culvert Construction	$ 300,000	item	3	$ 900,000
9.3	Inlet / Outlet Structures	$ 10,000	item	2	$ 20,000
9.7			item	-	$ -
				Subtotal	**$ 1,804,000**
9	**Allowance for Timber Piling under base slab units (say 6 culvert lengths of base slab in low lying areas)**				
9.1	300 Diameter F17 Grade hardwood timber piles to H5 treatment class driven to 500kN load capacity (assumed 10m pile lenths) - assumes 4No. Piles per Culvert Unit	$ 290	m	240	$ 69,600
9.2	Allowance to Cut Timber Piles to Length	$ 60	item	24	$ 1,440
9.3	Allowance for M24 Coach Screws galv embedded 250mm into timber piles	$ 150	item	24	$ 3,600
				Subtotal	**$ 74,640**
10	**Scour Protection**				
10.1	Geotextile Fabric	$ 7	sqm	100	$ 650
10.2	Allow for 800mm thick Rock Rip-Rap Armour	$ 150	sqm	100	$ 15,000
10.3	Allow for 400mm underlayer	$ 65	sqm	100	$ 6,500
				Subtotal	**$ 22,150**

SUBTOTAL (excl. GST)	**$ 5,179,944**
Engineering Design (4%)	$ 207,197.75
Environmental Assessment and Approvals	$ 50,000
Tender Preparation (0.6%)	$ 31,080
Supervision and Contract Administration (2%)	$ 103,598.88
Contingency (30%)	$ 1,553,983
TOTAL (excl. GST)	**$ 7,125,803**

Budget Cost Estimate

Haskoning Australia Pty Ltd

Date: 5-Dec-16

Client: Dungog Shire Council **RHDHV Job No.** PA1316

Project Name: Dungog Floodplain Risk Management Study & Plan

OPTION O5 - Channel Vegetation Removal with Scour Protection

Item #	Description	Rate	Unit	Qty	Total
1	**General**				
1.1	Site establishment	$ 20,000	item	1	$ 20,000
1.2	Supervision, management, amenities	$ 2,500	Weeks	12	$ 30,000
1.3	Survey, Service Location and setout of works by surveyor	$ 5,000	Days	2	$ 10,000
1.4	Geotechnical testing and certification of pavements	$ 150	Tests	1	$ 150
1.5	Relocation and protection of Services	$ 15,000	item	1	$ 15,000
1.6	Relocation and protection of Fauna	$ 200,000	item	1	$ 200,000
1.7	Traffic control	$ 20,000	item	1	$ 20,000
1.8	Preparation and implementation of Works EMP	$ 20,000	item	1	$ 20,000
				Subtotal	**$ 315,150**
2	**Clearing**				
2.1	Clear trees mulch and stockpile on site	$ 20.00	sqm	25,000	$ 500,000
2.2	Transport of Mulch Offsite for Re-use	$ 15.00	tonne	20,000	$ 300,000
				Subtotal	**$ 800,000**
3	**Scour Protection for Channel Invert**				
3.1	Geotextile Fabric	$ 7	sqm	5,000	$ 32,500
3.2	Allow for 800mm thick Rock Rip-Rap Armour	$ 150	sqm	5,000	$ 750,000
3.3	Allow for 400mm underlayer	$ 65	sqm	5,000	$ 325,000
				Subtotal	**$ 1,107,500**
4	**Bed Stabilisation with Less Dense Vegetation**				
4.1	150mm topsoil on bank areas	$ 5.60	cum	2,850	$ 15,960
4.2	Planting	$ 15.00	sqm	15,000	$ 225,000
				Subtotal	**$ 240,960**
				SUBTOTAL (excl. GST)	**$ 2,463,610**
				Design (4%)	$ 98,544.40
				Environmental Assessment and Approvals	$ 150,000
				Tender Preparation (0.6%)	$ 14,782
				Supervision and Contract Administration (2%)	$ 49,272.20
				Contingency (30%)	$ 739,083
				TOTAL (excl. GST)	**$ 3,515,291**