LITHGOW CITY COUNCIL

LITHGOW FLOODPLAIN RISK MANAGEMENT STUDY AND PLAN 2023

AUGUST 2023

VOLUME 1 – REPORT

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FOREWORD

NSW Government's Flood Policy

The NSW Government's Flood Policy is directed at providing solutions to existing flooding problems in developed areas and to ensuring that new development is compatible with the flood hazard and does not create additional flooding problems in other areas.

Under the Policy, the management of flood liable land remains the responsibility of local government. The State subsidises flood mitigation works to alleviate existing problems and provides specialist technical advice to assist councils in the discharge of their floodplain management responsibilities. The Policy provides for technical and financial support by the State through the following four sequential stages:

1.	Data Collection and Flood Study	Collects flood related data and undertakes an investigation to determine the nature and extent of flooding.
2.	Floodplain Risk Management Study	Evaluates management measures for the floodplain in respect of both existing and proposed development.
3.	Floodplain Risk Management Plan	Involves formal adoption by Council of a plan of management for the floodplain.
4.	Implementation of the Plan	Construction of flood mitigation works to protect existing development. Use of Local Environmental Plans to ensure new development is compatible with the flood hazard. Improvements to flood emergency management procedures.

Presentation of Study Results

The results of an updated flood study that was commissioned by Lithgow City Council as part of the present study (***Updated Flood Study***) are presented in **Appendix B** of this report. Both the *Updated Flood Study* and the *Floodplain Risk Management Study* have been prepared under the guidance of the Floodplain Risk Management Committee comprising representatives from Lithgow City Council, the NSW Department of Planning and Environment, the NSW State Emergency Service and community representatives.

All figures referred to in this report are bound in a separate A3 volume (denoted herein as "**Volume 2**").

ACKNOWLEDGEMENT

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ABBREVIATIONS

AEP	Annual Exceedance Probability (%)
AHD	Australian Height Datum
ARI	Average Recurrence Interval (years)
ARR 1987	Australian Rainfall and Runoff (1987 Edition)
ARR 2019	Australian Rainfall and Runoff (2019 Edition)
BoM	Bureau of Meteorology
Council	Lithgow City Council
DECC	Department of Environment and Climate Change
DPE	Department of Planning and Environment
FDM	Floodplain Development Manual, 2005
FRMC	Floodplain Risk Management Committee
FPL	Flood Planning Level
FPA	Flood Planning Area
FRMS	Floodplain Risk Management Study
FRMP	Floodplain Risk Management Plan
FRMS&P	Floodplain Risk Management Study and Plan
LEP	Local Environmental Plan
LiDAR	Light Detection and Ranging (survey)
MHFL	Minimum Habitable Floor Level
NSWG	New South Wales Government
NSW SES	New South Wales State Emergency Service
PMF	Probable Maximum Flood
VP	Voluntary Purchase

SUMMARY

S1 Study Objectives

Lithgow City Council (**Council**) commissioned the preparation of a contemporaneous floodplain risk management study and plan for Lithgow and its immediate environs. The overall objectives of the *Lithgow Floodplain Risk Management Study 2023* (***Lithgow FRMS 2023***) were to review the *Lithgow Floodplain Management Plan* that was prepared on behalf of Council in 1991 (***Lithgow FMP 1991***), reassess the impacts of flooding on existing development, review existing Council policies as they relate to development of land in flood liable areas, consider measures for the management of flood affected land and to develop *Lithgow Floodplain Risk Management Plan 2023* (***Lithgow FRMP 2023***) which:

i) Proposes modifications to existing Council policies to ensure that the development of flood affected land is undertaken so as to be compatible with the flood hazard and risk.

ii) Sets out the recommended program of works and measures aimed at reducing over time, the social, environmental and economic impacts of flooding.

iii) Provides a program for implementation of the proposed works and measures.

The study area for *Lithgow FRMP 2023* applies to areas that are affected by the following two types of flooding in the Farmers Creek and Marrangaroo Creek catchments at Lithgow:

- **Main Stream Flooding**, which occurs when floodwater surcharges the inbank area of the existing creek systems. Main Stream Flooding is typically characterised by relatively deep and fast flowing floodwater, but may be shallower and slower moving in flood fringe areas.
- **Major Overland Flow** which occurs during storms which result in the surcharge of the existing piped stormwater drainage system. It is also present in the upper reaches of the study catchments.

Figure 1.1 (2 sheets) is a location and catchment plan, while **Figure 2.1** (4 sheets) shows the key features of the existing stormwater drainage system at Lithgow.

S2 Study Activities

The activities undertaken in *Lithgow FRMS 2023* included:

1. Undertaking a consultation program over the course of the study to ensure that the Lithgow community was informed of the objectives, progress and outcomes over the course of the study (**Chapter 1** and **Appendix A**).
2. Review and updating of flooding patterns in Lithgow for flood events up to the Probable Maximum Flood (**PMF**). (**Chapter 2**, as well as **Appendix B**).
3. Assessment of the economic impacts of flooding, including the numbers of affected properties and estimation of flood damages (**Chapter 2** and **Appendix C**).
4. Review of current flood related planning controls for Lithgow and their compatibility with flooding conditions (**Chapter 2**).
5. Strategic review of potential floodplain risk management works and measures aimed at reducing flood damages, including an economic assessment of the most promising measures (**Chapter 3** and **Appendix D**).
6. Ranking of works and measures using a multi-objective scoring system which took into account economic, financial, environmental and planning considerations (**Chapter 4**).
7. Preparation of *Lithgow FRMP 2023* (**Chapter 5**).

S3 Summary of Flood Impacts

Figures 2.2 and **2.3** (4 sheets each) show the indicative extent and depths of inundation of the 1% Annual Exceedance Probability (**AEP**) and PMF events, respectively, while **Figure 2.4** shows design water surface profiles along the major watercourses that are located in the study area. **Figure 2.5** shows the time of rise of floodwaters, while **Figure 2.6** shows the indicate extent of flooding at Lithgow for flood of between 20% and PMF events.

Figures 2.2 and **2.3** show the location and indicative depth of above-floor inundation in properties that are affected by the 1% AEP and PMF events, respectively. Also shown on **Figure 2.2** and **2.3** are a number of regions that represent clusters of properties that are impacted by flooding in the Farmers Creek catchment (referred to herein as "Damage Centres").

Within the Farmers Creek catchment, 265 dwellings, 48 commercial/industrial buildings and one public building would be subject to above-floor inundation at the 1% AEP level of flooding, with the total flood damages amounting to $41.4 Million.

Within the Marrangaroo Creek catchment, two dwellings and one public building would be subject to above-floor inundation at the 1% AEP level of flooding, with the total flood damages amounting to $0.46 Million.

The *Present Worth Value* of damages likely to be experienced in the Farmers Creek and Marrangaroo Creek catchments for all flood events up to the 1% AEP is $46.9 Million and $0.7 Million, respectively. A combination of flood mitigation measures costing up to these amounts could be economically justified if they eliminated flood damages for all flood events up to this level. While schemes costing more than this value would have a benefit/cost ratio less than 1, they may still be justified according to a multi-objective approach which considers other criteria in addition to economic feasibility.

S4 Lithgow Floodplain Management Study 1991

Chapter 9 of the *Lithgow Floodplain Management Study* (Kinhill, 1991) sets out the measures that comprised *Lithgow FMP 1991*. **Table 3.1** in **Chapter 3** of this report lists the measures that comprised *Lithgow FMP 1991* and highlights which measures have been either partially or fully implemented by Council and also those which have yet to be implemented.

Based on a review of measures that comprised *Lithgow FMP 1991* and after taking the current views of the community into consideration, a range of potential floodplain risk management measures were assessed for possible inclusion in *Lithgow FRMP 2023*.

S5 Flood Risk and Development Controls

An approach which uses the concepts of *flood hazard* and *hydraulic categorisation,* and is aimed at imposing a graded set of controls over development according to the flood risk has been recommended for incorporation into *Lithgow Development Control Plan 2021* (***Lithgow DCP 2021***). The delineation of flood planning constraint categories is based on the proximity to flow paths, depths and velocities of flow, the rate of rise of floodwaters and ease of evacuation from the floodplain in the event of a flood emergency.

Figure D1.1 in **Appendix D** is an extract from the *Flood Planning Map* relating to Lithgow. The extent of the Flood Planning Area (**FPA**) (the area subject to flood related development controls) has been defined as follows:

- In areas subject to Main Stream Flooding, the FPA is based on the traditional definition of the area that lies at or below by the 1% AEP plus 0.5 m freeboard.
- In areas subject to Major Overland Flow, the FPA is defined as the extent of areas which act as a floodway, as well as areas where depths of inundation exceed 0.1 m in a 1% AEP event.

Figure D1.2 in **Appendix D** is an extract of the *Flood Planning Constraint Category Map* for the study area which shows the subdivision of the floodplain into four categories which have been used as the basis for developing the graded set of planning controls.

Minimum habitable floor level (**MHFL**) requirements would be imposed on future development in properties that are identified as lying either partially or wholly within the extent of the FPA shown on **Figure D1.1**. The MHFLs for residential land use types is the level of the 1% AEP flood event plus freeboard, whereas for commercial and industrial land use types the MHFL is to be as close to the 1% AEP flood level plus freeboard as practical, but no lower than the 5% AEP flood level plus freeboard. In situations where the MHFL is below the 1% AEP flood level plus freeboard, a mezzanine area equal to 30% of the total habitable floor area is to be provided, the elevation of which is to be set no lower than the 1% AEP flood level plus freeboard.[1]

A *Special Flood Consideration Zone*, the extent of which is shown on **Figures D1.1** and **D1.2**, has also been included which relates to areas where the flood risk is considered to be high enough to require additional controls to be applied to future development that is located on land which lies between the Main Stream Flooding FPA and the PMF.

S6 Lithgow Floodplain Risk Management Plan 2023

Lithgow FRMP 2023 setting out the recommended floodplain risk management measures for the study area is presented in **Chapter 5** of this report, with the recommended works and measures summarised in **Table S1** at the end of this Summary. The recommended works and measures have been given a provisional priority ranking, confirmed by the Floodplain Risk Management Committee, according to a range of criteria, details of which are set out in **Section 4** of the report.

Lithgow FRMP 2023 comprises six "non-structural" management measures which could be implemented by Council with the assistance of NSW State Emergency Service (**NSW SES**) using existing data and without requiring Government funding. The measures are as follows:

- **Measure 1** – Inclusion of a new special flood considerations clause in the *Lithgow Local Environmental Plan 2014 (**Lithgow LEP 2014**)* which would apply to land which lies between the FPA and the extent of the PMF.
- **Measure 2** - The application of a graded set of planning controls for future development that recognise the location of the development within the floodplain; to be applied through the update of *Lithgow DCP 2021*. Suggested wording for inclusion in *Lithgow DCP 2021* is set out in **Appendix D**.
- **Measures 3** - Improvements in the NSW SES emergency planning, including use of the flood related information contained in this study to update the *Lithgow City Local Flood Plan*. Information in this report which would be of assistance to NSW SES includes data on the nature and extent of flooding at Lithgow, times of rise of floodwaters, duration and depths of inundation at major road crossings for a range of flood events and properties affected by flooding.

[1] Freeboard is equal to 0.5 m for development being assessed in areas affected by Main Stream Flooding and 0.3 m for development being assessed in areas affected by Major Overland Flow.

- **Measure 4** - Council should take advantage of the information on flooding presented in this report, including the flood mapping, to inform occupiers of the floodplain of the flood risk. This could be achieved through the preparation of a *Flood Information Brochure* which could be prepared by Council with the assistance of NSW SES containing both general and site specific data and distributed with rate notices.
- **Measure 5** involves the update of the flood models that were relied upon for the purpose of preparing the *Lithgow FRMS&P 2023* to include details of recently constructed subdivision type development. This measure also includes the updating of the associated flood mapping.
- **Measure 6** – Council should prepare a stormwater and flood risk management strategy for the future release areas within the Marrangaroo Creek catchment. The strategy would determine the scope of measures which would be required to mitigate the impact that future development would otherwise have on both the quality and quantity of stormwater runoff, as well as determine the land-take requirements for the construction of such measures.

In addition to the above measures, *Lithgow FRMP 2023* includes the following three additional "non-structural" type measures which would require Government Funding:

- **Measure 7** involves the investigation and design of an integrated flood warning system for Lithgow which would include the installation of a network of pluviographic rain gauges, along with a series of telemetered stream gauges. An automated alarm and public announcement system should be linked to the telemetered stream gauges warning residents and business owners that a key trigger level(s) has been reached and to monitor and take action where required. Other improvements include the installation of warning signs and self-deploying boom gates on low level creek crossings.
- **Measure 8** involves the implementation of the abovementioned integrated flood warning system for Lithgow.
- **Measure 9** involves the commissioning of a *Voluntary Purchase and House Raising Feasibility Study* for a maximum of 30 residential properties that are located in a High Hazard Floodway area (which depending on their date of construction) are potentially eligible for inclusion in the NSW Government's *Voluntary Purchase Scheme*) and a maximum of nine dwellings that are of weatherboard type construction and also located in hazardous flood storage area (which again depending on their date of construction) are eligible for inclusion in the NSW Government's *Voluntary House Raising Scheme*. Although subject to confirmation of the date of construction, agreement by the affected owners and the timing of the implementation of **Measure 15**, this measure includes the estimated cost of purchasing the 30 properties and raising the floor levels of the nine existing dwellings.

Lithgow FRMP 2023 includes the investigation and design of the following flood modification type measures that would also require Government Funding:

- **Measure 10** comprises an investigation to assess the feasibility of constructing the George Coates Street Drainage Improvement Works and the preparation of concept design documentation, while **Measure 11** comprises its detailed design and construction.
- **Measure 12** comprises an investigation to assess the feasibility of constructing the Lithgow High School Detention Basin and the preparation of concept design documentation, while **Measure 13** comprises its detailed design and construction.

- **Measure 14** comprises an investigation to assess the feasibility of constructing the e Farmers Creek Channel Works – Stages 3, 4, 5 and 6 and the preparation of concept design documentation, while **Measure 15** comprises its detailed design and construction.
- **Measure 16** comprises the preparation and implementation of a *Vegetation Management Pla*n for Farmers Creek and its major tributaries.
- **Measure 17** comprises the review and update of a previous investigation into the existing sewerage system at Lithgow using the flooding and drainage information that is set out in this report.

S7 Timing and Funding of FRMP Measures

The total estimated cost to implement *Lithgow FRMP 2023* is a maximum of **$36.80 Million**, exclusive of Council, NSW SES and Bureau of Meteorology staff costs. The timing of the measures will depend on Council's overall budgetary commitments and the availability of both Local and State Government funds.

Assistance for funding qualifying projects included in *Lithgow FRMP 2023* may be available upon application under the Commonwealth and State funded floodplain management programs, currently administered by the NSW Department of Planning and Environment.

S8 Action Plan

1. Council to update *Lithgow LEP 2014* to include the NSW Government's *Special Flood Considerations* clause and also *Lithgow DCP 2021* to incorporate the suggested form of wording set out in **Appendix D** of this report (**Measures 1** and **2** of *Lithgow FRMP 2023*).
2. NSW SES to update the *Lithgow City Local Flood Plan* using information on flooding patterns, peak flood levels, times of rise of floodwaters and flood prone areas identified in this report (**Measure 3** of *Lithgow FRMP 2023*).
3. Council to inform residents of the flood risk, based on the information presented in *Lithgow FRMS 2023* (e.g. displays of flood mapping at Council offices, preparation of *Flood Information Brochure* for distribution with rate notices, etc) (**Measure 4** of *Lithgow FRMP 2023*).
4. Council to commission the update of the flood models and mapping in areas where recent subdivision development has occurred (**Measure 5** of *Lithgow FRMP 2023*).
5. Council to prepare a stormwater and flood risk management strategy for the Marrangaroo Creek catchment prior to the rezoning of land to facilitate future development (**Measure 6** of *Lithgow FRMP 2023*).
6. Council to commission the investigation, design and implementation of an integrated flood warning system for Lithgow (**Measure 7** and **8** of *Lithgow FRMP 2023*).
7. Council to commission the *Voluntary Purchase and House Raising Feasibility Study* (initial phase of **Measure 9** of *Lithgow FRMP 2023*).
8. Council to commission investigations into the feasibility of implementing the George Coates Street Drainage Works, Lithgow High School Detention Basin and Farmers Creek Channel Works – Stages 3, 4, 5 and 6 (**Measures 10** to **15** of *Lithgow FRMP 2023*).
9. Council to develop and implement a *Vegetation Management Plan* for Farmers Creek and its major tributaries (**Measure 16** of *Lithgow FRMP 2023*), as well as commission the review and update of the previous investigation into the operation of the existing sewerage system at Lithgow (**Measure 17** of *Lithgow FRMP 2023*).

TABLE S1
RECOMMENDED MEASURES FOR INCLUSION IN LITHGOW FLOODPLAIN RISK MANAGEMENT PLAN 2023

Measure	Required Funding	Features of the Measure	Benefit Cost Ratio	Priority
1. Update of *Lithgow LEP 2014*	Council's staff costs	➢ A new *special flood considerations* clause should be incorporated in *Lithgow LEP 2014* which applies to land that lies between the FPA and the PMF. The new clause relates to development with particular evacuation or emergency response issues (e.g. group homes, residential aged care facilities, etc). It is also aimed at protecting the operational capacity of emergency response facilities and critical infrastructure during extreme flood events.	-	**High Priority**: this measure is designed to mitigate the flood risk to future development and has a high priority for inclusion in the *Lithgow FRMP 2023*. It does not require Government funding.
2. Incorporate recommended approach to managing future development on flood prone land in *Lithgow DCP 2021*.	(Council's staff costs)	▪ Graded set of flood controls based on the type of development and their location within the floodplain, defined as land inundated by the PMF. ▪ Floodplain divided into five zones based on the assessed flood hazard and hydraulic categorisation. ▪ The minimum floor levels for all land use types is the level of the 1% AEP flood event plus 0.5 m freeboard in the case of areas affected by Main Stream Flooding and plus 0.3 m freeboard in areas affected by Major Overland Flow. ▪ Additional controls applied to development that is located on land which lies above the Flood Planning Level where the large flood range is considered to pose a significant risk to life.	-	**High Priority**: this measure is designed to mitigate the flood risk to future development and has a high priority for inclusion in the *Lithgow FRMP 2023*. It does not require Government funding.
3. Ensure flood data in the *Lithgow FRMS 2023* are available to the NSW SES for improvement of flood emergency planning.	NSW SES costs	➢ NSW SES should update the *Lithgow City Local Flood Plan* using information on flooding patterns, times of rise of floodwaters and flood prone areas identified in this report.	-	**High Priority**: this measure would improve emergency response procedures and has a high priority. It does not require Government funding.
4. Implement flood awareness and education program	Council staff costs	➢ Council to inform residents of the flood risk, based on the information presented in the *Lithgow FRMS 2023*. (e.g. displays of flood mapping at Council offices, preparation of *Flood Information Brochure* for distribution with rate notices, etc).	-	**High Priority**: this measure would improve the flood awareness of the community and has a high priority. It does not require Government funding.
5. Update the flood models to more accurately define the nature of flooding in recently constructed subdivision areas.	$0.10 Million	➢ Commission new LiDAR survey data in areas where new subdivision development has occurred since the development of the flood models. ➢ Update the flood models to incorporate details of the new subdivision development, including the recently constructed stormwater drainage system. ➢ Update the flood mapping that is set out in this report.	-	**High Priority**: this measure would assist in Council in its responsibilities in regards floodplain risk management.
6. Prepare a stormwater and flood risk management strategy for future release areas located in the Marrangaroo Creek catchment.	Council cost	➢ Council to engage a suitably qualified consultant to the prepare a stormwater and flood risk management strategy for future release areas located in the Marrangaroo Creek catchment ➢ The strategy will determine the scope of measures which would be required to mitigate the impact that future development would have on both the quality and quantity of stormwater runoff, as well as determine the land-take requirements for the construction of such measures.	-	**Low Priority**: this measure need only be implemented prior to Council seeking to rezone the land to facilitate future development
7. Investigate and design an integrated flood warning system for Lithgow	$0.07 Million	➢ Liaison with the Bureau of Meteorology to determine whether the flood forecasting and warning system that it is in the process of developing is sufficiently detailed to provide sufficient advance warning to occupiers of the floodplain at Lithgow, noting that the Farmers Creek and Marrangaroo Creek catchments are located in the headwaters of the valley. ➢ If the system that BoM is in the process of developing is deemed unsuitable for Lithgow, then this measure would comprise the development of an integrated flood warning system which is specific to Lithgow. As a minimum, such a system would include: o The installation of a network of telemetered pluviographic rain gauges in combination with a series of telemetered stream gauges would assist BoM and NSW SES in providing more accurate and timely flood warnings for urbanised areas in Lithgow. o The linking of an alarm and public announcement system to the telemetered stream gauges (where applicable) would warn residents and business owners that a key trigger level(s) has been reached and to monitor and take action where required. o The installation of warning signs and self-deploying boom gates at low-level creek crossings would prevent motorists and pedestrians from accessing inundated roads and footpaths.	-	**High Priority**: this measure would reduce flood damages by providing advance warning of potential flooding.
8. Implement integrated flood warning system for Lithgow	$0.50 Million			

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TABLE S1 (Cont'd)
RECOMMENDED MEASURES FOR INCLUSION IN LITHGOW FLOODPLAIN RISK MANAGEMENT PLAN 2023

Measure	Required Funding	Features of the Measure	Benefit Cost Ratio	Priority
9. Commission *Voluntary Purchase and House Raising Feasibility Study* at an estimated cost of $50,000 for a maximum of 30 residential properties that are located in a High Hazard Floodway area and raise a maximum of nine dwellings that are located in High Hazard Flood Storage areas.	$13.43 Million[(1)]	▪ Council to approach the owners of the 30 properties that are located in the High Hazard Floodway area to assess their willingness to participate in the NSW Government's *Voluntary Purchase Scheme*. Upon gaining agreement, Council to seek grant funding from the NSW Government to purchase the relevant properties. ➢ Council to approach the owners of the nine dwellings that are located in hazardous flood storage areas to assess their willingness to participate in the NSW Government's *Voluntary House Raising Scheme*. Upon gaining agreement, Council to seek grant funding from the NSW Government to raise the dwelling to the required level.	0.18 (VP) 0.42 (VHR)	**High Priority**: this measure would reduce flood risk within existing development
10. Investigate and prepare concept design for George Coates Street Drainage Improvement Works	$0.08 Million	➢ Underground utilities search ➢ Geotechnical investigation to assess foundation conditions ➢ Hydraulic modelling to confirm sizes of the key elements of individual elements of the measure ➢ Prepare concept design and cost estimate ➢ Cost-benefit analysis to confirm the economics of the scheme ➢ Prepare a submission for Council and Government funding for detailed design and construction	0.02	**Medium Priority**: this measure would reduce the flood risk in parts of Lithgow
11. Prepare detailed design and construct George Coates Street Drainage Improvement Works	$6.22 Million	➢ Tasks involved are as follows: o Prepare detailed design and documentation o Prepare a submission for Council and Government funding. o Construct drainage improvements.		
12. Investigate and prepare concept design for Lithgow High School Detention Basin	$0.08 Million	➢ Underground utilities search ➢ Geotechnical investigation to assess foundation conditions and basin embankment requirements ➢ Hydraulic modelling to confirm sizes of the key elements of individual elements of the measure ➢ Prepare concept design and cost estimate ➢ Cost-benefit analysis to confirm the economics of the scheme ➢ Prepare a submission for Council and Government funding for detailed design and construction	1.31	**Medium Priority**: this measure would reduce the flood risk in parts of Lithgow
13. Prepare detailed design and construct Lithgow High School Detention Basin	$0.57 Million	➢ Tasks involved are as follows: o Prepare detailed design and documentation o Prepare a submission for Council and Government funding. o Construct drainage improvements.		
14. Investigate and prepare concept design for Farmers Creek Channel Works – Stages 3, 4, 5 and 6	$0.20 Million	➢ Underground utilities search ➢ Geotechnical investigation to assess foundation conditions ➢ Hydraulic modelling to confirm sizes of the key elements of individual elements of the measure ➢ Prepare concept design and cost estimate ➢ Cost-benefit analysis to confirm the economics of the scheme ➢ Prepare a submission for Council and Government funding for detailed design and construction	0.11	**High Priority**: this measure would reduce the flood risk in a significant number of properties that are located adjacent to the main arm of Farmers Creek
15. Prepare detailed design and construct Farmers Creek Channel Works – Stages 3, 4, 5 and 6	$15.0 Million	➢ Tasks involved are as follows: o Prepare detailed design and documentation o Prepare a submission for Council and Government funding. o Construct drainage improvements.		
16. Develop and implement *Vegetation Management Plan* for Farmers Creek and its major tributaries	$0.4 Million	➢ The *Vegetation Management Plan* will identify the reaches of Farmers Creek and its major tributaries which require regular maintenance. It will also describe the scope of any rehabilitation works which would be required following the completion of any inbank works. ➢ The required funding would permit the development of the *Vegetation Management Plan*, the removal of dense vegetation from the inbank area of the watercourse and the implementation of a regular maintenance program over a five year period.	-	**Medium Priority**: this measure would reduce the risk of a blockage being experienced at the various road crossings, as well as reduce the frequency of nuisance flooding.

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TABLE S1 (Cont'd)
RECOMMENDED MEASURES FOR INCLUSION IN LITHGOW FLOODPLAIN RISK MANAGEMENT PLAN 2023

Measure	Required Funding	Features of the Measure	Benefit Cost Ratio	Priority
17. Review and update of investigation into operation of existing sewerage system at Lithgow	$0.15 Million	➢ Review and update previous investigation that was undertaken in about 2008-09 into the existing sewerage system at Lithgow using the flooding and drainage information set out in the *Lithgow FRMS 2023* report.	-	**Low Priority**: while this measure would reduce the social and environmental impacts associated with sewer overflows, it would not reduce the flood risk at Lithgow.
Total Estimated Cost	**$36.80 Million**			

1. The number of affected properties and therefore the cost to implement this measure would reduce by an estimated $2.7 Million if **Measure 15** is implemented in advance.

1 INTRODUCTION

1.1 Study Background

Lithgow City Council (**Council**) commissioned the preparation of a Floodplain Risk Management Study and Plan for the city of Lithgow (***Lithgow FRMS&P 2023***) in accordance with the New South Wales Government's *Flood Prone Land* policy. *Lithgow FRMS&P 2023* represents an update of the *Lithgow Floodplain Management Study and Plan* that was prepared on behalf of Council in 1991.

Figure 1.1 (2 sheets) shows the location of Lithgow, as well as the extent of the catchment contributing to flow in the main creek systems which control runoff in the study area, those being Farmers Creek and Marangaroo Creek. It also shows the extent of the catchment which contributes to flow in the upper reaches of Bowens Creek near the southern limits of the study area.

The *Lithgow Floodplain Risk Management Study (**Lithgow FRMS 2023**)* reviewed baseline flooding conditions, including an assessment of economic impacts and the feasibility of potential measures aimed at reducing the impact of flooding on both existing and future development. The review was based on flood behaviour which was defined using updated versions of the flood models that were originally developed as part of the *Lithgow Flood Study Review* (Lyall & Associates, 2017) (herein referred to as the ***Updated Flood Study***). This process allowed the formulation of a Floodplain Risk Management Plan for Lithgow (***Lithgow FRMP 2023***).

1.2 Background Information

The following documents were used in the preparation of this report.

- *Floodplain Development Manual* (New South Wales Government (NSWG), 2005)
- *Lithgow Local Environmental Plan, 2014* (***Lithgow LEP 2014***)
- *Lithgow Development Control Plan 2021 (**Lithgow DCP 2021**)*
- *Lithgow City Local Flood Plan* (NSW State Emergency Service (**NSW SES**), 2014) (***Lithgow City Local Flood Plan**)*
- *Lithgow Flood Study Report* (Department of Water Resources (**DWR**), 1988)
- *Lithgow Floodplain Management Study* (Kinhill, 1991)
- *An Assessment of Vegetation in the Riparian Zones of Farmers Creek, Lithgow, NSW* (Slaven, 1995)
- *Flood Mitigation Works – Hermitage Flat, Lithgow – Stage 1 Report – Detailed Analysis of Flood Mitigation Options* (Bewsher, 1996)
- *Lithgow Stormwater Management Plan – Draft Final Report* (PPK Environment & Infrastructure, 2000)
- *Flood Mitigation Works – Hermitage Flat, Lithgow – Options Assessment* (Bewsher, 2001)
- *Flood Mitigation Works – Hermitage Flat, Lithgow – Review of Environmental Factors* (Bewsher, 2002)
- *Additional Investigation into Site Contamination – Flood Mitigation Works for Farmers Creek at Hermitage Flat, Lithgow* (Parsons Brinckerhoff (**PB**), 2002)
- *Remedial Action Plan – Flood Mitigation Works Farmers Creek, Lithgow, NSW* (PB, 2003)

- *Flood Mitigation Works – Hermitage Flat, Lithgow – Environmental Documentation and Approvals* (Bewsher, 2003)
- *Preliminary Investigation into Voluntary Purchase and House Raising Schemes for Flood-Affected Areas of Hermitage Flat, Lithgow* (Bewsher, 2004)
- *Famers Creek Flood Mitigation Works – Stage 1 Hydraulic Modelling Report* (PB, 2004)
- *Lithgow Flood Study Review* (Lyall & Associates, 2017)

1.3 Overview of Lithgow FRMS&P 2023 Report

The results of the *Lithgow FRMS 2023* and the *Lithgow FRMP 2023* are set out in this report. Contents of each Chapter of the report are briefly outlined below:

- **Chapter 2**, **Baseline Flooding Conditions**. This Chapter includes a description of the existing drainage system at Lithgow, as well as the nature of flood behaviour in the study area based on the findings of the *Updated Flood Study*. The Chapter also summarises the economic impacts of flooding on existing urban development, reviews Council's flood planning controls and management measures and NSW SESs flood emergency planning.
- **Chapter 3**, **Potential Floodplain Management Measures**. This Chapter reviews the feasibility of floodplain management measures for their possible inclusion in *Lithgow FRMP 2023*. The list of measures considered is based on input from the Community Consultation process, which sought the views of residents and business owners in the study area in regard to potential flood management measures which could be included in *Lithgow FRMP 2023*. The measures are investigated at the strategic level of detail, including indicative cost estimates of the most promising measures and benefit/cost analysis.
- **Chapter 4**, **Selection of Floodplain Management Measures**. This Chapter assesses the feasibility of potential floodplain management strategies using a multi-objective scoring procedure which was developed in consultation with the Floodplain Risk Management Committee and outlines the preferred strategy.
- **Chapter 5, Lithgow Floodplain Risk Management Plan 2023** presents *Lithgow FRMP 2023* for Lithgow which comprises a number of structural and non-structural measures which are aimed at increasing the flood awareness of the community and ensuring that future development is undertaken in accordance with the local flood risk.
- **Chapter 6** contains a glossary of terms used in the study.
- **Chapter 7** contains a list of References.

Five technical appendices provide further information on the study results:

Appendix A – Community Consultation and Historic Flooding summarises residents' and business owners' views on potential flood management measures which could be incorporated in *Lithgow FRMP 2023*. It also contains a number of photos showing historic flooding at Lithgow.

Appendix B – Hydrologic and Hydraulic Modelling Update deals with the update of the hydrologic and hydraulic models that were developed as part of Lyall & Associates, 2017 based on the procedures set out in ARR 2019. Appendix B also sets out the findings of an investigation which was undertaken to assess the difference between design peak flows derived using the procedures set out in the 1987 and 2016 editions of Australian Rainfall and Runoff.

Appendix C – **Flood Damages** is an assessment of the economic impacts of flooding to existing residential, commercial and industrial development, as well as public buildings at Lithgow. The damages have been assessed using the results of the updated flood modelling, as well as surveyed and estimated floor levels, the latter which were derived from a combination of a "drive-by" property survey, as well as data from LiDAR survey.

Appendix D – **Suggested Wording for Inclusion in Lithgow Development Control Plan** presents guidelines for the control of future urban development in flood prone areas in the Lithgow local government area. The guidelines cater for both Main Stream Flooding of the river and creek systems, as well as Major Overland Flow resulting from surcharging of the trunk drainage systems in the overland flow paths draining the developed parts of Lithgow.

1.4 Community Consultation

Following the Inception Meeting of the Floodplain Risk Management Committee, a *Community Newsletter* was prepared by the Consultants and distributed to residents and business owners by Council. A *Community Questionnaire* was also distributed by Council seeking details from residents and business owners regarding their attitudes toward potential floodplain management measures. Community responses are summarised in **Chapter 3** of this report, with supporting information in **Appendix A**. The views of the community on potential flood management measures to be considered in the study were also taken into account in the assessment presented in **Chapter 3** of this report.

The draft *Lithgow FRMS&P 2023* report was placed on public exhibition for a period of 42 days commencing on 17 March 2023. Council wrote to all residents and business owners who were affected by flooding up to the PMF. A total of 2,839 letters were sent, with property-specific letters sent to those identified for voluntary purchase and house raising.

As part of the public exhibition process, Council hosted a flood information session with the Consultant presenting the draft study and plan to the community at the Maldhan Ngurr Ngurra Transformation Hub on 28 March 2023. The event was attended by over 120 residents who raised concerns regarding their individual properties being identified as Flood Prone Land. Due to the level of community interest, Council sought the services of the Consultant to be part of a two-day consultation session of which members of the community would book in 15-minute sessions. Members of the public were also able to contact Council throughout the exhibition period to ask questions. These enquiries could be raised either by using the enquiry form on Council's website, directly calling Council, or in person at Council's Administration Building. A total of fifty enquiry submissions were received from the website, with over 100 requests by phone and in-person.

At the end of the public exhibition period, 48 formal submissions had been made to Council. The main concerns raised in the submissions were:

- Impact to insurance/rates/house prices
- Notification/identification of flood affectation
- Maintenance of Council stormwater assets (particularly Marrangaroo Fields)
- Vegetation along Farmers Creek – Tree removal and weeds
- Impact from PMF

- Ground truthing of data, particularly in areas where significant amounts of new development has taken place i.e., South Bowenfels
- Implications to 10.7 Planning Certificates for properties identified with slithers of flood affectation
- Application of the House Raising/Purchasing scheme

Responses to the 48 submissions were prepared by both Council and the Consultant.

1.5 Flood Frequency and Terminology

In this report, the frequency of floods is referred to in terms of their Annual Exceedance Probability (**AEP**). The frequency of floods may also be referred to in terms of their Average Recurrence Interval (**ARI**). The approximate correspondence between these two systems is:

Annual Exceedance Probability (AEP) – %	Average Recurrence Interval (ARI) – years
0.2	500
0.5	200
1	100
2	50
5	20
10	10
20	5

The AEP of a flood represents the percentage chance of its being equalled or exceeded in any one year. Thus a 1% AEP flood, which is equivalent to a 100 year ARI, has a 1% chance of being equalled or exceeded in any one year and would be experienced, on the average, once in 100 years; similarly, a 20 year ARI flood has a 5% chance of exceedance, and so on.

The 1% AEP flood (plus freeboard) is usually used to define the Flood Planning Level and Flood Planning Area for the application of flood related controls over residential and commercial/industrial development. While a 1% AEP flood is a major flood event, it does not define the upper limit of possible flooding. Over the course of a human lifetime of, say 70 years, there is a 50 per cent chance that a flood at least as big as a 1% AEP event will be experienced. Accordingly, a knowledge of flooding patterns in the event of larger flood events up to the Probable Maximum Flood (**PMF**), the largest flood that could reasonably be expected to occur, is required for land use and emergency management planning purposes. In the *Updated Flood Study*, flooding patterns in the study area have been assessed for design floods ranging between 20% AEP event and the PMF.

2 BASELINE FLOODING CONDITIONS

2.1 Physical Setting

The Lithgow Local Government Area (**LGA**) has a population of about 20,000 and is located 140 km west of Sydney on the Great Western Highway. The study area lies in the upper reaches of the Hawkesbury-Nepean Valley and is drained by Farmers Creek, Marangaroo Creek and Bowens Creek. **Figure 1.1** shows the extent of the catchments which comprise the study area, while **Figure 2.1** shows the general layout of the existing drainage system at Lithgow.

Existing residential development at Lithgow is mainly located on the eastern side of the Great Western Highway in the Farmers Creek catchment, while commercial development is concentrated along the Main Western Railway between the Great Western Highway and Chifley Road on its southern side and Union Street and James Street on its northern side. Light industrial type development is concentrated on both sides of the Vale of Clwydd near its confluence with Farmers Creek and also on the southern side of Farmers Creek in the following three areas:

- immediately upstream of the Lithgow State Mine Railway line;
- along Donald Street between Inch Street and Union Street;
- downstream of the Tony Luchetti Sports Centre; and
- south of Farmers Creek and the Main Western Railway in the suburb for Littleton.

2.2 Drainage System

2.2.1 Farmers Creek

Figure 1.1 shows the extent of the catchment which contributes to flow in Farmers Creek at the location of the Mount Walker stream gauge. The headwaters of the Farmers Creek catchment are located about 7 km east of Lithgow in the Newnes State Forest. The catchment is characterised by a mixture of heavily wooded areas on the steeper slopes and cleared pastoral land on the milder, more undulating western draining slopes of the Great Dividing Range. The urbanised parts of Lithgow are located at the base of the steeper heavily wooded slopes, extending onto the floodplain of Farmers Creek and its major tributaries.

Farmers Creek runs in a westerly direction through the urbanised parts of Lithgow with various tributaries contributing flows to the system from the north and south. Ida Falls Creek, Vale of Clwydd Creek, Good Luck Hollow and two unnamed tributary (herein referred to as **Sheedys Gully Tributary** and **South Bowenfels Tributary**) join Farmers Creek from the south, while Oakey Park Creek, State Mine Creek and another unnamed tributary (herein referred to as **McKellars Park Tributary**) join from the north.

Farmers Creek continues to flow in a westerly direction downstream of Lithgow where it discharges into Lake Lyell on the Coxs River. The Coxs River forms parts of the Hawkesbury-Nepean River system and is one of the major sources of inflows to Warragamba Dam.

In the 1930s the Department of Public Works (**PWD**) undertook major stream improvement works along Farmers Creek in response to severe flooding that occurred in 1928 which broke through the roof of the Cobar Colliery (DWR, 1988). The invert of the creek was concrete lined and realigned over a distance of about 2.5 km, extending from a location 260 m downstream of Tank Street to the Geordie Street low level causeway.

Figure 2.1, sheet 2 shows the extent of channel which was concrete lined, as well as the location where the colliery roof collapsed. The initial 250 m length of concrete lined channel ranges between 11 - 15 m in width and is up to 2.5 m deep. This section of channel formed the repair over the collapsed section of colliery roof. The remaining 2.25 km length of concrete lined channel ranges between 4.8 - 6.1 m in width and is up to 1.4 m deep.

In addition to the lining of the channel, the floodplain of Farmers Creek has been modified over time by the importing of fill to construct railway embankments, sporting fields and residential development.

Channel works along a 1040 m length of Farmers Creek in the vicinity of Hermitage Flat aimed at reducing the impact of flooding on properties located in this area were identified in Bewsher, 2001. The first stage of the channel works, which involved enlarging of the waterway along a 350 m reach of Farmers Creek, was split into two works packages (denoted **Stage 1A** and **1B**) by Council. Construction of the Stage 1A and 1B, works were completed in 2006 and 2008, respectively. Construction of the Stage 2 works, which involved enlarging of the waterway under the Albert Street Bridge and along a 340 m reach of Farmers Creek was completed in 2015. There are currently no plans to constructed stages 3 and 4 of channel works.[2]

A stormwater drainage system comprising a pit and pipe network controls runoff from the urbanised parts of Lithgow, the layout of which is shown on **Figure 2.1** (4 sheets). The stormwater drainage system at Lithgow can be characterised as follows:

- **Northern side of Farmers Creek** - Runoff from the urbanised areas Oakey Park, Morts Estate, State Mine Gully, Cobar Park, McKellars Park and Hermitage Flat are controlled by a series of stormwater drainage lines that discharge into semi-natural reaches of channel that flow into Farmers Creek. Major tributaries on the northern side of Farmers Creek include Oakey Park Creek, State Mine Creek and McKellars Park Tributary.
- **Southern side of Farmers Creek east of the Great Western Highway** - Runoff from the urbanised areas of Corney Town, Vale of Clwydd, Lithgow, Pottery Estate and Littleton is controlled by a series of stormwater drainage lines that run in a northerly direction and discharge into Farmers Creek. The Main Western Railway bisects this area in an east-west direction and has an impact on local drainage patterns. Major tributaries on the southern side of Farmers Creek include Ida Falls Creek, Vale of Clwydd and Sheedys Gully Tributary.
- **Southern side of Farmers Creek west of the Great Western Highway** - Runoff from the urbanised areas in Bowenfels, South Littleton and South Bowenfels are controlled by a series of stormwater drainage lines that run in either a westerly or northerly direction to their point of discharge into Farmers Creek. A number of small stormwater detention basins have also been built in this area as part of several recent residential subdivision developments, further details of which are provided in **Section 2.5** of this report. Good Luck Hollow and South Bowenfels Tributary are the major tributaries west of the Great Western Highway

2.2.2 Marangaroo Creek

Similar to the Farmers Creek catchment, the Marrangaroo Creek catchment comprises a mixture of heavily wooded areas in its steeper upper reaches and cleared pastoral land in its flatter middle reaches. While the network of channels in the middle reaches of the catchment have generally been cleared for farming purposes, a riparian corridor has been maintained along the main arm of the creek.

[2] The impacts that Stages 3 and 4 will have on flood behaviour will be assessed as part of the present study.

Both the Main Western Railway and Great Western Highway run in a north-south direction through the catchment and cross the main arm of the creek via multiple span bridge structures (refer **Figure 2.1**, sheet 4 for location). The catchment area of Marrangaroo Creek at the Great Western Highway is about 48 km^2. Reserve Road, which runs to the east of the Great Western Highway, is the only other formal road crossing of the channel system in the catchment.

Marrangaroo Creek flows generally in a south-westerly direction downstream of the road and rail bridges where it runs through a steep heavily wooded area before joining the Coxs River. The catchment area of Marrangaroo Creek at its confluence with the Coxs River is about 54 km^2.

Runoff from a residential subdivision which is located on the western side of the Main Western Railway in the southern portion of the catchment drains across the rail corridor and the Great Western Highway via a series of piped transverse drainage structures (refer **Figure 2.1**, sheet 4 for location). Runoff from the residential subdivision contributes to flow in the main arm of the creek at the aforementioned road and rail bridges. The Lithgow Correctional Centre is located on the eastern (upstream) side of the highway and rail corridors on the northern overbank area of the creek (refer **Figure 2.1**, sheet 4 for location).

2.3 Flood History

There have been seven storm events that are known to have caused major flooding in Lithgow. These occurred in February 1928, June 1963, June 1964, March 1978, August 1986 and February 1990. **Table 2.2** is taken from Kinhill, 1991 and gives a brief summary of the storms that occurred prior to the February 1990 event, while **Table 2.3** over the page provides a comparison of the maximum water levels that have been recorded by WaterNSW's *Farmers Creek at Mount Walker* stream gauge (GS 212042) (**Mount Walker stream gauge**) which was first established in August 1980 when a telemetered stream gauge was installed on the left bank of Farmers Creek about 7.4 km (by river) downstream of the Great Western Highway with peak design floods levels derived as part of the *Updated Flood Study*.

TABLE 2.2
SUMMARY OF MAJOR STORM EVENTS
PRE- FEBRUARY 1990 STORM

Date	Description
February 1928	*This was the first severe flood in Lithgow and caused widespread damage. The flood broke through the roof of the Cobar Colliery in the vicinity of Sandford Avenue. One person was killed.*
June 1963	*Roads were cut*
June 1964	*Roads were cut. Again flood water broke through the roof of the Cobar Colliery in the vicinity of Sandford Avenue*
March 1978	*This approximately 7% AEP flood event was used as a calibration for the DWR, 1988 report. It caused widespread damage to cars, houses and roads, and caused landslides. Health risks rose through the overflow of sewers.*
August 1986	*This 10-20% AEP flood event was not as extensive as the March 1978 event. However, it caused widespread damage and one person was killed. This flood was used as a calibration event for the DWR report.*

Reproduced from Table 2.1 of Kinhill, 1991.

TABLE 2.3
FLOOD HISTORY AND DESIGN FLOOD LEVELS[1,2]
FARMERS CREEK AT MOUNT WALKER (GS 212042)

Flood Event	Height on Mount Walker Stream Gauge (m)
PMF Event	10.53
0.2% AEP	3.64
0.5% AEP	3.44
1% AEP	3.26
2% AEP	2.87
5% AEP	2.55
January 2011	2.50
February 2013	2.44
10% AEP	2.37
February 1981	2.35
August 1986	2.31
September 2016	2.3
August 1998	2.14
February 1990	2.13
20% AEP	2.09
December 2018	2.00
April 2015	1.87
January 2019	1.84

1. Design peak flood levels derived using a HEC-RAS model of Farmers Creek in the vicinity of the Mount Walker stream gauge that was developed as part of the present study.
2. Gauge zero on Mount Walker gauge is to an assumed datum. A gauge zero of RL 808.1 m AHD has been estimated from the available LiDAR survey data and the WaterNSW gauge cross section.

The March 1978 event produced the highest flood levels of the historic storm events, followed by February 1990 and August 1986 events. At the Mount Walker stream gauge, the peak level recorded in the August 1986 event (2.31 m) was higher than the February 1990 event (2.04 m), indicating that heavy rain probably fell in the lower reaches of the catchment which resulted in the higher gauge reading.

A number of storm events that have caused localised flooding in parts of Lithgow were also identified as part of the *Flood Study*. These occurred in 1981, 1985, 1996, 1997, 2004, and more recently in January 2011 and February 2013. While only anecdotal evidence is available on the extent and depth that property was inundated during these storm events, flooding in the Vale of Clwydd area during the two most recent storm events is reported to have been a result of surcharge of the local stormwater drainage system.

2.4 Design Flood Behaviour

2.4.1 Background to Previous Studies

Design flood behaviour in the Farmers Creek catchment was first assessed in 1988 as part of the *Lithgow Flood Study Report* (DWR, 1988). The study included the development of a hydrologic (RAFTS) and hydraulic (HEC-2) model of the reach of Farmers Creek which runs between Oakey Park and Good Luck Hollow and the lower reaches of State Mine Creek. Peak flows and flood levels were derived for a design storm event with an average exceedance probability (**AEP**) of 1 per cent based on the procedures set out in a draft version of the 1987 edition of *Australian Rainfall & Runoff* (**ARR 1987**).

DWR, 1988 was reviewed and updated as part of the *Lithgow Floodplain Management Study* in 1991 (Kinhill, 1991). The hydrologic (RAFTS) model developed as part of DWR, 1988 was updated to incorporate the design rainfalls and temporal patterns from the final edition of ARR 1987, while the hydraulic (HEC-2) model developed as part of the same study was updated to incorporate the Great Western Highway road bridges. Peak flows and flood levels were derived for a design storm events ranging between 20% and 1% AEP.

The definition of flood behaviour in the Farmers Creek catchment was again updated in 2017 as part of the *Lithgow Flood Study Review* (Lyall & Associates, 2017) (***Flood Study Review***). Design flood behaviour in the Marangaroo Creek catchment was also defined as part of the *Flood Study Review*.

Hydrologic (DRAINS) and two-dimensional in plan hydraulic (TUFLOW) models were developed as part of the *Flood Study Review* and used to define contemporary flood behaviour in both the Farmers Creek and Marangaroo Creek catchments for design storms with AEPs of 20%, 10%, 2%, 1% and 0.5%, as well as the PMF. While design flows for storms up to 0.5% AEP in intensity were derived based on procedures set out in ARR 1987, those for the PMF were derived based on procedures that are set out in the 2003 update of BoM, 1994 (BoM, 2003).

2.4.2 Background to Development of Updated Flood Models

The hydrologic and hydraulic models that were developed as part of the *Flood Study Review* were updated as part of the present study using the procedures set out in ARR 2019. The structure of the models was also updated to incorporate any upgrades to the stormwater drainage system that have occurred since the adoption of the *Flood Study*.

The updated flood models were used to define the nature of flooding in Lithgow for design storms of between 20% and 0.2% AEP, as well as the PMF event. **Appendix B** of this report sets out the details of the hydrologic and hydraulic modelling that was undertaken as part of the present study.

2.4.3 Design Flooding Patterns

Figures 2.2 and **2.3** show the nature of flooding at Lithgow for the 1% AEP and PMF events, respectively, while **Figures B4.1** to **B4.6** in **Appendix B** show similar information for the 20%, 10%, 5%, 2%, 0.5% and 0.2% AEP flood events. These figures show the indicative extent and depth of inundation along Farmers Creek, Marangaroo Creek and their associated tributaries, as well as along the major overland flow paths for the assessed design flood events. Also shown on

these figures are Peak Flow Locations (**PFLs**) which are referred in the following discussion. Peak flows for the assessed design flood events at each PFL are tabulated in **Table B1** in **Attachment B4** of **Appendix B**, while **Table B2** in **Attachment B5** of **Appendix B** contains information in relation to the inundation of existing road and pedestrian crossings at Lithgow.

Figure 2.4 shows design water surface profiles along Farmers Creek and its major tributaries, as well as for the main arm of Marrangaroo Creek, while **Table 2.3** sets out the design peak flood levels at the Mount Walker stream gauge. **Figure 2.5** shows the time of rise of floodwater at key locations throughout the study area, including at several major road crossings.
The key features of flooding along Farmers Creek and its tributaries are as follows:

- Flooding is generally confined to the inbank area of Farmers Creek and its major tributaries where they run through the urbanised parts of Lithgow in a 10% AEP storm event. However, floodwater surcharges the banks of Farmers Creek in a 20% AEP event at the following locations:
    - on the right (northern) bank of Farmers Creek in the vicinity of its confluence with the Lithgow Valley Gully (refer PFL Q14 on sheet 1 of series);
    - along a 300 m length of Macaulay Street on the upstream (eastern) side of its intersection with Tank Street (refer PDL Q07 on sheet 3). Macaulay Street is inundated to a depth of up to 650 mm in a 20% AEP event;
    - along Coalbrook Street in Hermitage Flat, where floodwater surcharges the right (northern) bank of Farmers Creek and inundates the rear of several residential properties that back onto Farmers Creek[3] (refer sheet 3) to depths of inundation generally less than 300 mm in a 20% AEP event;
    - Along Lockyer Street, Bowenfels where floodwater is shown to extend into the rear of several residential properties that are located a short distance downstream of the Great Western Highway bridge crossing of Farmers Creek. The depths of inundation in these properties exceed 1 m at the 20% AEP event;
    - on Sheedys Gully Tributary immediately south (upstream) of the Main Western Railway (refer PFL Q35 on sheet 2) where floodwater that surcharges the enclosed reach of the tributary between Queen Elizabeth Park and Farmers Creek ponds on the southern side of the railway, before flowing overland through the Young Street underpass beneath the railway.
- The number of properties affected by floodwater increases significantly at the 2% AEP level of flooding. Locations where both residential and commercial properties are affected the greatest include:
    - on the right (northern) bank of Farmers Creek upstream of the Brewery Lane crossing (refer PFL Q02 on sheet 1) where residential allotments are inundated to a maximum depth of 400 mm;
    - on the right (northern) bank of Farmers Creek between Mills Street and Victoria Street (refer PFLs Q03 and Q04, respectively on sheet 1) where the depth of inundation in residential properties is a maximum of 600 mm;

[3] Note that several of the affected properties are located along the reach of channel which was recently upgraded by LCC as part of the Stage 1A, 1B and 2 channel improvement works (refer **Figure 2.2**, Sheet 2 for extent of the works).

- on the right (northern) bank of Farmers Creek in the vicinity of Atkinson Street (refer PFL Q06 on sheet 1) where depths of inundation in several residential properties exceed 1 m;
- on both banks of Farmers Creek in the vicinity of its confluence with State Mine Creek (refer PFL Q26 on sheet 1) where maximum depths of inundation in several commercial properties range between 600 mm and 1.3 m;
- on the left (southern) bank of Farmers Creek upstream of the Tank Street bridge crossing (refer PFL Q07 on sheet 2) where the depth of inundation exceeds 1 m in several residential allotments;
- on the right (northern) bank of Farmers Creek along Sandford Avenue immediately downstream (west) of Tank Street, where depths of inundation in two residential allotments exceed 700 mm;
- on the right (northern) bank of Farmers Creek in the Hermitage Flat area, where depths of flow in a large number of residential properties exceed 600 mm;
- on the right (northern) bank of Farmers Creek opposite the Jim Monaghan Athletics Track (refer PFL Q10 on sheet 2) where depths of inundation in existing residential and commercial development exceeds 1 m;
- on the left (western) bank of Vale of Clwydd Creek upstream of the Chifley Road culverts (refer PFL Q21 on sheet 1) where the maximum depth of inundation in a commercial property exceeds 400 mm;
- on the reach of Vale of Clwydd Creek that is located between Lake Pillans Wetlands and Inch Street (north of PFL Q22 on sheet 1) where floodwater surcharges the wetlands and flows in northerly direction through existing residential development to depth of up to 500 mm;
- on the left (eastern) bank of McKellars Park Tributary approximately 150-170 m upstream of the Sandford Avenue culverts (refer PFL Q31 on sheet 2) where maximum depths of inundation in the rear of several residential properties exceed 600 mm; and

- A number of additional properties are affected by main stream flooding at the 1% AEP level of flooding. These are principally located along Farmers Creek at the following locations:
  - in the vicinity of Mills Street and Hay Street (refer PFL Q03 on sheet 1);
  - on the upstream side of the Atkinson Street bridge crossing (refer PFL Q06 on sheet 1);
  - on the upstream side of the Tank Street bridge crossing (refer PFL Q07 on sheet 2); and
  - in the Hermitage Flat area (refer PFL Q09 on sheet 2).
- While the number of properties affected by floods of between 1% and 0.2% AEP does not increase significantly (refer **Section 2.12** for further discussion), there is a significant increase in the footprint of land which is affected by the PMF. The reason for this is that the upper envelope of flooding generally lies between 3-5 m above peak flood levels generated by floods of up to 0.2% AEP (refer comparison of design water surface profiles shown on **Figure 2.4**).

- **Table B2** in **Attachment B5** of **Appendix B** shows that the road crossings will generally remain flood free for flood events up to about 2% AEP, with the following exceptions:
    - The Mills Street and Geordie Street causeways on Farmers Creek, both of which will be inundated during freshes in the creek system.
    - The Victoria Avenue crossing of Farmers Creek is overtopped in a 10% AEP storm event, which will result in the isolation of the residents of Oakey Park.
    - The Atkinson Street and Tank Street crossings of Farmers Creek are overtopped during a 5% AEP storm event.
    - The Chifley Road crossing of Vale of Clywdd Creek is overtopped during a 5% AEP storm event.
    - The State Mine Gully Road crossing of State Mine Creek will also be overtopped during a 2% AEP storm event, isolating the residents of Morts Estate.

The key features of flooding along Marangaroo Creek and its tributaries are as follows:

- Main stream flooding within the Marrangaroo Creek catchment is generally confined to undeveloped areas, with the following two notable exceptions:
    - Within the Lithgow Correctional Centre, parts of which are shown to be inundated by floodwater at the 5% AEP level of flooding (refer PFL Q51 on sheet 4 of series). It is noted that the access road into the Centre has a hydrologic standard of greater than 1% AEP (refer **Figure 6.4**, **Sheet 4**). It is further noted that the Centre is located wholly on the floodplain of Marrangaroo Creek in an area where the depth of inundation will exceed 2 m during a PMF event.
    - In the vicinity of two rural residential properties which are located on the northern (downstream) side of Reserve Road along one of the tributary arms of Marrangaroo Creek (refer watercourse along which Peak Flow Identifier Q61 is located). While the watercourse meanders through these properties, a continuous overland flow path is shown to develop on its western (left) overbank at about the 2% AEP level of flooding. It is noted that depths of flow along this continuous flow path generally do not exceed 300 mm in a 1% AEP storm event.
- **Table B2** in **Attachment B5** of **Appendix B** shows that the Great Western Highway will generally remain flood free for flood events up to about 2% AEP, while Reserve Road will be inundated where it crosses two unnamed tributaries of Marrangaroo Creek during storms as frequent as 10% AEP. It is noted that the inundation of Reserve Road will result in the isolation of several rural residential properties.

The key features of major overland flow in Lithgow are as follows:

- Areas affected by major overland flow within the Farmers Creek catchment are generally confined to the following areas:
    - In the vicinity of Hartley Valley Road, Ramsay Street and Redgate Street in Vale of Clwydd (refer PFL Q19 on sheet 1 in the series). Several residential properties in this area are affected by major overland flow which occurs when the enclosed reach of a tributary arm of Vale of Clwydd Creek is surcharged. Surcharge of the enclosed reach of the drainage system commences in storm events more frequent than 20% AEP.

- Along the line of a stormwater drainage line which runs in a northerly direction from Lithgow High School to the left (southern) bank of Farmers Creek downstream of the Tank Street bridge (refer PFLs Q27 and Q28 on sheets 1 and 2 in the series, respectively). The drainage line surcharges in a 20% AEP storm event as a result of the design blockage factor derived using the procedures set out in ARR, 2019 (refer **Section 2.10** and **Section B3.2** of **Appendix B** for further discussions) and flows in a northerly direction through existing residential development and ponds on the southern side of the Main Western Railway. Major ponding is shown at this location in a 1% AEP storm event, with depths of inundation exceeding 1 m in several residential properties which back onto Gas Works Lane.
- In the upper reaches of the Sheedys Gully Tributary catchment where commercial development is affected by major overland flow which approaches the main arm of the watercourse north of Valley Drive (refer overland flow path east of PFL Q33 on sheet 2).
- Along the line of a stormwater drainage line which crosses the Main Western Railway line at the northern end of Cupro Street (refer PFL Q37 on sheet 2). Major ponding is shown to occur in Main Street and George Coates Street at the 20% AEP storm event. Several residential properties located to the south (upstream) of the Main Western Railway between Academy Street and Laurence Street are also shown to be affected by overland flow at the 10% AEP level of flooding.
- Along several stormwater drainage lines which control runoff in Littleton and South Littleton and cross the Main Western Railway line immediately south of the Jim Monaghan Athletics Track (refer overland flow paths along which PFLs Q39, Q40, Q41, Q42 and Q43 are located on sheet 2). While depths of overland flow along these flow paths are generally less than 300 mm for storms up to 10% AEP, major ponding is shown to occur along the southern (upstream) side of the Main Western Railway line at this level of flooding. At the 1% AEP level of flooding, depths of overland flow exceed 500 mm in several residential properties that are located between Lone Pine Avenue and the railway.
- In the upper reaches of the Good Luck Hollow catchment, where several residential properties located immediately downstream of the Munbinga Drive Detention Basin No. 2 are affected by depths of overland flow of up to 600 mm in a 1% AEP storm event. The detention basin, which has been designed as an offline temporary storage area is surcharged at the 10% AEP level of flooding.
- Along two overland flow paths which run through the developed part of South Bowenfels east (upslope) of the Great Western Highway. Several residential properties are affected by overland flow which commences to surcharge the road reserve along Bursaria Place in a 10% AEP storm event. Major ponding is also shown to occur 20% AEP storm event in two residential properties that are located adjacent on the eastern (upslope) side of the Great Western Highway in the vicinity of its intersection with Col Drewe Drive.

- Several residential properties located to the south of the Lithgow Golf Club in the Marrangaroo Creek catchment are also affected by major overland flow at the 1% AEP storm event. Depths of overland flow generally do not exceed 300 mm in a storm event of this magnitude.

2.5 Existing Flood Mitigation Measures

Figure 2.1 shows the location of seven detention basins that have been constructed by either Council or private developers in the study area, details of which are given in **Table 2.4** over the page. These works generally attempt to minimise hazardous flooding conditions that present a high risk to occupants of the floodplain and reduce the extent and severity of flood-related property damages. They also serve to offset the increase in catchment runoff from large residential subdivisions.

TABLE 2.4
DETAILS OF EXISTING REGIONAL FLOOD DETENTION BASINS AT LITHGOW

Basin ID	Basin Name	Year of Construction	Outlet Structure[2]		Spillway Elevation (m AHD)
			Dimensions (mm)	Invert Level (m AHD)	
B01	Lake Pillans Wetlands	pre-2003[3]	Weir	924.25 (min)	925.65
B02	Lone Pine Avenue Detention Basin	2004	1 off 2700 x 900 RCBC	929.50	932.50
B03	Munbinga Drive Detention Basin No. 1	2006	1 off 1500 RCP	962.00	964.00
B04	Munbinga Drive Detention Basin No. 2	2006	2 off 1350 RCPs	948.30	950.65
B05	Thornton Avenue Detention Basin	2006	1 off 1050 RCP	917.25	920.40
B06	Robina Drive Detention Basin	pre-2003[3]	1 off 900 RCP	947.08	948.40
B07	Sandalwood Drive Detention Basin	2006-2009[3]	Outlet dimensions unknown		949.50

1. RCP = reinforced concrete pipe, RCBC = reinforced concrete box culvert.
2. Refer **Figure 2.2** for location.
3. Exact date of construction unknown.

Council has also implemented the following measures that in part formed *Lithgow FMP 1991* which is set out in Chapter 9 of Kinhill, 1991:

- Detailed assessment of the stormwater drainage system in the city (undertaken as part of Lyall & Associates, 2017).
- Implemented building, development and zoning controls through the development of the *Lithgow Development Control Plan 2021*.
- Enlarging of the waterway along a 690 m reach of Farmers Creek in the vicinity of Hermitage Flat, including the enlarging of the waterway area under the Albert Street Bridge (construction completed in 2015).[4]
- Clearing of inbank vegetation and enlarging of waterway area of a 100 m reach of Farmers Creek in the vicinity of its confluence with State Mine Creek (construction completed in 1998).
- Clearing of inbank vegetation and enlarging of waterway area of a 180 m reach of Farmers Creek immediately downstream of Victoria Avenue (construction completed in 1998).

[4] These works comprised Stage 1 and 2 of the proposed flood mitigation works at Hermitage Flat.

- Construction of the Lake Pillans Wetland detention basin (construction completed prior to 1998).
- Voluntary purchase of nineteen (19) dwellings, the most recent of which was purchased as late as 2014.
- Voluntary house raising of one dwelling.[5]

Further discussion on the full set of measures that comprised *Lithgow FMP 1991* is contained in **Chapter 3** of this report.

2.6 Economic Impacts of Flooding

The economic consequences of floods are discussed in **Appendix C** of this report, which assesses flood damages to residential, commercial/industrial property and public buildings in areas affected by both main stream flooding and major overland flow. There were only limited data provided by respondents to the *Community Questionnaire* on historic flood damages to the urban sectors in the study area. Accordingly, it was necessary to use data on damages experienced as a result of historic flooding in other urban centres. The residential flood damages were based on the publication *Floodplain Risk Management Guideline No. 4, 2007* (**Guideline No. 4**) published by the Department of Environment and Climate Change (**DECC**) (now DPE). Damages to industrial and commercial development, as well as public buildings were evaluated using data from previous floodplain risk management investigations in NSW.

It is to be noted that the principal objectives of the damages assessment were to gauge the severity of urban flooding likely to be experienced at Lithgow and also to provide data to allow the comparative economic benefits of various flood modification measures to be evaluated in **Chapter 3** of the report. As explained in **Appendix C**, it is not the intention to determine the depths of inundation or the damages accruing to *individual properties*, but rather to obtain a reasonable estimate of damages experienced over the extent of the urban area in the town for the various design flood events. The estimation of damages using *Guideline No. 4* (in lieu of site specific data determined by a loss adjustor) also allows a uniform approach to be adopted by Government when assessing the relative merits of measures competing for financial assistance in flood prone centres in NSW.

The floor levels of individual dwellings/buildings were derived from Kinhill, 1991 where available, else they were assessed by adding the height of floor above a representative natural surface within the allotment (as estimated by visual inspection) to the natural surface elevation determined from LiDAR survey. The type of structure and potential for property damage were also assessed during the visual inspection. If a property was not accessible to undertake a visual inspection, the height of the floor was assumed to be 300 mm above the adjacent natural surface level.

The number of properties that are predicted to be flood affected (floodwater on the allotment) and "above-floor" inundated in the Farmers Creek and Marrangaroo Creek catchments for floods ranging between 20% AEP and the PMF is set out in **Tables 2.5** and **2.6**, respectively. Also set out in the two tables are the total flood damages that would be experienced in the two catchments. **Figures 2.2** and **2.3** shows the indicative depth of above-floor inundation that would be experienced in individual properties during 1% AEP and PMF events, respectively. **Figures B4.1**, **B4.2**, **B4.3**, **B4.4**, **B4.5** and **B4.6** in **Appendix B** shows similar results for the 20%, 10%, 5%, 2%, 0.5% and 0.2% AEP storm events.

[5] Based on visual inspection in Google Street View.

Within the Farmers Creek catchment, 265 dwellings, 48 commercial/industrial type buildings and one public building would be subjected to above-floor inundation at the 1% AEP level of flooding, resulting in total flood damages of $41.4 Million. During a PMF event, 1,486 dwellings, 143 commercial/industrial type buildings and one public building would experience above-floor inundation, resulting in total flood damages of $296 Million.

Flood damages within the Farmers Creek catchment are generally concentrated in ten geographical locations (denoted herein as “damage centres”), the location and extent of which are shown in **Figures 2.2** and **2.3**, as well as **Figures B4.1 to B4.6** in **Appendix B**. **Table 2.7** sets out the total flood damages for floods ranging between 20% AEP and the PMF, while **Table 2.8** sets out the *Present Worth Value* of flood damages at the 1% AEP level of flooding based on a discount rate of 7% and an economic life of 50 years in the ten damage centres. It is noted that one or more schemes costing up to the amounts set out in **Table 2.8** could be economically justified if they eliminated damages in the individual damage centres for all floods up to 1% AEP in magnitude.

While flood damages are greatest in the Hermitage Flat Damage Centre at the 1% AEP level of flooding, the *Present Worth Value* of damages is the second lowest of the ten damage centres. This is because significant flood damages do not commence to occur until about the 2% AEP level of flooding. Conversely, while the Vale of Clywdd Damage Centre has the fifth highest flood damages at the 1% AEP level of flooding, it has the greatest *Present Worth Value* of damages given that significant flood damages are incurred during more frequent flood events.

Within the Marrangaroo Creek catchment, two dwellings and one public building would be subjected to above-floor inundation at the 1% AEP level of flooding, resulting in total flood damages of $0.46 Million. During a PMF event, 33 dwellings, three commercial/industrial type buildings and two public building would experience above-floor inundation, resulting in total flood damages of $20.1 Million. The *Present Worth Value* of flood damages in the Marrangaroo Creek catchment at the 1% AEP level of flooding based on a discount rate of 7% and an economic life of 50 years is about $0.4 Million.

TABLE 2.5
FLOOD DAMAGES
FARMERS CREEK CATCHMENT

Design Flood Event (% AEP)	Residential			Commercial/Industrial			Public			Total Damage ($ Million)
	Number of Properties		Damage ($Million)	Number of Properties		Damage ($Million)	Number of Properties		Damage ($Million)	
	Flood Affected	Flood Above Floor Level		Flood Affected	Flood Above Floor Level		Flood Affected	Flood Above Floor Level		
20	162	33	5.31	26	23	1.24	1	0	0.02	6.57
10	225	49	7.59	32	27	1.62	2	0	0.04	9.25
5	319	89	12.2	41	36	3.92	3	0	0.06	16.2
2	498	165	21.3	48	43	5.82	3	0	0.06	27.2
1	648	265	32.9	52	48	8.39	4	1	0.1	41.4
0.5	739	332	40.7	64	54	9.85	5	1	0.14	50.7
0.2	835	399	48.7	69	58	12.2	6	3	0.23	61.1
PMF	1,932	1,486	216	149	143	74.6	16	10	5.83	296

TABLE 2.6
FLOOD DAMAGES
MARRANGAROO CREEK CATCHMENT

Design Flood Event (% AEP)	Residential			Commercial/Industrial			Public			Total Damage ($ Million)
	Number of Properties		Damage ($Million)	Number of Properties		Damage ($Million)	Number of Properties		Damage ($Million)	
	Flood Affected	Flood Above Floor Level		Flood Affected	Flood Above Floor Level		Flood Affected	Flood Above Floor Level		
20	1	0	0.02	0	0	0	0	0	0	0.02
10	4	0	0.08	0	0	0	1	0	0.02	0.10
5	7	1	0.18	0	0	0	1	1	0.04	0.22
2	10	1	0.24	0	0	0	1	1	0.06	0.30
1	11	2	0.36	0	0	0	1	1	0.10	0.46
0.5	14	5	0.51	0	0	0	1	1	0.12	0.63
0.2	17	6	0.66	1	0	0.02	1	1	0.16	0.84
PMF	52	33	4.42	3	3	0.62	2	2	15.1	20.1

TABLE 2.7
FLOOD DAMAGES IN INDIVIDUAL DAMAGE CENTRES
$ MILLION

Design Flood Event (%AEP)	Damage Centre									
	Oakey Park	Morts Estate	Tank Street	Hermitage Flat	Vale of Clwydd	Gas Works Lane	Lithgow CBD	Sheedys Gully	Cupro Street	Enfield Avenue
20	0.08	0.32	0.02	0.09	0.79	0.53	0.48	0.21	0.80	0.30
10	0.12	0.55	0.08	0.09	1.32	0.70	0.56	0.37	1.14	0.62
5	0.17	1.01	0.59	0.51	2.18	1.09	0.65	2.32	1.61	1.38
2	1.05	2.93	1.10	4.19	2.56	1.49	0.69	2.89	2.08	2.45
1	2.56	5.24	2.38	9.60	2.99	1.89	0.81	3.56	2.38	3.19
0.5	3.38	7.16	3.31	12.6	3.13	2.22	0.91	3.70	2.98	3.55
0.2	4.22	8.73	3.87	14.0	3.19	2.55	0.98	4.45	3.65	4.88
PMF	23.4	71.4	24.4	45.7	6.28	7.50	3.68	16.9	20.0	24.7

TABLE 2.8
PRESENT WORTH VALUE OF DAMAGES AT 1% AEP LEVEL OF FLOODING(1)
$ MILLION

Damage Centre									
Oakey Park	Morts Estate	Tank Street	Hermitage Flat	Vale of Clwydd	Gas Works Lane	Lithgow CBD	Sheedys Gully	Cupro Street	Enfield Avenue
1.0	3.2	1.0	2.3	5.7	3.3	2.5	3.3	5.1	3.2

1. Based on a discount rate of 7% and an economic life of 50 years

2.7 Impact of Flooding on Vulnerable Development and Critical Infrastructure

Figure 2.6 (4 sheets) shows the location of vulnerable development and critical infrastructure relative to the extent of the inundation resulting from the assessed flood events while **Table 2.9** sets out the frequency of floods which would impact this type of development/infrastructure.[6]

Community Assets

The majority of the sewage pumping stations remain flood free in a 1% AEP storm event, with the following exceptions:

- SPS2001 (refer SS2 in **Table 2.9**) in the vicinity of the intersection of Windarra Place and Golf Links Road in Marangaroo is inundated in a 20% AEP event;
- SPS1230 (SS14) and SPS2155 (SS13) in the vicinity of the Geordie Street causeway crossing of Farmers Creek are inundated in a 20% and 5% AEP event, respectively;
- SPS2156 (SS15) on the left bank of Farmers Creek immediately upstream of the Albert Street bridge is inundated in a 5% AEP event;
- SPS2163 (SS25) at the northern end of Fernbrook Close in Marrangaroo is inundated in a 5% AEP event; and
- SPS2152 (SS8) at the northern end of Tweed Road in Bowenfels is inundated in a 2% AEP event.

Several road crossings are also inundated by floodwater during floods that are more frequent than 1% AEP, further details of which are set out in **Section 2.8** below.

Emergency Services

The Lithgow Fire Station (F&R1) and Lithgow PCYC (EC2), the latter which is identified as an evacuation centre in the *Lithgow Valley Local Flood Plan*, are located on land that is impacted by shallow overland flow in a PMF event.

Vulnerable Development

The majority of the vulnerable development is located off the floodplain, with the exception of the Lithgow Aged Care Limited aged care facility (AC4), Jack and Jill Preschool child care facility (CC1), Lithgow Correction Centre and Zig Zag Public School education facility (EF9) that are impacted in a PMF event.

[6] Critical infrastructure has been split into two categories; community assets and emergency services.

TABLE 2.9
IMPACT OF FLOODING ON VULNERABLE DEVELOPMENT AND CRITICAL INFRASTRUCTURE LOCATED IN THE STUDY AREA[(1)]

Type	Development/Structure	Location Identifier[)]	Design Flood Event							
			20% AEP	10% AEP	5%AEP	2% AEP	1% AEP	0.5%	0.2%	PMF
Community Assets	Electrical Substation (Barton Street)	-	NF	NF	NF	NF	NF	NF	NF	NF
	Telephone Exchange (Roy Street)	-	NF	NF	NF	NF	NF	NF	NF	NF
	Major Road Crossing (Farmers Creek – Brewery Lane)	Q02	NF	NF	NF	NF	F	F	F	F
	Major Road Crossing (Farmers Creek - Mills Street)	Q03	F	F	F	F	F	F	F	F
	Major Road Crossing (Farmers Creek - Victoria Avenue)	Q04	NF	F	F	F	F	F	F	F
	Major Road Crossing (Farmers Creek - Atkinson Street)	Q06	NF	NF	F	F	F	F	F	F
	Major Road Crossing (Farmers Creek - Tank Street)	Q07	NF	NF	F	F	F	F	F	F
	Major Road Crossing (Farmers Creek – Sandford Avenue)	Q08	NF	NF	NF	NF	NF	NF	F	F
	Major Road Crossing (Farmers Creek - Albert Street)	Q09	NF	NF	NF	NF	NF	F	F	F
	Major Road Crossing (Farmers Creek - Geordie Street)	Q10	F	F	F	F	F	F	F	F
	Major Road Crossing (Farmers Creek - Great Western Highway)	Q12	NF	NF	NF	NF	NF	NF	NF	F
	Major Road Crossing (Vale Of Clwydd Creek - Chifley Road)	Q21	NF	NF	F	F	F	F	F	F
	Major Road Crossing (State Mine Creek - Laidley Street)	Q26	NF	NF	NF	NF	F	F	F	F
	Major Road Crossing (Marrangaroo Creek - Local Access Road)	Q48	NF	NF	NF	NF	NF	F	F	F
	Major Road Crossing (Marrangaroo Creek - Great Western Highway)	Q52	NF	NF	NF	F	F	F	F	F
	Major Road Crossing (Marrangaroo Creek Tributary - Upstream Reserve Road)	Q61	NF	F	F	F	F	F	F	F
	Major Road Crossing (Marrangaroo Creek Tributary - Reserve Road)	Q67	NF	NF	F	F	F	F	F	F
	Sewerage System (Lithgow Sewage Treatment Plant)	SS1	NF	NF	NF	NF	NF	NF	NF	NF
	Sewerage System (Pumping Station SPS2001)	SS2	F	F	F	F	F	F	F	F
	Sewerage System (Pumping Station SPS174)	SS3	NF	NF	NF	NF	NF	NF	NF	F
	Sewerage System (Pumping Station SPS1214)	SS4	NF	NF	NF	NF	NF	NF	NF	NF
	Sewerage System (Pumping Station SPS1217)	SS5	NF	NF	NF	NF	NF	NF	NF	NF
	Sewerage System (Pumping Station SPS1226)	SS6	NF	NF	NF	NF	NF	NF	NF	F
	Sewerage System (Pumping Station SPS1227)	SS7	NF	NF	NF	NF	NF	NF	NF	F
	Sewerage System (Pumping Station SPS2152)	SS8	NF	NF	NF	F	F	F	F	F
	Sewerage System (Pumping Station SPS2153)	SS9	NF	NF	NF	NF	NF	NF	NF	F
	Sewerage System (Pumping Station SPS2154)	SS10	NF	NF	NF	NF	NF	NF	NF	F
	Sewerage System (Pumping Station SPS1228)	SS11	NF	NF	NF	NF	NF	NF	NF	NF
	Sewerage System (Pumping Station SPS1229)	SS12	NF	NF	NF	NF	NF	NF	NF	NF

Refer over for footnotes to table

TABLE 2.9 (Cont'd)
IMPACT OF FLOODING ON VULNERABLE DEVELOPMENT AND CRITICAL INFRASTRUCTURE LOCATED IN THE STUDY AREA[(1)]

Type	Development/Structure	Location Identifier[)]	Design Flood Event							
			20% AEP	10% AEP	5%AEP	2% AEP	1% AEP	0.5%	0.2%	PMF
Community Assets	Sewerage System (Pumping Station SPS2155)	SS13	NF	NF	F	F	F	F	F	F
	Sewerage System (Pumping Station SPS1230)	SS14	F	F	F	F	F	F	F	F
	Sewerage System (Pumping Station SPS2156)	SS15	NF	NF	F	F	F	F	F	F
	Sewerage System (Pumping Station SPS2157)	SS16	NF	NF	NF	NF	F	F	F	F
	Sewerage System (Pumping Station SPS2158)	SS17	NF	NF	NF	NF	NF	F	F	F
	Sewerage System (Pumping Station SPS2159)	SS18	NF	NF	NF	NF	NF	NF	NF	F
	Sewerage System (Pumping Station SPS2160)	SS19	NF	NF	NF	NF	NF	NF	NF	NF
	Sewerage System (Pumping Station SPS2161)	SS20	NF	NF	NF	NF	NF	NF	NF	NF
	Sewerage System (Pumping Station SPS2162)	SS21	NF	NF	NF	NF	NF	F	F	F
	Sewerage System (Pumping Station SPS1388)	SS22	NF	NF	NF	NF	NF	NF	NF	F
	Sewerage System (Pumping Station SPS1389)	SS23	NF	NF	NF	NF	NF	NF	NF	NF
	Sewerage System (Pumping Station SPS1390)	SS24	NF	NF	NF	NF	NF	NF	NF	F
	Sewerage System (Pumping Station SPS2163)	SS25	NF	NF	F	F	F	F	F	F
	Water Supply (Oakey Park Water Treatment Plant)	WS1	NF	NF	NF	NF	NF	NF	NF	F
	Water Supply (Pumping Station Wp100165)	WS2	NF	NF	NF	NF	NF	NF	NF	NF
	Water Supply (Pumping Station Wp100307)	WS3	NF	NF	NF	NF	NF	NF	NF	NF
	Water Supply (Pumping Station Wp100411)	WS4	NF	NF	NF	NF	NF	NF	NF	F
	Water Supply (Pumping Station Wp102261)	WS5	NF	NF	NF	NF	NF	NF	NF	F
	Water Supply (Pumping Station Wp102262)	WS6	NF	NF	NF	NF	NF	NF	NF	NF
Emergency Services	Ambulance Facility (Lithgow Ambulance Station)	-	NF	NF	NF	NF	NF	NF	NF	NF
	Evacuation Centre (Lithgow PCYC)	EC1	NF	NF	NF	NF	NF	NF	NF	F
	Evacuation Centre (Lithgow Seventh Day Adventist Church Hall)	EC2	NF	NF	NF	NF	NF	NF	NF	NF
	Evacuation Centre (Lithgow & District Workmen's Club)	EC3	NF	NF	NF	NF	NF	NF	NF	NF
	F&R NSW Station (Lithgow Fire Station)	F&R1	NF	NF	NF	NF	NF	NF	NF	F
	F&R NSW Station (Lithgow West Fire Station)	F&R2	NF	NF	NF	NF	NF	NF	NF	NF
	NSW SES Station (Lithgow SES)	SES1	NF	NF	NF	NF	NF	NF	NF	NF
	NSW SES Station (Western Mines Rescue Station)	SES2	NF	NF	NF	NF	NF	NF	NF	NF

Refer over for footnotes to table

TABLE 2.9 (Cont'd)
IMPACT OF FLOODING ON VULNERABLE DEVELOPMENT AND CRITICAL INFRASTRUCTURE LOCATED IN THE STUDY AREA[(1)]

Type	Development/Structure	Location Identifier[)]	Design Flood Event							
			20% AEP	10% AEP	5%AEP	2% AEP	1% AEP	0.5%	0.2%	PMF
Emergency Services	Police Station (Lithgow Police Station)	-	NF	NF	NF	NF	NF	NF	NF	NF
	RFS Station (Marrangaroo RFB)	RFS1	NF	NF	NF	NF	NF	NF	NF	NF
	RFS Station (Lithgow Fire Control Centre)	RFS2	NF	NF	NF	NF	NF	NF	NF	NF
Vulnerable Development	Aged Care Facility (Treeview Estates)	AC1	Located outside of study area							
	Aged Care Facility (Three Tree Lodge)	AC2	NF	NF	NF	NF	NF	NF	NF	NF
	Aged Care Facility (Kirkley Gardens)	AC3	NF	NF	NF	NF	NF	NF	NF	NF
	Aged Care Facility (Lithgow Aged Care Limited)	AC4	NF	NF	NF	NF	NF	NF	NF	F
	Caravan Park (Lithgow Tourist And Van Park)	-	NF	NF	NF	NF	NF	NF	NF	NF
	Child Care Facility (Jack And Jill Preschool)	CC1	NF	NF	NF	NF	NF	NF	NF	F
	Child Care Facility (First Grammer Lithgow)	CC2	NF	NF	NF	NF	NF	NF	NF	NF
	Child Care Facility (Gowrie NSW Lithgow Early Education And Care)	CC3	NF	NF	NF	NF	NF	NF	NF	NF
	Child Care Facility (Gumnut Childcare Centre)	CC4	NF	NF	NF	NF	NF	NF	NF	NF
	Correctional Centre (Lithgow Correctional Centre)	-	NF	NF	NF	NF	NF	NF	NF	F
	Educational Facility (St Patrick'S Catholic Primary School)	EF1	NF	NF	NF	NF	NF	NF	NF	NF
	Educational Facility (La Salle Academy)	EF2	NF	NF	NF	NF	NF	NF	NF	NF
	Educational Facility (Lithgow Public School)	EF3	NF	NF	NF	NF	NF	NF	NF	NF
	Educational Facility (Lithgow High School)	EF4	NF	NF	NF	NF	NF	NF	NF	NF
	Educational Facility (Cooerwull Public School)	EF5	NF	NF	NF	NF	NF	NF	NF	NF
	Educational Facility (Cooerwull Public School)	EF6	NF	NF	NF	NF	NF	NF	NF	NF
	Educational Facility (University Of Western Sydney Lithgow Campus)	EF7	NF	NF	NF	NF	NF	NF	NF	NF
	Educational Facility (Lithgow Tafe College)	EF8	NF	NF	NF	NF	NF	NF	NF	NF
	Educational Facility (Zig Zag Public School)	EF9	NF	NF	NF	NF	NF	NF	NF	F
	Educational Facility (Scots All Saints College Lithgow Campus)	EF10	Located outside of study area							
	Hospital (Lithgow Community Private Hospital)	H1	NF	NF	NF	NF	NF	NF	NF	NF
	Hospital (Lithgow Community Mental Health Centre)	H2	NF	NF	NF	NF	NF	NF	NF	NF

1. Refer **Figure 2.6** (4 sheets) for location of vulnerable development and critical infrastructure.

"NF" = Infrastructure not impacted by flooding.
"F" = Infrastructure impacted by flooding.

2.8 Hydrologic Standard of Existing Road Network

Both major and minor roads in the study area are vulnerable to inundation during flood events as frequent as 20% AEP. Identification of such roads is important to providing knowledge to NSW SES, identifying hazardous areas during floods, and evacuation planning.

Floodwater commences to inundate road crossings at the following locations:

- Brewery Lane crossing of Farmers Creek (refer Q02 in **Table 2.9**) in a 1% AEP storm event, resulting in the isolation of the dwellings that are located on the eastern side of Oakey Park Creek in the suburb of Oakey Park.
- Mills Street (Q03) and Geordie Street (Q10) causeway crossings of Farmers Creek during freshes in the creek.
- Victoria Avenue crossing of Farmers Creek (refer Q04) in a 10% AEP storm event, resulting in the isolation of the dwellings that are located on the western side of Oakey Park Creek in the suburb of Oakey Park.
- The Atkinson Street (Q06) and Tank Street (Q07) crossings of Farmers Creek in a 5% AEP event, resulting in the isolation of the suburb of Morts Estate.
- While the Sandford Avenue (Q08) bridge crossing of Farmers Creek remains flood free in a 0.5% AEP event, the suburbs of Cobar Park and McKellars Park commence to become isolated in a 1% AEP as access to the crossing is cut by floodwater that surcharges the right bank of the creek approximately 200 m upstream of the bridge crossing.
- While the Albert Street (Q09) crossing of Farmers Creek remains flood free in a 1% AEP event, the suburb of Hermitage Flat commences to become isolated as road access to the bridge is cut in a 2% AEP.
- The Chifley Road crossing of Vale of Clwydd (Q21) is inundated in a 5% AEP storm event.
- The Laidley Street crossing of State Mine Creek (Q26) is inundated in a 1% AEP storm event.
- Reserve Road commences to become inundated in a 10% AEP storm event, resulting in the isolation of several rural properties in Marrangaroo.
- The Great Western Highway crossing of Marrangaroo Creek commences to become inundated in a 2% AEP storm event.

2.9 Potential Impacts of a Change in Hydraulic Roughness

An analysis was undertaken to assess the sensitivity of flood behaviour to potential changes in hydraulic roughness. **Figure 2.7** (4 sheets) shows the impact that a 20% increase in the "best estimate" hydraulic roughness values would have on flood behaviour for a 1% AEP flood event.[7]

Peak 1% AEP flood levels along the main arm of Farmers Creek are typically increased in the range 100-200 mm, with increases of up to 300 mm present at several locations. Increases in the range 300 mm to 500 mm are also present in the reach of channel which runs along the northern side of Marjorie Jackson Oval.

[7] The sensitivity analysis was undertaken for the 1% AEP 3 hour storm duration storm burst 9 which was generally found to be critical for deriving design peak flood levels along the main arm of Farmers Creek for unblocked conditions.

Increases in peak 1% AEP flood levels along the tributary arms of Farmers Creek are generally in the range 20-100 mm, with increases in the range 100-200 mm present in isolated locations. Increases in the depth of overland flow in the urbanised parts of Lithgow are typically in the range 10-50 mm.

The typical increase in peak 1% AEP flood levels along the main arm of Marrangaroo Creek is typically in the range 100-200 mm, with increases of up to 300 mm present at several locations. Increases in peak flood levels in the range 10-50 mm are present along the tributary arms.

2.10 Potential Impacts of a Partial Blockage of Hydraulic Structures

The mechanism and geometrical characteristics of blockages in hydraulic structures and piped drainage systems are difficult to quantify due to a lack of recorded data and would no doubt be different for each system and also vary with flood events. Realistic scenarios would be limited to waterway openings becoming partially blocked during a flood event (no quantitative data are available on instances of blockage of the drainage systems which may have occurred during historic flood events).

A blockage assessment at Lithgow was undertaken based on the procedures set out in ARR, 2019. **Section B3.2** of **Appendix B** sets out the methodology and blockage factors that were adopted as part of the present study.

Figure 2.8 (4 sheets) shows the impact that a partial blockage of the hydraulic structures would have on flood behaviour at Lithgow for a 1% AEP storm event, as well as the plan location and magnitude of the adopted blockage factors. The effects of blockage are greatest immediately upstream of the bridge and culvert structures and in several locations results in a redistribution of flood flows across the floodplain. Peak 1% AEP flood levels would increase by up to 500 mm immediately upstream of culvert and bridge crossings on the main creeks and their tributaries, and generally up to 50 mm along the major overland flow paths. Greater increases extent and depth of inundation would also occur in flood storage areas.

At several locations the partial blockage of a culvert or bridge structure results in a minor reduction in the peak flow immediately downstream of its location which in turn results in a reduction in peak flood levels of up to 30 mm.

The *Floodplain Risk Management Guide – Incorporating 2016 Australian Rainfall and Runoff in Studies* (Office of Environment & Heritage, 2019) recommends that in areas where flood behaviour is sensitive to structure blockage, an envelope approach that amalgamates the results of different blockage scenarios should be used to define design flood behaviour. As the flood behaviour along the main creeks and their tributaries is sensitive to structure blockage, the design flood behaviour presented in the present study (refer **Figures 2.2** and **2.3** (not attached) of the Main Report and **Figures B6.1** to **B6.6** of **Appendix B** (not attached)) represents an envelope of the “unblocked” and “partially blocked” conditions.

2.11 Potential Impacts of Future Urbanisation

Future urbanisation has the potential to increase the rate and volume of runoff conveyed by the various watercourses, as well as increase the frequency of surcharge of the local stormwater drainage system. It is also likely to result in changes to the existing drainage system. For example, while existing minor watercourses are likely to be retained and formalised in drainage reserves, piped drainage systems associated with urban subdivisions will result in significant amendments to existing overland flow paths leading to the watercourses.

While there is evidence that Council is requiring developers to incorporate flow control measures such as detention basins in residential subdivisions, infill development at an individual allotment scale has the potential to increase flow in the receiving drainage lines.

Based on the maximum permissible hard stand area set out in the *Lithgow DCP 2021*, a value of 65% was applied to areas zoned *R2 Low Density Residential*, while a value of 80% was applied to areas zoned *R1 General Residential*, *B1 Neighbourhood Centre*, *B2 Local Centre*, *B4 Mixed Use*, *B6 Enterprise Corridor*, *B7 Business Park*, *IN1 General Industrial* and *IN2 Light Industrial*. **Figures 2.9** and **2.10** show the impact that infill development could have on flood behaviour in a 20% and 1% AEP storm event, respectively. Note that the assessment undertaken as part of the present study is of a broad-scale and strategic nature, and that more detailed site specific assessments would need to be undertaken as part of any future development.

Figure 2.9 shows that infill development in the headwaters of the catchments in the vicinity of Sheedys Gully, Littleton, South Littleton and South Bowenfels has the potential to increase peak flood levels in the tributaries of Farmers Creek by between 50 and 200 mm in a 20% AEP storm event, with increases of up to 500 mm present in flood storage areas. Increases in peak flood levels in Farmers Creek are generally in the range 20-100 mm during a storm event of this intensity.

Figure 2.9 also shows that increased development in the Marangaroo Creek catchment has the potential to increase peak flood levels in the tributaries by up to 300 mm in a 20% AEP storm event. The impact of infill development generally has a negligible effect in the urbanised parts of Lithgow in a storm event of this intensity where the contributing catchments are relatively small.

Figure 2.10 shows that infill development would generally have less of an impact on flood behaviour in a 1% AEP storm event, with increases in peak flood levels in the range 20-100 mm along the tributaries of Farmers Creek and Marangaroo Creek, with increases of up to 200 mm present at several locations.

2.12 Potential Impacts of Future Climate Change

DPE recommends that its guideline *Practical Consideration of Climate Change, 2007* be used as the basis for examining climate change in projects undertaken under the State Floodplain Management program and the *FDM, 2005*. The guideline recommends that until more work is completed in relation to the climate change impacts on rainfall intensities, sensitivity analyses should be undertaken based on increases in rainfall intensities ranging between 10 and 30 per cent.

On current projections the increase in rainfalls within the service life of developments or flood management measures is likely to be around 10 per cent, with the higher value of 30 per cent representing an upper limit which may apply near the end of the century. Under present day climatic conditions, increasing the 1% AEP design rainfall intensities by 10 per cent would produce about a 0.5% AEP flood; and increasing those rainfalls by 30 per cent would produce about a 0.2% AEP event.

For the purpose of the present study, the impact 10% and 30% increases in design 1% AEP rainfall intensities would have on flooding behaviour was assessed by comparing the peak flood levels which were derived from the flood modelling for design events with AEP's of 1, 0.5 and 0.2 per cent.

Figures 2.11 and **2.12** (4 sheets each) show the increase in peak 1% AEP flood levels that would occur if rainfall intensities were to increase by 10% and 30% as a result of future climate change, respectively, while **Figure 2.13** (4 sheets) shows the impact these potential changes would have on the extent of a 1% AEP flood event.

The impact of a potential 10% increase in 1% AEP rainfall intensities on flooding patterns in the study area may be summarised as follows:

- Peak flood levels along the main arm of Farmers Creek would be increased in the range 100-300 mm, while increases of up to about 500 mm are shown to occur along the reach of Farmers Creek which runs around the northern side of Marjorie Jackson Oval.
- Peak flood levels along the tributary arms of Farmers Creek increased in the range 20-100 mm, while increases in the range 10-50 mm occur in the urbanised parts of the Farmers Creek catchments that are subject to Major Overland Flow.
- Peak flood levels along the main arm of Marrangaroo Creek would be increased in the range 50-100 mm, while increases up to 300 mm are shown to occur along the reach of the creek immediately downstream (west) of the Great Western Highway.
- Increases in peak 1% AEP flood levels in the range 10-50 mm would occur along the tributary arms of Marrangaroo Creek.
- Due to the relatively steep sided nature of the floodplain at Lithgow there would be a relatively minor increase in the extent of inundation.

The impact of a potential 30% increase in 1% AEP rainfall intensities on flooding patterns in the study area may be summarised as follows:

- Peak flood levels on the main arm of Farmers Creek would be increased in the range 200-500 mm, while increases of up to about 600 mm are shown to occur upstream of Victoria Avenue in Oakey Park and in the reach of channel adjacent to Marjorie Jackson Oval. Increases of up to 900 mm are shown to occur immediately upstream of the Lithgow State Mine Railway line.
- Peak flood levels along the tributary arms of Farmers Creek would be increased in the range 50-200 mm.
- Increases in peak flood level in the range 20-100 mm are shown to occur in the urbanised parts of the Farmers Creek catchments that are subject to Major Overland Flow, while increases of up to 500 mm are shown to occur in existing flood storage areas.
- Peak flood levels along the main arm of Marrangaroo Creek would be increased in the range 100-300 mm, while increases up to 500 mm are shown to occur along the reach of the creek immediately downstream (west) of the Great Western Highway.
- Increases in peak flood levels in the range 100-300 mm would occur along the tributary arms of Marrangaroo Creek.
- Due to the relatively steep sided nature of the floodplain at Lithgow there would be a relatively minor increase in the extent of inundation.

2.13 Flood Hazard Vulnerability and Hydraulic Categorisation of the Floodplain

2.13.1 General

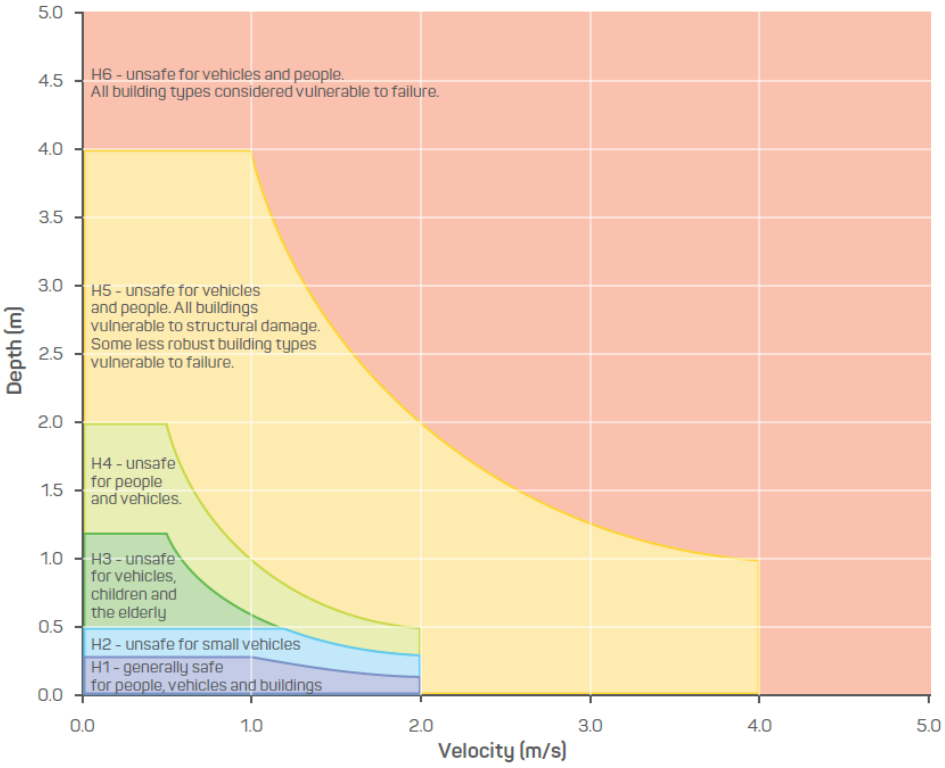
According to Appendix L of *NSWG, 2005*, in order to achieve effective and responsible floodplain risk management, it is necessary to divide the floodplain into areas that reflect:

1. The impact of flooding on existing and future development and people. To examine this impact it is necessary to divide the floodplain into *"flood hazard vulnerability"* categories, which are provisionally assessed on the basis of the velocity and depth of flow. This task was undertaken as part of the present study where the floodplain was divided six flood hazard vulnerability zones. **Section 2.13.2** below provides details of the procedure adopted.
2. The impact of future development activity on flood behaviour. Development in active flow paths (i.e. *"floodways"*) has the potential to adversely re-direct flows towards adjacent properties. Examination of this impact requires the division of flood prone land into various *"hydraulic categories"* to assess those parts which are effective for the conveyance of flow, where development may affect local flooding patterns. Hydraulic categorisation of the floodplain was also undertaken in the *Flood Study* and was reviewed and updated in this present study. **Section 2.13.3** below summarises the procedure adopted.

2.13.2 Flood Hazard Vulnerability Categorisation

Flood hazard categories may be assigned to flood affected areas in accordance with the definitions contained in the publication entitled "*Managing the Floodplain: A Guide to Best Practice in Flood Risk Management in Australia*" (Australian Institute for Disaster Resilience (**AIDR**), 2017). Flood prone areas may be classified into six hazard categories based on the depth of inundation and flow velocity that relate to the vulnerability of the community when interacting with floodwater as shown in the illustration over which has been taken from AIDR, 2017.

Figures 2.14 and **2.15** show the *Flood Hazard Vulnerability Classification* based on the procedures set out in AIDR, 2017 for the 1% AEP and PMF events, respectively.



While areas classified as H5 and H6 are generally limited to the inbank areas of the major watercourses and incised flow paths in a 1% AEP flood event, they do extend out onto the overbank areas of the main arms of Farmers Creek and Marrangaroo Creek at a number of locations.

The flooding that is experienced at the road crossings of the major watercourses that are inundated in a 1% AEP event falls within the H1 category with the following exceptions:

- The Mills Street and Geordie Street causeway crossings of Farmers Creek, where the flow over the road is classified as H6;
- At the following crossings where the flow over the road is classified as H5:
    - The Brewery Lane, Victoria Avenue, Atkinson Street, Tank Street and Cooerwull Street crossings of Farmers Creek;
    - The Chifley Road and Bells Line of Road crossings of the Vale of Clwydd Creek;
    - The Lithgow Street crossing of Sheedys Gully; and
    - The Sandford Avenue crossing of McKellars Park Tributary.
- The Great Western Highway crossing of Marangaroo Creek, where the flow over the road is classified as H4; and
- The Reserve Road crossings of the tributaries of Marangaroo Creek, where the flow over the road is classified as H2.

The Major Overland Flow paths in the urbanised parts of Lithgow are generally classified as either H1 or H2 in a 1% AEP storm event, with the exception of areas where floodwater ponds on the upstream side of roads where it is generally classified as either H3 or H4. There are also several localised areas where the resulting Major Overland Flow is classified as H5:

- Maple Crescent between Boronia Street and Elm Street;
- Crane Road north of its intersection with Sandford Avenue in Cobar Park;
- Bent Street between Lithgow Street and Silcock Street;
- Valley Drive south of its intersection with Kirkland Link;
- James Street between Main Street and Young Street;
- Rabaul Street between Mena Place and Sulva Street;
- Lemnos Street between Beaufort Street and Amiens Street;
- Enfield Avenue between Methven Street and Main Street; and
- Bursaria Place, Claret Ash Avenue and Birch Close in South Bowenfels.

For the PMF event, the width of the H5 and H6 hazard zones increases significantly, mainly along the main arms of Farmers Creek, Marrangaroo Creek and their major tributaries. The hazard category along the majority of the remaining drainage lines increases to between H3 and H5 during a flood of this magnitude.

2.13.3 Hydraulic Categorisation of the Floodplain

According to the *FDM*, the floodplain may be subdivided into the following three hydraulic categories:

- Floodways;
- Flood storage; and
- Flood fringe.

Floodways are those areas of the floodplain where a significant discharge of water occurs during floods. They are often aligned with obvious naturally defined channels. Floodways are the areas that, even if only partially blocked, would cause a significant re-distribution of flow, or a significant increase in flood level which may in turn adversely affect other areas. They are often, but not necessarily, areas with deeper flow or areas where higher velocities occur.

Flood storage areas are those parts of the floodplain that are important for the temporary storage of floodwaters during the passage of a flood. If the capacity of a flood storage area is substantially reduced by, for example, the construction of levees or by landfill, flood levels in nearby areas may rise and the peak discharge downstream may be increased. Substantial reduction of the capacity of a flood storage area can also cause a significant redistribution of flood flows.

Flood fringe is the remaining area of land affected by flooding, after floodway and flood storage areas have been defined. Development in flood fringe areas would not have any significant effect on the pattern of flood flows and/or flood levels.

Floodplain Risk Management Guideline No. 2 Floodway Definition, offers guidance in relation to two alternative procedures for identifying floodways. They are:

- **Approach A**. Using a *qualitative approach* which is based on the judgement of an experienced hydraulic engineer. In assessing whether or not the area under consideration was a floodway, the qualitative approach would need to consider; whether obstruction would divert water to other existing flow paths; or would have a significant impact on upstream flood levels during major flood events; or would adversely re-direct flows towards existing development.
- **Approach B**. Using the hydraulic model, in this case TUFLOW, to define the floodway based on *quantitative experiments* where flows are restricted or the conveyance capacity of the flow path reduced, until there was a significant effect on upstream flood levels and/or a diversion of flows to existing or new flow paths.

One quantitative experimental procedure commonly used is to progressively encroach across either floodplain towards the channel until the designated flood level has increased by a significant amount (for example 0.1 m) above the existing (un-encroached) flood levels. This indicates the limits of the hydraulic floodway since any further encroachment will intrude into that part of the floodplain necessary for the free flow of flood waters – that is, into the floodway.

The *quantitative assessment* associated with **Approach B** is technically difficult to implement. Restricting the flow to achieve the 0.1 m increase in flood levels can result in contradictory results, especially in unsteady flow modelling, with the restriction actually causing reductions in computed levels in some areas due to changes in the distribution of flows along the main drainage line.

Accordingly the *qualitative approach* associated with **Approach A** was adopted, together with consideration of the portion of the floodplain which conveys approximately 80% of the total flow and also the findings of *Howells et al, 2004* who defined the floodway based on velocity of flow and depth. Howells et al suggested the following criteria for defining those areas which operate as a "floodway" in a 1% AEP event:

- Velocity x Depth greater than 0.25 m^2/s **and** Velocity greater than 0.25 m/s in areas subject to Main Stream Flooding, and

  Velocity x Depth greater than 0.15 m^2/s **and** Velocity greater than 0.25 m/s in areas subject to Major Overland Flow; or

- Velocity greater than 1 m/s.

Flood storage areas are identified as those areas which do not operate as floodways in a 1% AEP event but where the depth of inundation exceeds 300 mm. The remainder of the flood affected area was classified as flood fringe.

Figure 2.16 show the division of the floodplain into floodway, flood storage and flood fringe areas for the 1% AEP event.

As the hydraulic capacity of the creeks is not large enough to convey the 1% AEP flow, the overbank area also function as a floodway at a number of locations. Floodways are also generally present along the Major Overland Flow paths described in **Section 2.4.3**.

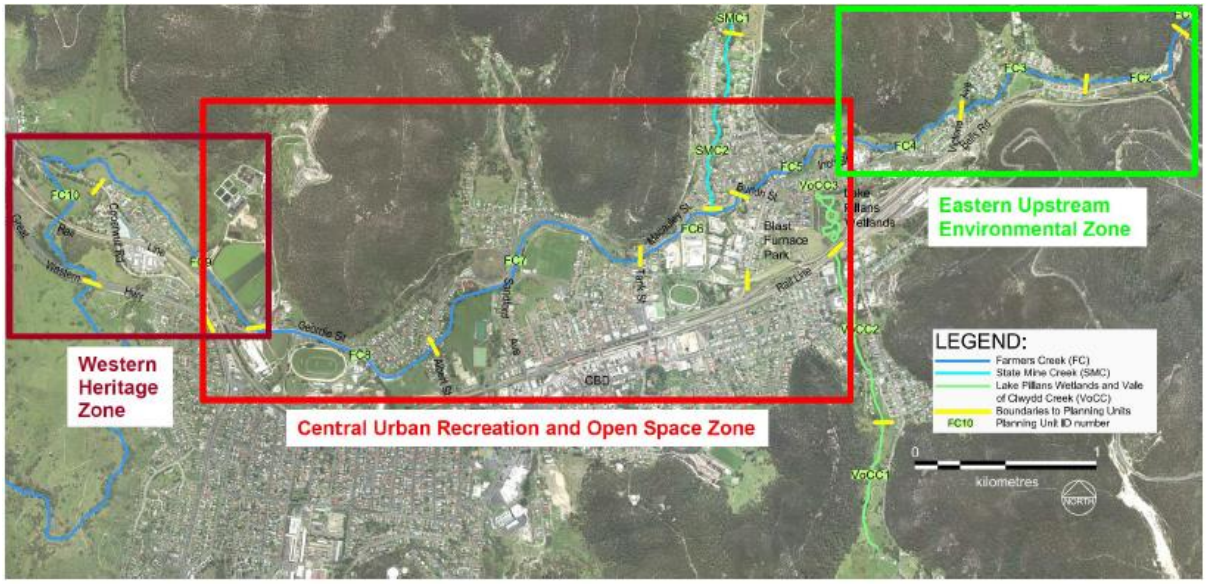
Flood storage areas are present on the overbank area of both Farmers Creek and Marangaroo Creek, as well as in the major ponding areas that are located on the upstream side of existing road and rail embankments.

2.14 Environmental Considerations

2.14.1 Farmers Creek Precinct Masterplan

Council prepared a master plan for Farmers Creek and its major tributaries in August 2017 (**Farmers Creek Precinct Masterplan**) (Gondwana Consulting, 2017). The project area extended from the historic Farmers Creek No. 2 Dam downstream through the Lithgow urban area and associated tributaries, then on to Lake Lyell, as shown in the illustration below which was taken from Gondwana Consulting, 2017.

The Farmers Creek Precinct Masterplan was split up into three zones, as shown in the illustration below which was taken from Gondwana Consulting, 2017.



The stated objectives of the project were as follows:

- Prepare the Farmers Creek Precinct Masterplan, including detailed maps, descriptive sheets, recommendations and priorities – describing the environmental and recreational measures proposed for each "project section" of the creek. The masterplan would be a foundation for, and description of, the recommended strategic framework for future environmental and recreational works along Farmers Creek. Identification of an overarching "inspirational and visionary" future for Farmers Creek that can be endorsed by the community is a key element of the masterplan.
- Identify a connected network of public open space areas along the Farmers Creek Precinct, and show these linkages spatially.
- Identify measures for the improvement of public access and increased recreational use or opportunities (such as walking/cycle paths) and provide better linkages along the main section of Farmers Creek, State Mine Creek, Vale of Clwyd Creek, Lake Pillans Wetlands and Blast Furnace Park.
- Identify locations with the potential to be visitor nodes and provide educational opportunities for the built and natural environment. Identify measures to provide for the protection and management of the historic and cultural "icons" and historic fabric of Farmers Creek.
- Identify key areas for revegetation to improve biodiversity values – including in-stream habitat values – and measures to protect, enhance and restore remnant vegetation and biodiversity values in the catchment (including identifying stream reaches not under Council management but likely to impact upon the management of urban waterways).
- Identify measures to enhance the existing Lake Pillans Wetlands, and assess opportunities for additional aquatic habitat.
- Identify opportunities for water sensitive urban design and improvements in water quality in Farmers Creek – including stormwater drain treatment, litter management, and water quality enhancements.

- Identify soft engineering options for flood mitigation, such as wetlands, where consistent with the *Flood Study Review*.
- Develop a framework for the future management of open space and recreational facilities, and the reduction in costs associated with the ongoing maintenance of public reserves.

It is understood that Council has commenced the implementation of the Farmers Creek Precinct Masterplan, which has involved the installation of new shared pathways, as well as several new pedestrian bridge crossings of Farmers Creek and its tributaries.

2.14.2 Sewerage System Overflows

During the FRMC meeting that was held on 28 June 2022, concerns were raised about the overloading and surcharge of the sewerage system at Lithgow during wet weather events and its social and environmental impacts. Surcharge of the existing sewerage system is said to be associated with the deterioration of the existing system, as well as stormwater inflows. Flooding at some sewage pumping stations may also be the reason for the overloading and surcharge of the existing sewerage system at Lithgow.

While it is noted that Council undertook a study in about 2008-09 on the management of its sewerage system with funding support from Sydney Catchment Authority (now Water NSW), there is scope to update the findings of the earlier report using the information contained in this report.

2.15 Council's Existing Planning Instruments and Policies

2.15.1 General

The *Lithgow Local Environmental Plan, 2014* (***Lithgow LEP 2014***) is the principal statutory planning document used by Council for controlling development by defining zoning provisions, establishing permissibility of land use and regulating the extent of development in the Lithgow City LGA.

The *Lithgow Development Control Plan 2021* (***Lithgow DCP 2021***) supplements *the Lithgow LEP 2014* by providing general information and detailed guidelines and controls which relate to the decision making process.

2.15.2 Land Use Zoning – Lithgow Local Environmental Plan 2014

Figure 2.17 (2 sheets) shows the zonings that are incorporated in *Lithgow LEP 2014* for the study area. The study area comprises a mixture of business (B1, B2, B4, B6 and B7), environmental (E1, E3 and E4), industrial (IN1 and IN2), residential (R1, R2 and R5), public recreation (RE1 and RE2) and rural (RU1, RU2 and RU5) based zonings.

2.15.3 Flood Provisions – Lithgow LEP 2014

Clause 5.21 of *Lithgow LEP 2014* entitled "*Flood planning*" outlines its objectives in regard to development of land that is located within the extent of the FPA. Clause 5.21 was inserted into *Lithgow LEP 2014* by the NSW Government on 14 July 2021 and replaced clause 7.2 which was repealed at the time. Unlike the wording in repealed clause 7.2, the FPL is not defined in Clause 5.21.

Clause 5.21 states that development consent must not be granted unless the consent authority is satisfied that the development:

(a) is compatible with the flood function and behaviour on the land, and

(b) will not adversely affect flood behaviour in a way that results in detrimental increases in the potential flood affectation of other development or properties, and

(c) will not adversely affect the safe occupation and efficient evacuation of people or exceed the capacity of existing evacuation routes for the surrounding area in the event of a flood, and

(d) incorporates appropriate measures to manage risk to life in the event of a flood, and

(e) will not adversely affect the environment or cause avoidable erosion, siltation, destruction of riparian vegetation or a reduction in the stability of river banks or watercourses.

It also states that in deciding whether to grant development consent on land to which this clause applies, the consent authority must consider the following matters:

(a) the impact of the development on projected changes to flood behaviour as a result of climate change,

(b) the intended design and scale of buildings resulting from the development,

(c) whether the development incorporates measures to minimise the risk to life and ensure the safe evacuation of people in the event of a flood,

(d) the potential to modify, relocate or remove buildings resulting from development if the surrounding area is impacted by flooding or coastal erosion.

While the heading of clause 5.22 entitled "*Special flood considerations"* was inserted in *Lithgow LEP 2014* by the NSW Government on 14 July 2021, Council is awaiting the outcomes of the present study prior to making a decision on its possible adoption. It is noted that the new clause forms part of the updated *NSW Flood Prone Land Package* and has the following objectives:

- in relation to development with particular evacuation or emergency response issues (e.g. schools, group homes, residential care facilities, hospitals, etc.) to enable evacuation of land which lies above the FPL; and
- to protect the operational capacity of emergency response facilities and critical infrastructure during extreme flood events.

The new clause would apply to land that lies outside the FPA but within the extent of the PMF. The form of wording that would comprise Clause 5.22 is set out in **Section 3.5.1.4**.

2.15.4 Flood Related Development Controls

Section 3.5 of *Lithgow DCP 2021* entitled "*Flood Prone Land*" sets out the controls that apply to development of land to which the now repealed clause 7.2 of Lithgow LEP 2014 applied.[8] The stated objectives of the chapter are:

[8] Clause 7.2 stated that the requirements of the clause related to land that is located at or below the FPL, which was denoted therein as the 1% AEP flood level plus 0.5 m freeboard.

O1. To promote awareness of potential flood risks associated with the use and development of land (including mapping of flood risk) and inform the community of Council's flood policy

O2. To manage flood risk through appropriate development controls for development at or below the relevant Flood Planning Level (FPL)

O3. To avoid detrimentally increasing the potential flood affectation on other development or adjacent properties by significantly modifying flood characteristics

O4. To avoid unduly sterilising land where flood compatible uses are appropriate and a design response can minimise flood impacts

O5. To ensure construction methods and materials on flood liable land are compatible with flooding and flood conveyance

O6. To ensure new development does not impose significant additional burdens on, or risk to, State Emergency Services (SES) or other emergency personnel during flood emergencies.

Section 3.8 of *Lithgow DCP 2021* entitled "*Appendices: Flood Maps*" contains a set of figures which are taken from the *Updated Flood Study* showing the provision flood hazard for the 1% AEP flood event, as well as the interim FPA for main stream flooding and major overland flow affected areas at Lithgow.

The key controls on new development that is proposed on land that lies at or below the FPL are set out as follows:

Development at or below the Flood Planning Level (FPL)

1) *All development that is at or below the Flood Planning Level (FPL) requires the consent of Council.*
2) *All developments shall be assessed in accordance with the latest edition of the NSW Floodplain Development Manual (as amended by the NSW Government).*
3) *Development is prohibited unless Council is satisfied that it will not increase* ***the flood hazard*** *rating or likely flood damage to any other property.*

Development within High Hazard Flood Areas

1) *No alteration in ground levels will be permitted, whether by excavation (cut) or filling, without the submission of a* ***Flood Study*** *and prior development consent.*
2) *The carrying out of any work or the erection of any structure, including fence, on land in the* ***High Hazard Flood Area*** *will only be permitted if the land is outside the* ***Floodway****, subject to low velocities, and is supported by a* ***Flood Impact Assessment (FIA)*** *showing that the works will have no adverse flooding affects* [sic] *on any other property.*

Development within Low Hazard Flood Areas

1) ***Low Hazard – Floodway****: No alteration in ground levels, whether by excavation or filling, will be permitted without the submission of a* ***Flood Study*** *and prior development consent. Neither the carrying out of any work, nor the erection of any structure, including fences, will be permitted in Low Hazard Floodway areas.*

2) ***Low Hazard – Flood Storage and Flood Fringe****: Development consent is required to be obtained prior to any activity, work or building being carried out within the* ***Flood Planning Area (FPL)*** *and a* ***Flood Study*** *may be required.*

3) ***Subdivision****: Subdivision for the purpose of new* ***residential accommodation or tourist and visitor accommodation*** *or other flood-sensitive development must demonstrate that every lot created or resulting from the subdivision is capable of providing a suitable building envelope (for dwellings a minimum of 200m2) and access to a public road that is above the Flood Planning Level (FPL).*

4) ***New Development – Non-Residential****: Where the proposed floor level of any building is below the FPL, there must be suitable area(s) available for the permanent or temporary storage of hazardous materials and valuable goods above the FPL and this area must be a minimum of 20% of the gross floor area of the building.*

5) ***Existing Development – Non-Residential****: Alterations and additions to existing non-residential buildings may be constructed at the same floor level as the existing building subject to compliance with the DCP Section Construction Requirements & Flood Proofing to the FPL.*

6) ***New Development – Residential****: New dwellings must have a floor level located at or above the FPL.*

7) ***Existing Development – Residential****: Alterations and additions to existing residential buildings that have an existing floor level below the FPL will be determined by Council on the application's merits, having regard to the following matters:*

   a) *Where the existing floor level is below the 1% AEP flood level, any extension at the same floor level is limited to 20% of the existing habitable floor area or 50% if it is built at or above the 1% AEP flood level;*

   b) *The extension is to be flood proofed to the FPL.*

8) ***Carports and Open Sheds****: Carports and open sheds below the* ***FPL*** *are constructed from* ***flood compatible materials*** *under DCP Section Construction Requirements & Flood Proofing and may be constructed at existing floor levels.*

9) ***Change of Use****: A change of use occurs when an approved use of a building is changed from one use to another use. Some flexibility is provided for commercial/industrial changes of use to facilitate re-use of existing buildings.*

   a) *If a change of use is from a commercial/ industrial/ other use to a residential use (or use with a residential component) then the requirements for residential accommodation apply.*

   b) *If a change of use is from a non-residential use to another non-residential use then:*

      i) *If there is no modification to the building footprint required as part of the change of use, existing floor levels need not be changed;*

      ii) *Otherwise, the requirements for non-residential uses (including alterations and additions) apply.*

Recommendations relating to the update of the approach set out in *Lithgow DCP 2021* are set out in **Section 3.5.1.4**, while **Appendix D** of this report contains suggested wording for incorporation into the document.

2.16 Flood Warning and Flood Preparedness

The NSW SES is nominated as the principal combat and response agency for flood emergencies in NSW. NSW SES is responsible for the issuing of relevant warnings (in collaboration with BoM), as well as ensuring that the community is aware of the flood threat and how to mitigate its impact.

The *Lithgow City Local Flood Plan* which is dated September 2014 published by NSW SES covers preparedness measures, the conduct of response operations and the coordination of immediate recovery measures for all levels of flooding within the Lithgow City local government area. *Lithgow City Local Flood Plan* is administered by the Lithgow Local Commander[9] who controls flood operations within the Lithgow City area. NSW SES maintains a local headquarters at No. 3 Silcock Street, Lithgow.

Volume 1 of *Lithgow City Local Flood Plan* entitled '*Lithgow City Flood Emergency Sub Plan*' includes sections on flood preparedness, response and recovery. Volume 1 follows the standard NSW SES template and is divided into the following sections:

- ***Introduction****;* this section of the document identifies the responsibilities of the NSW SES Local Commander and NSW SES members and supporting services such as the Police, BoM, Ambulance, Fire Brigades, Council, etc. It also identifies the importance for NSW SES and Council to coordinate the development and implementation of a public education program to advise the population of the flood risk.
- ***Preparedness****;* this section of the document deals with activities required to ensure the *Lithgow City Local Flood Plan* functions during the occurrence of the flood emergency. The Plan will devote considerable attention to flood alert and emergency response.
- ***Response***; The NSW SES maintains an operation centre at the Local NSW SES Headquarters at No. 3 Silcock Street. Response operations will commence: on receipt of a BoM Preliminary Flood Warning, Flood Warning, Flood Watch, Severe Thunderstorm Warning or a Severe Weather Warning for flash flooding; on receipt of a dam failure alert; or when other evidence leads to an expectation of flooding within the council area.
- ***Recovery****,* involving measures to ensure the long term welfare for people who have been evacuated, recovery operations to restore services and clean up and de-briefing of emergency management personnel to review the effectiveness of the *Lithgow City Local Flood Plan.*

Annex A of the *Lithgow City Local Flood Plan* deals with the flood threat in the Lithgow area. The document states that one of the defining characteristics of flooding within the Lithgow City area is the speed with which floods rise and fall, with little warning apart from the rain which causes the flood events. While background information is provided on five dams that are present in the Lithgow City area, none are located in the study area.

[9] It is noted that the *Lithgow City Local Flood Plan* refers to the "Lithgow Local Controller" who has now been given the title "Lithgow Local Commander".

The table over is an extract from Annex A of the *Lithgow City Local Flood Plan* which sets out the impact that flooding on Farmers Creek has had on existing development and infrastructure in the Lithgow City area.

It is noted that there appears to be a formatting issue with the data that is given for the August 1986 and February 1990 flood events, whereby the ARI and AEP of the events is given in date format. For example, the "5-Oct" should read "5-10" for 5 year ARI, "Oct-20" should read "10-20" for 20% AEP and "1-Feb" should read "1-2" for 1-2 year ARI.

Month, Year	***Average Recurrence Interval (years)***	***Annual Exceedence Probability (%)***	***Impacts***
Feb-28	*Not known*		*Very severe, widespread damage; water broke through colliery roof.*
Jun-63	*Not known*		*Roads cut.*
Jun-64	*Not known*		*Roads cut; water broke through colliery roof.*
Mar-78	*14*	*7*	*Caused landslides, extensive damage to cars, houses and roads.*
Feb-81	*Not known, but possibly similar to Feb 1990 event.*		
Oct-83	*Not known*		*Hail and torrential rain – local drainage problems caused widespread damage to cars, houses, businesses, and roads. Farmers Creek rose 2 metres in 30 minutes.*
*Aug 1986**	*5-Oct* [sic]	*Oct-20* [sic]	*Heavy rain, snow and ice. Houses/businesses inundated from Farmers Creek and local drainage problems. Widespread damage.*
Feb-90	*1-Feb* [sic]	*50-90*	*Heavy rain – 36mm falling in 35 mins. About 50 houses/businesses suffered flood damage from Farmers Creek and local drainage problems.*
April, 1990	*Not Known*		*Heavy rain and hail. Houses/businesses inundated from Farmers Creek and local drainage problems. Road closures. Landslips.*
Aug-90	*Not Known*		*Heavy rain and hail – 112mm falling in 24 hour period. Houses/businesses inundated from Farmers Creek and local drainage problems. Road closures. Landslips. Glen Davis, Wolgan Valley, Kanimbla Valley isolated.*
Jan-06	*Not Known*		*Heavy rain – 63mm < 1 hour. Less than 10 houses/ businesses threatened or inundated from Farmers Creek and local drainage problems.*
Jan-08	*Not known*		*Heavy rain – 50mm < 1 hour. Less than 10 houses/ businesses threatened or inundated from Farmers Creek and local drainage problems. Heavy rain and hail. Less than 10 houses/businesses threatened or inundated from Farmers Creek and local drainage problems.*
	Not known		*Very severe, widespread damage; water broke through colliery roof.*

Annex B of the *Lithgow City Local Flood Plan* deals with the effects of flooding on the local community. The document identifies the following number of properties in Lithgow that are impacted by floods of varying AEP:

Design Flood Event	Number of Properties Impacted by Flooding	
	Residential	Industrial/Commercial
1 EY	48	1
50% AEP	87	1
20% AEP	121	4
5% AEP	170	9
1% AEP	233	12

The document states that some 700 people would need to be evacuated from their homes in a 1% AEP flood event. The document also identifies the following areas in the Farmers Creek valley where existing development is most at risk:

*"**Oakley Park**: this is the uppermost urbanised section of Farmers Creek, and channel capacity is lower here than in downstream areas. More than 40 properties could experience over-floor flooding in the area upstream of the junction of Farmers and Vale of Clwydd creeks in a 1% flood event. The number affected in lesser events in much lower, only about 10 dwellings being inundated beyond floor level in a 20% (once-in-five-years) event.*

Properties likely to experience flooding of yards or buildings in a 1% flood are located in Bells Rd, Island Pde, Bragg, Brisbane, Mills, Hay and Brooks street and Victoria Ave. Part of the site of the Zig Zag Public School would also be inundated.

***Vale of Clwydd Creek**: three properties (one residential and two commercial) in the area upstream of Chifley Rd can be flooded in a 1% event. Chifley Road (the Bells Line of Road) can be closed between Hartley Valley Road and Clwydd Street.*

***Morts Estate**: more than 80 properties, including several premises, could experience over-floor inundation in this area in a 1% event. About 30 of these would be flooded in a 20 % flood.*

Properties likely to experience inundation of yards or buildings in a 1% event are located in Willes, Laidley, Atkinson, Guy, Macaulay and Montague streets and Sandford Ave on the north side of Farmers Creek and Inch, Burton, Union, Tank and Gay streets on the south side. More than half of the properties are to the north of the creek.

***Hermitage Flat**: this is the area of Lithgow which has suffered most severely from flooding in the past. About 40% of the town's flood-liable properties are located here, more than 100 properties being likely to experience flooding beyond floor level in a 1% event. Two thirds of these are flooded in a 50% (once-in-two-years) flood.*

The affected properties are located in Sandford Ave and Coalbrook, Stephenson, Wear, Geordie and Davey streets to the north of Farmers Creek. The Tank Street, Sandford Avenue and Alvert Street bridges are liable to closure.

***Bowenfels**: two dwellings to the south of Farmers Creek in Cooerwul Rd (the old Great Western Highway) could experience over-floor inundation.*

***South Bowenfels**: the channel here is relatively large and incised, but a low-lying, flat portion of Lockyer St and Tweed Rd could be inundated in a 1% event. About 10 properties would be affected but none are expected to experience over-floor flooding in such a flood. The Cooerwall Road Bridge could be affected."*

3 POTENTIAL FLOOD RISK MANAGEMENT MEASURES

3.1 Range of Available Measures

A variety of measures can be implemented which are aimed at reducing the impact that flooding currently has on the Lithgow community. They may be divided into three categories, as follows:

Flood modification measures change the behaviour of floods in regard to discharges and water surface levels to reduce flood risk. This can be done by the construction of levees, detention basins, channel improvements and upgrades of piped drainage systems in urban areas. Such measures are also known as "structural" measures as they involve the construction of engineering works. Vegetation management is also classified as a flood modification measure.

Property modification measures reduce risk to properties through appropriate land use zoning, specifying minimum floor levels for new developments, voluntary purchase of residential property in high hazard and/or floodway areas, or raising existing residences in the less hazardous areas. Such measures are largely planning (i.e. "non-structural") measures, as they are aimed at ensuring that the use of floodplains and the design of buildings are consistent with flood risk. Property modification measures could comprise a mix of structural and non-structural methods of damage minimisation to individual properties.

Response modification measures change the response of flood affected communities to the flood risk by increasing flood awareness, implementation of flood warning and broadcast systems and the development of emergency response plans for property evacuation. These measures are entirely non-structural.

3.2 Lithgow Floodplain Management Plan 1991

Lithgow FMP 1991 included a range of measures for further consideration, including voluntary purchase of flood prone properties, large-scale channel works, levees, general channel clearing and maintenance, flood storage areas, flood warning and the implementation of a flood evacuation plan.

Table 3.1 sets out the range of measures that comprised *Lithgow FMP 1991*, as well as a brief description of when and to what extent they have been implemented by Council. Further details of the scope of flood mitigation measures that have been implemented by Council are set out in **Section 2.5** of this report

3.3 Contemporaneous Community Views

Comments on potential flood risk management measures were sought from the community by way of the *Community Questionnaire* which was distributed at the commencement of the present study. The responses are summarised in **Appendix A** of this report. Question 8 in the *Community Questionnaire* sort the community's view on a range of potential flood management measures, the responses to which are set out in **Table 3.2**.

TABLE 3.1
MEASURES COMPRISING LITHGOW FMP 1991 AND THEIR IMPLEMENTATION STATUS

Area	Structural Floodplain Management Measures [Taken from Table 9.1(a) of Lithgow Floodplain Management Plan 1991]									Non-Structural Floodplain Management Measures [Taken from Table 9.1(b) of Lithgow Floodplain Management Plan 1991]			
	Levees	**Channel Improvement Works**	**Flood Storage Works**	**Detention Basins**	**Channel Clearing and Maintenance**	**Temporary Levees (Sandbagging)**	**Diversion of Flows into Mines**	**Assessment of City Drainage**	**Other**	**Voluntary Purchase Scheme**	**House Raising and Individual Flood Proofing**	**Building, Development and Zoning Controls**	**Flood Warning and Public Education**
City-wide management options for floodplain areas of Lithgow					Recommended as high priority measure in localised areas	Recommended only as localised emergency measure		Detailed study recommended as high priority measure ***[Undertaken as part of Lithgow Flood Study Review (Lyall & Associates, 2017)]***				Recommended as high priority and long term measure ***[Incorporated into Lithgow DCP 2021]***	Formulation and implementation of Lithgow flood evacuation plan. Recommended as high priority measure. ***[Preparation of Lithgow Local Flood Plan]***
South Bowenfels	Lockyer Street levee Cost: $20,000 BCR: 0.7 to 1.1 Recommended as low priority/long term measure				Recommended as high priority measure in localised areas	Recommended only as localised emergency measure		High priority measure in localised areas ***[Undertaken as part of Lithgow Flood Study Review (Lyall & Associates, 2017)]***			Individual flood proofing may be suitable to some individual properties.	Address future development on both sides on creek. Ensure all future development is compatible with designated flood hazard. High priority and long term measure. ***[Incorporated into Lithgow DCP 2021]***	Public awareness of flooding required. High priority measure
Bowenfels Area		Large scale works will be necessary for development of right hand floodplain			Recommended as high priority measure in localised areas	Recommended only as localised emergency measure		High priority measure in localised areas ***[Undertaken as part of Lithgow Flood Study Review (Lyall & Associates, 2017)]***	Raise STP pond embankments and establish alternative access. Flood warning signs or gates for Great Western Highway. High priority measures.	Priority 1: cost to purchase (3 priorities) = $160,000 BCR: 1.1 to 1.8 Recommended as long term measure. ***[Voluntary purchase of a single dwelling since adoption of Lithgow Floodplain Management Plan 1991]***	May be suitable to some individual home owners.	Address future development on right bank: large channel required. Long term measure. Ensure future development is compatible with designated flood hazard. High priority measure. ***[Incorporated into Lithgow DCP 2021]***	Public awareness of flooding required. High priority measure

	Implemented		Partially Implemented		Not Yet Implemented		Not Known if Implemented

Cont'd Over

TABLE 3.1 (Cont'd)
MEASURES COMPRISING LITHGOW FMP 1991 AND THEIR IMPLEMENTATION STATUS

Area	Structural Floodplain Management Measures [Taken from Table 9.1(a) of Lithgow Floodplain Management Plan 1991]									Non-Structural Floodplain Management Measures [Taken from Table 9.1(b) of Lithgow Floodplain Management Plan 1991]			
	Levees	**Channel Improvement Works**	**Flood Storage Works**	**Detention Basins**	**Channel Clearing and Maintenance**	**Temporary Levees (Sandbagging)**	**Diversion of Flows into Mines**	**Assessment of City Drainage**	**Other**	**Voluntary Purchase Scheme**	**House Raising and Individual Flood Proofing**	**Building, Development and Zoning Controls**	**Flood Warning and Public Education**
Lithgow Showground					Recommended as high priority measure in localised areas	Recommended only as localised emergency measure		High priority measure in localised areas ***[Undertaken as part of Lithgow Flood Study Review (Lyall & Associates, 2017)]***	Remove Geordie Street causeway or construct bridge.			Caution if filling showground opposite as Geordie Street opposite. Long term measure.	In short term maintain warning signs at Geordie Street crossing. ***[Warning sign and gates maintained on Geordie Street]***
									Maintain warning facilities at Geordie Street causeway. High priority measure ***[Warning sign and gates maintained on Geordie Street]***			Ensure future development is compatible with designated flood hazard. High priority measure. ***[Incorporated into Lithgow DCP 2021]***	In long term examine construction of bridge or closure of road.
													Public awareness of flooding required. High priority measure.
Hermitage Flat			For 1% AEP flows lowering of Watsford Conran, and Glanmire oval to provide flood storage. Some sections of gabion-lined channel; some small levees: Cost: $7.52 million BCR: 0.9 to 1.5 Recommended as long term measure in lieu of voluntary purchase. **[660 m reach of Farmers Creek widened since adoption of *Lithgow Floodplain Management Plan 1991*]**		Recommended as high priority measure in localised areas	Recommended only as localised emergency measure		High priority measure in localised areas ***[Undertaken as part of Lithgow Flood Study Review (Lyall & Associates, 2017)]***	Flood warning signs for Albert Street bridge. High priority measure	No. all flood-affected properties = 134. Cost to purchase = $8.21 million (with premium). BCR = 0.8 to 1.3 Priority 1: cost to purchase (66 properties) = $3.92 million (with premium). High social impacts. Recommended as long term measure in lieu of flood storage works.	May be suitable to some individual home owners. ***[Single dwelling may have been raised since adoption of Lithgow Floodplain Management Plan 1991]***	Caution of any development as most of this area high flood hazard. Long term measure.	Public awareness of flooding required.
												Ensure future development is compatible with designated flood hazard. High priority measure. ***[Incorporated into Lithgow DCP 2021]***	Construction of flood escape route to McKellars Paddock and feasibility into provisions of short term emergency facilities on McKellars Paddock.
													Installation of flood gauge plates and warning system. High priority measure.

	Implemented		Partially Implemented		Not Yet Implemented		Not Known if Implemented

TABLE 3.1 (Cont'd)
MEASURES COMPRISING LITHGOW FMP 1991 AND THEIR IMPLEMENTATION STATUS

Area	Structural Floodplain Management Measures [Taken from Table 9.1(a) of Lithgow Floodplain Management Plan 1991]									Non-Structural Floodplain Management Measures [Taken from Table 9.1(b) of Lithgow Floodplain Management Plan 1991]			
	Levees	**Channel Improvement Works**	**Flood Storage Works**	**Detention Basins**	**Channel Clearing and Maintenance**	**Temporary Levees (Sandbagging)**	**Diversion of Flows into Mines**	**Assessment of City Drainage**	**Other**	**Voluntary Purchase Scheme**	**House Raising and Individual Flood Proofing**	**Building, Development and Zoning Controls**	**Flood Warning and Public Education**
Sandford Avenue	Levee to maintain Sandford Ave as flood escape route. Cost: $20,000 Recommended as high priority measure				Recommended as high priority measure in localised areas	Recommended only as localised emergency measure		Detailed assessment of area behind Sandford Ave. Recommended as high priority measure ***[Undertaken as part of Lithgow Flood Study Review (Lyall & Associates, 2017)]***			Individual flood proofing. Recommended as low priority measure in lieu of Sandford Ave levee.	Ensure future development is compatible with designated flood hazard. High priority measure. ***[Incorporated into Lithgow DCP 2021]***	Flooding and local drainage problems to be solved to ensure flood escape route is available to McKellars Paddock. Installation of flood gauge plates and warning system. High priority measure.
Montague Street/Tank Street/Union Street	For levees to be feasible, would also require removal of nine houses in Montague Street and construction of grass lined channel (base width of 30m as well as gabion-lined channel upstream of Tank Street Bridge. Cost: $1.51 million BCR: 0.4 to 0.7 Recommended as long term measure in lieu voluntary purchase				Recommended as high priority measure in localised areas	Recommended only as localised emergency measure		High priority measure in localised areas ***[Undertaken as part of Lithgow Flood Study Review (Lyall & Associates, 2017)]***	Flood warning signs for Tank Street Bridge. Flood escape route at western end of Montague Street up to Sandford Ave. High priority measure.	No, all flood-affected properties = 36. Cost to purchase = $2.40 million (with premium). BCR = 0.3 to 0.4 Priority 1: cost to purchase (14 properties) = $0.7 million (with premium). High social impacts. Recommended as long term measure in lieu of levee works. **[Voluntary purchase of only nine dwellings (eight in Montague Street and one in Union Street) since adoption of *Lithgow Floodplain Management Plan 1991*]**	May be suitable to some individual home owners.	Ensure future development is compatible with designated flood hazard. High priority measure. ***[Incorporated into Lithgow DCP 2021]***	Public awareness of flooding required. Installation of flood gauge plates and warning system. High priority measure.

	Implemented		Partially Implemented		Not Yet Implemented		Not Known if Implemented

TABLE 3.1 (Cont'd)
MEASURES COMPRISING LITHGOW FMP 1991 AND THEIR IMPLEMENTATION STATUS

Area	Structural Floodplain Management Measures [Taken from Table 9.1(a) of Lithgow Floodplain Management Plan 1991]									Non-Structural Floodplain Management Measures [Taken from Table 9.1(b) of Lithgow Floodplain Management Plan 1991]			
	Levees	**Channel Improvement Works**	**Flood Storage Works**	**Detention Basins**	**Channel Clearing and Maintenance**	**Temporary Levees (Sandbagging)**	**Diversion of Flows into Mines**	**Assessment of City Drainage**	**Other**	**Voluntary Purchase Scheme**	**House Raising and Individual Flood Proofing**	**Building, Development and Zoning Controls**	**Flood Warning and Public Education**
Morts Estate and Donald Street Industrial Area	Combine gabion-lined channel behind industrial area with levees protecting industrial areas of Morts Estate with removal of up to 15 houses required. Cost: $3.81 million BCR: 0.6 to 1.2 Recommended as long term measure in lieu of voluntary purchase	(see under levee works)			Recommended as high priority measure in localised areas ***[Aerial photography from 1998 shows evidence of clearing a minor channel works along 100 m reach of Farmers Creek in immediate vicinity of its confluence with State Mine Creek]***	Recommended only as localised emergency measure		High priority measure in localised areas ***[Undertaken as part of Lithgow Flood Study Review (Lyall & Associates, 2017)]***	Flood warning signs for Atkinson Street Bridge and in Macaulay Street coming down from State Mine Creek.. Localised road raising in Willes Street as flood escape route. High priority measure	No, all flood-affected properties = 91. Cost to purchase = $6.18 million (with premium). BCR = 0.13 to 0.23 Priority 1: cost to purchase (16 properties) = $1.02 million (with premium). High social impact. Recommended as long term measure in lieu of levee and channel improvement works. ***[Voluntary purchase of only six dwellings (two in Guy Street, two in Laidley Street and two in Macauley Street) since adoption of Lithgow Floodplain Management Plan 1991]***	May be suitable to some individual home owners and industries. False floors may also be suitable to individual industrial properties.	Ensure future development is compatible with designated flood hazard especially in industrial area. High priority measure. ***[Incorporated into Lithgow DCP 2021]***	Feasibility into provisions of short term emergency facilities in Morts Estate area. Installation of flood gauge plates and warning system. Public awareness of flooding required. High priority measure.
Oakey Park		Gabion-lined channel with base width of 20m would protect Oakey Park area up to 1% AEP event. At least five houses would require removal and small levees would be required in isolated areas. Cost: $3.58 million BCR: 0.09 to 0.17 Recommended as long term measure in lieu of voluntary purchase			Local channel widening may reduce flood levels and nuisance flooding in some areas. Recommended as high priority measure in localised areas ***[Aerial photography from 1998 shows evidence of clearing a minor channel works along 180 m reach of Farmers Creek immediately downstream of Victoria Avenue]***	Recommended only as localised emergency measure		High priority measure in localised areas ***[Undertaken as part of Lithgow Flood Study Review (Lyall & Associates, 2017)]***	Flood warning signs for Victoria Avenue and Island Parade bridges. Closure of Mills Street Causeway. High priority measure. Enlarge Victoria Avenue bridge for local flood reductions upstream. Cost: $200,000 Long term measures.	No, all flood-affected properties = 54. Cost to purchase = $3.79 million (with premium). BCR = 0.08 to 0.16 Priority 1: cost to purchase (9 properties) = $0.54 million (with premium). High social impact. Additional houses may require removal owing to isolation of remaining houses. Recommended as long term measure in lieu of channel works. ***[Voluntary purchase of only three dwellings (two in Brooks Street and one in Mills Street) since adoption of Lithgow Floodplain Management Plan 1991]***	May be suitable to some individual home owners.	Ensure all future development is compatible with designated flood hazard. High priority measure. ***[Incorporated into Lithgow DCP 2021]***	Installation of flood gauge plates and warning system. Public awareness of flooding required. Formalise use of Zig Zag Public School as short term emergency accommodation. Construct all weather access to school from Brisbane and Bragg Street. High priority measure.

	Implemented		Partially Implemented		Not Yet Implemented		Not Known if Implemented

TABLE 3.1 (Cont'd)
MEASURES COMPRISING LITHGOW FMP 1991 AND THEIR IMPLEMENTATION STATUS

Area	Structural Floodplain Management Measures [Taken from Table 9.1(a) of Lithgow Floodplain Management Plan 1991]									Non-Structural Floodplain Management Measures [Taken from Table 9.1(b) of Lithgow Floodplain Management Plan 1991]			
	Levees	**Channel Improvement Works**	**Flood Storage Works**	**Detention Basins**	**Channel Clearing and Maintenance**	**Temporary Levees (Sandbagging)**	**Diversion of Flows into Mines**	**Assessment of City Drainage**	**Other**	**Voluntary Purchase Scheme**	**House Raising and Individual Flood Proofing**	**Building, Development and Zoning Controls**	**Flood Warning and Public Education**
State Mine Creek	For flood prone properties refer to Morts Estate	Recommended only as localised measure			Recognised as high priority measure in localised areas	Recommended only as localised emergency measure		Detailed assessment required, especially in the Percy Street area. Recommended as high priority measure. ***[Undertaken as part of Lithgow Flood Study Review (Lyall & Associates, 2017)]***	Enlargement of Laidley Street bridge to provide flood escape route from Macaulay Street. Some localised channel works would be required. Recommended as short term measure.	(Flood prone properties included under Morts Estate)		Ensure all future development is compatible with designated flood hazard. ***[Incorporated into Lithgow DCP 2021]***	Public awareness of flooding required.
												Ensure natural creek is not encroached upon. High priority measure.	Flood escape route required to Morts Estate (preferably via Laidley Street). High priority measure.
Vale of Clwydd Creek		The conversion of Lake Pillans into an open channel would be a long term measure in lieu of use as permanent lake and tourist feature.		Construction of Lake Pillans as a permanent lake and tourist feature in lieu of demolition and construction of channel (would not effect flood levels in Farmers Creek). Recommended as long term measure. ***[Lake Pillans wetland constructed between 1991 and 1998]***	High priority measure in localised areas especially upstream of Chifley Road	Recommended only as localised emergency measure		Detailed assessment required, especially in the Vale of Clwydd and Doctors Gap. Recommended as high priority area. ***[Undertaken as part of Lithgow Flood Study Review (Lyall & Associates, 2017)]***	Enlargement of the Chifley Road bridge to provide access up to the 1% AEP event. Cost: $200,000 Long term low priority measure. Scour protection. High priority in localised areas.		Likely to be most economic management measure for this area. False floors and/or flood compatible management practices may be suitable to individual industrial/commercial properties.	Ensure natural creek is not encroached upon. Long term measure.	Public awareness of flooding required. High priority measure.
												Address overtopping problem and provision of flow paths at Lake Pillans in light of new industrial subdivision. ***[Lake Pillans wetland constructed between 1991 and 1998]***	
												Ensure all future development is compatible with designated flood hazard. High priority measures. ***[Incorporated into Lithgow DCP 2021]***	

	Implemented		Partially Implemented		Not Yet Implemented		Not Known if Implemented

TABLE 3.2
CONTEMPORANEOUS COMMUNITY VIEWS ON
POTENTIAL FLOOD RISK MANAGEMENT MEASURES

Flood Management Measure	Classification	Respondent's Views		
		Yes	No	Don't Know
Management of vegetation along creek corridors to provide flood mitigation, stability, aesthetic and habitat benefits	Flood Modification Measure	171	0	6
Widening and/or concrete lining of watercourses		113	38	14
Construct detention basins		81	26	39
Construction of permanent levees along the creeks to contain floodwaters		105	34	18
Improve stormwater system		163	6	4
Removal of floodplain obstructions		136	7	18
Voluntary purchase of the most severely affected flood liable properties	Property Modification Measure	73	41	37
Provide funding or subsidies to raise houses above major flood level in low hazard areas		45	83	26
Flood proofing of individual properties by waterproofing walls, putting shutters across doors, etc		41	81	32
Specify controls on future development in flood-liable areas (eg. controls on extent of filling, minimum floor levels)		142	9	12
Providing a Planning Certificate to purchasers in flood prone areas, stating that the property is flood affected		146	14	7
Ensuring all information about the potential risks of flooding is available to all residents and business owners	Response Modification Measure	173	1	0
Improve flood warning and evacuation procedures both before and during a flood.		144	7	10
Community education, participation and flood awareness programs.		126	20	12
Ensure all residents and business owners have Flood Action Plans – these outline WHAT people should do, WHERE they should go and WHO they should contact in a flood		126	27	10

Based on the responses to Question 8, the community favoured the following measures:

- Management of vegetation along creek corridors.
- Improvements in the stormwater system.
- Removal of floodplain obstructions
- Ensuring all information about the potential risks of flooding is available to all residents and business owners
- Advice of flood affectation via Planning Certificates for properties located in flood liable areas.
- Improved flood warning, evacuation and flood response procedures both before and during a flood.
- Flood related controls over future development in flood liable areas.
- Community education to promote flood awareness.

The followings sections of this Chapter set out the findings of a strategic assessment that was undertaken as part of the present study into a range of potential flood risk management measures. When undertaking the assessment, the status of the measures that are set out in *Lithgow FMP 1991* were taken into account, as were the community's current views. Where considered appropriate, the assessed measures were then tested for feasibility on a range of assessment criteria in **Chapter 4**. Following consideration of the results by the Floodplain Risk Management Committee, selected measures were then included in *Lithgow FRMP 2023* in **Chapter 5**.

3.4 Flood Modification Measures

Based on a review of the flood modification measures that formed part of *Lithgow FMP 1991* and the also findings of the *Updated Flood Study*, and after taking into consideration the current views of the community, a strategic assessment was undertaken in relation to a number of potential flood modification measures which are aimed at reducing the impact of flooding on the community.

Table 3.3 lists the potential flood modification measures that were assessed as part of the present study, as well as their key features. Also set out in **Table 3.1** is the outcome of an economic assessment that was undertaken of the more favourable measures, as well as the advantages and disadvantages of each.

Figure 3.1 shows the plan location of the assessed flood modification measures, while **Figures 3.2** to **3.11** show the key features of each measure, as well as the impact that their implementation would have on flood behaviour for storms with AEPs of 20%, 5% and 1%.

Based on the findings of the assessment, it is recommended that the following flood modification measures be considered for inclusion in *Lithgow FRMP 2023*:

- George Coates Street Drainage Improvement Works
- Lithgow High School Detention Basin
- Farmers Creek Channel Works – Stages 3, 4, 5 and 6

TABLE 3.3
SUMMARY OF ASSESSED FLOOD MODIFICATION MEASURES

Flood Modification Measure[(1)]	Key Features	Capital Cost Estimate ($M)	Estimated Present Worth Value of Damages Saved ($M)	Benefit-Cost Ratio	Advantages	Disadvantages
James Street Drainage Improvement Works (FM1)	• **Figure 3.2** shows the following key features comprising the James Street Drainage Improvement Works: ○ Lowering of Young Street and James Street to remove the rise in pavement levels that is present on the northern side of the Main Western Railway. ○ Lowering of an existing 375 RCP in order to maintain adequate cover.	Not Assessed	Not Assessed	-	• None	• Only results in a minor reduction in peak flood levels south (upstream) of Main Western Railway for all storms up to 1% AEP in intensity. • Would require additional works to mitigate the adverse impacts on flooding that are shown to occur to the north (downstream) of James Street. • By inspection, the capital cost of the works would be significant, resulting in an extremely low benefit-cost ratio. • Measures provides limited benefit in terms of the frequency and depth of inundation in existing development.
George Coates Street Drainage Improvement Works (FM2)	• **Figure 3.3** shows the following key features comprising the George Coates Street Drainage Improvement Works: ○ Jacking of a 9 m wide pre-cast box section through the Main Western Railway embankment. ○ Provision of a 900 mm high opening in the base of the jacked pre-cast box section for the conveyance of stormwater runoff. ○ Connection of 2 off 2700 x 900 RCBCs to the 900 mm high opening in the base of the jacked pre-cast box section. ○ Provision of 2 off 900 RCPs extending from Wylde Street to the main arm of Farmers Creek. ○ Provision of a 6 m wide grassed swale along the eastern side of the existing trees which line George Coates Street. Swale to extend from a location adjacent to the existing sag in George Coates Street to the main arm of Farmers Creek.	6.3	0.13	0.02	• Would result in a reduction in the frequency, depth and duration of inundation that is experienced in existing development and along both Main Street and George Coates Street for all storms up to 1% AEP in intensity. • Would significantly improve pedestrian and road safety by reducing frequent flooding and also providing a safe underpass of the Main Western Railway.	• Expensive to implement. • Benefits mainly confined to areas of road reserve, hence the extremely low benefit-cost ratio.
Barton Street Drainage Improvement Works (FM3)	• **Figure 3.4** shows the following key features comprising the Barton Street Drainage Improvement Works: ○ Replacement of the existing transverse drainage structure under Barton Street with a new 4.05 m wide by 1.35 m high bridge structure. ○ Demolish and remove existing 1200 RCP and 1500 RCP over 200 m length and widen existing concrete lined channel to 3.5 m.	1.5	0.21	0.14	• Would reduce the impact on flooding that is experienced at the intersection of Main Street and Enfield Avenue during less frequent storm events.	• Doesn't reduce the frequency, depth and duration of inundation that is experienced in existing development and along both Main Street and Enfield Avenue for the more frequent storm events. • Access is constrained due to 200 m reach of trunk drainage system north (downstream) of Barton Street being located in private property.

Cont'd Over

TABLE 3.3 (Cont'd)
SUMMARY OF ASSESSED FLOOD MODIFICATION MEASURES

Flood Modification Measure[(1)]	Key Features	Capital Cost Estimate ($M)	Estimated Present Worth Value of Damages Saved ($M)	Benefit-Cost Ratio	Advantages	Disadvantages
Berry Street Detention Basin (FM4)	• Construction of detention basin on presently vacant but privately owned land that is located on tributary arm of Vale of Clwydd Creek. • **Figure 3.5** is a sketch showing the plan layout and key features of the Berry Street Detention Basin.	Not Assessed	Not Assessed	-	• Would result in a reduction in the frequency, depth and duration of inundation that is experienced in existing residential development during relatively frequent storm events.	• Would only have a limited benefit in terms of reducing flood damages in existing development for less frequent storm events. • Would require the acquisition of presently privately owned land to facilitate the construction of the detention basin. • By inspection, the measure could not be justified on economic grounds given the capital costs would be relatively large and the present worth value of flood damages saved would be relatively small.
Lithgow High School Detention Basin (FM5)	• Construction of detention basin on presently vacant land that is located in the grounds of Lithgow High School. • **Figure 3.6** is a sketch showing the plan layout and key features of the Lithgow High Detention Basins.	0.65	0.85	1.31	• Would result in a significant reduction in the frequency, depth and duration of inundation that is experienced in existing residential and commercial/industrial development that is located between the high school and the Main Western Railway for all storms up to 1% AEP in intensity. • Would significantly reduce the flood damages experienced in existing residential development. • Can be justified on economic grounds given it has a benefit cost ratio of greater than 1.	• Flood mitigation works required to be located on school grounds. • Area would need to be fenced off due to the depth of ponding in the basin, as well as the rapid rise in water levels.
Hassan Walls Reserve Detention Basin (FM6)	• Construction of detention basin on presently vacant Crown land that spans Sheedys Gully Tributary. • **Figure 3.7** is a sketch showing the plan layout and key features of the Reserve Detention Basin.	Not Assessed	Not Assessed	-	• None	• Only results in a minor reduction in peak flood levels for all storms up to 1% AEP in intensity. • Due to its large footprint, the online basin would result in adverse environmental impacts on the existing watercourse and its overbank area. • By inspection, the measure could not be justified on economic grounds given the capital costs would be relatively large and the present worth value of flood damages saved would be relatively small.

Cont'd Over

TABLE 3.3 (Cont'd)
SUMMARY OF ASSESSED FLOOD MODIFICATION MEASURES

Flood Modification Measure[(1)]	Key Features	Capital Cost Estimate ($M)	Estimated Present Worth Value of Damages Saved ($M)	Benefit-Cost Ratio	Advantages	Disadvantages
Farmers Creek Channel Works –Stages 3 and 4 (FM7)	• Completion of the final two stages of the original Hermitage Flat flood mitigation works as envisaged in *Lithgow FMP 1991*. • Widening of a 550 m length of Farmers Creek immediately upstream of the already constructed Stages 1 and 2 works. • Enlargement of the waterway area beneath the existing Sandford Road bridge so as to match that of the widened creek. • **Figure 3.8** (2 sheets) shows the plan extent of the Farmers Creek Channel Works – Stages 3 and 4.	5.7	0.46	0.08	• Would result in a reduction in the depth and extent of inundation that is experienced in a number of residential properties that are located along Coalbrook Street and Stephenson Street east (upstream) of the Albert Street bridge crossing of Farmers Creek. • Peak 1% AEP flood levels would generally be reduced in existing residential development that is located in Hermitage Flat, albeit by less than 0.1 m. • Works could enhance the environmental values of the creek corridor while providing a flood mitigation benefit.	• Cannot be justified on economic grounds. • Results in a minor reduction of the flood mitigation benefits that have been provided by the construction of Stages 1 and 2.
Farmers Creek Channel Works –Stages 3, 4 and 5 (FM8)	• Completion of the final two stages of the original Hermitage Flat flood mitigation works as envisaged in *Lithgow FMP 1991*. • Widening and rehabilitation of a 1 km length of Farmers Creek immediately upstream of the already constructed Stages 1 and 2 works. • Enlargement of the waterway area beneath the existing Sandford Road bridge so as to match that of the widened creek. • **Figure 3.9** (2 sheets) shows the plan extent of the Farmers Creek Channel Works – Stages 3, 4 and 5.	10.8	0.80	0.07	• When compared to the Stages 3 and 4 works alone, the addition of the Stage 5 works would result in a greater reduction in the depth and extent of inundation that is experienced in a number of residential properties that are located along Coalbrook Street, Stephenson Street and Sandford Avenue east (upstream) of the Albert Street bridge crossing of Farmers Creek,. • Peak 1% AEP flood levels would generally be reduced in existing residential development that is located in Hermitage Flat, albeit by less than 0.1 m. • Works would enhance the environmental values of the creek corridor while providing a flood mitigation benefit.	• Cannot be justified on economic grounds. • Results in a minor reduction of the flood mitigation benefits that have been provided by the construction of Stages 1 and 2.
Farmers Creek Channel Works –Stage 6 (FM9)	• Widening and rehabilitation of a 420 m length of Farmers Creek principally upstream of the Tank Street bridge. • Enlargement of the waterway area beneath the existing Tank Street bridge so as to match that of the widened creek. • **Figure 3.10** (2 sheets) shows the plan extent of the Farmers Creek Channel Works – Stage 6.	4.4	0.84	0.19	• Would result in a significant reduction in the depth and extent of inundation that is experienced in a number of residential and commercial/industrial properties that are located on both sides of Farmers Creek upstream of the Tank Street bridge. • Works would enhance the environmental values of the creek corridor while providing a flood mitigation benefit. • Would offset the cost of acquiring six of the seven Tank Street Damage Centre properties that are eligible for inclusion in a contemporaneous Voluntary Purchase Scheme for Lithgow (Estimated Cost: $2.1M). Refer **Section 3.5.3** of this report for further details.	• Cannot be justified on economic grounds. • Results in a broad increase in peak flood levels downstream of the Tank Street bridge for all storms up to 1% AEP in intensity. • Requires the undertaking of additional channel works downstream in order to mitigate the abovementioned impacts.
Farmers Creek Channel Works –Stages 3, 4, 5 and 6 (FM10)	• Completion of the final two stages of the original Hermitage Flat flood mitigation works as envisaged in *Lithgow FMP 1991*. • Widening and rehabilitation of a 1.42 km length of Farmers Creek immediately upstream of the already constructed Stages 1 and 2 works. • Enlargement of the waterway area beneath the existing Sandford Road and Tank Street bridges so as to match that of the widened creek. • **Figure 3.11** (2 sheets) shows the plan extent of the Farmers Creek Channel Works – Stages 3, 4, 5 and 6.	15.2	1.60	0.11	• Would result in a significant reduction in the depth and extent of inundation that is experienced in a large number of residential and commercial/industrial properties that are located on both sides of Farmers Creek upstream of the Albert Street bridge. • Works would enhance the environmental values of the creek corridor while providing a flood mitigation benefit. • Would offset the cost of acquiring six of the seven Tank Street Damage Centre properties that are eligible for inclusion in a contemporaneous Voluntary Purchase Scheme for Lithgow (Estimated Cost: $2.1M). Refer **Section 3.5.3** of this report for further details.	• Cannot be justified on economic grounds. • Results in a minor reduction of the flood mitigation benefits that have been provided by the construction of Stages 1 and 2. • Results in a minor increase in the depth and extent of inundation that would be experienced along the main arm of Farmers Creek west (downstream) of Hermitage Flat.

1. Refer **Figure 3.1** for plan location of individual flood modification measure.

In addition to the measures that are set out in **Table 3.3**, the implementation of management programs in creeks can reduce the frequency and severity of flooding that is experienced in existing development. These management programs typically involve maintenance of batters, the removal of sediment, removal of dense vegetation and the clearance of flood debris after significant flow events. Clearance of debris within the stream corridor reduces the potential for future capture by the flow and blockage of culverts.

Recent high flow events in Farmers Creek and its major tributaries have highlighted the potential for large amounts of woody debris to be conveyed by floodwater. An inspection of the creek corridors also identified that there is the potential for exotic species such as poplars to obstruct the passage of floodwater and therefore increase peak flood levels at a number of locations.

Based on the above finding, it is recommended that a vegetation management strategy be developed for Farmers Creek and its major tributaries as this would assist in reducing the frequency and severity of flooding in parts of Lithgow. It would also reduce the risk of existing hydraulic structures experiencing a partial blockage during a flood event. For this reason it has been included in *Lithgow FRMP 2023*.

Further to the above and as identified in **Section 2.14.2** of this report, concerns were raised during a FRMC meeting regarding the overloading and surcharge of the existing sewerage system during periods of wet weather. While a study was undertaken in about 2008-09 into the management of the existing sewerage system at Lithgow, it is recommended that the findings of the study be reviewed and updated based on the flooding and stormwater related information that is set out in this report.

3.5 Property Modification Measures

3.5.1 Controls over Future Development

3.5.1.1 Current Government Policy

The NSW Government has recently finalised reforms of the *NSW Flood Prone Land Package*. As part of the reform, the wording in the flood planning clause of all NSW Councils was updated on 14 July 2021. As part of the reform, Council will need to nominate the FPL or levels that it wishes to define the FPA and make alternative arrangements for making flood planning maps publicly available where previously solely reliant on LEP flood overlay maps. While the reforms also included an optional clause titled *special flood considerations* which applies to land which lies between the FPA and the extent of the PMF, Council made the decision to await the outcomes of the present study before including it in *Lithgow LEP 2014*.

3.5.1.2 Considerations for Setting Freeboard Requirements

Selection of the FPL for an area is an important and fundamental decision as the standard is the reference point for the preparation of floodplain risk management plans. It is based on the adoption of the peak level reached by a particular flood plus an appropriate allowance for freeboard. It involves balancing social, economic and ecological considerations against the consequences of flooding, with a view to minimising the potential for property damage and the risk to life and limb. If the adopted FPL is too low, new development in areas outside the FPA (particularly where the difference in level is not great) may be inundated relatively frequently and damage to associated public services will be greater. Alternatively, adoption of an excessively high FPL will subject land that is rarely flooded to unwarranted controls. Councils are responsible for determining the appropriate FPLs within their local government area.

Freeboard provides reasonable certainty that the risk exposure selected in deciding on a particular flood is actually provided. It is a factor of safety typically used in relation to the setting of floor levels, levee crest and basement entrance levels, etc. Design variables that are typically incorporated in the derivation of freeboard typically comprise the following:

- increases in peak flood levels due to wind and wave action;
- increases in peak flood levels due to local water surge;
- uncertainties in the design flood level estimates due to the confidence limits associated with the design peak flow estimates for Narromine, inaccuracies in the LiDAR survey data and possible variations in key parameters such as hydraulic roughness; and
- increases in peak flood levels due to future climate change.

Table 3.4 provides a summary of a joint probability analysis which was undertaken to assess the freeboard allowance which should be incorporated in the FPL for areas at Lithgow that are affected by Main Stream Flooding, noting the methodology for deriving the various components of the freeboard allowance is based on the approach set out in NSW Public Works, 2010.

TABLE 3.4
SUMMARY OF FREEBOARD ANALYSIS
AREAS AFFECTED BY MAIN STREAM FLOODING

Design Variable [A]	Probability of Occurrence [B]	Maximum Allowance (m) [C]	Joint Probability Allowance (m) [D]
Wave Action	50%	0.07	0.04
Inaccuracies in Peak 1% AEP Flood Level Estimate			
- LiDAR survey data	100%	0.15	0.15
- Peak flow estimate	50%	0.20	0.10
- Hydraulic roughness	25%	0.20	0.05
Future Climate Change	50%	0.50	0.25
TOTAL			**0.59**

The maximum allowance for uncertainties in the peak 1% (1 in 100) AEP flood level estimate is comprised of the following

- inaccuracies in the LiDAR survey data (+0.15 m);
- provision for a 10% increase in the best-estimate peak 1% (1 in 100) AEP flow derived by the flood frequency analysis (+0.2 m); and
- increase in peak flood levels associated with a possible 20% increase in the best-estimate hydraulic roughness values (generally a maximum of +0.2 m based on the information shown on **Figure 2.7**).

In regards the potential impacts of future climate change on flood behaviour at Lithgow, the *ARR Data Hub* gives the following interim climate change factors for Representative Concentration Pathways (**RCPs**) of 4.5 and 8.5 in the years 2050 and 2090:

Year	RCP 4.5	RCP 8.5
2050	6.4%	9.0%
2090	9.5%	19.7%

A flood with an AEP of 0.5% is commonly considered to be analogous to a flood that would result from a 10% increase in 1% AEP rainfall intensities. By comparison with the interim climate change factors, the adoption of the 0.5% AEP would provide a reasonable indicator of the potential for future climate change to impact peak 1% AEP flood levels at Lithgow (generally a maximum of +0.52 m based on the information shown on **Figure 2.11**).

While the joint probability analysis set out in **Table 3.4** indicates a freeboard slightly greater than the traditional value of 0.5 m would be appropriate in areas that are affected by Main Stream Flooding, given a larger portion of this relates to the potential impacts of future climate change, the exact nature of which cannot yet be determined, it is considered reasonable to adopt a freeboard of 0.5 m for setting the FPL at Lithgow.

While the flood range in the major watercourses which traverse the study area is such that the traditional 0.5 m freeboard is appropriate for setting the FPL, its adoption in areas affected by Major Overland Flow would lead to the FPA extending onto land which would not experience damaging or hazardous flooding during a 1% AEP storm event, even allowing for all the variables which comprise freeboard.

Considerable reduction in the number of properties in Major Overland Flow areas classified as "flood affected" would result by the adoption of a threshold depth of inundation under 1% AEP conditions of 0.1 m as the criterion for defining area which would be subject to the majority of flood related development controls, compared with the traditional approach. Properties with depths of inundation 0.1 m or greater, or in a floodway (i.e. traversed by significant overland flows which may in some cases be less than 0.1 m in depth) would therefore be considered to lie within the FPA. Properties with depths of inundation under 1% AEP non-floodway conditions of less than 0.1 m would be classified as "Local Drainage" and, as such would be subject to controls such as the Building Code of Australia (**BCA**) requirements, rather than attracting a flood affectation notice. This approach is supported by NSWG, 2005 and would not adversely impact on Council's duty of care in regard to management of flood prone lands. The proposed categorisation of the floodplain, terminology and controls are shown on **Table 3.5**.

Figure D1.1 in **Appendix D** is an extract from the *Flood Planning Map* at Lithgow. The figure includes areas subject to both Main Stream Flooding and Major Overland Flow. The extent of the FPA (the area subject to flood related development controls) is shown in a solid mauve (Main Stream Flooding) and green (Major Overland Flow) colour in **Figure D1.1** and has been defined as follows:

- In areas subject to Main Stream Flooding, the FPA is based on the traditional definition of the area that lies at or below by the 1% AEP plus 0.5 m freeboard.
- In areas subject to Major Overland Flow, the FPA is defined as the extent of areas which act as a floodway, as well as areas where depths of inundation exceed 0.1 m in a 1% AEP event.

Also shown in **Figure D1.1** is the extent of the Outer Floodplain, which is the area of land which lies between the extent of the FPA and the PMF.

TABLE 3.5
PROPOSED CATEGORISATION OF THE FLOODPLAIN

Category (FDM, 2005)	Proposed Terminology used to define inundation in the Lithgow *FRMS&P 2023* report	Are Development Controls Required?	Is Section S10.7 Notification Warranted?
Main Stream Flooding	"Main Stream Flooding"	Yes	Yes
Local Overland Flooding - Local Drainage - Major Drainage	 "Local Drainage" "Major Overland Flow"	 No (ref. footnote 1). Yes (ref. footnote 2).	 No (ref footnote 1) Yes (ref footnote 3)

1. Inundation in Local Drainage areas is accommodated by the minimum floor level requirement of 0.15 m above finished surface level contained in the BCA and does not warrant a flood affectation notice in S10.7 Planning Certificates.
2. These are the deeper flooded areas with higher flow velocities. Development controls are specified in **Appendix D**.
3. Depth and velocity of inundation in Major Overland Flow areas are sufficient to warrant a flood affectation notice in S10.7 Planning Certificates. Inundation is classified as "flooding".

3.5.1.3 Proposed Planning Controls for Lithgow

While *Lithgow DCP 2021* contains a set of flood related development controls, these are linked to flood mapping and peak flood levels that have been superseded by the *Updated Flood Study*. As a result, it is recommended that Council review and update *Lithgow DCP 2021* based on the findings of the present study, as well as the suggested wording that is set out in **Appendix D** of this report.

Annexures 2A and **2B** in **Appendix D** set out the graded set of flood related planning controls which have been developed for areas that are subject to Main Stream Flooding and Major Overland Flow, respectively, while **Figure D1.1** in **Appendix D** shows the areas where the graded set of flood related planning controls set out in **Annexures 2A** and **2B** apply.

Minimum habitable floor level (**MHFL**) requirements would be imposed on future development in properties that are identified as lying either partially or wholly within the extent of the FPA shown on **Figure D1.1**. The MHFLs for residential land use types is the level of the 1% AEP flood event plus freeboard, whereas for commercial and industrial land use types the MHFL is to be as close to the 1% AEP flood level plus freeboard as practical, but no lower than the 5% AEP flood level plus freeboard. In situations where the MHFL is below the 1% AEP flood level plus freeboard, a mezzanine area equal to 30% of the total habitable floor area is to be provided, the elevation of which is to be set no lower than the 1% AEP flood level plus freeboard.[10]

For areas outside the FPA shown on **Figure D1.1**, the MHFL for all land use types is the level of the 1% AEP flood event plus 0.5 m freeboard, with the exception of essential community facilities and utilities which are critical for flood response and recovery, as well as sensitive uses and facilities where the MHFL is the level of the PMF.

Figure D1.2 in **Appendix D** is an extract of the *Flood Planning Constraint Category Map* for the Lithgow City LGA which shows the subdivision of the floodplain into a number of categories which have been used as the basis for developing the graded set of planning controls.

[10] Freeboard is equal to 0.5 m for development being assessed in areas affected by Main Stream Flooding and 0.3 m for development being assessed in areas affected by Major Overland Flow.

The floodplain has been divided into the following four categories:

- **Flood Planning Constraint Category 1 (FPCC 1)**, which comprises areas where factors such as the depth and velocity of flow, time of rise, and evacuation problems mean that the land is unsuitable for most types of development. The majority of new development types are excluded from this zone due to its potential impact on flood behaviour and the hazardous nature of flooding.
- **Flood Planning Constraint Category 2 (FPCC 2)**, which comprises areas which lie within the extent of the FPA where the existing flood risk warrants careful consideration and the application of significant flood related controls on future development.
- **Flood Planning Constraint Category 3 (FPCC 3)**, which comprises areas which lie within the extent of the FPA but outside areas designated FPCC1 and FPCC2. Areas designated FPCC3 are more suitable for new development and expansion of existing development provided it is carried out in accordance with the controls set out in this document.
- **Flood Planning Constraint Category 4 (FPCC 4)**, which comprises the area which lies above the FPL but within the extent of the PMF. Flood related controls in areas designated FPCC4 are typically limited to emergency response, although additional controls apply to essential community facilities and utilities that are critical for response and recovery, as well as sensitive uses and facilities. This area is identical to the *Special Flood Considerations Zone* shown on the *Flood Planning Map*.

The derivation of the four FPCCs firstly involved the derivation of a number of sub-regions which were based on the nature of flooding at Lithgow, the sub-categories of which are set out in **Table 3.6**. These sub-regions were then combined, with the resulting extents further refined in order to improve the area over which each FPCC applied.

3.5.1.4 Revision of Lithgow LEP 2014

Both *Lithgow FRMS 2023* and *Lithgow FRMP 2023* have been developed giving consideration to the following amended form of wording which automatically came into effect on 14 July 2021:

"6.2 Flood planning

(1) The objectives of this clause are as follows—

(a) to minimise the flood risk to life and property associated with the use of land,

(b) to allow development on land that is compatible with the flood function and behaviour on the land, taking into account projected changes as a result of climate change,

(c) to avoid adverse or cumulative impacts on flood behaviour and the environment,

(d) to enable the safe occupation and efficient evacuation of people in the event of a flood.

(2) Development consent must not be granted to development on land the consent authority considers to be within the flood planning area unless the consent authority is satisfied the development—

(a) is compatible with the flood function and behaviour on the land, and

(b) will not adversely affect flood behaviour in a way that results in detrimental increases in the potential flood affectation of other development or properties, and

TABLE 3.6
KEY ELEMENTS COMPRISING FLOOD PLANNING CONSTRAINT CATEGORIES FOR LITHGOW

Flooding	FPCC	Sub-category	Constraint
Main Stream Flooding	1	a	1% AEP Main Stream Flooding (MSF) Floodway
		b	1% AEP MSF Flood Hazard Vulnerability Classification H6
	2	a	1% AEP MSF Flood Storage
		b	1% AEP MSF Flood Hazard Vulnerability Classification H5
		c	0.2% AEP MSF Flood Hazard Vulnerability Classification H5 and H6
		d	1% AEP Flood Emergency Response Classification (Flooded - Isolated - Submerged)
		e	1% AEP Flood Emergency Response Classification (Flooded - Isolated - Elevated)
	3	-	Flood Planning Area
	4	-	Extent of PMF
Major Overland Flow	1	-	1% AEP Floodway AND Flood Hazard Vulnerability Classification H4 - H6
	2	a	1% AEP Floodway AND Flood Hazard Vulnerability Classification H1 - H3
		b	1% AEP Flood Storage Area
		c	0.2% AEP Flood Hazard Vulnerability Classification H5 and H6
		d	1% AEP Flood Emergency Response Classification (Flooded - Isolated - Submerged)
		e	1% AEP Flood Emergency Response Classification (Flooded - Isolated - Elevated)
	3	-	Flood Planning Area
	4	-	Extent of PMF

(c) will not adversely affect the safe occupation and efficient evacuation of people or exceed the capacity of existing evacuation routes for the surrounding area in the event of a flood, and

(d) incorporates appropriate measures to manage risk to life in the event of a flood, and

(e) will not adversely affect the environment or cause avoidable erosion, siltation, destruction of riparian vegetation or a reduction in the stability of river banks or watercourses.

(3) In deciding whether to grant development consent on land to which this clause applies, the consent authority must consider the following matters—

(a) the impact of the development on projected changes to flood behaviour as a result of climate change,

(b) the intended design and scale of buildings resulting from the development,

(c) whether the development incorporates measures to minimise the risk to life and ensure the safe evacuation of people in the event of a flood,

(d) the potential to modify, relocate or remove buildings resulting from development if the surrounding area is impacted by flooding or coastal erosion.

(4) A word or expression used in this clause has the same meaning as it has in the Considering Flooding in Land Use Planning Guideline unless it is otherwise defined in this clause.

(5) In this clause—

Considering Flooding in Land Use Planning Guideline means the *Considering Flooding in Land Use Planning Guideline* published on the Department's website on 14 July 2021.

flood planning area has the same meaning as it has in the Floodplain Development Manual.

Floodplain Development Manual means the *Floodplain Development Manual* (ISBN 0 7347 5476 0) published by the NSW Government in April 2005.

While Council chose not to include the optional new *special flood considerations* clause in *Lithgow LEP 2014*at the same time as the *flood planning* clause was automatically updated by the NSW Government, it is recommended that Council now look to include it in *Lithgow LEP 2014* as it will require consideration to be given to approving certain types of development on land that lies between the FPA and the PMF:

Special flood considerations

(1) The objectives of this clause are as follows—

(a) to enable the safe occupation and evacuation of people subject to flooding,

(b) to ensure development on land is compatible with the land's flood behaviour in the event of a flood,

(c) to avoid adverse or cumulative impacts on flood behaviour,

(d) to protect the operational capacity of emergency response facilities and critical infrastructure during flood events,

(e) to avoid adverse effects of hazardous development on the environment during flood events.

(2) This clause applies to—

(a) for sensitive and hazardous development—land between the flood planning area and the probable maximum flood, and

(b) for development that is not sensitive and hazardous development—land the consent authority considers to be land that, in the event of a flood, may—

(i) cause a particular risk to life, and

(ii) require the evacuation of people or other safety considerations.

(3) Development consent must not be granted to development on land to which this clause applies unless the consent authority is satisfied that the development—

(a) will not affect the safe occupation and efficient evacuation of people in the event of a flood, and

(b) incorporates appropriate measures to manage risk to life in the event of a flood, and

(c) will not adversely affect the environment in the event of a flood.

(4) A word or expression used in this clause has the same meaning as it has in the Considering Flooding in Land Use Planning Guideline unless it is otherwise defined in this clause.

(5) In this clause—

Considering Flooding in Land Use Planning Guideline*—see clause 5.21(5).*

flood planning area*—see clause 5.21(5).*

Floodplain Development Manual*—see clause 5.21(5).*

probable maximum flood *has the same meaning as it has in the Floodplain Development Manual.*

sensitive and hazardous development *means development for the following purposes—*

[list land uses]

Direction— Only the following land uses are permitted to be included in the list—

(a) boarding houses,

(b) caravan parks,

(c) correctional centres,

(d) early education and care facilities,

(e) eco-tourist facilities,

(f) educational establishments,

(g) emergency services facilities,

(h) group homes,

(i) hazardous industries,

(j) hazardous storage establishments,

(k) hospitals,

(l) hostels,

(m) information and education facilities,

(n) respite day care centres,

(o) seniors housing,

(p) sewerage systems,

(q) tourist and visitor accommodation,

(r) water supply systems

The steps involved in Council amending *Lithgow LEP 2014* following the finalisation and adoption of *Lithgow FRMS&P 2023* are:

1. Council Planning Staff consider the conclusions of *Lithgow FRMS&P 2023* and suggested amendments to *Lithgow LEP 2014*.
2. Council resolves to amend *Lithgow LEP 2014* in accordance with *Lithgow FRMS&P 2023*.
3. Council prepares a Planning Proposal in accordance with NSW Planning and Environment Guidelines. Planning Proposal submitted to NSW Planning and Environment in accordance with section 3.33 of the EP&A Act, 1979.
4. Planning Proposal considered by DPE and determination made in accordance with section 3.34(2) of the EP&A Act, 1979 as follows:
   (a) whether the matter should proceed (with or without variation),
   (b) whether the matter should be resubmitted for any reason (including for further studies or other information, or for the revision of the planning proposal),
   (c) community consultation required before consideration is given to the making of the proposed instrument (the community consultation requirements),
   (d) any consultation required with State or Commonwealth public authorities that will or may be adversely affected by the proposed instrument,
   (e) whether a public hearing is to be held into the matter by the Planning Assessment Commission or other specified person or body,
   (f) the times within which the various stages of the procedure for the making of the proposed instrument are to be completed.
5. Planning Proposal exhibited for public comment.
6. Planning Proposal reviewed following public submissions and submissions from relevant State and Commonwealth authorities.
7. Final Local Environmental Plan with proposed amendments drafted.
8. Amending Local Environmental Plan made by the Minister and gazetted.

3.5.2 Development of Stormwater and Flood Risk Management Strategy for Future Growth Areas

Given the potential for new development to adversely impact the quantity and quality of stormwater discharging to receiving drainage lines, it is recommended that a stormwater and flood risk management strategy be developed for the future growth areas that are located in the largely undeveloped Marrangaroo Creek catchment.

The stormwater and flood risk management strategy will identify the measures which are required to mitigate the impacts that new development would otherwise have on the creek environs, as well as identify the land requirements for implementing such measures. For example, the retention and detention of stormwater (including harvesting, reuse and recycling of stormwater) would be important. The planning for the future growth areas should be undertaken in a water sensitive context, noting that the highest level of efficiency in Integrated Water Cycle Management (**IWCM**) and Water Sensitive urban Design (**WSUD**) would be possible since Council is a Local Water Utility (**LWU**) and the stormwater manager (i.e. there is no fragmentation of assets and services (i.e. water, wastewater, stormwater, flood mitigation infrastructure and receiving waters) in the Lithgow City LGA, which would be suitable to generate integrated outcomes for urban water systems and services.

The stormwater and flood risk management strategy should be developed in consultation with other key disciplines such as urban planners and traffic engineers as it will be important to ensure that all of the major constraints associated with new development in the future growth areas are identified prior to the rezoning of the land. It is also recommended that Council develop policies and guidelines for IWCM and WSUD in the future growth areas using best practice.

3.5.3 Voluntary Purchase of Residential Properties

Removal of housing from high hazard floodway areas in the floodplain is generally accepted as a cost effective means of correcting previous decisions to build in such areas. The voluntary purchase of residential property in hazardous areas has been part of subsidised floodplain risk management programs in NSW for over 20 years.[11] After purchase, land is subsequently cleared and the site re-developed and re-zoned for public open space or some other flood compatible use. A further criterion applied by State Government agencies in assessing eligibility for funding is that the property must be in a high hazard floodway area, that is, in the path of flowing floodwaters where the depth and velocity at the peak of the flood are such that life could be threatened, damage of property is likely and evacuation difficult.

Under a Voluntary Purchase scheme the owner is notified that the body controlling the scheme, Council in the present case, is prepared to purchase the property when the owner is ready to sell. There is no compulsion whatsoever to sell at any time. The price is determined by independent valuers and the Valuer General, and by negotiation between Council and the owners. Valuations are not reduced due to the flood affected nature of the site.

Prior to progressing to the purchase of a property, it would first be necessary to undertake a *Voluntary Purchase Feasibility Study*, especially if Council intends to apply for NSW Government grant funding. The study is to include discussions with each eligible and agreeable property owner, as well as a detailed assessment of each property to determine a priority order and costing for each.

The *Lithgow FMP 1991* identified a total of 108 residential properties that were assigned a "Priority 1" listing in terms of the urgency of their acquisition under a Voluntary Purchase Scheme for Lithgow. Of the 108 residential properties, it is believed that only 19 have been acquired to date. **Table 3.7** provides a breakdown of the aforementioned residential properties by Damage Centre.

[11] State government funding is only available for properties where the buildings were approved and constructed prior to 1986 when the original Floodplain Development Manual was gazetted. Properties built after this date should have been constructed in accordance with the principles in the manual.

TABLE 3.7
SUMMARY OF VOLUNTARY PURCHASE SCHEME FOR LITHGOW ABSENT STAGE 6 FARMERS CREEK CHANNEL WORKS

Damage Centre[1]	Number of Residential Properties			Estimated Acquisition Cost ($M)	Estimated Present Worth Value of Flood Damages Saved ($M)	Benefit/Cost Ratio
	Recommended for Acquisition as part of *Lithgow FMP 1991*[2]	Acquired to Date	Recommended for Acquisition as part of *Lithgow FRMP 2023*			
Bowenfels	3	1	2	1.21	0.28	0.23
Hermitage Flat	66	0	12	3.94	0.55	0.14
Tank Street	14	9	7	2.53	0.69	0.27
Morts Estate	16	6	6	3.07	0.55	0.18
Oakey Park	9	3	3	1.28	0.14	0.11
TOTAL	**108**	**19**	**30**	**12.03**	**2.21**	**0.18**

1. Refer **Figure 3.1** for location of Damage Centre.
2. Identified as Priority 1 listings in *Lithgow FMP 1991*.

Based on the findings of the *Updated Flood Study*, it has been assessed that there are currently 30 residential properties that meet the criteria for inclusion in a contemporaneous Voluntary Purchase Scheme for Lithgow. **Table 3.7** identifies the number of residential properties that are located within each Damage Centre, as well as their indicative acquisition cost.

It is noted that the number of properties that have been assessed as being eligible for inclusion in a contemporaneous Voluntary Purchase Scheme is significantly less than is set out in *Lithgow FMP 1991*. The reasons for the large reduction in the number of eligible properties is a result of Council having completed Stages 1 and 2 of the Farmers Creek Channel Works which have reduced peak flood levels in Hermitage Flat, in combination with the more detailed flooding modelling upon which the present study is based.

While **Table 3.7** also shows that the flood damages that would be saved is significantly less than the acquisition cost (as indicated by the relatively low benefit cost ratio), their removal from high hazard floodway areas represents a significant social benefit as it would remove people from areas that are subject to highly hazardous flooding conditions.

Based on the above findings, it is recommended that a contemporaneous Voluntary Purchase Scheme which comprises the aforementioned 30 eligible residential properties be included in *Lithgow FRMP 2023*.

It is noted that the implementation of Stage 6 of the Farmers Creek Channel Works would reduce the number of residential properties that would be eligible for inclusion in the Voluntary Purchase Scheme in the Tanks Street Damage Centre from seven to one. Depending on the timing associated with implementing the Stage 6 works, the costs associated with acquiring the six residential properties (estimated to be about $2.1M) could be used to offset the cost of undertaking the channel works. It is also noted that the implementation of Stages 3, 4 and 5 of the Farmers Creek Channel Work would not reduce the number of residential properties that

would be eligible for inclusion in the Voluntary Purchase Scheme in the other four Damage Centres. **Table 3.8** sets out the results of the revised economic analysis assuming the Voluntary Purchase Scheme for Lithgow is implemented following the construction of the Stage 6 Farmers Creek Channel Works.

TABLE 3.8
SUMMARY OF VOLUNTARY PURCHASE SCHEME FOR LITHGOW
POST-STAGE 6 FARMERS CREEK CHANNEL WORKS

Damage Centre[1]	Number of Residential Properties			Estimated Acquisition Cost ($M)	Estimated Present Worth Value of Flood Damages Saved ($M)	Benefit/Cost Ratio
	Recommended for Acquisition as part of *Lithgow FMP 1991*[2]	Acquired to Date	Recommended for Acquisition as part of *Lithgow FRMP 2023*			
Bowenfels	3	1	2	1.21	0.28	0.23
Hermitage Flat	66	0	12	3.94	0.55	0.14
Tank Street	14	9	1	0.43	0.04	0.09
Morts Estate	16	6	6	3.07	0.55	0.18
Oakey Park	9	3	3	1.28	0.14	0.11
TOTAL	**108**	**19**	**24**	**9.93**	**1.56**	**0.16**

1. Refer **Figure 3.1** for location of Damage Centre.
2. Identified as Priority 1 listings in *Lithgow FMP 1991*.

3.5.4 Raising Floor Levels of Residential Properties

The term “house raising” refers to procedures undertaken, usually on a property by property basis, to protect structures from damage by floodwaters. The most common process is to raise the affected house by a convenient amount so that the floor level is at or above the MHFL. For weatherboard and similar buildings this can be achieved by jacking up the house, constructing new supports, stairways and balconies and reconnecting services. Alternatively, where the house contains high ceilings, floor levels can be raised within rooms without actually raising the house. It is usually not practical to raise brick or masonry houses. Most of the costs associated with this measure relate to the disconnection and reconnection of services. Accordingly, houses may be raised a considerable elevation without incurring large incremental costs.

State and Federal Governments have agreed that flood mitigation funds will be available for house raising, subject to the same economic evaluation and subsidy arrangements that apply to other structural and non-structural flood mitigation measures. In accepting schemes for eligibility, the Government has set out the following conditions:

- House raising should be part of the adopted Floodplain Risk Management Plan.
- The scheme should be administered by the local authority.

State government funding is only available for properties where the buildings were approved and constructed prior to 1986 when the original Floodplain Development Manual was gazetted. Properties built after this date should have been constructed in accordance with the principles in the manual. The Government also requires that councils carry out ongoing monitoring in areas where subsidised voluntary house raising has occurred to ensure that redevelopment does not occur to re-establish habitable areas below the design floor level. In addition, it is expected that councils will provide documentation during the conveyancing process so that subsequent owners are made aware of restrictions on development below the design floor level.

Council's principal role in subsidised voluntary house raising would be to:

- Define a habitable floor level, which it will have already done in exercising controls over new house building in the area.
- Guarantee a payment to the builder after satisfactory completion of the agreed work.
- Monitor the area of voluntary house raising to ensure that redevelopment does not occur to re-establish habitable areas below the design floor level.

Prior to progressing to the raising of a dwelling, it would first be necessary to undertake a *Voluntary House Raising Feasibility Study*, especially if Council intends to apply for NSW Government grant funding. The study is to include discussions with each eligible and agreeable property owner, as well as a detailed assessment of each property to determine a priority order and costing for each.

The current cost to raise a medium sized (150 m^2) house is about $150,000 based on recent experience in other centres.

While the number of dwellings that would be eligible for inclusion in a *Voluntary House Raising Scheme* were not identified in Lithgow FMP 1991, based on the findings of the Updated Flood Study and a review of the current construction types, it has been assessed that there are nine existing dwellings that would be eligible for inclusion in a contemporaneous scheme. **Table 3.9** sets out the number of eligible properties within each Damage Centre, along with the estimated cost to raise their floor levels above the peak 1% AEP flood level plus 0.5 m freeboard. **Table 3.9** also shows that the flood damages that would be saved is significantly less than the cost of raising the floor levels of all nine dwellings (as indicated by the relatively low benefit cost ratio).

While the implementation of Stages 3, 4, 5 and 6 of the Farmers Creek Channel Works would remove above-floor inundation in all four dwellings that are located within the Tank Street Damage Centre, thereby rendering them ineligible for inclusion in the Voluntary House Raising Scheme, an additional three dwellings that are located in the same damage centre would become eligible by virtue of the channel works removing hazardous flooding from the properties, thereby rendering them ineligible for inclusion in the Voluntary Purchase Scheme for Lithgow.

The implementation of Stages 3, 4, 5 and 6 of the Farmers Creek Channel Works would also remove above-floor inundation in one dwelling that is located in the Morts Estate Damage Centre for all floods up to the 1% AEP and reduce the depth of above-floor inundation in a further two dwellings that are located in the Oakey Park Damage Centre to less than 0.1 m during a 1% AEP flood event. **Table 3.10** sets out the number of eligible properties within each Damage Centre under post-Stages 3, 4, 5 and 6 Farmers Creek Channel Works conditions, along with the estimated cost to raise their floor levels above the peak 1% AEP flood level plus 0.5 m freeboard.

Based on the above finding, while a *Voluntary House Raising Scheme* is recommended for inclusion in *Lithgow FRMP 2023*, the number of dwellings that would require their floor levels to be raised would hinge on the implementation of the Farmers Creek Channel Works.

TABLE 3.9
SUMMARY OF VOLUNTARY HOUSE RAISING SCHEMES FOR LITHGOW
ABSENT STAGES 3, 4, 5 AND 6 OF THE FARMERS CREEK CHANNEL WORKS

Damage Centre[(1)]	Number of Dwellings Eligible for House Raising	Estimated Cost ($M)	Estimated Present Worth Value of Flood Damages Saved ($M)	Benefit/Cost Ratio
Bowenfels	0	-	-	-
Hermitage Flat	0	-	-	-
Tank Street	4	0.60	0.28	0.47
Morts Estate	2	0.30	0.14	0.47
Oakey Park	3	0.45	0.14	0.31
TOTAL	**9**	**1.35**	**0.56**	**0.42**

1. Refer **Figure 3.1** for location of Damage Centre.

TABLE 3.10
SUMMARY OF VOLUNTARY HOUSE RAISING SCHEMES FOR LITHGOW
POST-STAGES 3, 4, 5 AND 6 OF THE FARMERS CREEK CHANNEL WORKS

Damage Centre[(1)]	Number of Dwellings Eligible for House Raising	Estimated Cost ($M)	Estimated Present Worth Value of Flood Damages Saved ($M)	Benefit/Cost Ratio
Bowenfels	0	-	-	-
Hermitage Flat	0	-	-	-
Tank Street	3[(2)]	0.45	0.10	0.22
Morts Estate	1	0.15	0.04	0.27
Oakey Park	1	0.15	0.03	0.20
TOTAL	**5**	**0.75**	**0.17**	**0.23**

1. Refer **Figure 3.1** for location of Damage Centre.
2. The three dwelling in the Tank Street Damage Centre are not the same as those identified in **Table 3.9**. Rather, they are dwellings whereby the channel works would render them ineligible for inclusion in the Voluntary Purchase Scheme but eligible for inclusion in the Voluntary House Raising Scheme for Lithgow.

3.6 Response Modification Measures

3.6.1 Improvements to Flood Warning System

Improvements to the flood warning and response procedures were strongly favoured by the community during the community consultation process. An effective flood warning system has three key components, i.e. a flood forecasting system, a flood warning broadcast system and a

response/evacuation plan. All systems need to be underpinned by an appropriate public flood awareness program.

Presently warnings regarding the potential for flooding to occur at Lithgow are limited to BoMs *Severe Thunderstorm Warning* and *Severe Weather Warnings for Flash Flooding* alert services which are publicly available via the internet or on smart phones via free Apps.

It is understood that BoM is in the process of developing a flood forecasting and warning system for the Hawkesbury-Nepean Valley. It is therefore recommended that Council liaise with BoM to ascertain whether its system is sufficiently detailed to provide sufficient advance warning time for occupiers of the floodplain at Lithgow, noting that both the Farmers Creek and Marrangaroo Creek catchments are located in the headwaters of the valley.

If the system that BoM is in the process of developing is deemed unsuitable for Lithgow, then it would be necessary for Council to develop an integrated flood warning system which is specific to Lithgow. As a minimum, such a system would include:

- The installation of a network of pluviographic rain gauges both within and adjacent to the Farmers Creek and Marrangaroo Creek catchments which would allow BoM to monitor rainfall depths and intensities in real time.
- The installation of two new telemetered stream gauges on the main arm of Farmers Creek at the Tank Street and Albert Street bridges (**Tank Street and Albert Street telemetered stream gauges**).
- The installation of an automated public announcement system which would be triggered when key water levels on the Tank Street and Albert Street telemetered stream gauges are reached during a flood event. The automated public announcement system would warn residents and business owners that key trigger levels have been reached on the main arm of Farmers Creek and to monitor and take action where required.
- Installation of warning signs and self-deploying boom gates on low level creek crossings such as at the Geordie Street causeway and Burton Street pedestrian crossings of Farmers Creek.

Funding to establish local flash flood warning systems has traditionally been made available on the basis of no Council contribution to the initial capital cost in recognition of the high maintenance costs which Council would have to meet. The costs of maintaining the system would include such items as rain and stream gauges, warning communication systems and ongoing public awareness/education programs. The maintenance obligations need to be identified and included in any initial funding grant. An operation and maintenance manual would also need to be prepared for the system. Reference to the system would also need to be incorporated into the *Lithgow Local Flood Plan*.

Given the potential for hazardous flooding to impact existing development and occupiers of the floodplain, the development of a comprehensive flood warning system for Lithgow has been included in *Lithgow FRMP 2023*.

3.6.2 Improved Emergency Planning and Response

As mentioned in **Section 2.16**, the *Lithgow City Local Flood Plan* provides detailed information regarding preparedness measures, conduct of response operations and coordination of immediate recovery measures for all levels of flooding.

NSW SES should ensure information contained in this report on the impacts of flooding on urban development, as well as recommendations regarding flood warning and community education are used to update Volume 2 of the *Lithgow City Local Flood Plan*. Volume 2 should include the following sections:

1 – The Flood Threat includes the following sub-sections:

1.1 Land Forms and River Systems – ref. **Sections 2.1** and **2.2** of the report for information on these topics.

1.4 Characteristics of Flooding – Indicative extents of inundation for the 1% AEP and PMF events and the typical times of rise of floodwaters at key locations on the major watercourses are shown on **Figures 2.2**, **2.3** and **2.5**. The location of vulnerable development and critical infrastructure relative to the flood extents is shown on **Figure 2.6**.

1.5 Flood History – Recent flood experience at Lithgow is discussed in **Section 2.3** of the report.

1.6 Design Flood Heights – The design flood heights for the Mount Walker stream gauge should be updated based on the design peak flood levels set out in **Table 2.4** of the report.

1.7 Flood Mitigation Systems – Details of the flood mitigation systems that Council has implemented in the Farmers Creek catchment are set out in **Section 2.5** of this report.

1.8 Extreme Flood Events – The PMF was modelled and the indicative extent and depth of inundation presented on **Figure 2.3**.

2 – Effects on the Community

Information on the properties affected by the 1% AEP design flood are included in this report (**Figure 2.2**), noting that the floor level data used in this assessment were a combination of field survey and estimates which were made from the LiDAR survey and "drive by" survey.

Figure 2.5 shows stage hydrographs at road crossings at Lithgow, the locations of which are shown on **Figure 2.2**.

Figure 2.6 shows the location of vulnerable development and critical infrastructure in Lithgow relative to the flood extents ranging between 20% and 0.2% AEP, as well as the PMF. Refer **Section 2.7** for details of affected infrastructure.

Figures 3.12, **3.13** and **3.14** show the flood emergency response planning classifications for the 5% AEP, 1% AEP and PMF events, respectively, based on the definitions set out in AIDR, 2017.

3.6.3 Public Awareness Programs

Community awareness and appreciation of the existing flood hazards in the floodplain would promote proper land use and development in flood affected areas. A well informed community would be more receptive to requirements for flood proofing of buildings and general building and development controls imposed by Council. Council should also take advantage of the information on flooding presented in this report, including the flood mapping, to inform occupiers of the floodplains of the flood risk.

One aspect of a community's preparedness for flooding is the "flood awareness" of individuals. This includes awareness of the flood threat in their area and how to protect themselves against it. The overall level of flood awareness within the community tends to reduce with time, as memories fade and as residents move into and out of the floodplain. The improvements to flood warning arrangements described above, as well as the process of disseminating this information to the community, would represent a major opportunity for increasing flood awareness in Lithgow.

Means by which community awareness of flood risks can be maintained or may be increased include:

- displays at Council offices using the information contained in the present study and photographs of historic flooding in the area;
- talks by NSW SES officers with participation by Council and longstanding residents with first-hand experience of flooding in the area; and
- preparation of a *Flood Information Brochure* which could be prepared by Council with the assistance of NSW SES containing both general and site specific data and distributed with rate notices.

The community should also be made aware that a flood greater than historic levels or the flood planning level can, and will, occur at some time in the future.

4 SELECTION OF FLOODPLAIN RISK MANAGEMENT MEASURES

4.1 Background

NSWG, 2005 requires a Council to develop a Floodplain Risk Management Plan based on balancing the merits of social, environmental and economic considerations which are relevant to the community. This chapter sets out a range of factors which need to be taken into consideration when selecting the mix of works and measures that should be included in *Lithgow FRMP 2023*.

The community will have different priorities and, therefore, each needs to establish its own set of considerations used to assess the merits of different measures. The considerations adopted by a community must, however, recognise the State Government's requirements for floodplain management as set out in NSWG, 2005 and other relevant policies. A further consideration is that some elements of *Lithgow FRMP 2023* may be eligible for subsidy from State and Federal Government sources and the requirements for such funding must, therefore, be taken into account.

4.2 Ranking of Measures

NSWG, 2005 provides a basis for assessing the merits of various measures for possible inclusion in a Floodplain Risk Management Plan. It is a subjective scoring system which includes the weighing of each measure based on its level of importance to key stakeholders. The chief merits of such a system are that it allows comparisons to be made between alternatives using a common "currency". In addition, it makes the assessment of alternatives "transparent" (i.e. all important factors are included in the analysis). The system does not, however, provide an absolute "right" answer as to what should be included in *Lithgow FRMP 2023* and what should be left out. Rather, it provides a method by which Council can re-examine the measures and if necessary, debate the relative scoring given to aspects of *Lithgow FRMP 2023*.

The approach requires each measure to be given a score of between 1 and 5 for a range of criteria. A "Do Nothing" approach is weighted at 2.5 for each criterion as it does not have a cost of benefit to the community. This then provides a basis for ranking the assessed measures based upon their relative benefit or cost. Measures with positive benefits are scored >2.5 to 5, while options with negative impacts are scored from 0 to <2.5. The raw scores are then multiplied by a weighting factor of between 1 and 10 which is determined by the FRMC. The weighted scores are then tallied, with the resulting values providing an indication of which should be considered for inclusion in the Floodplain Risk Management Plan.

In the case of Lithgow, two separate sessions of the FRMC were held to determine the weighting factor which is to apply to each criterion. The first session was attended by representatives from Council, DPE and the Consultant, while the second session was attended by the community representatives on the FRMC. In order to derive a single value of between 1 and 10, the values derived during the first and second sessions were given a weighting of 3 to 1, respectively.

Table 4.1 at the end of this chapter sets out the list of criteria that were adopted for undertaking the assessment, as well as the weightings that were derived from the two separate sessions, while **Table 4.2** provides a key to the identifiers that were assigned to each measure. **Tables 4.2** and **4.3** present the raw and weighted scores for the potential flood modification measures, respective, while **Table 4.4** ranks each measure based on the outcomes of the assessment process.

4.3 Summary

Based on the outcomes of the assessment process, there are good reasons to consider including the following elements into Lithgow FRMP 2023:

- An update of the *Lithgow LEP 2014* to allow better management of the floodplain
- Improved planning controls through the update of *Lithgow DCP 2021* to incorporate the recommendations set out in this report.
- Incorporation of the catchment specific information on flooding impacts contained in this study in NSW SES Response Planning and Flood Awareness documentation for the study area.
- Improvements to the flood warning system for Lithgow through the implementation of a comprehensive flood warning system which would include the installation of a number of telemetered pluviographic rain and stream gauges, along with automated boom gates and a public announcement system.
- Improved public awareness of flood risk in the community.
- Development of stormwater and flood risk management strategy for future growth areas in the Marrangaroo Creek catchment.
- The commissioning of a *Voluntary Purchase and House Raising Feasibility Study* to assess the merits of including up to thirty (30) properties that are subject to relatively deep and potentially fast moving floodwater in the NSW Government's Voluntary Purchase Scheme and up to nine (9) dwellings that are subject to less hazardous flooding conditions and are of weatherboard type construction in the NSW Government's Voluntary House Raising Scheme.
- The commissioning of a feasibility study and concept design of the George Coates Street Drainage Improvement Works.
- The detailed design and construction of the George Coates Street Drainage Improvement Works.
- The commissioning of a feasibility study and concept design of the Lithgow High School Detention Basin.
- The detailed design and construction of the Lithgow High School Detention Basin.
- The commissioning of a feasibility study and concept design of the Farmers Creek Channel Works – Stages 3, 4, 5 and 6.
- The detailed design and construction of the Farmers Creek Channel Works – Stages 3, 4, 5 and 6.
- Development and implementation of a *Vegetation Management Plan* for Farmers Creek and its major tributaries.

During the public exhibition of the draft *Lithgow FRMS&P 2023* it became apparent that the flood models did not reflect flooding patterns in several areas where new subdivision development has occurred. Based on this finding, the update the flood models and associated mapping to more accurately define the nature of flooding in these areas has been included in *Lithgow FRMS&P 2023*.

TABLE 4.1
ADOPTED ASSESSMENT CRITERIA AND WEIGHTINGS

Criteria	Weight of Criteria (1 to 10)		
	FRMC Session 1	FRMC Session 2	Adopted Weighting
Feasibility			
Technical	9	-	9
Affordability to community considering the potential to attract funding	8	-	9
Adaptability to change for long-term feasibility	5	-	5
Community acceptability	5	4	5
Flood Behaviour - Impacts and Benefits			
In area served by FRM measure	9	10	9
In other areas	-	10	10
Hazard in FPA	10	7	9
Hazard in extreme	3	10	5
People - Impacts and Benefits			
Frequency/scale of exposure	10	-	10
Availability of warning	10	10	10
Ability to evacuate	10	6	9
Environmental			
Environmental impact of works	7	8	7
Inclusion of environmental enhancements	9	9	9
Social Set - Impacts and Benefits			
Wellbeing	7	9	8
Social disruptions	7	6	7
Recreation	4	2	4
Property values	2	5	3
Insurance costs	4	8	5
Cultural Impacts and Benefits			
Cultural heritage sites	5	2	4
Cultural events	-	3	3
Cultural flows	-	-	-
Public Administration - Impacts and Benefits			
Infrastructure outages	10	10	10
Ability of community to recover	10	9	10
Ability to manage risks as the community grows	10	8	10
Economic Efficiency			
Lifecycle benefits	8	-	8
Lifecycle cost	8	-	8
Cost-benefit ratio	5	-	5

TABLE 4.2
SUMMARY OF ASSESSED FLOOD MODIFICATION MEASURES

Identifier	Description of Measure
FM1	James Street Drainage Improvement Works
FM2	George Coates Street Drainage Improvement Works
FM3	Barton Street Drainage Improvement Works
FM4	Berry Street Detention Basin
FM5	Lithgow High School Detention Basin
FM6	Hassan Walls Reserve Detention Basin
FM7	Farmers Creek Channel Works – Stages 3 and 4
FM8	Farmers Creek Channel Works – Stages 3, 4 and 5
FM9	Farmers Creek Channel Works – Stage 6
FM10	Farmers Creek Channel Works – Stages 3, 4, 5 and 6
FM11	Vegetation Management
FM12	Review and Update of Sewerage System Assessment
PM1	Controls over Future Development (via update of *Lithgow LEP 2014* and *Lithgow LEP 2014* and Lithgow DCP 2021)
PM2	Voluntary Purchase of Residential Property Subject to Highly Hazardous Flooding Conditions
PM3	House Raising in Areas Subject to Less Hazardous Conditions
PM4	Stormwater and Flood Risk Management Strategy for Future Growth Areas in Marrangaroo Creek catchment
RM1	Improvements to Flood Warning System
RM2	Improved Emergency Planning and Response
RM3	Public Awareness Programs
Do Nothing	Do Nothing Approach

TABLE 4.3
ASSESSMENT OF POTENTIAL FLOODPLAIN RISK MANAGEMENT MEASURES
RAW SCORES

Criteria	Potential Measures																			
	Flood Modification													Property Modification				Response Modification		
	Do Nothing	FM1	FM2	FM3	FM4	FM5	FM6	FM7	FM8	FM9	FM10	FM11	FM12	PM1	PM2	PM3	PM4	RM1	RM2	RM3
Feasibility																				
Technical	2.5	1.5	3	3	3	4	3	4.5	4.5	4.5	4.5	5	5	5	4	4	5	5	5	5
Affordability to community considering the potential to attract funding	2.5	1.5	1.5	3	1.5	3	1.5	3	3	4	3	5	2.5	5	4	4	5	5	5	5
Adaptability to change for long-term feasibility	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	4	3	5	2.5	2.5	5	5	5	5
Community acceptability	2.5	5	5	5	2	3.5	3.5	3	3	3	3	5	4	5	2.5	2	5	4	5	3
Flood Behaviour - Impacts and Benefits																				
In area served by FRM measure	2.5	3	4	3.5	3.5	4.5	3	3	4.5	1	4.5	3.5	2.5	5	4	3	5	2.5	2.5	2.5
In other areas	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	1	2.5	3.5	2.5	5	0	0	0	2.5	2.5	2.5
Hazard in FPA	2.5	2.5	4	3.5	3.5	4.5	2.5	4	4.5	1	4.5	3.5	2.5	5	5	3	5	2.5	2.5	2.5
Hazard in extreme	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	3	5	3	3	2.5	2.5	2.5
People - Impacts and Benefits																				
Frequency/scale of exposure	2.5	2.5	4	3.5	3.5	4.5	2.5	4	4.5	2.5	4.5	3.5	3.5	4	5	4	4	5	5	5
Availability of warning	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	3	2.5	3	3	5	5	5
Ability to evacuate	2.5	2.5	4	3.5	3.5	4.5	2.5	4	4.5	2.5	4.5	3.5	2.5	4	2.5	3	4	5	5	5
Environmental																				
Environmental impact of works	2.5	2.5	2.5	2.5	2.5	2.5	1.5	3.5	3.5	3.5	3.5	3.5	4	2.5	3	2.5	4	2.5	2.5	2.5
Inclusion of environmental enhancements	2.5	2.5	2.5	2.5	2.5	2.5	1.5	3.5	3.5	3.5	3.5	3.5	3.5	2.5	3	2.5	4	2.5	2.5	2.5
Social Set - Impacts and Benefits																				
Wellbeing	2.5	2.5	2.5	2.5	2.5	2.5	2.5	3	3.5	2.5	3.5	3	3.5	4	4	3	4	4	2.5	3.5
Social disruptions	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	3	4	2.5	2.5	2.5
Recreation	2.5	2.5	2.5	2.5	2.5	2.5	2.5	3	3.5	2.5	3.5	3	2.5	2.5	4	2.5	4	2.5	2.5	2.5
Property values	2.5	2.5	2.5	2.5	2.5	2.5	2.5	3	3.5	2.5	3.5	2.5	2.5	4	2.5	3	4	2.5	2.5	2.5
Insurance costs	2.5	2.5	2.5	2.5	2.5	2.5	2.5	3	3.5	2.5	3.5	2.5	2.5	4	2.5	3	4	2.5	2.5	2.5
Cultural Impacts and Benefits																				
Cultural heritage sites	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	4	2.5	2.5	2.5
Cultural events	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	4	2.5	2.5	2.5
Cultural flows	-	-	-	-	-	-	-	-	-	-	-	-	2.5	-	-	-	-	-	-	-
Public Administration - Impacts and Benefits																				
Infrastructure outages	2.5	3	3.5	3.5	3.5	3.5	3.5	3.5	4	2.5	4	2.5	4	4	2.5	2.5	4	3.5	3.5	3.5
Ability of community to recover	2.5	3	3.5	3.5	3.5	3.5	3.5	3.5	4	2.5	4	2.5	4	4	5	4	4	3.5	3.5	3.5
Ability to manage risks as the community grows	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	4	4	2.5	2.5	4	3.5	3.5	3.5
Economic Efficiency																				
Lifecycle benefits	2.5	3	3	3	3.5	3.5	3	3.5	4	2.5	4	3	4	4	4	3.5	4	2.5	2.5	2.5
Lifecycle cost	2.5	4	4	4	3.5	3.5	3	3	3	3	3	3	4	4	4	3.5	4	2.5	2.5	2.5
Cost-benefit ratio	2.5	1	1	1	1	4.5	1	1	1	1.5	1.5	2.5	4	4	2.5	3.5	4	2.5	2.5	2.5

TABLE 4.4
ASSESSMENT OF POTENTIAL FLOODPLAIN RISK MANAGEMENT MEASURES
WEIGHTED SCORES

Criteria	Potential Measures																			
	Flood Modification													Property Modification				Response Modification		
	Do Nothing	FM1	FM2	FM3	FM4	FM5	FM6	FM7	FM8	FM9	FM10	FM11	FM12	PM1	PM2	PM3	PM4	RM1	RM2	RM3
Feasibility																				
Technical	22.5	13.5	27	27	27	36	27	40.5	40.5	40.5	40.5	45	45	45	36	36	45	45	45	45
Affordability to community considering the potential to attract funding	22.5	13.5	13.5	27	13.5	27	13.5	27	27	36	27	45	22.5	45	36	36	45	45	45	45
Adaptability to change for long-term feasibility	12.5	12.5	12.5	12.5	12.5	12.5	12.5	12.5	12.5	12.5	12.5	20	15	25	12.5	12.5	25	25	25	25
Community acceptability	12.5	25	25	25	10	17.5	17.5	15	15	15	15	25	20	25	12.5	10	25	20	25	15
Flood Behaviour - Impacts and Benefits																				
In area served by FRM measure	22.5	27	36	31.5	31.5	40.5	27	27	40.5	9	40.5	31.5	22.5	45	36	27	45	22.5	22.5	22.5
In other areas	25	25	25	25	25	25	25	25	25	10	25	35	25	50	0	0	0	25	25	25
Hazard in FPA	22.5	22.5	36	31.5	31.5	40.5	22.5	36	40.5	9	40.5	31.5	22.5	45	45	27	45	22.5	22.5	22.5
Hazard in extreme	12.5	12.5	12.5	12.5	12.5	12.5	12.5	12.5	12.5	12.5	12.5	12.5	12.5	15	25	15	15	12.5	12.5	12.5
People - Impacts and Benefits																				
Frequency/scale of exposure	25	25	40	35	35	45	25	40	45	25	45	35	35	40	50	40	40	50	50	50
Availability of warning	25	25	25	25	25	25	25	25	25	25	25	25	25	30	25	30	30	50	50	50
Ability to evacuate	22.5	22.5	36	31.5	31.5	40.5	22.5	36	40.5	22.5	40.5	31.5	22.5	36	22.5	27	36	45	45	45
Environmental																				
Environmental impact of works	17.5	17.5	17.5	17.5	17.5	17.5	10.5	24.5	24.5	24.5	24.5	24.5	28	17.5	21	17.5	28	17.5	17.5	17.5
Inclusion of environmental enhancements	22.5	22.5	22.5	22.5	22.5	22.5	13.5	31.5	31.5	31.5	31.5	31.5	31.5	22.5	27	22.5	36	22.5	22.5	22.5
Social Set - Impacts and Benefits																				
Wellbeing	20	20	20	20	20	20	20	24	28	20	28	24	28	32	32	24	32	32	20	28
Social disruptions	17.5	17.5	17.5	17.5	17.5	17.5	17.5	17.5	17.5	17.5	17.5	17.5	17.5	17.5	17.5	21	28	17.5	17.5	17.5
Recreation	10	10	10	10	10	10	10	12	14	10	14	12	10	10	16	10	16	10	10	10
Property values	7.5	7.5	7.5	7.5	7.5	7.5	7.5	9	10.5	7.5	10.5	7.5	7.5	12	7.5	9	12	7.5	7.5	7.5
Insurance costs	12.5	12.5	12.5	12.5	12.5	12.5	12.5	15	17.5	12.5	17.5	12.5	12.5	20	12.5	15	20	12.5	12.5	12.5
Cultural Impacts and Benefits																				
Cultural heritage sites	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	16	10	10	10
Cultural events	7.5	7.5	7.5	7.5	7.5	7.5	7.5	7.5	7.5	7.5	7.5	7.5	7.5	7.5	7.5	7.5	12	7.5	7.5	7.5
Cultural flows	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Public Administration - Impacts and Benefits																				
Infrastructure outages	25	30	35	35	35	35	35	35	40	25	40	25	40	40	25	25	40	35	35	35
Ability of community to recover	25	30	35	35	35	35	35	35	40	25	40	25	40	40	50	40	40	35	35	35
Ability to manage risks as the community grows	25	25	25	25	25	25	25	25	25	25	25	25	40	40	25	25	40	35	35	35
Economic Efficiency																				
Lifecycle benefits	20	24	24	24	28	28	24	28	32	20	32	24	32	32	32	28	32	20	20	20
Lifecycle cost	20	32	32	32	28	28	24	24	24	24	24	24	32	32	32	28	32	20	20	20
Cost-benefit ratio	12.5	5	5	5	5	22.5	5	5	5	7.5	7.5	12.5	20	20	12.5	17.5	20	12.5	12.5	12.5
TOTALS	**477.5**	**495.0**	**569.5**	**564.5**	**536.0**	**620.5**	**487.0**	**599.5**	**651.0**	**484.5**	**653.5**	**619.5**	**624.0**	**754.0**	**628.0**	**560.5**	**755.0**	**657.0**	**650.0**	**648.0**

TABLE 4.5
RANKING OF ASSESSED FLOOD MANAGEMENT MEASURES

Rank	Identifier	Description of Measure	Total Weighted Score
1	PM4	Stormwater and Flood Risk Management Strategy for Future Growth Areas in Marrangaroo Creek catchment	755.0
2	PM1	Controls over Future Development (via update of Lithgow LEP 2014 and Lithgow LEP 2014 and Lithgow DCP 2021)	754.0
3	RM1	Improvements to Flood Warning System	657.0
4	FM10	Farmers Creek Channel Works – Stages 3, 4, 5 and 6	653.5
5	FM8	Farmers Creek Channel Works – Stages 3, 4 and 5	651.0
6	RM2	Improved Emergency Planning and Response	650.0
7	RM3	Public Awareness Programs	648.0
8	PM2	Voluntary Purchase of Residential Property Subject to Highly Hazardous Flooding Conditions	628.0
9	FM12	Review and Update of Sewerage System Assessment	624.0
10	FM5	Lithgow High School Detention Basin	620.5
11	FM11	Vegetation Management	619.5
12	FM7	Farmers Creek Channel Works – Stages 3 and 4	599.5
13	FM2	George Coates Street Drainage Improvement Works	569.5
14	FM3	Barton Street Drainage Improvement Works	564.5
15	PM3	House Raising in Areas Subject to Less Hazardous Conditions	560.5
16	FM4	Berry Street Detention Basin	536.0
17	FM1	James Street Drainage Improvement Works	495.0
18	FM6	Hassan Walls Reserve Detention Basin	487.0
19	FM9	Farmers Creek Channel Works – Stage 6	484.5
20	Do Nothing	Do Nothing Approach	477.5

5 LITHGOW FLOODPLAIN RISK MANAGEMENT PLAN 2023

5.1 The Floodplain Risk Management Process

The *Lithgow Floodplain Risk Management Study 2023 (**Lithgow FRMS 2023**)* and *Lithgow Floodplain Risk Management Plan 2023* (***Lithgow FRMP 2023***) have been prepared for the township of Lithgow (**study area**) as part of a Government program to mitigate the impacts of major floods and reduce the hazards in the floodplain. The *Lithgow FRMP 2023* which is set out in this Chapter has been prepared as part of the Floodplain Risk Management Process in accordance with NSW Government's Flood Prone Land Policy.

The first steps in the process of preparing the *Lithgow FRMP 2023* was the update of the *Lithgow Flood Study Review* (Lyall & Associates, 2017) based on the procedures set out in the recently released edition of *Australian Rainfall and Runoff* (Geoscience Australia, 2019) (***Updated Flood Study***), details of which are set out in **Appendix B** of the *Lithgow FRMS 2023* report.

5.2 Purpose of the Plan

The overall objectives of *Lithgow FRMS 2023* were to assess the impacts of flooding, review policies and measures for management of flood affected land and to develop *Lithgow FRMP 2023* which:

- Sets out the recommended program of works and measures aimed at reducing over time, the social, environmental and economic impacts of flooding and establishes a program and funding mechanism for *Lithgow FRMP 2023*.
- Proposes amendments to Lithgow City Council's (**Council's**) existing policies to ensure that the future development of flood affected land in the study area is undertaken so as to be compatible with the flood hazard and risk.
- Ensures *Lithgow FRMP 2023* is consistent with NSW State Emergency Services (**NSW SES's**) local emergency response planning procedures.
- Ensures that *Lithgow FRMP 2023* has the support of the community.

5.3 The Study Area

The study area for *Lithgow FRMP 2023* applies to areas that are affected by the following two types of flooding in the Farmers Creek and Marrangaroo Creek catchments at Lithgow:

- **Main Stream Flooding**, which occurs when floodwater surcharges the inbank area of the existing creek system. Main Stream Flooding is typically characterised by relatively deep and fast flowing floodwater, but may be shallower and slower moving in flood fringe areas.
- **Major Overland Flow** which occurs during storms which result in the surcharge of the existing stormwater drainage system. It is also present in the upper reaches of the study catchments. Major Overland Flow is typically characterised by relatively shallow and slow moving floodwater.

Figure 1.1 (2 sheets) is a location and catchment plan, while **Figure 2.1** (4 sheets) shows the key features of the existing stormwater drainage system at Lithgow.

5.4 Community Consultation

The Community Consultation process provided valuable direction over the course of the investigations, bringing together views from key Council staff, other departments and agencies, and importantly, the views of the community gained through:

- the delivery of a *Community Newsletter and Questionnaire* to residents and business owners in the study area which allowed the wider community to gain an understanding of the issues being addressed as part of the study and sort their view on a range of potential floodplain risk management measures;
- the public exhibition of the draft *Lithgow FRMS 2023* and *Lithgow FRMP 2023*;
- the hosting of a public information session and the holding of one-on-one sessions with concerned residents and the Consultant during the exhibition period;
- the preparation of responses to 48 formal submissions that were received by the close of the public exhibition period.

Based on the responses to *Community Questionnaire*, the following measures were favoured by the community:

- Management of vegetation along creek corridors
- Improvements in the stormwater system
- Removal of floodplain obstructions
- Ensuring all information about the potential risks of flooding is available to all residents and business owners
- Advice of flood affectation via Planning Certificates for properties located in flood liable areas
- Improved flood warning, evacuation and flood response procedures both before and during a flood
- Flood related controls over future development in flood liable areas
- Community education to promote flood awareness

Meetings were also held with the Floodplain Risk Management Committee to discuss the findings of *Lithgow FRMS 2023* and also the recommended set of measures set out in *Lithgow FRMP 2023*.

5.5 Existing Flood Behaviour

Lithgow has experienced several large floods that have inundated parts of the floodplain and in some cases impacted existing development. These occurred in February 1928, June 1963, June 1964, March 1978, August 1986 and February 1990. The March 1978 event is said to have produced the highest flood levels, followed by the February 1990 and August 1986 events.

A number of storm events that have caused localised flooding in parts of Lithgow were also identified as part of Lyall & Associates, 2017. These occurred in 1981, 1985, 1996, 1997, 2004, and more recently in January 2011 and February 2013. More recently, major flooding was experienced in parts of Lithgow in January 2022, when intense rainfall resulted in the surcharge of the existing stormwater drainage systems that are located to the south of the Main Western Railway.

Figures 2.2 and **2.3** in **Volume 2** of the *Lithgow FRMS 2023* report show the indicate extent and depth of inundation for the 1% Annual Exceedance Probability (**AEP**) and Probable Maximum Flood (**PMF**) events, respectively, while **Figure 2.4** shows design water surface profiles along the major watercourses in the study area. **Figure 2.5** shows the time of rise of floodwaters at a number of key locations in Lithgow, while **Figure 2.6** shows the indicate extent of flooding at Lithgow for floods of between 20% AEP and the PMF event.

5.6 Existing Flood Mitigation Measures

A total of seven detention basins have been built by either Council or private developers to minimise hazardous flooding conditions that present a high risk to occupants of the floodplain and reduce the extent and severity of flood-related property damages. The detention basins also serve to offset the increase in catchment runoff from large residential subdivisions.

Council has also implemented the following measures which formed part of the *Lithgow Floodplain Management Plan* that was prepared on behalf of Council in 1991 (***Lithgow FMP 1991***):

- Detailed assessment of the stormwater drainage system in the city (undertaken as part of Lyall & Associates, 2017).
- Implemented building, development and zoning controls through the development of the *Lithgow Development Control Plan 2021* (***Lithgow DCP 2021***).
- Enlarging of the waterway along a 690 m reach of Farmers Creek in the vicinity of Hermitage Flat, including the enlarging of the waterway area under the Albert Street Bridge (construction completed in 2015). These works comprised Stage 1 and 2 of the proposed flood mitigation works at Hermitage Flat.
- Clearing of inbank vegetation and enlarging of waterway area of a 100 m reach of Farmers Creek in the vicinity of its confluence with State Mine Creek (construction completed in 1998).
- Clearing of in-bank vegetation and enlarging of waterway area of a 180 m reach of Farmers Creek immediately downstream of Victoria Avenue (construction completed in 1998).
- Construction of the Lake Pillans Wetland detention basin (construction completed prior to 1998).
- Voluntary purchase of nineteen (19) dwellings, the most recent of which was purchased as late as 2014.
- Voluntary house raising of one dwelling.

A complete list of the measures that comprised *Lithgow FMP 1991,* along with their status in terms of their implementation is set out in **Table 3.1** in **Chapter 3** of the *Lithgow FRMS 2023* report.

5.7 Economic Impacts of Flooding

Tables 5.1 and **5.2** shows the number of properties that would be flooded to above-floor level and the damages experienced in residential and commercial/industrial development, as well as public buildings in the Farmers Creek and Marrangaroo Creek catchments, respectively.

At the 1% AEP level of flooding, 265 dwellings, 48 commercial/industrial buildings and one public building that are located in the Farmers Creek catchment are subjected to above-floor inundation,

while an additional 1,221 dwellings and 95 commercial/industrial would experience above-floor inundation in a PMF event.

The total flood damages in the Farmers Creek catchment amounts to $41.4 Million in the event of a 1% AEP flood, increasing to about $296 Million in a PMF event. For a discount rate of 7% pa and an economic life of 50 years, the *Present Worth Value* of damages for all flood events up to the 1% AEP flood is about $46.9 Million.

TABLE 5.1
ECONOMIC IMPACTS OF FLOODING IN THE FARMERS CREEK CATCHMENT

Design Flood Event (% AEP)	Properties Flooded Above-Floor Level						Total Flood Damages
	Residential		Commercial/Industrial		Public		
	No.	$ Million	No.	$ Million	No.	$ Million	$ Million
20	33	5.31	23	1.24	0	0.02	6.57
10	49	7.59	27	1.62	0	0.04	9.25
5	89	12.2	36	3.92	0	0.06	16.2
2	165	21.3	43	5.82	0	0.06	27.2
1	265	32.9	48	8.39	1	0.1	41.4
0.5	332	40.7	54	9.85	1	0.14	50.7
0.2	399	48.7	58	12.20	3	0.23	61.1
PMF	1,486	216	143	74.6	10	5.83	296

TABLE 5.2
ECONOMIC IMPACTS OF FLOODING IN THE MARRANGAROO CREEK CATCHMENT

Design Flood Event (% AEP)	Properties Flooded Above-Floor Level						Total Flood Damages
	Residential		Commercial/Industrial		Public		
	No.	$ Million	No.	$ Million	No.	$ Million	$ Million
20	0	0.02	0	0	0	0	0.02
10	0	0.08	0	0	0	0.02	0.10
5	1	0.18	0	0	1	0.04	0.22
2	1	0.24	0	0	1	0.06	0.30
1	2	0.36	0	0	1	0.10	0.46
0.5	5	0.51	0	0	1	0.12	0.63
0.2	6	0.66	0	0.02	1	0.16	0.84
PMF	33	4.42	3	0.62	2	15.1	20.1

It is noted that the assessed flood hazard in existing residential development has reduced when compared to the findings of *Lithgow FMP 1991* (as evidenced by the reduced number of properties that have been deemed eligible for inclusion in a contemporaneous Voluntary Purchase scheme for Lithgow (refer **Section 3.5.3** of the *Lithgow FRMS* report for further details)). The principal reasons for this are that Council has subsequently completed Stages 1 and 2 of the Farmers Creek Channel Works which have reduced the severity of flooding in Hermitage Flat, in combination with the more detailed flood modelling which has more accurately defined the nature of flooding at Lithgow.

Within the Marrangaroo Creek catchment, only two dwellings and one public building would experience above-floor inundation during a 1% AEP flood event, increasing to 33 dwellings, three commercial/industrial buildings and two public buildings during a PMF event. The total flood damages in the Marrangaroo Creek catchment would amount to $0.46 Million in the event of a 1% AEP flood, increasing to about $20.1 Million in a PMF event. For a discount rate of 7% pa and an economic life of 50 years, the *Present Worth Value* of damages for all flood events up to the 1% AEP flood is about $0.7 Million.

5.8 Structure of Lithgow Floodplain Risk Management Plan 2023

A summary of *Lithgow FRMP 2023* proposed for the study area along with broad funding requirements for the recommended measures are shown in **Table S1** at the commencement of the *Lithgow FRMS 2023* report. These measures comprise preparation of planning documentation by Council, improvements to the flood warning system and community education on flooding by Council and NSW SES to improve flood awareness and response, as well as the investigation and design of a number of flood modification measures. The measures will over time achieve the objectives of reducing the flood risk to existing and future development for the full range of floods.

Lithgow FRMP 2023 is based on the following mix of measures which have been given a provisional priority ranking according to a range of economic, social, environmental and other criteria that are set out in **Table 4.1** of the *Lithgow FRMS 2023* report:

- **Measure 1** – Include special flood considerations clause in the *Lithgow Local Environmental Plan, 2014* (***Lithgow LEP 2014***)
- **Measure 2** – Improvements to planning and development controls for future development in flood prone areas
- **Measure 3** – Improvements to emergency response planning
- **Measure 4** – Increase public awareness of the risks of flooding in the community
- **Measure 5** – Update of the flood models and associated mapping to more accurately define the nature of flooding in new subdivision development.
- **Measure 6** - Preparation of stormwater and flood risk management strategy for future growth areas in the Marrangaroo Creek catchment
- **Measure 7** – Investigation and design of an integrated flood warning system for Lithgow
- **Measure 8** – Implementation of an integrated flood warning system for Lithgow
- **Measure 9** – Commissioning of a *Voluntary Purchase and House Raising Feasibility Study* and subject to agreement with the affected property owners and confirmation of the date of construction, the purchase of up to thirty (30) residential properties and the raising of up to nine (9) dwellings that are of weatherboard type construction

- **Measure 10** - Investigation and concept design of George Coates Street Drainage Works
- **Measure 11** – Detailed design and construction of George Coates Street Drainage Works
- **Measure 12** - Investigation and concept design of Lithgow High School Detention Basin
- **Measure 13** – Detailed design and construction of Lithgow High School Detention Basin
- **Measure 14** - Investigation and concept design of Farmers Creek Channel Works – Stages 3, 4, 5 and 6
- **Measure 15** – Detailed design and construction of Farmers Creek Channel Works – Stages 3, 4, 5 and 6
- **Measure 16** – Development and implementation of a *Vegetation Management Plan* for Farmers Creek and its major tributaries
- **Measure 17** – Review and update previous investigation into the existing sewerage system at Lithgow using the flooding and drainage information set out in the *Lithgow FRMS 2023* report.

5.9 Planning and Development Controls

The results of *Lithgow FRMS 2023* indicate that an important measure for Council to adopt in the floodplain would be strong floodplain risk management planning applied consistently by all of its branches.

5.9.1 Revision of Lithgow Local Environmental Plan 2014

Clause 5.21 of *Lithgow LEP 2014* entitled “Flood planning” outlines its objectives in regard to development of land which lies within the Flood Planning Area (**FPA**). The wording in the flood planning clause was updated on 14 July 2021 as part of recent reforms that have been implemented by the NSW Government.

While the wording of the *flood planning* clause was automatically updated on 14 July 2021, Council chose not to include a new *special flood considerations* clause that also formed part of the recent reform package. Based on the findings of *Lithgow FRMS 2023*, it is recommended that Council now look to include this additional clause in *Lithgow LEP 2014* (**Measure 1**), noting that its objectives are:

a) in relation to development with particular evacuation or emergency response issues (e.g. group homes, residential care facilities, etc.), to enable evacuation of land subject to flooding in events exceeding the flood planning level; and

b) to protect the operational capacity of emergency response facilities and critical infrastructure during extreme flood events.

The new clause would apply to land which lies between the FPA and the extent of the PMF. Wording in relation to this new clause is given in **Section 3.5.1.4** of the *Lithgow FRMS 2023* report.

5.9.2 Lithgow Development Control Plan 2021

The recommended approach to managing future development in the study area uses the concepts of *flood hazard* and *hydraulic categorisation* to develop controls for future development in flood prone land (**Measure 2**). **Figure D1.1** in **Appendix D** is an extract from the *Flood Planning Map* relating to the study area. The extent of the FPA has been defined as follows:

- In areas subject to Main Stream Flooding, the FPA is based on the traditional definition of the area inundated by the 1% AEP plus 0.5 m freeboard.
- In areas subject to Major Overland Flow, the FPA is defined as the extent of floodway areas, as well as areas where depths of inundation in a 1% AEP event exceed 0.1 m.

It is proposed that properties are located either partially or wholly within the extent of the FPA would be subject to S10.7 flood affectation notification and planning controls graded according to flood hazard and hydraulic categorisation. **Annexures 2A** and **2B** in **Appendix D** set out the graded set of flood related planning controls which apply to development in areas that are affected by Main Stream Flooding and Major Overland Flow, respectively. **Figure D1.1** in **Appendix D** shows the areas where the graded set of flood related planning controls set out in **Annexures 2A** and **2B** apply.

Minimum habitable floor level (**MHFL**) requirements would be imposed on future development in properties that are identified as lying either partially or wholly within the extent of the FPA shown on **Figure D1.1**. The MHFLs for residential land use types is the level of the 1% AEP flood event plus freeboard, whereas for commercial and industrial land use types the MHFL is to be as close to the 1% AEP flood level plus freeboard as practical, but no lower than the 5% AEP flood level plus freeboard. In situations where the MHFL is below the 1% AEP flood level plus freeboard, a mezzanine area equal to 30% of the total habitable floor area is to be provided, the elevation of which is to be set no lower than the 1% AEP flood level plus freeboard.[12]

Figure D1.2 in **Appendix D** is an extract of the *Flood Planning Constraint Category Map* for Lithgow. The figure shows the subdivision of the floodplain into the following four categories which have been used as the basis for developing the graded set of planning controls:

- **Flood Planning Constraint Category 1 (FPCC 1)**, which comprises areas where factors such as the depth and velocity of flow, time of rise, and evacuation problems mean that the land is unsuitable for most types of development. The majority of new development types are excluded from this zone due to its potential impact on flood behaviour and the hazardous nature of flooding.
- **Flood Planning Constraint Category 2 (FPCC 2)**, which comprises areas which lie within the extent of the *Flood Planning Area* where the existing flood risk warrants careful consideration and the application of significant flood related controls on future development.
- **Flood Planning Constraint Category 3 (FPCC 3)**, which comprises areas which lie within the extent of the *Flood Planning Area* but outside areas designated FPCC1 and FPCC2. Areas designated FPCC3 are more suitable for new development and expansion of existing development provided it is carried out in accordance with the controls set out in this document.

[12] Freeboard is equal to 0.5 m for development being assessed in areas affected by Main Stream Flooding and 0.3 m for development being assessed in areas affected by Major Overland Flow.

- **Flood Planning Constraint Category 4 (FPCC 4)**, which comprises the area which lies between the extent of the *Flood Planning Area* and the PMF. Flood related controls in areas designated FPCC4 are typically limited to flood evacuation and emergency response, although additional controls apply to essential community facilities and utilities that are critical for response and recovery, as well as community hospitals, residential care facilities and group homes. This area is identical to the *Special Flood Considerations Zone* shown on the *Flood Planning Map*.

5.10 Improvements to Flood Warning, Emergency Response Planning and Community Awareness

Three measures are proposed in *Lithgow FRMP 2023* to improve flood warning, emergency response planning and community awareness to the threat posed by flooding.
Measure 3 involves the update by NSW SES of the *Lithgow City Local Flood Plan* using information on flooding patterns, times of rise of floodwaters and flood prone areas identified in the *Lithgow FRMS 2023* report. Figures have been prepared showing indicative extents of flooding, high hazard areas, expected rates of rise of floodwaters in key areas and locations where flooding problems would be expected. **Section 3.6.2** references the locations of key data within the *Lithgow FRMS 2023* report.

Council should also take advantage of the information on flooding presented in this report, including the flood mapping, to inform occupiers of the floodplains of the flood risk (included as **Measure 4** of *Lithgow FRMP 2023*). This information could be included in a *Flood Information Brochure* to be prepared by Council with the assistance of NSW SES containing both general and site specific data and distributed with the rate notices. The community should also be made aware that a flood greater than historic levels or the planning level can, and will, occur at some time in the future. *Lithgow FRMP 2023* should be publicised and exhibited at community gathering places to make residents aware of the measures being proposed.

Measure 7 firstly involves discussions with the Bureau of Meteorology (**BoM**) to ascertain whether the flood forecasting and warning system that it is in the process of developing for the Hawkesbury-Nepean Valley is sufficiently detailed to provide sufficient advance warning to occupiers of the floodplain at Lithgow, noting that the Farmers Creek and Marrangaroo Creek catchments lie in the headwaters of the valley.

If the system that is being developed by BoM is deemed unsuitable for Lithgow, then **Measure 7** would comprise the investigation and design of an integrated flood warning system which is specific to Lithgow. As minimum, this would involve the installation of a network of pluviographic rain gauges, along with a series of telemetered stream gauges. An automated alarm and public announcement system would also be linked to the telemetered stream gauges warning residents and business owners that key trigger levels have been reached and to monitor and take action where required. Other improvements include the installation of warning signs and self-deploying boom gates on low-level creek crossings. **Measure 8** involves the implementation of an integrated flood warning system for Lithgow.

5.11 Update of Flood Models and Associated Mapping

During the community consultation process it became apparent that the structure of the flood models did not reflect as-built conditions in a number of newly constructed subdivision development. It is therefore recommended that Council commission the capture of new LiDAR

survey data and for these data to be used along with additional information on the as-built stormwater drainage system to update the structure of the flood models and associated mapping so as to more accurately define the nature of Main Stream Flooding and major Overland Flow in these areas (**Measure 5**).

5.12 Marrangaroo Creek Catchment Stormwater and Flood Risk Management Strategy

Measure 6 involves the preparation of a stormwater and flood risk management strategy for future release areas that are located in the Marrangaroo Creek catchment. The strategy would determine the scope of measures which would be required to mitigate the impact that future development would otherwise have on both the quality and quantity of stormwater runoff, as well as determine the land-take requirements for the construction of such measures.

It is recommended that the stormwater and flood risk management strategy incorporate both Integrated Water Cycle Management (**IWCM**) and Water Sensitive Urban Design (**WSUD**) given that Council is a Local Water Utility (**LWU**). It is also recommended that Council develop policies and guidelines for the application of IWCM and WSUD in future growth areas using best practice materials.

5.13 Voluntary Purchase and House Raising Scheme

Measure 9 involves the commissioning of a *Voluntary Purchase and House Raising Feasibility Study* for a maximum of thirty (30) residential properties that are subject to relatively deep and potentially fast moving floodwater (which makes them eligible for inclusion in a *Voluntary Purchase Scheme*) and a maximum of nine (9) dwellings that are of weatherboard type construction and are located in hazardous flood storage areas (which makes them eligible for inclusion in a *Voluntary House Raising Scheme*). Although subject to confirmation of the date of construction, agreement by the affected owners and the timing of the Farmers Creek Channel Works (refer below for further details), this measure includes the cost of purchasing the thirty (30) residential properties and raising the floor levels of the nine (9) dwellings.

5.14 Flood Modification Works

Based on a review of measures that comprised *Lithgow FMP 1991* and after taking the current views of the community into consideration, a range of potential flood modification measures were assessed for possible inclusion in *Lithgow FRMP 2023*, the details of which are set out in **Table 3.3** of the *Lithgow FRMS 2023* report. Based on the findings of the multi-criteria assessment which is set out in **Chapter 4** of the *Lithgow FRMS 2023* report, the following three "structural" flood modification measures were recommended for inclusion in *Lithgow FRMP 2023*:

- **George Coates Street Drainage Improvement Works**, which would involve the upgrade of the existing stormwater drainage system extending from the intersection of Main Street and Cupro Street, and the main arm of Farmers Creek. The measure would also include the provision of a new pedestrian underpass of the Main Western Railway. **Measure 10** comprises the feasibility and concept design of the measure, while **Measure 11** comprises its detailed design and construction.
- **Lithgow High School Detention Basin**, which would involve the construction of a detention basin within the grounds of Lithgow High School. **Measure 12** comprises the feasibility and concept design of the measure, while **Measure 13** comprises its detailed design and construction.

- **Farmers Creek Channel Works – Stages 3, 4, 5 and 6**, which would involve the widening and rehabilitation of a 1.42 km length of Farmers Creek extending upstream of the Albert Street bridge. **Measure 14** comprises the feasibility and concept design of the measure, while **Measure 15** comprises its detailed design and construction.

Given the high debris load that is present in flood flows at Lithgow, coupled with the potential for vegetation to partially obstruct flood flows and hence cause a rise in flood levels, *Lithgow FRMP 2023* includes the preparation and implementation of a *Vegetation Management Plan* for Farmers Creek and its major tributaries (**Measure 16**).

Due to ongoing concerns regarding the overloading and surcharge of the existing sewerage system at Lithgow during periods of wet weather, *Lithgow FRMP 2023* includes the review and update of a previous investigation that was undertaken in about 2008-09 using the flooding and drainage information that is set out in the *Lithgow FRMS 2023* report (**Measure 17**).

5.15 Implementation Program

The steps in progressing the floodplain management process from this point onwards are:

1. Consider public comment, modify the document if and as required, and submit to Council.
2. Council adopts *Lithgow FRMP 2023* and submits an application for funding assistance.
3. Assistance for funding qualifying projects included in *Lithgow FRMP 2023* may be available upon application under the Commonwealth and State funded floodplain management programs, currently administered by the Department of Planning, Industry and Environment.
4. As funds become available from Government agencies and/or Council's own resources, implement the measures in accordance with the established priorities.

Lithgow FRMP 2023 should be regarded as a dynamic instrument requiring review and modification over time. The catalysts for change could include new flood events and experiences, legislative change, alterations in the availability of funding, reviews of Council's planning strategies and importantly, the outcome of some of the studies proposed in this report as part of *Lithgow FRMP 2023*. In any event, a thorough review every ten years is warranted to ensure the ongoing relevance of *Lithgow FRMP 2023*.

6 GLOSSARY OF TERMS

Note: For expanded list of definitions, refer to Glossary contained within the NSW Government Floodplain Development Manual, 2005.

TERM	DEFINITION
Annual Exceedance Probability (AEP)	The chance of a flood of a given or larger size occurring in any one year, usually expressed as a percentage. For example, for a flood magnitude having five per cent AEP, there is a five per cent probability that there would be floods of greater magnitude each year.
Australian Height Datum (AHD)	A common national surface level datum corresponding approximately to mean sea level.
Floodplain	Area of land which is subject to inundation by floods up to and including the Probable Maximum Flood (**PMF**) event, that is, flood prone land.
Flood Planning Area	The area of land that is shown to be in the Flood Planning Area on the *Flood Planning Map*.
Flood Planning Map	The *Flood Planning Map* shows the extent of land on which flood related development controls apply.
Flood Planning Constraint Category 1 (FPCC 1)	Comprises areas where factors such as the depth and velocity of flow, time of rise, and evacuation problems mean that the land is unsuitable for most types of development. The majority of new development types are excluded from this zone due to its potential impact on flood behaviour and the hazardous nature of flooding
Flood Planning Constraint Category 2 (FPCC 2)	Comprises areas which lie below the *Flood Planning Level* where the existing flood risk warrants careful consideration and the application of significant flood related controls on future development.
Flood Planning Constraint Category 3 (FPCC 3)	Comprises areas which lie below the *Flood Planning Level* but outside areas designated FPCC1 and FPCC2. Areas designated FPCC3 are more suitable for new development and expansion of existing development provided it is carried out in accordance with the controls set out in this document.
Flood Planning Constraint Category 4 (FPCC 4)	Comprises the area which lies above the *Flood Planning Level* but within the extent of the PMF. Flood related controls in areas designated FPCC4 are typically limited to flood evacuation and emergency response, although additional controls apply to essential community facilities and utilities that are critical for response and recovery, as well as community hospitals, residential care facilities and group homes.
Flood Planning Level (FPL)	Flood levels selected for planning purposes, as determined by the relevant adopted floodplain risk management study and plan, or as part of a site specific study In the absence of an adopted floodplain risk management study and plan for a particular location, the FPL is defined as the peak 1% AEP flood level plus the addition of a 0.5 m freeboard.

TERM	DEFINITION
Flood Prone/Flood Liable Land	Land susceptible to flooding by the PMF. Flood Prone land is synonymous with Flood Liable land.
Floodway	Those areas of the floodplain where a significant discharge of water occurs during floods. They are often aligned with naturally defined channels. Floodways are areas that, even if only partially blocked, would cause a significant redistribution of flood flow, or a significant increase in flood levels.
Flood Storage Area	Those parts of the floodplain that may be important for the temporary storage of floodwaters during the passage of a flood. Loss of flood storage can increase the severity of flood impacts by reducing natural flood attenuation.
Freeboard	Provides reasonable certainty that the risk exposure selected in deciding a particular flood chosen as the basis for the *Flood Planning Level* is actually provided. It is a factor of safety typically used in relation to the setting of floor levels, levee crest levels, etc. Freeboard is included in the *Flood Planning Level*.
Habitable Room	In a residential situation: a living or working area, such as a lounge room, dining room, kitchen, bedroom or workroom. In an industrial or commercial situation: an area used for offices or to store valuable possessions susceptible to flood damage in the event of a flood.
Local Drainage	Land on an overland flow path where the depth of inundation during the 1% AEP storm event is less than 0.1 m.
Main Stream Flooding	Inundation of normally dry land occurring when water overflows the natural or artificial banks of a stream, river, estuary, lake or dam.
Major Overland Flow	Where the depth of overland flow during the 1% AEP storm event is greater than 0.1 m.
Probable Maximum Flood (PMF)	The largest flood that could conceivably occur at a particular location. Generally, it is not physically or economically possible to provide complete protection against this event. The PMF defines the extent of flood prone land, that is, the floodplain.

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APPENDIX A

COMMUNITY CONSULTATION

TABLE OF CONTENTS

ATTACHMENTS

A1 INTRODUCTION

At the commencement of the *FRMS,* the Consultants prepared a *Community Newsletter* and a *Community Questionnaire*, both of which were distributed by Council to the residents and business owners in Lithgow (refer to **Attachment 1**). The purpose of the *Community Newsletter* was to introduce the objectives of the study and set the scene on flooding conditions so that the community would be better able to respond to the *Community Questionnair*e and contribute to the study process.

The *Community Newsletter* contained the following information:

- A plan showing the extent of the study area.
- A statement of the objectives of the *FRMS&P*; namely the development of a strategy for reducing the flood risk and minimising the long-term impact of flooding on the community.

The *Community Questionnaire* was structured with the objectives of:

- Determining residents' and business owners' attitudes to controls over future development in flood liable areas.
- Inviting community views on possible flood management options which could be considered for further investigation in the *FRMS* and possible inclusion in the resulting *FRMP*.
- Obtaining feedback on any other flood related issues and concerns which the residents and business owners cared to raise.

This **Appendix** to the *FRMS&P* report discusses the responses to the nine questions that were included in the *Community Questionnaire* and comments made by respondents.

Chapter A2 deals with the residents' and business owners' views on the relative importance of classes of development over which flood-related controls should be imposed by Council.

Chapter A3 identifies residents' and business owners' views on the suitability of the various options which could be considered in more detail in the *FRMS.*

Chapter A4 discusses the best methods by which the community could provide feedback to the consultants over the course of the study.

Chapter A5 summarises the findings of the community consultation process.

A2 RESIDENT PROFILE AND FLOOD AWARENESS

A2.1 General

Residents were requested to complete the *Community Questionnaire* and return it to the Consultants by 28 August 2020. The deadline was extended to include any submissions that were received after this date. The Consultants received 196 responses in total out of the 2950 that had been distributed.

The Consultants have collated the responses which are shown in graphical format in **Attachment 2**.

A2.2 Respondent Profile

The first four questions of the *Community Questionnaire* canvassed information such as whether the respondent was a resident or business owner, length of time that the respondent had occupied the property and the type of property (e.g. house, unit/flat).

Of the 196 responses, 168 were residents and 17 were business owners, noting that seven respondents indicated they were both residents and business owners (**Question 2**). Twelve respondents owned property in the study area but lived elsewhere.

The length of time respondents had been at the address was found to be varied, with approximately 18% of respondents having lived at the residence for between '1-5 years', 37% for '5 to 20 years' and 43% for 'more than 20 years' (**Question 3**). Note that 3% of respondents did not answer this question.

The majority of respondents occupied residential type property (**Question 4**), which included houses (183 respondents), villas/townhouses (4) and one unit/flat/apartment. Three responses received were concerned with property which is vacant land. Nine respondents owned non-residential type property, which included stand alone warehouses or factories (5 respondents), shops/commercial premises (2), one industrial unit and one community building. The five respondents that selected 'other' occupied semi-rural farms. Note that some respondents indicated that they occupied more than one property classification type.

A2.3 Controls over Development in Flood Prone Areas

The respondents were asked to rank from 1 to 6 the classes of development which they consider should receive protection from flooding (**Question 5**). Rank 1 was the most important and rank 6 the least.

The classes in decreasing order of importance to respondents ranged from:

- residential property;
- vulnerable residential (e.g. aged persons accommodation);
- essential community facilities (e.g. schools, evacuation centres);
- commercial/business type development;
- new subdivisions; and
- minor developments and additions.

These results gave a guide to the Consultants as to the appropriate location of future development of the various classes within the floodplain. For example, on the basis of community views, consideration should be given to applying flood related development controls to residential development which lies above the FPL, while vulnerable residential type development and essential community facilities should receive the highest level of protection by locating future development of this nature outside the floodplain.

In **Question 6**, respondents were asked about the level of control Council should place on new development to minimise flood-related risks. The most popular responses were:

- to prohibit all development on land with any potential to flood;
- place restrictions on developments to reduce the potential for flood damage (e.g. minimum floor level controls or the use of compatible building materials); and
- to advise of the flood risks, but allow the individual the choice as to whether they develop or not provided they take steps to minimise the potential flood risks

The next most favoured response was to prohibit all new development only in locations that would be extremely hazardous to persons or properties during floods. Three respondents felt that Council should provide no advice regarding the potential flood risks or measures that could minimise those risks while four respondents said they did not know. Three respondents were concerned that flood planning measures raising insurance premiums while three respondents warned of overly onerous flood planning restrictions would discourage new businesses from establishing in Lithgow and restrict the expansion of existing commercial enterprises.

Respondents were also asked in **Question 7** about what notifications Council should give about the flood affectation of individual properties. The community were strongly in favour of advising existing residents (122 respondents) and prospective purchasers (98) of the known potential flood threat, while 28 respondents favoured only advising those who enquire to Council about the known potential flood risk. Three respondents favoured not providing any notification.

Ten respondents provided other suggestions on the level of advice council should give to individual property owners, which included:

- provide advice in a yearly newsletter;
- provide advice in local newspaper;
- include flood categorisation maps and advice on where to acquire further information with rate notices; and
- ensure that the 1 in 100 year flood map available on Council's website.

A3 POTENTIAL FLOOD MANAGEMENT MEASURES

The respondents were asked for their opinion on potential flood management measures which could be evaluated in the *FRMS* (and if found to be feasible included in the *FRMP*), by ticking "yes" or "no" to the fifteen potential options identified in **Question 8**.

The options comprised a range of *structural flood management measures* (e.g. programs by Council to manage vegetation along creek corridors; widening and/or concrete lining of watercourses; construction of detention basins; construction of permanent levees; improving the stormwater drainage system and removing of floodplain obstructions), as well as a range of *non-structural management measures* (e.g. voluntary purchase of residential properties in high hazard areas; raising floor levels of houses in low hazard areas; flood related controls over new developments; improvements to flood warning and evacuation procedures; community education on flooding; flood advice certificates). The options were not mutually exclusive, as the adopted *FRMP* could, in theory, include all of the options set out in the *Community Questionnaire*, or indeed, other measures nominated by the respondents or the FRMC.

The most popular structural measure was the management of vegetation along the natural reaches of creek and the removal of floodplain obstructions (i.e. debris and rubbish) along the concrete lined reaches of the watercourses. Improving the stormwater drainage system in the town was another popular structural measure.

Widening and/or concrete lining of watercourses was also strongly favoured by the community. Five respondents favoured concrete lining of the widened watercourse, while five respondents preferred a more natural looking channel upgrade that would encourage biodiversity and increase the visual amenity of the creeks. It is noted that one respondent to the *Community Questionnaire* was under the impression that the Hermitage Flat area was no longer flood prone due to the recent widening of Farmers Creek in its vicinity.

Seven respondents were concerned about erosion and the stability of the creek banks along the natural reaches of the watercourses, particularly on the reach of Farmers Creek upstream of the Atkinson Street bridge. One respondent suggested recommissioning the Lithgow No. 2 Dam to operate for flood mitigation purposes.

Seven respondents were concerned that debris carried by floodwaters blocked culverts/bridges at the following locations:

- Victoria Avenue, Atkinson Street, Tank Street and Geordie Street crossings of Farmers Creek;
- Vale of Clwydd Creek in the vicinity of Hutchinson Street;
- Culvert beneath the railway in the vicinity of the intersection of Main Street and Enfield Avenue; and
- Laidley Street crossing of State Mine Creek.

The construction of detention basins and permanent levees were also favoured by the community, albeit to a lesser extent than the other structural measures.

Of the non-structural measures, the most popular was ensuring all information about the potential risks of flooding is available to all residents and business owners, specifying controls on future

development in flood-liable areas, providing a Planning Certificate to purchasers in flood-prone areas and improvements to flood warning and evacuation procedures both before and during a flood were other popular non-structural measures.

A mostly negative response was given to flood proofing of individual properties. Providing funding or subsidies to raise houses above major flood level in low hazard areas was also unpopular.

A4 INPUT TO THE STUDY AND FEEDBACK FROM THE COMMUNITY

In **Question 9,** residents were asked for their view on the best methods of their providing input to the study and feedback to the Consultants over the course of the investigation. Council's website and articles in the local newspaper were the most popular methods, followed by the FRMC. Other suggestions raised by respondents, in decreasing order of popularity, include:

- Mail/newsletters mailed to residents with rates notices
- Email
- Social media
- Local area meetings
- Personal visits to those with properties in flood affected areas.
- Local library

A5 SUMMARY

One-hundred and ninety-six responses were received to the *Community Questionnaire* which was distributed by Council to residents and business owners in Lithgow. The responses amounted to about 7 per cent of the total number of questionnaires that were distributed to the community.

The issues identified by the responses to the *Community Questionnaire* support the objectives of the study as nominated in the attached *Community Newsletter,* and the activities nominated in the Study Brief. Of interest is that about one-third (60 respondents) of the respondents to the *Community Questionnaire* were in favour of prohibiting all new development on land with any potential to flood. About one-quarter of the respondents to the *Community Questionnaire* (51) were in favour of placing restrictions on future developments which reduce the potential for flood damage and an almost equal number of respondents (50) who were in favour of Council advising of the flood risks, but allowing the individual a choice to develop so long as potential flood risks are minimised.

Of the *structural measures* which could be incorporated in the *FRMP*, the most popular were management of vegetation along the creek corridors, improving the capacity of the stormwater system, the removal of floodplain obstructions and widening/concrete lining of watercourses. The construction of detention basins and permanent levees were also favoured by the community, albeit to a lesser extent that the other structural measures.

Ensuring all information about the potential risks of flooding is available to all residents and business owners, specifying controls on future development in flood-liable areas, providing a Planning Certificate to purchasers in flood-prone areas and improvements to flood warning and evacuation procedures both before and during a flood were the most popular of the potential *non-structural measures* set out in the *Community Questionnaire*.

Flood proofing of individual properties and providing funding or subsidies to raise houses above major flood level in low hazard areas were given a mostly negative response.

Lastly and of special interest is that one of the respondents was under the impression that the recent channel widening works on Farmers Creek had rendered the Heritage Flat area flood free which indicates a possible lack of understanding within the broader community about the level of flood protection afforded by these works. It also highlights the importance of implementing and maintaining a public awareness programme on the flood risk at Lithgow.

ATTACHMENT A1

COMMUNITY NEWSLETTER AND QUESTIONNAIRE

Lithgow Floodplain Risk Management Study and Plan

To Residents and Business Owners of Lithgow:

Lithgow City Council has engaged consultants to undertake the *Lithgow Floodplain Risk Management Study and Plan*. The purpose of the study is to assist Council in refining strategic plans for mitigating and managing the effects of existing flood risk (associated with existing development on flood prone land), future flood risk (associated with any new development on flood prone land) and continuing flood risk (the risk remaining in both existing and future development areas after floodplain risk management measures are implemented) in the Farmers Creek and Marrangaroo Creek catchments at Lithgow.

The study is jointly funded by Council and the NSW Department of Planning, Industry and Environment and aims to build community resilience towards flooding through informing better planning of development, emergency management and community awareness. Council has established a Floodplain Risk Management Committee which is comprised of relevant council members, state government agencies and community representatives.

The study will build on the results of the recently completed *Lithgow Flood Study Review* which was completed in 2017 and will reassess the measures which were recommended as part of the *Lithgow Floodplain Management Plan* which was prepared in 1991. **Figure 1** attached shows the indicative extent of the 1 in 100 year flood in the Farmers Creek and Marrangaroo Creek catchments, as well as the extent of flood prone land (as defined by the extent of the Probable Maximum Flood) under present day climatic conditions.

An electronic copy of the *Lithgow Flood Study Review* can be found on Council's website at http://council.lithgow.com/lithgow-floodplain-management/.

Have Your Say on Floodplain Management

An important first step in the study is to appraise what flood related issues are important to the community. The attached **questionnaire** has been provided to residents and businesses to assist the Consultant in gathering this important information. The questionnaire may also be completed online via Council's website at http://www.haveyoursay.lithgow.com. All information provided will remain confidential and for use in this study only. Please return the completed questionnaire in the reply paid envelope provided by **Friday 28 August 2020**.

Contact: Lithgow City Council

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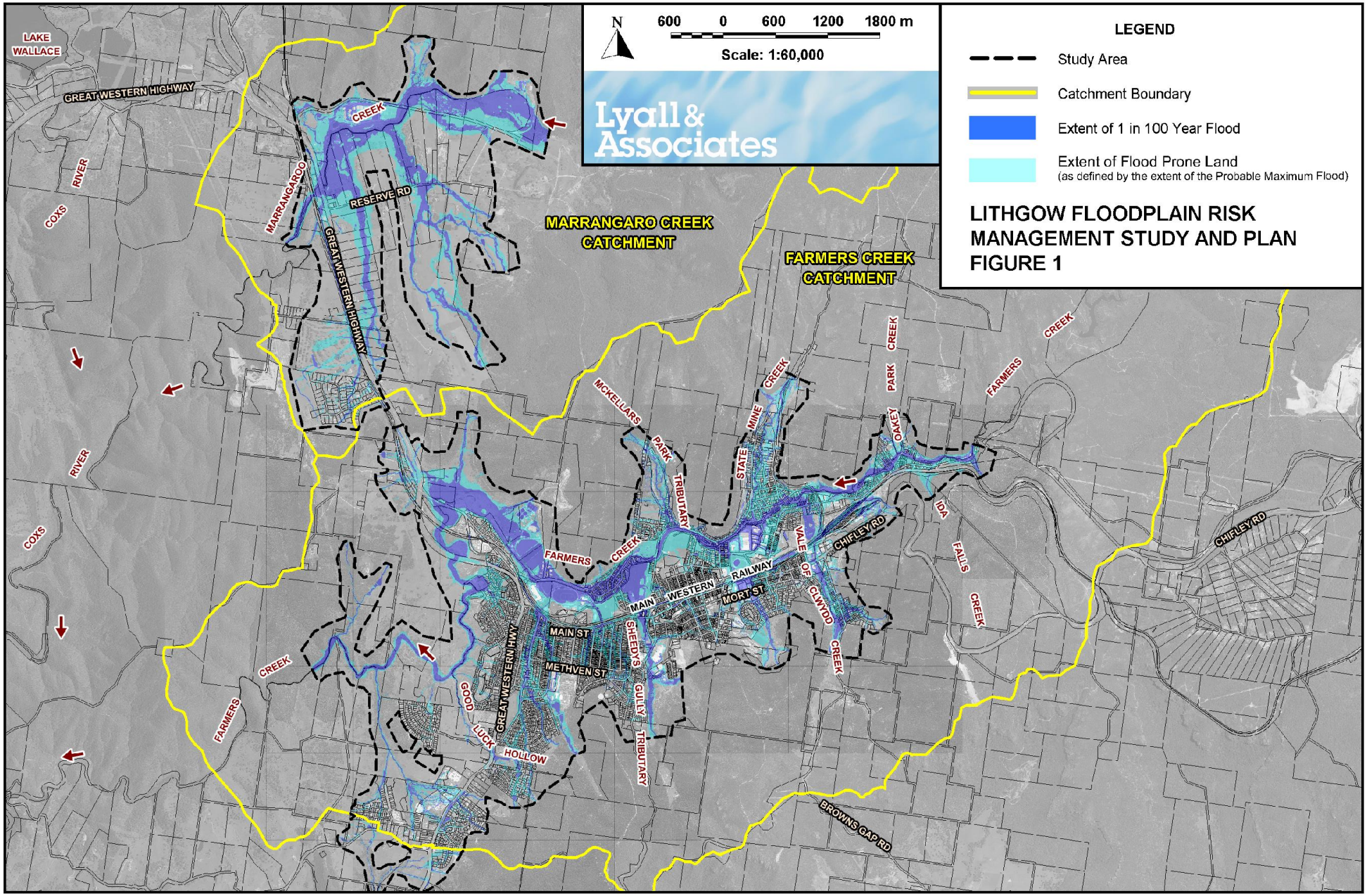
Email: council@lithgow.nsw.gov.au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Lyall & Associates
LEGEND
Study Area
Catchment Boundary
Extent of 1 in 100 Year Flood
Extent of Flood Prone Land
(as defined by the extent of the Probable Maximum Flood)
LITHGOW FLOODPLAIN RISK MANAGEMENT STUDY AND PLAN
FIGURE 1
MARRANGARO CREEK CATCHMENT
FARMERS CREEK CATCHMENT
LAKE WALLACE
GREAT WESTERN HIGHWAY
COXS RIVER
MARRANGAROO CREEK
RESERVE RD
MCKELLARS PARK TRIBUTARY
MINE STATE OAKEY CREEK
PARK CREEK
FARMERS CREEK
IDA FALLS CREEK
CHIFLEY RD
VALE OF CLWYDD CREEK
MAIN WESTERN RAILWAY
MORT ST
MAIN ST
METHVEN ST
SHEEDYS GULLY TRIBUTARY
GOOD LUCK HOLLOW
BROWNS GAP RD

Lithgow Floodplain Risk Management Study and Plan

Community Questionnaire

This Questionnaire is part of the *Lithgow Floodplain Risk Management Study and Plan* which is currently being undertaken by Lithgow City Council with the financial support of the NSW Department of Planning, Industry and Environment. Your responses to the questionnaire will help us determine the flood issues that are important to you.

Please return your completed Questionnaire in the reply paid envelope provided by **Friday 28 August 2020**. No postage stamp is required. If you have misplaced the supplied envelope or wish to send an additional submission the address is:

Lyall & Associates Consulting Water Engineers
Reply Paid 85163
NORTH SYDNEY NSW 2060

1. Your name (optional):_____

Address:_____

About your property

2. Please tick as appropriate:

- ☐ I am a resident
- ☐ I am a business owner
- ☐ Other (please specify_____)

3. How long have you been at this address?

- ☐ 1 year to 5 years
- ☐ 5 years to 20 years
- ☐ More than 20 years (… years)

4. What is your property?

- ☐ House
- ☐ Villa/Townhouse
- ☐ Unit/Flat/Apartment
- ☐ Vacant land
- ☐ Industrial unit in larger complex
- ☐ Stand alone warehouse or factory
- ☐ Shop
- ☐ Community building
- ☐ Other (_____)

Your attitudes to Council's development controls

5. Please rank the following development types according to which you think are the most important to protect from floods

(1=highest priority to 6=least priority)

Development Type	Rank
Commercial/Business	
Residential	
Vulnerable residential development (e.g. aged persons accommodation)	
Essential community facilities (e.g. schools, evacuation centres)	
Minor developments and additions	
New subdivisions	

6. What level of control do you consider Council should place on new development to minimise flood-related risks?

(Tick only one box)

(In addition to being favoured by the Community, these options would also need to comply with legislation)

- ☐ Prohibit all new development on land with any potential to flood
- ☐ Prohibit all new development only in those locations that would be extremely hazardous to persons or property due to the depth and/or velocity of floodwaters, or evacuation difficulties
- ☐ Place restrictions on developments which reduce the potential for flood damage (e.g. minimum floor level controls or the use of flood compatible building materials)
- ☐ Advise of the flood risks, but allow the individual a choice as to whether they develop or not, provided steps are taken to minimise potential flood risks
- ☐ Provide no advice regarding the potential flood risks or measures that could minimise those risks
- ☐ Don't know

7. What notifications do you consider Council should give about the potential flood affectation of individual properties?

(Tick one or more boxes)

- ☐ Advise every resident and property owner on a regular basis of the known potential flood threat
- ☐ Advise only those who enquire to Council about the known potential flood threat
- ☐ Advise prospective purchasers of property of the known potential flood threat.
- ☐ Provide no notifications
- ☐ Other

(_____

_____

_____

_____)

Your opinions on floodplain risk management measures

8. Below is a list of possible options that may be looked at to try to minimise the effects of flooding in the study area.

This list is not in any order of importance and there may be other options that you think should be considered. For each of the options listed, please indicate "yes" or "no" to indicate if you favour the option. Please leave blank if undecided.

Option	Yes	No	Don't Know
Management of vegetation along creek corridors to provide flood mitigation, stability, aesthetic and habitat benefits			
Widening and/or concrete lining of watercourses			
Construct detention basins			
Construction of permanent levees along the creeks to contain floodwaters			
Improve stormwater drainage system			
Removal of floodplain obstructions			
Voluntary purchase of the most severely affected flood-liable properties			
Provide funding or subsidies to raise houses above major flood level in low hazard areas.			
Flood proofing of individual properties by waterproofing walls, putting shutters across doors, etc.			
Specify controls on future development in flood-liable areas (e.g. controls on extent of filling, minimum floor levels, etc.)			
Provide a Planning Certificate to purchasers in flood prone areas, stating that the property is flood affected.			
Ensuring all information about the potential risks of flooding is available to all residents and business owners			
Improve flood warning and evacuation procedures both before and during a flood.			
Community education, participation and flood awareness programs.			
Ensuring all residents and business owners have Flood Action Plans - these outline WHAT people should do, WHERE they should go and WHO they should contact in a flood			

Other Information

9. What do you think is the best way for us to get input and feedback from the local community about the results and proposals from this study? (Tick one or more boxes)

- ☐ Council's website
- ☐ Articles in local newspaper
- ☐ Through Council's Floodplain Management Committee
- ☐ Other (please specify) _____

10. If you wish us to contact you so you can provide further information, please provide your details below:

Name: _____

Address: _____

_____

Phone: _____

Email: _____

Who can I contact for further information?

Lithgow City Council
Christian Matthews | Graduate Strategic Planner
Phone: (02) 6354 9999
Email: council@lithgow.nsw.gov.au

Copies of this Questionnaire can be obtained from at
http://www.haveyoursay.lithgow.com

COMMENTS

Please write any additional comments here:

_____

_____

_____

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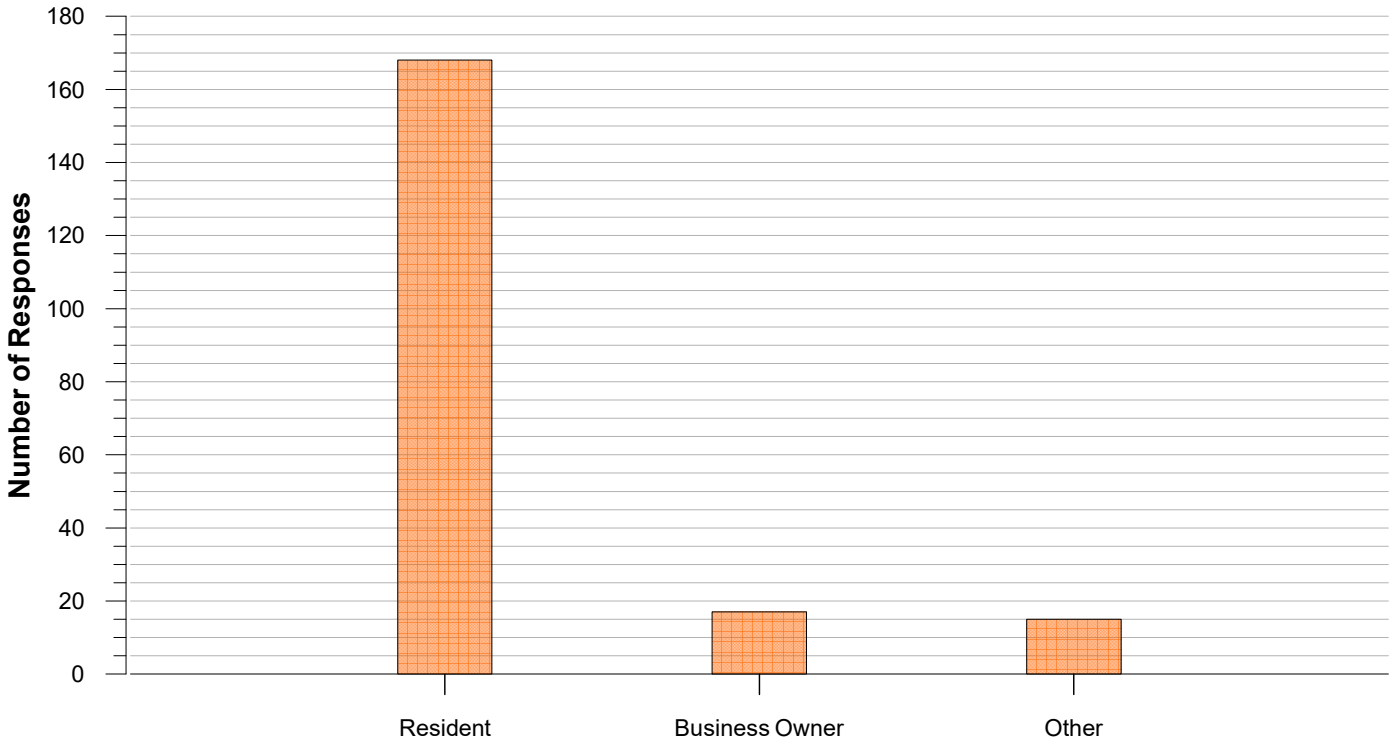
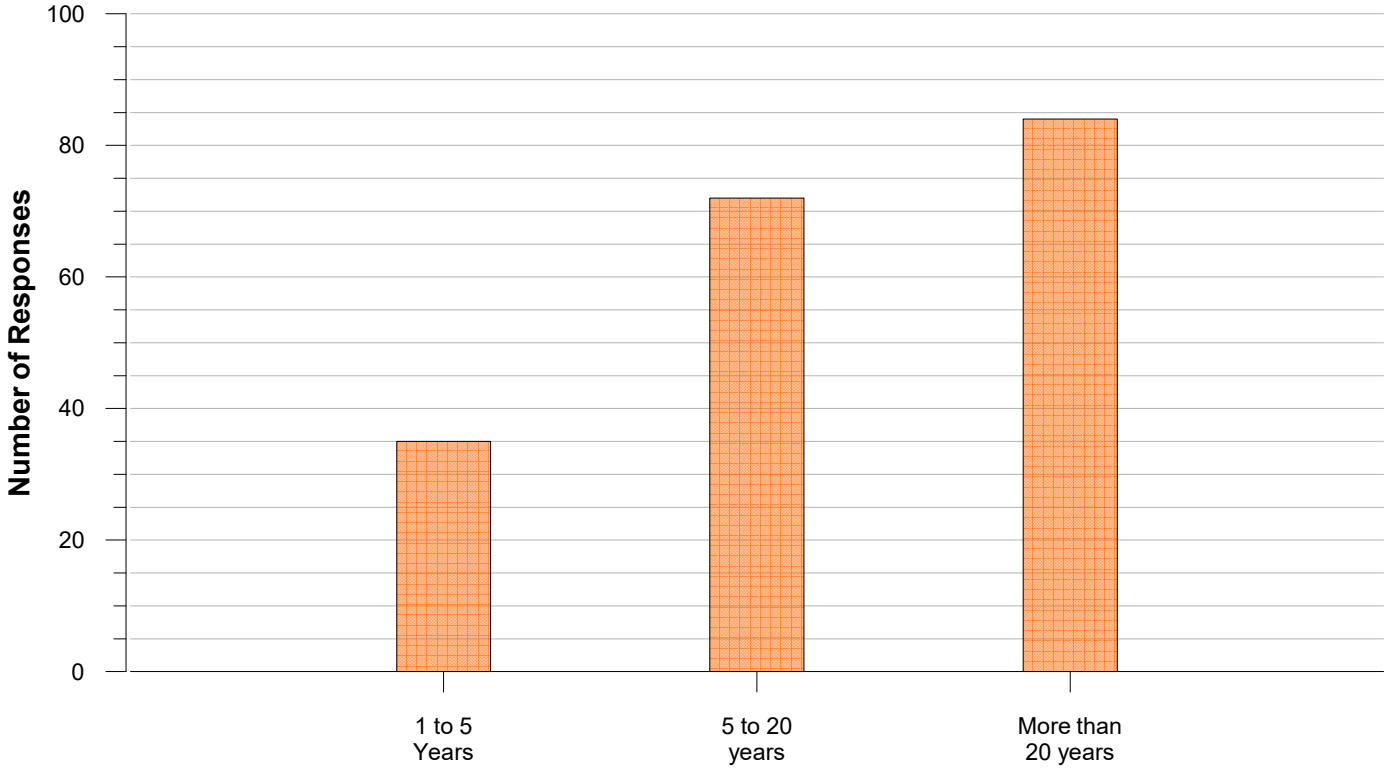
ATTACHMENT A2

RESPONSES TO COMMUNITY QUESTIONNAIRE

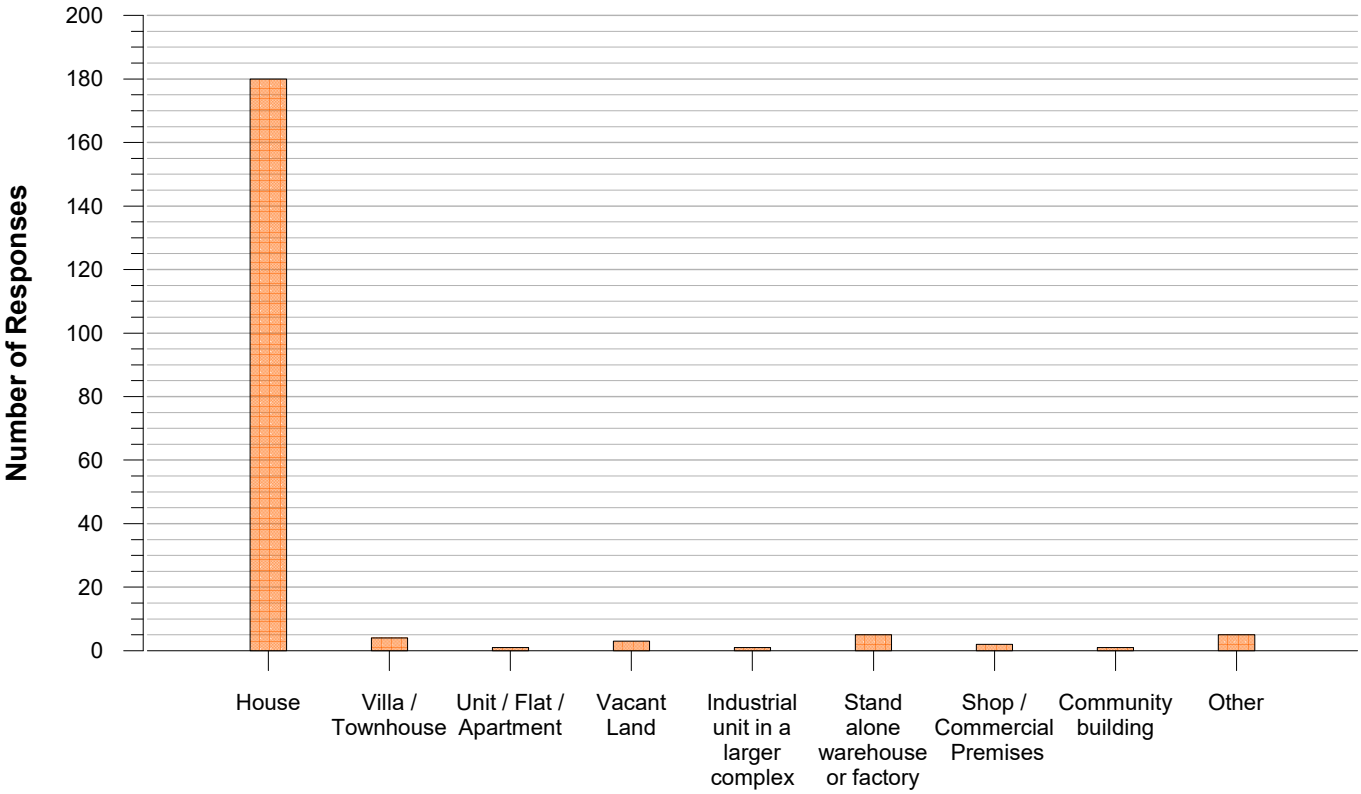
Q2. Residential Status



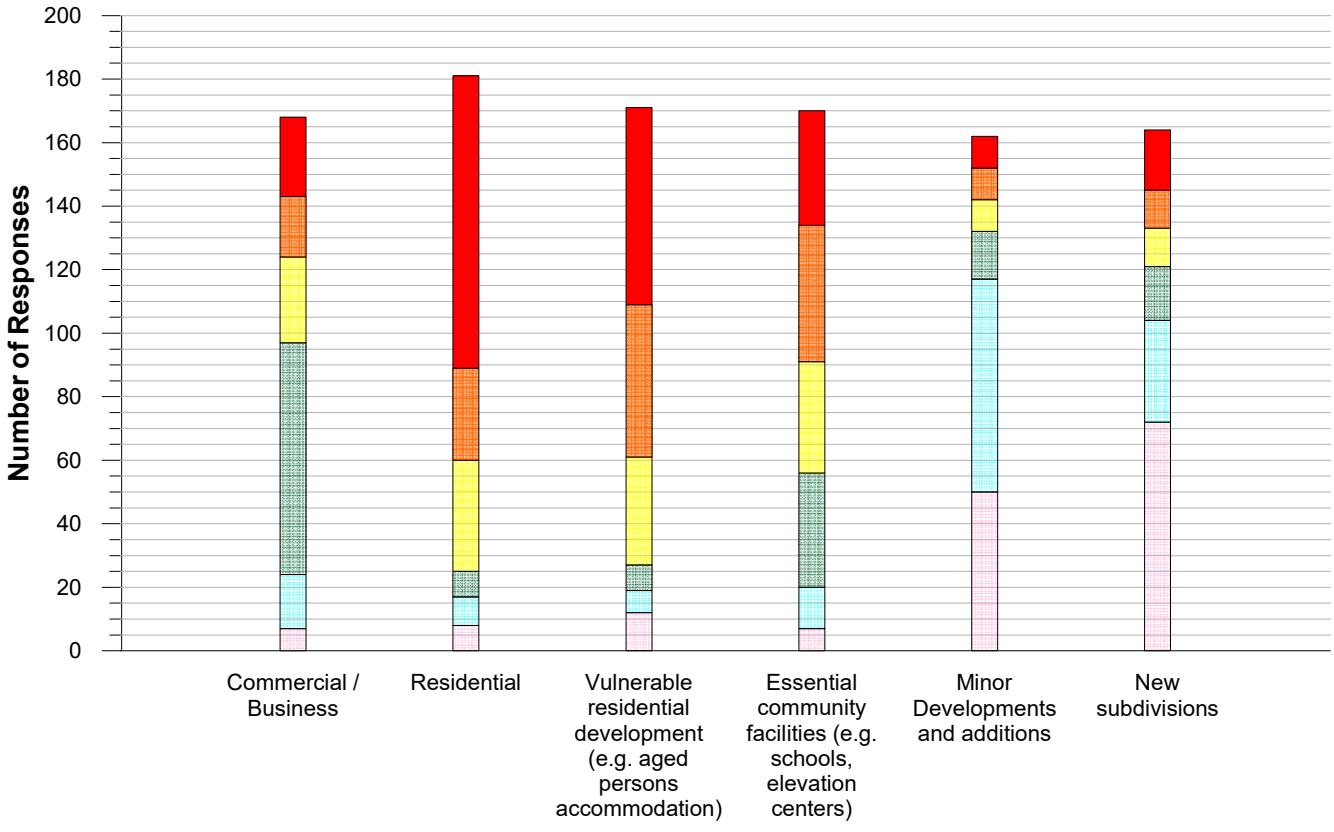
Q3. How long have you been at this address?

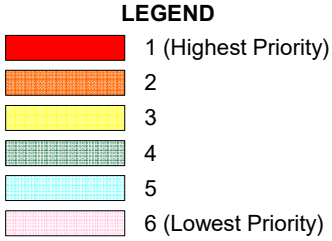


Q4. Type of Property

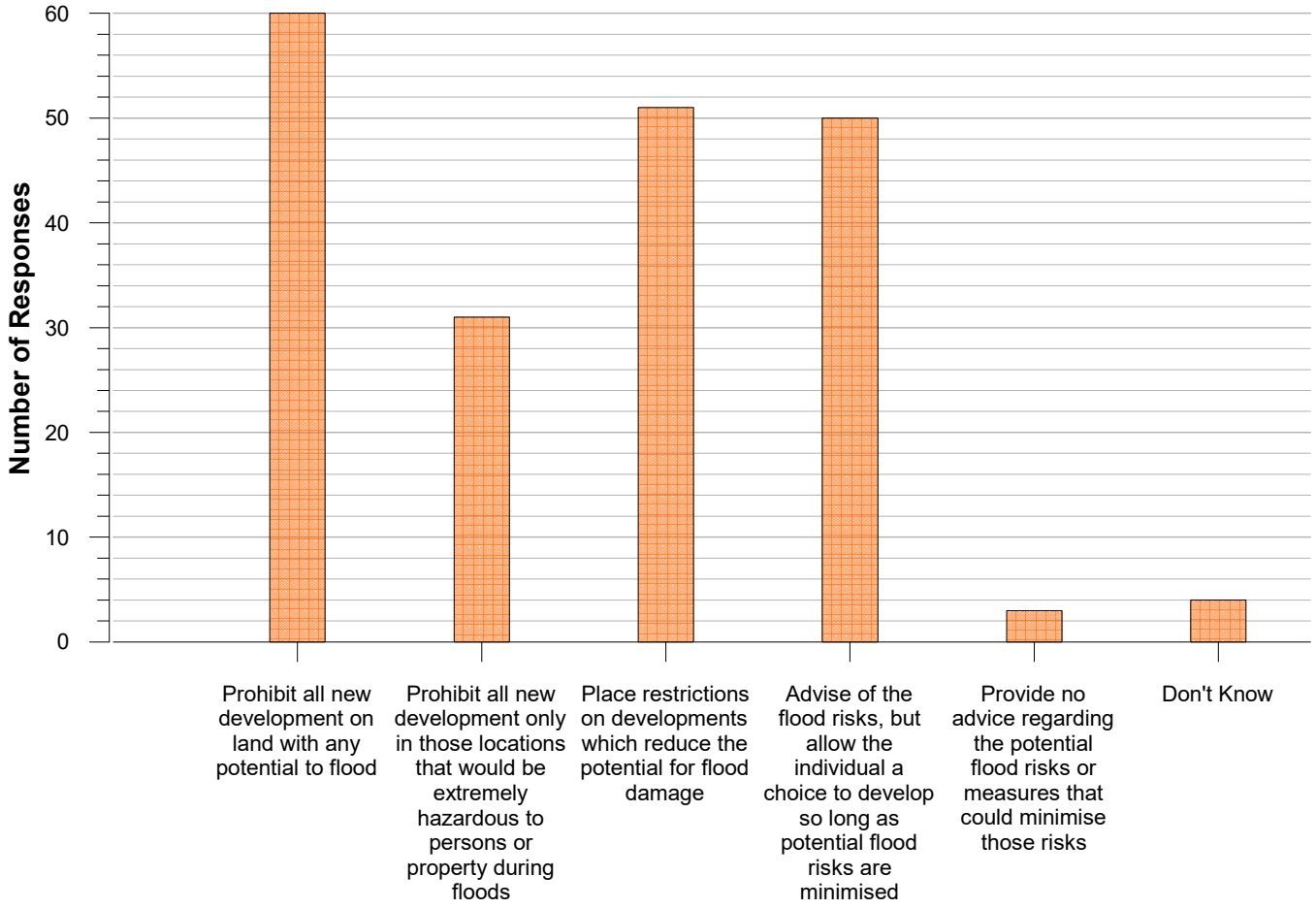


Q5. Ranking of development types by importance to protect from floods

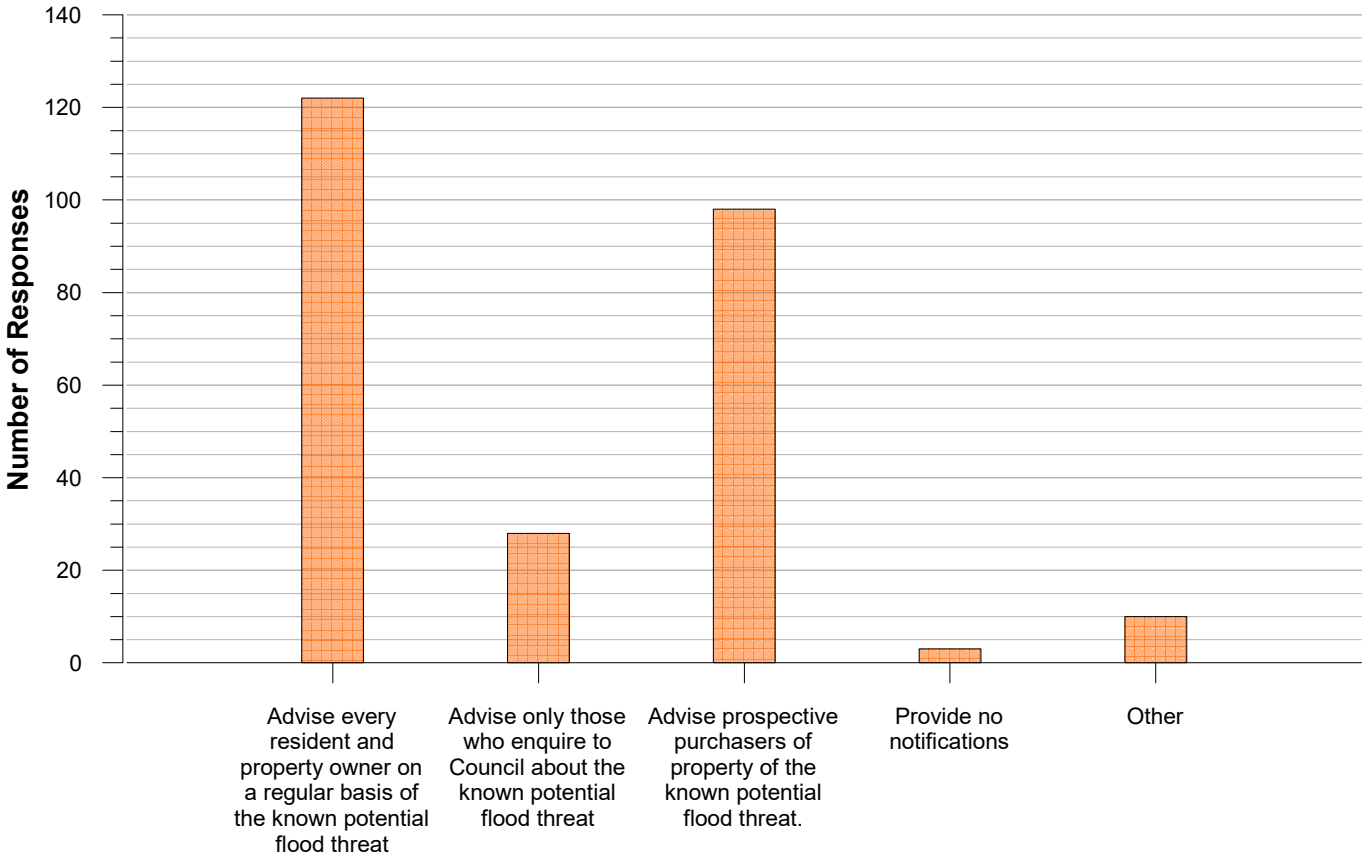




Q6. What level of control should Council place on new development to minimise flood-related risks?

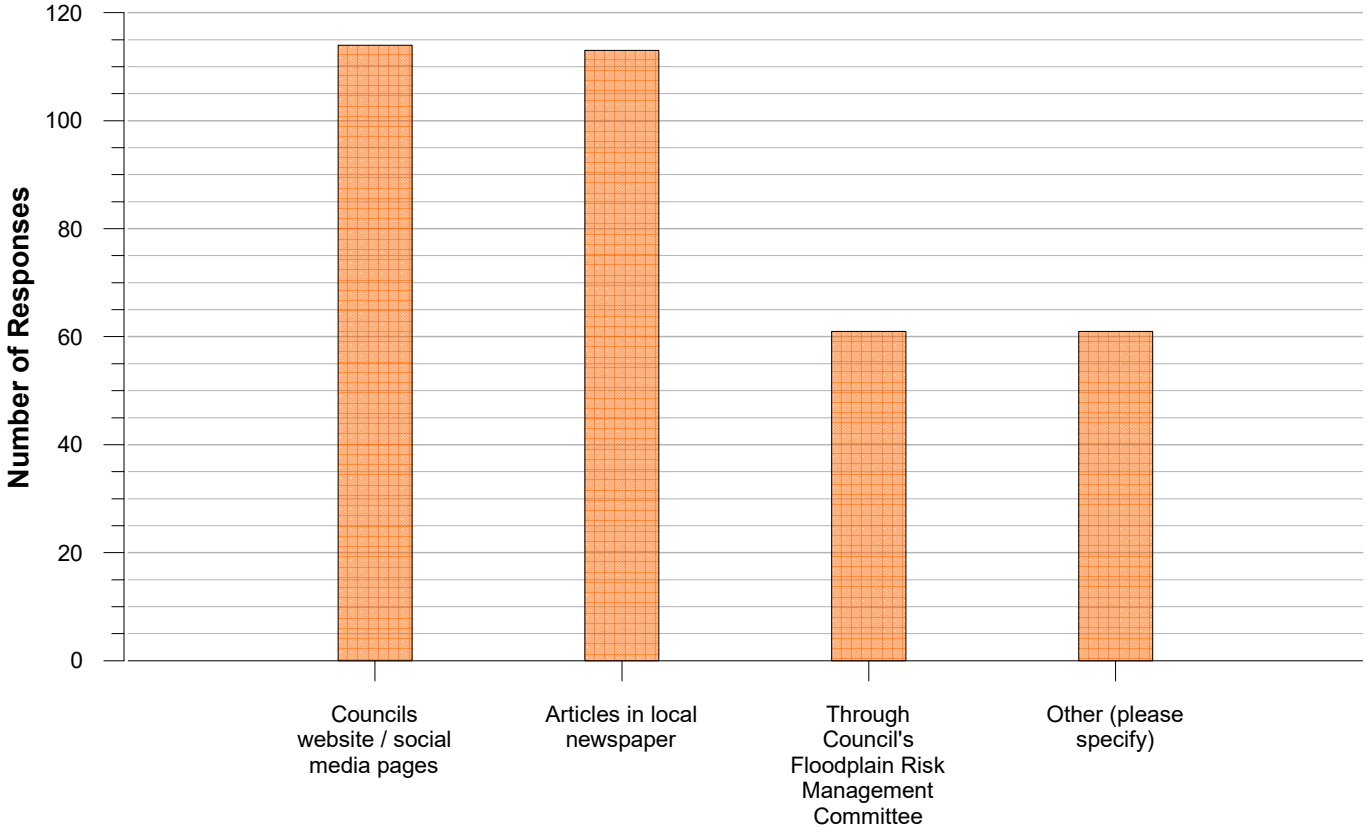


Q7. What notifications should Council give about the potential flood affectation of properties?



Q8. Possible Floodplain Management Measures

Q9. Best methods to get input and feedback from the local community



APPENDIX B

HYDROLOGIC AND HYDRAULIC MODELLING UPDATE

TABLE OF CONTENTS

ATTACHMENTS

FIGURES
(BOUND IN VOLUME 2)

B1. FLOOD FREQUENCY ANALYSIS

B1.1 Background Information

A flood frequency analysis was undertaken at the WaterNSW operated Mount Walker stream gauge (GS 212042)[1] (**Mount Walker stream gauge**) as part of the *Lithgow Flood Study Review* (Lyall & Associates, 2017) (***Flood Study***) by fitting a Log-Pearson Type III (**LP3**) probability distribution to the annual series of flood peaks for the 33 year period between 1981 and 2013. **Column B** of **Table B1.1** at the end of this chapter and the left-hand side (**LHS**) of **Figure B1.1** shows the results of the flood frequency analysis which were derived using a spreadsheet-based modelling approach.[2] The peak 1% AEP flow at the gauge site derived as part of the *Flood Study* using the full period of record was 337 m^3/s.

Values at the low end of the observed range of flood peaks can distort the fitted probability distribution and affect the estimates of large floods. Deletion of these low values may improve the fitting of the remaining data. **Column C** of **Table B1.1** and the right-hand side (**RHS**) of **Figure B1.1** shows that omitting the 14 flows less than 25 m^3/s from the analysis had a minor impact on the design peak flow estimates at the gauge site, lowering the peak 1% AEP flow to 320 m^3/s.

The design peak flow estimates in **Column C** of **Table B1.1** were given greatest weight when deriving design discharge hydrographs as part of the *Flood Study*.

For comparison purposes, design peak flow estimates at the Mount Walker stream gauge were derived using the Regional Flood Frequency Estimation (**RFFE**) model, procedures for which are set out in the 2019 edition of *Australian Rainfall and Runoff* (Geoscience Australia, 2019) (**ARR 2019**). **Column D** of **Table B1.1** shows that based on the raw output from the RFFE model the peak 1% AEP flow at the Mount Walker stream gauge is 408 m^3/s which is about 30% higher than the corresponding value that was adopted as part of the *Flood Study*.

Further investigation into the nearby gauges relied upon for the RFFE model shows that the Mount Walker stream gauge is one of the gauged catchments used to derived peak flow estimates as part of the model. **Column E** of **Table B1.1** shows that the peak 1% AEP flow estimate derived as part of the development of the RFFE model is 520 m^3/s, which is 200 m^3/s higher than the corresponding value that was adopted as part of the *Flood Study* (**Column C**), and more than 100 m^3/s higher than the raw RFFE derived estimate (**Column D**).

Interrogation of the RFFE model results show that the RFFE Mount Walker peak flow estimates shown in **Column E** of **Table B1.1** were derived using 27 years of annual maximum data, despite the gauge being in operation for over 30 years at the time the RFFE model was developed. It is not clear which 27 year period of data were relied upon, or why a shorter period of record was adopted. Based on the above, the RFFE derived peak flow estimate is not considered suitable for use in the present study.

A flood frequency analysis was also undertaken at the Mount Walker stream gauge as part of *The Review of ARR Design Inputs for NSW* (WMAwater, 2019). **Column F** of **Table B1.1** shows that the design peak flow estimates derived as part of WMAwater, 2019 are comparable to those derived a part of the *Flood Study*.

[1] Note that the stream gauge was operated by the Department of Primary Industries – Office of Water at the time of the *Flood Study*.

[2] Note that an expected probability adjustment was not applied as part of the *Flood Study*.

B1.2 Review of Flood Study

For comparison purposes, the flood frequency analyses undertaken as part of the *Flood Study* using a spreadsheet-based modelling approach were repeated using the TUFLOW Flike (**Flike**) software. The LHS of **Figure B1.1** shows that while the Flike derived LP3 fitted curve derived as part of the present study is similar to that of the *Flood Study* for the full period of record, application of the expected probability adjustment results in a peak 1% AEP flow estimate (refer **Column G** of **Table 1.1**) of 430 m^3/s which is significantly higher than those derived as part of the *Flood Study*, and about 2.3 times the largest peak flow at the gauge in the 39 years since the gauge site was established (i.e. a discharge of 184 m^3/s in January 2011).

Column H of **Table B1.1** and the RHS of **Figure B1.1** shows that when flows less than 25 m^3/s are omitted from the Flike derived flood frequency analysis, the resultant curves differ significantly from those derived as part of the *Flood Study*. Omitting the 14 flows lower than 25 m^3/s reduced the peak 1% AEP flow to 286 m^3/s.

B1.3 Updates to Flood Frequency Analysis

The flood frequency analysis was updated to incorporate the six additional years of annual maximum flow data between 2014 and 2019.[3] **Column I** of **Table B1.1** and the LHS of **Figure B1.2** show that incorporating the additional six years of data results in a peak flow estimates which are the same as those derived as part of the *Flood Study*.

Column J of **Table 1.1** and the RHS of **Figure B1.2** show that omitting flows less than 25 m^3/s lowers the peak 1% AEP flow by 55 m^3/s to 283 m^3/s but does not impact the peak flow estimates for design flood events in the more frequent events. It is noted that the expected probability adjustment shown on the RHS of **Figure B1.2** lies on the LP3 fit for flood events with AEPs of between 10 and 1 per cent.

The RHS of **Figure B1.2** shows that the flood frequency relationship is heavily influenced by the plotting position assigned to the largest flood event that was recorded since the gauge was established. The plotting position was derived using procedures set out in ARR 2019 and is based on the rank of the flood event and the number of years in the period of record (i.e. 39 years in total).

The largest event which occurred in January 2011 when the gauge reached RL 2.50 m and the peak discharge was 184 m^3/s was assigned a plotting position of 1.6% AEP, while the second largest event which occurred in February 2013 when the gauge reached RL 2.44 m and the peak discharge was 175 m^3/s (which is only 9 m^3/s or 5% lower than the flow for the largest event) was assigned a plotting position of 4.1% AEP. Adoption of such a low AEP for the January 2011 flood event is considered to skew the results of the flood frequency analysis and result in an underestimate for the peak 1% AEP flow.

Additionally, it was also not possible to obtain a good match between the hydrologic and hydraulic models developed as part of the present study (refer **Chapters B2** and **B3** for further discussion) and the results of the flood frequency analysis with the omission of the low flows set out in **Column J** of **Table B1.1** using reasonable hydrologic model parameters.

[3] **Table B1** in **Attachment B1** contains a list of the annual maximum peak heights and discharges recorded at the Mount Walker stream gauge.

Given that the peak flow estimates derived as part of the *Flood Study* (refer **Column C**) are very similar to those set out in **Column I**, it is concluded that the inclusion of the additional six years of annual maximum flow data in combination with the updated methodology for undertaking flood frequency analyses as prescribed in ARR 2019 has not lead to a change in the design peak flow estimates for Farmers Creek at the location of the Mount Walker stream gauge.

TABLE B1.1
COMPARISON OF DESIGN PEAK FLOW ESTIMATES AT LOCATION OF MOUNT WALKER STREAM GAUGE
(m^3/s)

AEP (%)	*Flood Study*		RFFE Model		WMAwater, 2019	Present Study			
	LP3 1981-2013		Raw RFFE Output	Mount Walker Stream Gauge		LP3 1981-2013		LP3 1981-2019	
	Uncensored[1]	Q < 25 m^3/s Omitted				Uncensored	Q < 25 m^3/s Omitted	Uncensored	Q < 25 m^3/s Omitted
[A]	[B]	[C]	[D]	[E]	[F]	[G]	[H]	[I]	[J]
20	76	80	71.1	58	76	80	99	76	79
10	118	119	118	102	117	126	148	116	118
2	256	245	294	326	237	296	240	248	220
1	337	320	408	520	299	430	286	338	283

1. Expected probability adjustment not applied.

B2. HYDROLOGIC MODELLING

B2.1 Review of Flood Study

The following three hydrologic models were developed as part of the *Flood Study* (**Flood Study Hydrologic Models**):

- Farmers Creek Lumped Hydrologic Model
- Farmers Creek Hydrologic Model
- Marangaroo Creek Hydrologic Model

The hydrologic models developed for the Farmers Creek catchment were calibrated using rainfall and stream flow data which were available for storms that occurred in August 1986, February 1990, January 2011 and February 2013. Hydrologic model parameters found to achieve a good match between modelled and recorded data for the Farmers Creek catchment were then applied to the Marangaroo Creek Hydrologic Model.

Design flood estimation was undertaken based on the procedures set out in the 1987 edition of *Australian Rainfall and Runoff* (The Institution of Engineers Australia, 1987) (**ARR 1987**). It is noted that Aerial Reduction Factors (**ARFs**) were not applied to the hydrologic models developed as part of the *Flood Study* as the models were used to define flood behaviour in the middle and upper reaches of the study catchments where higher ARFs would generally apply.

Column C of **Table B2.1** shows that the Farmers Creek Lumped Hydrologic Model produced higher design peak flow estimates at the Mount Walker stream gauge when compared with those derived from the flood frequency analysis (**Column B**) (refer **Chapter B1** for more detail). The *Flood Study* found that the Farmers Creek Lumped Hydrologic Model overestimates the design peak flow estimates at the Mount Walker Stream Gauge as it is not capable of modelling the floodplain storage that is present in the Farmers Creek catchment.

TABLE B2.1
COMPARISON OF DESIGN PEAK FLOW ESTIMATES AT MOUNT WALK STREAM DERIVED USING PROCEDURES SET OUT IN ARR 1987 and ARR 2019 (m^3/s)

AEP (%)	*Flood Study*[1]			Present Study[2]				
	Flood Frequency Analysis	Farmers Creek Lumped Hydrologic Model	Farmers Creek TUFLOW Model	Farmers Creek Lumped Hydrologic Model				Farmers Creek TUFLOW Model
				CL=2 mm/hr	CL=3 mm/hr	CL=4 mm/hr	CL=5 mm/hr	
[A]	[B]	[C]	[D]	[E]	[F]	[G]	[H]	[I]
20	80	112	113	142	129	122	117	110
10	119	157	161	201	189	178	166	150
2	245	285	264	311	297	275	266	241
1	320	372	330	375	359	343	319	318

1. Derived using the procedures set out in ARR 1987
2. Derived using the procedures set out in ARR 2019

The design discharge hydrographs were input to the TUFLOW models that were developed as part of the *Flood Study* (refer **Chapter B3** for discussion) which were then used to route the flood wave through the study area. **Column D** of **Table B2.1** shows that the Farmers Creek TUFLOW Model achieved a good match with the flood frequency derived peak flow estimates (**Column B**).

B2.2 Updates to Hydrologic Model

B2.2.1 General

The Flood Study Hydrologic Models were updated as part of the present study (**Updated Hydrologic Models**) using the ensemble approach to design flood estimation that is set out in ARR 2019. The methodology for modelling the urbanised catchments, which were previously modelled using the ILSAX Hortonian loss modelling approach were updated using the initial loss-continuing loss (**IL-CL**) modelling approach which is compatible with the procedures set out in ARR 2019.[4]

B2.2.2 Rainfall Intensity

Design rainfall data were downloaded from the Bureau of Meteorology's (**BoMs**) website and input to the Updated Hydrologic Models. The LHS of **Figure B2.1** shows a comparison of the Intensity-Frequency-Duration (**IFD**) curves derived using ARR 1987 and ARR 2019. The rainfall intensities for storm events with durations less than 1.5 hours have increased by up to 12%, while the rainfall intensities for storm durations between 1.5 and 18 hours have decreased by up to 15%.

B2.2.3 Temporal Patterns

ARR 2019 prescribes the analysis of an ensemble of 10 temporal patterns per storm duration for various zones in Australia. These patterns are used in the conversion of a design rainfall depth with a specific AEP into a design flood of the same frequency. The patterns may be used for AEPs down to 0.2 per cent where the design rainfall data is extrapolated for storm events with an AEP less than 1 per cent.

The temporal pattern ensembles that are applicable to Frequent (more frequent than 14.4% AEP), Intermediate (between 3.2 and 14.4% AEP) and Rare (rarer than 3.2% AEP) storm events were obtained from the ARR Data Hub. A copy of the data extracted from the ARR Data Hub for Lithgow is contained in **Attachment B2**.

B2.2.4 Design Loss Values

The initial and continuing loss values to be applied in flood hydrograph estimation were derived using the NSW jurisdictional specific procedures set out in the ARR Data Hub.

The raw probability neutral burst initial loss values obtained from the ARR Data Hub were reviewed and adjusted to remove inconsistencies in values with varying storm probability and durations. The RHS of **Figure B3.2** shows the original probability neutral burst initial curves derived from the tables obtained from the ARR Data Hub, together with the adopted probability neutral burst initial loss curves following the adjustments that were made for the purpose of the present study.

[4] A sensitivity analysis showed that adopting the IL-CL modelling approach instead of the ILSAX Hortonian loss modelling approach in the Flood Study Hydrologic Models increased the peak flow off the individual sub-catchments by between 15-25%.

Based on the NSW jurisdictional advice contained on the ARR Data Hub, the raw continuing loss (**CL**) value of 5.9 mm/hr was multiplied by a factor of 0.4, resulting in a CL of 2.0 mm/hr which was applied to the Farmers Creek Lumped Hydrologic Model. **Column E** of **Table B3.1** shows that adopting a CL of 2.0 mm/hr achieves a good match with the those derived as part of the *Flood Study* for the 1% AEP flow (**Column C**), but overestimated the peak flow for the more frequent events. **Column F** of **Table B2.1** shows that a CL of 3 mm/hr was required to achieve a good fit for the 2% AEP flood event, while **Column H** shows that a CL of 5 mm/hr was required for the 10% and 20% AEP events.

B2.3 Derivation of Design Discharge Hydrographs

The Updated Hydrologic Models were run with the design rainfall data set out in **Sections B2.2.1** to **B2.2.4**, as well as the hydrologic parameters that were derived as part of the *Flood Study* in order to obtain design discharge hydrographs for input to the hydraulic models.

Table B2.1 shows that the Updated Hydrologic Models provides a good match with the flood frequency derived peak flow estimates at the Mount Walker stream gauge for the full range of design storm events.

The storm duration of 30 minutes was generally found to be critical for maximising peak flows for individual sub-catchments where the catchment area is less than 50 ha, with the critical storm duration generally increasing with an increase in catchment area. Peak PMF flow rates for individual sub-catchments computed by the hydrologic model for the critical 15 minute PMP storm duration were generally between 5 and 7 times greater than the corresponding 1% AEP flow rates, with an upper and lower limit of 8.7 and 1.9, respectively. These values lie within the range of expected multiples for a small urban catchment.

B3. HYDRAULIC MODELLING

B3.1 Updates to Hydraulic Model

The TUFLOW models that were developed as part of the *Flood Study* were updated (**Updated TUFLOW Models**) to incorporate the results of the Updated Hydrologic Models, as well as the following upgrades to the stormwater drainage system that have been constructed since the *Flood Study* was adopted:

- Upgraded piped drainage system between Ramsey Street and Hartley Valley Road in the Vale of Clwydd; and
- New pipe drainage line running in a northerly direction through the Lithgow Golf Club.

Due to the size of the models and the run time involved with running the ensemble approached prescribed by ARR 2019, the Updated TUFLOW Models were run using the latest TUFLOW engine.[5]

The Updated TUFLOW Models were run for the full ensembles of temporal patterns for storm durations ranging between 0.5 and 12 hours for the 20%, 10%, 5%, 2%, 1%, 0.5% and 0.2% AEP events. The Updated TUFLOW Models were also run for storm durations ranging between 0.25 and 3 hours for the PMF.

B3.2 Partial Blockage of Hydraulic Structures

The mechanism and geometrical characteristics of blockages in hydraulic structures and piped drainage systems are difficult to quantify due to a lack of recorded data and would no doubt be different for each system and also vary with flood events. Realistic scenarios would be limited to waterway openings becoming partially blocked during a flood event (no quantitative data are available on instances of blockage of the drainage systems which may have occurred during historic flood events).

A blockage assessment was undertaken based on the procedures set out in ARR 2019. There are three sources of debris at Lithgow:

- State forest areas comprising steep heavily wooded areas that are generally located in the upper reaches of Farmers Creek and Marangaroo Creek, including several of their tributaries;
- Rural residential areas comprising cleared pastoral type land that is generally located on the southern side of Marangaroo Creek; and
- Urbanised areas comprising residential, commercial and industrial type developments in the Farmers Creek catchment.

Table B3.1 provides a summary of the blockage factors that were applied to headwall and bridge structures for the three abovementioned sources of debris, while a copy of the completed blockage assessment forms which set out the derivation of the blockage factors are contained in **Annexure 1**. Blockage factors of 50% and 20% were also applied to sag and on-grade stormwater inlet pits.

[5] The latest version of TUFLOW was adopted as processing efficiencies have been incorporated in the software since the adoption of the *Flood Study*, including the ability to run the models on high-end graphics processor units which reduced the model run times at Lithgow by about 60%.

TABLE B3.1
SUMMARY OF BLOCKAGE FACTORS[1,2]

Source Area	L_{10} (m)	Inlet Clear Width[3]	Floating Debris			Non-Floating Debris		
			> 5% AEP	5% AEP – 0.5% AEP	< 5% AEP	> 5% AEP	5% AEP – 0.5% AEP	< 5% AEP
State Forest Area	2.5	$W < L_{10}$	50%	100%	100%	25%	25%	15%
		$L_{10} \leq W \leq 3 \times L_{10}$	10%	20%	20%	25%	25%	15%
		$W > 3 \times L_{10}$	0%	10%	10%	25%	25%	15%
Rural Residential Area	2	$W < L_{10}$	100%	50%	25%	25%	15%	0%
		$L_{10} \leq W \leq 3 \times L_{10}$	20%	10%	0%	25%	15%	0%
		$W > 3 \times L_{10}$	10%	0%	0%	25%	15%	0%
Urbanised Area	1.5	$W < L_{10}$	100%	50%	25%	25%	15%	0%
		$L_{10} \leq W \leq 3 \times L_{10}$	20%	10%	0%	25%	15%	0%
		$W > 3 \times L_{10}$	10%	0%	0%	25%	15%	0%

1. Refer **Annexure 1** for derivation of blockage factors.
2. Cells highlighted in green indicate design blockage factors that were applied for the range AEPs that were assessed as part of the present study.
3. W = clear width of inlet.

The *Floodplain Risk Management Guide – Incorporating 2016 Australian Rainfall and Runoff in Studies* (Office of Environment & Heritage, 2019) recommends that in areas where flood behaviour is sensitive to structure blockage, an envelope approach that amalgamates the results of different blockage scenarios should be used to define design flood behaviour. As the flood behaviour along the main creeks and their tributaries is sensitive to structure blockage, the design flood behaviour presented in the present study represents an envelope of the "unblocked" and "partially blocked" conditions.

Section 2.10 of the Main Report provides a summary of the impacts that a partial blockage of the hydraulic structures would have on flood behaviour at Lithgow.

B3.3 Presentation of Results

Figures 2.2 and **2.3** of the Main Report show the nature of flooding at Lithgow for the 1% AEP and PMF events, respectively, while **Figures B3.1** to **B3.6** show similar information for the 20%, 10%, 5%, 2%, 0.5% and 0.2% AEP flood events. These diagrams show the indicative extent and depth of inundation along Farmers Creek, Marangaroo Creek and their associated tributaries, as well as along the major overland flow paths for the range of design flood events.

Figure 2.4 of the Main Report shows water surface profiles along the along Farmers Creek, Marangaroo Creek, Oakey Park Creek, Vale of Clwydd Creek, State Mine Creek and McKellars Park Tributary for the full range of design flood events, while **Figure 2.5** shows the time of rise of floodwater at key locations throughout the study area, including at several major road crossings.

The key features of flooding at Lithgow are set out in **Section 2.4.3** of the Main Report.

B3.4 Differences in Design Flood Estimation – ARR 1987 versus ARR 2019

Figure B3.7 (4 sheets) shows the difference in peak flood levels derived using procedures set out in ARR 1987 and ARR 2019 for the 1% AEP storm event[6], noting that a positive afflux indicates that the ARR 2019 derived peak flood levels are higher, and conversely a negative afflux indicates that the ARR 2019 derived peak flood levels are lower than those derived using ARR 1987. **Table B3.2** at the end of this Chapter shows a comparison of the peak 1% AEP flows at a number of locations within the study area.

The impact that the adoption of ARR 2019 has on flood behaviour in areas subject to Main Stream Flooding are as follows:

- While the *Flood Study* found that the 9 hour storm duration was found to be critical for maximising peak flows (and hence peak flood levels) along the main arms of Farmers Creek (refer Peak Flow Location (**PFL**) Q01, Q05, Q08, Q10, Q12 and Q13) and Marangaroo Creek (Q49, Q52 and Q53), the present study found that application of the ARR 2019 methodology resulted in the 3 hour storm duration becoming critical at the same locations.
- The peak flows along Farmers Creek are comparable between the *Flood Study* and the present study upstream of the Geordie Street causeway (refer PFL Q01, Q05, Q08 and Q10), but are between about 25 and 35 m^3/s lower further downstream. As a result, peak

[6] The Flood Study TUFLOW Models were re-run using the latest version of the TUFLOW software in order to determine the true impact of adopting the procedures set out in ARR 2019 versus ARR 1987.

flood levels are about 80 mm lower downstream of the Great Western Highway when compared with the findings of the *Flood Study*.

- Peak flood levels are up to 0.2 m higher on the major tributary arms of Farmers Creek (refer PFL Q16, Q18, Q19, Q24, Q26, Q30 and Q33 in **Table B3.2**) as a result of increases in peak flows of up to 25%. Larger increases in peak flood levels of up to 0.5 m occur on the upstream side of several road/railway crossings.
- Peak flood levels are up to 0.1 m lower on the main arm of Marangaroo Creek when compared with the *Flood Study* due to a slight reduction in peak flows (refer PFL Q49, Q52 and Q53 in **Table B3.2**).
- Peak flood levels are up to 0.1 m higher along the tributary arms of Marangaroo Creek (refer PFL Q56, Q61, Q62, Q65, Q67 and Q69 in **Table B3.2**) as a result of increases of up to 35% in peak flow.
- The resulting change in peak flood levels has only a minor impact on the extent of land that would be inundated by a 1% AEP flood event in both the Farmers Creek and Marangaroo Creek catchments.

The key findings of the assessment as they relate to areas subject to Major Overland Flow are as follows:

- Depths of overland flow have generally increased by 10-50 mm, with larger increases of up to 200 mm present in the trapped low points on the upstream side of several road/rail crossings.
- The increase in peak flood levels does not result in a significant increase on the extent of land which would be subject to major Overland Flow in a 1% AEP storm event.

TABLE B3.2
COMPARISON OF PEAK 1% AEP FLOWS

Peak Flow Location ID[1]	Tributary	Location	*Flood Study*[2]		Present Study[3]			
			Discharge (m^3/s)	Critical Storm Duration (hr)	Discharge (m^3/s)	Critical Storm Duration (hr)	Critical Storm Temporal Pattern	Difference[4] (m^3/s)
Q01	Farmers Creek	Upstream Extent of Farmers Creek TUFLOW Model	112.4	9	118.0	2	2	5.6
Q05		Lithgow State Mine Railway	153.6	9	160.1	3	9	6.5
Q08		Sandford Avenue	249.2	9	251.9	3	9	2.7
Q10		Geordie Street	281.2	9	278.8	3	9	-2.4
Q12		Great Western Highway	329.3	9	303.9	3	9	-25.4
Q13		Downstream Extent of Farmers Creek TUFLOW Model	354.5	9	318.6	3	9	-35.9
Q16	Oakey Park Creek	Upstream Farmers Creek Confluence	17.7	2	21.5	0.5	5	3.8
Q18	Vale of Clwydd Creek	Inflow to TUFLOW Model	21.6	9	22.4	2	2	0.8
Q19	Vale of Clwydd Tributary	Upstream Redgate Street	12.5	2	15.3	0.5	6	2.8
Q24	State Mine Creek	State Mine Gully Road	24.1	9	25.2	2	2	1.1
Q26		Laidley Street	38.2	12	47.6	2	4	9.4
Q27	Unnamed Tributary	Lithgow High School	11.3	2	11.8	0.5	5	0.5
Q30	McKellars Park Tributary	Downstream Gell Street	14.3	2	16.9	1	8	2.6
Q33	Sheedys Gully Tributary	Upstream Valley Drive	17.7	9	18.6	2	6	0.9

Refer over for footnotes to table.

TABLE B3.2 (Cont'd)
COMPARISON OF PEAK 1% AEP FLOWS

Peak Flow Location ID[1]	Tributary	Location	*Flood Study*[2]		Present Study[3]			
			Discharge (m^3/s)	Critical Storm Duration (hr)	Discharge (m^3/s)	Critical Storm Duration (hr)	Critical Storm Temporal Pattern	Difference[4] (m^3/s)
Q38	Major Overland Flow	Finlay Avenue	9.4	2	10.4	1	7	1.0
Q42		Enfield Avenue	10.2	6	12.6	1	2	2.4
Q46	Good Luck Hollow	Upstream Confluence with Farmers Creek	12.9	2	15.0	0.5	5	2.1
Q49	Marrangaroo Creek	-	227.9	9	224.0	3	9	-3.9
Q52		Great Western Highway	271	9	270.0	3	9	-1.0
Q53		Downstream Extent of TUFLOW Model	280.9	9	278.9	3	9	-2.0
Q56	Major Overland Flow	-	18.6	2	23.5	1	2	4.9
Q61		Upstream Reserve Road	37.7	2	46.6	1	7	8.9
Q62		-	6.6	2	8.1	1	2	1.5
Q65		-	18.6	2	25.0	0.5	5	6.4
Q67		Reserve Road	22.1	9	30.0	2	2	7.9
Q69		-	1.7	2	1.9	1	2	0.2

1. Refer **Figure B3.2** (4 sheets) for location of peak flow comparison.
2. Derived using procedures set out in ARR 1987.
3. Derived using procedures set out in ARR 2019.
4. A positive value indicates an increase, and conversely a negative value indicates a decrease in peak flow as a result of the adoption of ARR 2019.

B4. REFERENCES

The Institution of Engineers Australia, 1987. ***"Australian Rainfall and Runoff – A Guide to Flood Estimation"***, Volumes 1 and 2.

Geoscience Australia, 2019. ***"Australian Rainfall and Runoff – A Guide to Flood Estimation"***

Lyall & Associates, 2017. ***"Lithgow Flood Study Review"***

Office of Environment & Heritage, 2019. ***"Floodplain Risk Management Guide – Incorporating 2016 Australian Rainfall and Runoff in Studies"***

WMAwater, 2019. ***"The Review of ARR Design Inputs for NSW"***

ATTACHMENT B1
FARMERS CREEK AT MOUNT WALKER STREAM GAUGE (GS 212042) DATA

TABLE B1
RECORDED ANNUAL PEAK HEIGHT AND DISCHARGE DATA IN DATE ORDER
MOUNT WALKER STREAM GAUGE(1)

Year	Peak Height (m)	Peak Discharge (m^3/s)
1981	2.351	153
1982	0.839	4
1983	1.519	38
1984	1.279	21
1985	0.982	8
1986	2.307	146
1987	1.062	10
1988	1.667	54
1989	1.332	24
1990	2.126	119
1991	0.953	9
1992	1.536	44
1993	1.127	16
1994	1.119	15
1995	1.131	16
1996	1.095	14
1997	1.001	11
1998	2.135	119
1999	1.404	33
2000	1.585	50
2001	0.996	10
2002	1.425	35
2003	1.253	23
2004	1.378	31
2005	1.268	24
2006	1.645	56
2007	1.403	33
2008	1.685	60
2009	1.809	74
2010	1.492	41
2011	2.498	184
2012	1.768	69
2013	2.443	174
2014	1.822	38
2015	1.873	41
2016	2.293	65
2017	1.693	22
2018	2.002	41
2019	1.839	30

1. Note that the stream gauge was shifted upstream a short distance in September 2007 while the zero on the gauge, which is to an assumed datum, was maintained. Due to flood slope in Farmers Creek, direct comparison should not be made of recorded gauge heights either side of this date.

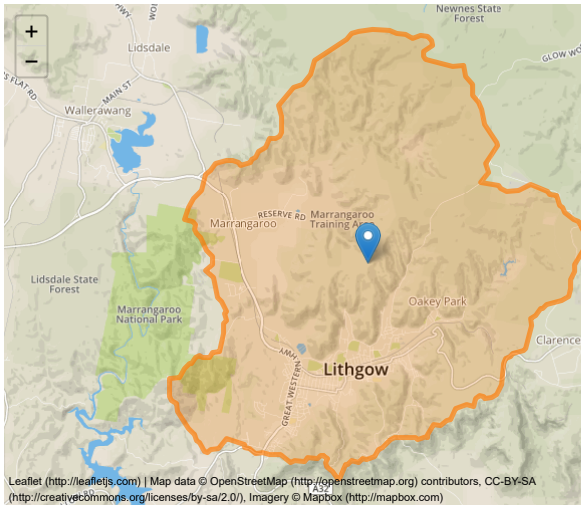
ATTACHMENT B2
DESIGN INPUT DATA FROM ARR DATA HUB

ATTENTION: This site was updated recently, changing some of the functionality. Please see the changelog (./changelog) for further information

Australian Rainfall & Runoff Data Hub - Results

Input Data

Longitude	150.161
Latitude	-33.451
Selected Regions (clear)	
River Region	show
ARF Parameters	show
Storm Losses	show
Temporal Patterns	show
Areal Temporal Patterns	show
BOM IFDs	show
Median Preburst Depths and Ratios	show
10% Preburst Depths	show
25% Preburst Depths	show
75% Preburst Depths	show
90% Preburst Depths	show
Interim Climate Change Factors	show
Probability Neutral Burst Initial Loss (./nsw_specific)	show



Data

River Region

Division	South East Coast (NSW)
River Number	12
River Name	Hawkesbury River
Shape Intersection (%)	100.0

Layer Info

Time Accessed	20 July 2020 10:58AM
Version	2016_v1

ARF Parameters

$$ARF = Min\left\{1, \left[1 - a\left(Area^{b} - c\log_{10}Duration\right)Duration^{-d} + eArea^{f}Duration^{g}\left(0.3 + \log_{10}AEP\right) + h10^{iArea\frac{Duration}{1440}}\left(0.3 + \log_{10}AEP\right)\right]\right\}$$

Layer Info

Time Accessed	20 July 2020 10:58AM
Version	2016_v1

Zone	a	b	c	d	e	f	g	h	i	Shape Intersection (%)
SE Coast	0.06	0.361	0.0	0.317	8.11e-05	0.651	0.0	0.0	0.0	100.0

Short Duration ARF

$$ARF = Min\left[1, 1 - 0.287\left(Area^{0.265} - 0.439\log_{10}(Duration)\right).Duration^{-0.36} + 2.26 \text{ x } 10^{-3} \text{ x } Area^{0.226}.Duration^{0.125}\left(0.3 + \log_{10}(AEP)\right) + 0.0141 \text{ x } Area^{0.213} \text{ x } 10^{-0.021\frac{(Duration-180)^2}{1440}}\left(0.3 + \log_{10}(AEP)\right)\right]$$

Storm Losses

Note: Burst Loss = Storm Loss - Preburst

Note: These losses are only for rural use and are **NOT FOR DIRECT USE** in urban areas

Note: As this point is in NSW the advice provided on losses and pre-burst on the NSW Specific Tab of the ARR Data Hub (./nsw_specific) is to be considered. In NSW losses are derived considering a hierarchy of approaches depending on the available loss information. The continuing storm loss information from the ARR Datahub provided below should only be used where relevant under the loss hierarchy (level 5) and where used is to be multiplied by the factor of 0.4.

Storm Initial Losses (mm)	38.0
Storm Continuing Losses (mm/h)	5.7

Layer Info

Time Accessed	20 July 2020 10:58AM
Version	2016_v1

Temporal Patterns | Download (.zip) (static/temporal_patterns/TP/ECsouth.zip)

code	ECsouth
Label	East Coast South
Shape Intersection (%)	100.0

Layer Info

Time Accessed	20 July 2020 10:58AM
Version	2016_v2

Areal Temporal Patterns | Download (.zip) (./static/temporal_patterns/Areal/Areal_ECsouth.zip)

code	ECsouth
arealabel	East Coast South
Shape Intersection (%)	100.0

Layer Info

Time Accessed	20 July 2020 10:58AM
Version	2016_v2

BOM IFDs

Click here (http://www.bom.gov.au/water/designRainfalls/revised-ifd/?year=2016&coordinate_type=dd&latitude=-33.4513633121&longitude=150.160566046&s to obtain the IFD depths for catchment centroid from the BoM website

Layer Info

Time Accessed	20 July 2020 10:58AM

Median Preburst Depths and Ratios

Values are of the format depth (ratio) with depth in mm

min (h)\AEP(%)	50	20	10	5	2	1
60 (1.0)	0.5 (0.020)	0.5 (0.015)	0.4 (0.013)	0.4 (0.011)	0.5 (0.010)	0.5 (0.010)
90 (1.5)	0.2 (0.009)	0.3 (0.010)	0.4 (0.010)	0.5 (0.010)	0.4 (0.007)	0.4 (0.006)
120 (2.0)	0.3 (0.009)	0.4 (0.011)	0.5 (0.012)	0.6 (0.012)	0.6 (0.010)	0.6 (0.009)
180 (3.0)	0.4 (0.013)	0.8 (0.019)	1.0 (0.021)	1.3 (0.022)	1.5 (0.023)	1.7 (0.023)
360 (6.0)	1.0 (0.024)	1.5 (0.028)	1.9 (0.029)	2.2 (0.030)	8.3 (0.096)	12.9 (0.134)
720 (12.0)	0.0 (0.000)	4.5 (0.061)	7.5 (0.086)	10.4 (0.103)	9.4 (0.080)	8.7 (0.066)
1080 (18.0)	0.1 (0.001)	1.8 (0.020)	3.0 (0.028)	4.1 (0.033)	7.2 (0.050)	9.5 (0.059)
1440 (24.0)	0.0 (0.000)	1.7 (0.016)	2.8 (0.023)	3.8 (0.027)	6.9 (0.041)	9.2 (0.049)
2160 (36.0)	0.0 (0.000)	0.6 (0.005)	1.0 (0.006)	1.3 (0.008)	2.3 (0.011)	3.1 (0.014)
2880 (48.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
4320 (72.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)

Layer Info

Time Accessed	20 July 2020 10:58AM
Version	2018_v1
Note	Preburst interpolation methods for catchment wide preburst has been slightly altered. Point values remain unchanged.

10% Preburst Depths

Values are of the format depth (ratio) with depth in mm

min (h)\AEP(%)	50	20	10	5	2	1
60 (1.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
90 (1.5)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
120 (2.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
180 (3.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
360 (6.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
720 (12.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
1080 (18.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
1440 (24.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
2160 (36.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
2880 (48.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
4320 (72.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)

Layer Info

Time Accessed	20 July 2020 10:58AM
Version	2018_v1
Note	Preburst interpolation methods for catchment wide preburst has been slightly altered. Point values remain unchanged.

25% Preburst Depths

Values are of the format depth (ratio) with depth in mm

min (h)\AEP(%)	50	20	10	5	2	1
60 (1.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
90 (1.5)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
120 (2.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
180 (3.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
360 (6.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
720 (12.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
1080 (18.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
1440 (24.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
2160 (36.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
2880 (48.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
4320 (72.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)

Layer Info

Time Accessed	20 July 2020 10:58AM
Version	2018_v1
Note	Preburst interpolation methods for catchment wide preburst has been slightly altered. Point values remain unchanged.

75% Preburst Depths

Values are of the format depth (ratio) with depth in mm

min (h)\AEP(%)	50	20	10	5	2	1
60 (1.0)	10.3 (0.456)	8.4 (0.277)	7.1 (0.200)	5.9 (0.144)	6.5 (0.134)	6.9 (0.127)
90 (1.5)	13.0 (0.506)	11.7 (0.343)	10.8 (0.270)	10.0 (0.217)	12.7 (0.234)	14.8 (0.242)
120 (2.0)	10.6 (0.379)	13.4 (0.359)	15.2 (0.348)	16.9 (0.338)	14.5 (0.246)	12.7 (0.193)
180 (3.0)	14.5 (0.451)	18.5 (0.435)	21.1 (0.425)	23.7 (0.416)	30.9 (0.464)	36.4 (0.488)
360 (6.0)	18.6 (0.449)	25.1 (0.458)	29.4 (0.459)	33.5 (0.457)	47.8 (0.555)	58.5 (0.609)
720 (12.0)	10.6 (0.191)	23.6 (0.318)	32.2 (0.369)	40.4 (0.403)	41.9 (0.355)	42.9 (0.326)
1080 (18.0)	13.6 (0.207)	20.1 (0.225)	24.4 (0.230)	28.5 (0.232)	37.0 (0.256)	43.4 (0.269)
1440 (24.0)	9.1 (0.122)	13.6 (0.133)	16.5 (0.135)	19.3 (0.136)	26.5 (0.158)	32.0 (0.171)
2160 (36.0)	0.7 (0.008)	5.6 (0.045)	8.8 (0.060)	11.9 (0.069)	19.6 (0.096)	25.4 (0.111)
2880 (48.0)	0.3 (0.003)	3.4 (0.025)	5.4 (0.033)	7.4 (0.037)	9.9 (0.042)	11.8 (0.045)
4320 (72.0)	0.1 (0.001)	0.5 (0.003)	0.7 (0.004)	1.0 (0.004)	0.7 (0.002)	0.4 (0.001)

Layer Info

Time Accessed	20 July 2020 10:58AM
Version	2018_v1
Note	Preburst interpolation methods for catchment wide preburst has been slightly altered. Point values remain unchanged.

90% Preburst Depths

Values are of the format depth (ratio) with depth in mm

min (h)\AEP(%)	50	20	10	5	2	1
60 (1.0)	24.2 (1.064)	21.1 (0.696)	19.1 (0.533)	17.2 (0.416)	26.0 (0.534)	32.6 (0.598)
90 (1.5)	37.6 (1.463)	42.3 (1.237)	45.4 (1.128)	48.3 (1.046)	46.5 (0.856)	45.2 (0.743)
120 (2.0)	23.1 (0.824)	35.7 (0.958)	44.0 (1.006)	52.0 (1.036)	84.2 (1.427)	108.3 (1.642)
180 (3.0)	42.6 (1.329)	48.2 (1.137)	51.9 (1.045)	55.4 (0.974)	70.4 (1.054)	81.6 (1.094)
360 (6.0)	35.7 (0.863)	48.3 (0.881)	56.6 (0.883)	64.5 (0.879)	94.2 (1.094)	116.5 (1.212)
720 (12.0)	31.0 (0.562)	56.2 (0.759)	72.8 (0.837)	88.8 (0.886)	93.1 (0.789)	96.3 (0.732)
1080 (18.0)	34.9 (0.530)	48.4 (0.541)	57.3 (0.541)	65.8 (0.537)	77.7 (0.537)	86.7 (0.537)
1440 (24.0)	28.7 (0.385)	38.5 (0.377)	45.0 (0.370)	51.3 (0.361)	56.3 (0.336)	60.0 (0.320)
2160 (36.0)	13.2 (0.150)	24.2 (0.198)	31.6 (0.214)	38.6 (0.223)	44.2 (0.215)	48.4 (0.211)
2880 (48.0)	10.3 (0.106)	21.9 (0.160)	29.6 (0.177)	36.9 (0.187)	37.1 (0.158)	37.2 (0.142)
4320 (72.0)	9.3 (0.084)	11.5 (0.073)	13.0 (0.067)	14.4 (0.062)	24.2 (0.089)	31.6 (0.103)

Layer Info

Time Accessed	20 July 2020 10:58AM
Version	2018_v1
Note	Preburst interpolation methods for catchment wide preburst has been slightly altered. Point values remain unchanged.

Interim Climate Change Factors

	RCP 4.5	RCP6	**RCP 8.5**
2030	**0.869 (4.3%)**	0.783 (3.9%)	**0.983 (4.9%)**
2040	**1.057 (5.3%)**	1.014 (5.1%)	**1.349 (6.8%)**
2050	**1.272 (6.4%)**	1.236 (6.2%)	**1.773 (9.0%)**
2060	**1.488 (7.5%)**	1.458 (7.4%)	**2.237 (11.5%)**
2070	**1.676 (8.5%)**	1.691 (8.6%)	**2.722 (14.2%)**
2080	**1.810 (9.2%)**	1.944 (9.9%)	**3.209 (16.9%)**
2090	**1.862 (9.5%)**	2.227 (11.5%)	**3.679 (19.7%)**

Layer Info

Time Accessed	20 July 2020 10:58AM
Version	2019_v1
Note	ARR recommends the use of RCP4.5 and RCP 8.5 values. These have been updated to the values that can be found on the climate change in Australia website.

Probability Neutral Burst Initial Loss

min (h)\AEP(%)	50	20	10	5	2	1
60 (1.0)	22.2	16.4	15.0	15.2	15.3	13.7
90 (1.5)	25.0	13.8	12.7	13.0	12.5	11.2
120 (2.0)	27.3	16.2	13.5	12.9	11.4	9.5
180 (3.0)	25.0	14.0	12.4	12.1	10.8	6.9
360 (6.0)	24.2	15.2	12.7	12.4	10.1	4.6
720 (12.0)	25.9	16.9	14.2	13.5	11.7	8.2
1080 (18.0)	25.9	18.9	18.4	17.5	15.4	7.7
1440 (24.0)	27.7	21.6	21.8	22.2	18.7	12.1
2160 (36.0)	32.5	26.2	26.2	26.7	22.5	13.5
2880 (48.0)	33.5	27.4	27.8	30.3	25.1	18.0
4320 (72.0)	34.5	30.3	31.8	37.1	30.4	22.5

Download TXT (downloads/ef4846fc-a3f4-46fe-99a4-2d7eab00d023.txt)

Download JSON (downloads/f3f18d20-9be2-4381-b151-6ecb11ccda3d.json)

Generating PDF... (downloads/fbdf446f-e95b-4053-ad87-e29f60ba6be6.pdf)

Layer Info

Time Accessed	20 July 2020 10:58AM
Version	2018_v1
Note	As this point is in NSW the advice provided on losses and pre-burst on the NSW Specific Tab of the ARR Data Hub (./nsw_specific) is to be considered. In NSW losses are derived considering a hierarchy of approaches depending on the available loss information. Probability neutral burst initial loss values for NSW are to be used in place of the standard initial loss and pre-burst as per the losses hierarchy.

ATTACHMENT B3
COMPLETED BLOCKAGE ASSESSMENT FORMS

PROJECT: LITHGOW FLOODPLAIN RISK MANAGEMENT STUDY & PLAN

DESCRIPTION: BLOCKAGE ASSESSMENT FORM - STATE FOREST AREAS

DEBRIS TYPE / MATERIAL / L_{10} / SOURCE AREA - There may be more than one material type to consider!

Debris Type/Material	L_{10}	Source Area	Assessment Method
Floating	2.5	State Forest Area	StreetView and Site Photos

DEBRIS AVAILABILITY (HML) - for the selected debris type/size and its source area

Classification	Typical Source Area Characteristics (1% AEP Event)	Notes
High	Dense forest with thick vegetation, extensive canopy cover, difficult to walk through with considerable fallen limbs, leaves and high levels of floor litter.	✓
	Streams with boulder/cobble beds and steep bed slopes and steep banks showing signs of substantial past bed/bank movements.	
	Arid areas, where loose vegetation and exposed loose soils occur and vegetation is sparse.	
	Urban areas that are not well maintained and/or old paling fences, sheds, cars and/or stored loose material etc., are present on the floodplain close to the water course.	
Medium	State forest areas with clear understory, grazing land with stands of trees.	
	Source areas generally falling between the High and Low categories.	
Low	Well maintained rural lands and paddocks with minimal outbuildings or stored materials in the source area.	
	Streams with moderate to flat slopes and stable bed and banks.	
	Arid areas where vegetation is deep rooted and soils are resistant to scour.	
	Urban areas that are well maintained with limited debris present in the source area.	

DEBRIS MOBILITY (HML) - for the selected type/size and its source are

Classification	Typical Source Area Characteristics (1% AEP Event)	Notes
High	Steep source area with fast response times and high annual rainfall and/or storm intensities and/or source areas subject to high rainfall intensities with sparse vegetation cover.	✓
	Receiving streams that frequently overtop their banks.	
	Main debris source areas close to streams.	✓
Medium	Source areas generally falling between the High and Low mobility categories.	
Low	Low rainfall intensities and large, flat source areas.	
	Receiving streams infrequently overtops their banks.	
	Main debris source areas well away from streams.	

DEBRIS TRANSPORTABILITY (HML) - for the selected debris type/size and its stream characteristics

Transportability	Typical Transporting Stream Characteristics (1% AEP Event)	Notes
High	Steep bed slopes (> 3%) and/or high stream velocity (V > 2.5 m/s)	✓
	Deep stream relative to vertical debris dimension (D > $0.5L_{10}$)	✓
	Wide streams relative to horizontal debris dimension.(W > L_{10})	✓
	Streams relatively straight and free of major constrictions/snag points.	
	High temporal variability in maximum stream flows.	
Medium	Streams generally falling between High and Low categories.	
Low	Flat bed slopes (< 1%) and/or low stream velocity (V<1m/s).	
	Shallow stream relative to vertical debris dimension (D < $0.5L_{10}$).	
	Narrow streams relative to horizontal debris dimension (W < L_{10}).	
	Streams meanders with frequent constrictions/snag points.	✓
	Low temporal variability in maximum stream flows.	

PROJECT: LITHGOW FLOODPLAIN RISK MANAGEMENT STUDY & PLAN
DESCRIPTION: BLOCKAGE ASSESSMENT FORM - STATE FOREST AREAS

SITE BASED DEBRIS POTENTIAL 1% AEP (HML) - for the selected debris type/size arriving at size

Debris Potential	Combinations of the Above (any order)	Notes
DP_{High}	HHH or HHM	HHH
DP_{Medium}	MMM or HML or HMM or HLL	
DP_{Low}	LLL or MML or MLL	

AEP ADJUSTED SITE DEBRIS POTENTIAL (HML) - for selected debris type/size

Event AEP	(1% AEP) Debris Potential at Structure			AEP Adjusted At Site Debris
	DP_{High}	DP_{Medium}	DP_{Low}	
AEP > 5%	Medium	Low	Low	
AEP 5% - AEP 0.5%	High	Medium	Low	
AEP < 0.5%	High	High	Medium	

Debris Blockage

MOST LIKELY DEISGN INLET BLOCKAGE LEVEL (B_{des}%) for the selected debris type/size

Control Dimension Inlet Width (W) (m)	AEP Adjusted Debris Potential At Structure		
	High	Medium	Low
$W < L_{10}$	100%	50%	25%
$L_{10} \leq W \leq 3*L_{10}$	20%	10%	0%
$W > 3*L_{10}$	10%	0%	0%
B_{des} %	AEP<0.5%	AEP 0.5% - AEP 5%	AEP>5%

Barrel Blockage

LIKELIHOOD OF SEDIMENT BEING DROPPED IN THE BARREL OR WATERWAY (HML)

Peak Velocity Through Structure (m/s)	Mean Sediment Size Present				
	Clay/Silt 0.001 to 0.04 mm	Sand 0.04 to 2 mm	Gravel 2 to 63 mm	Cobbles 63 to 200 mm	Boulders >200 mm
>= 3	L	L	L	L	M
1.0 to < 3.0	L	L	L	M	M
0.5 to < 1.0	L	L	L	M	H
0.1 to < 0.5	L	L	M	H	H
< 0.1	L	M	H	H	H

MOST LIKELY DESIGN BARREL BLOCKAGES (B_{des}%) for sediment of a particular mean size is then;

Likelihood that Deposition will Occur	AEP Adjusted Sediment Potential		
	High	Medium	Low
High	100%	60%	25%
Medium	60%	40%	15%
Low	25%	15%	0%

Event AEP	B_{des} %
AEP > 5%	15%
AEP 5% - AEP 0.5%	25%
AEP < 0.5%	25%

PROJECT: LITHGOW FLOODPLAIN RISK MANAGEMENT STUDY & PLAN

DESCRIPTION: BLOCKAGE ASSESSMENT FORM - RURAL RESIDENTIAL AREAS

DEBRIS TYPE / MATERIAL / L_{10} / SOURCE AREA - There may be more than one material type to consider!

Debris Type/Material	L_{10}	Source Area	Assessment Method
Floating	2	Rural Residential Areas	StreetView and Site Photos

DEBRIS AVAILABILITY (HML) - for the selected debris type/size and its source area

Classification	Typical Source Area Characteristics (1% AEP Event)	Notes
High	Dense forest with thick vegetation, extensive canopy cover, difficult to walk through with considerable fallen limbs, leaves and high levels of floor litter.	
	Streams with boulder/cobble beds and steep bed slopes and steep banks showing signs of substantial past bed/bank movements.	
	Arid areas, where loose vegetation and exposed loose soils occur and vegetation is sparse.	
	Urban areas that are not well maintained and/or old paling fences, sheds, cars and/or stored loose material etc., are present on the floodplain close to the water course.	
Medium	State forest areas with clear understory, grazing land with stands of trees.	✓
	Source areas generally falling between the High and Low categories.	
Low	Well maintained rural lands and paddocks with minimal outbuildings or stored materials in the source area.	
	Streams with moderate to flat slopes and stable bed and banks.	
	Arid areas where vegetation is deep rooted and soils are resistant to scour.	
	Urban areas that are well maintained with limited debris present in the source area.	

DEBRIS MOBILITY (HML) - for the selected type/size and its source are

Classification	Typical Source Area Characteristics (1% AEP Event)	Notes
High	Steep source area with fast response times and high annual rainfall and/or storm intensities and/or source areas subject to high rainfall intensities with sparse vegetation cover.	✓
	Receiving streams that frequently overtop their banks.	
	Main debris source areas close to streams.	
Medium	Source areas generally falling between the High and Low mobility categories.	
Low	Low rainfall intensities and large, flat source areas.	
	Receiving streams infrequently overtops their banks.	
	Main debris source areas well away from streams.	

DEBRIS TRANSPORTABILITY (HML) - for the selected debris type/size and its stream characteristics

Transportability	Typical Transporting Stream Characteristics (1% AEP Event)	Notes
High	Steep bed slopes (> 3%) and/or high stream velocity (V > 2.5 m/s)	
	Deep stream relative to vertical debris dimension (D > $0.5L_{10}$)	
	Wide streams relative to horizontal debris dimension.(W > L_{10})	
	Streams relatively straight and free of major constrictions/snag points.	
	High temporal variability in maximum stream flows.	
Medium	Streams generally falling between High and Low categories.	✓
Low	Flat bed slopes (< 1%) and/or low stream velocity (V<1m/s).	
	Shallow stream relative to vertical debris dimension (D < $0.5L_{10}$).	
	Narrow streams relative to horizontal debris dimension (W < L_{10}).	
	Streams meanders with frequent constrictions/snag points.	
	Low temporal variability in maximum stream flows.	

PROJECT: LITHGOW FLOODPLAIN RISK MANAGEMENT STUDY & PLAN
DESCRIPTION: BLOCKAGE ASSESSMENT FORM - RURAL RESIDENTIAL AREAS

SITE BASED DEBRIS POTENTIAL 1% AEP (HML) - for the selected debris type/size arriving at size

Debris Potential	Combinations of the Above (any order)	Notes
DP_{High}	HHH or HHM	
DP_{Medium}	MMM or HML or HMM or HLL	MHM
DP_{Low}	LLL or MML or MLL	

AEP ADJUSTED SITE DEBRIS POTENTIAL (HML) - for selected debris type/size

Event AEP	(1% AEP) Debris Potential at Structure			AEP Adjusted At Site Debris Potential
	DP_{High}	DP_{Medium}	DP_{Low}	
AEP > 5%	Medium	Low	Low	
AEP 5% - AEP 0.5%	High	Medium	Low	
AEP < 0.5%	High	High	Medium	

Debris Blockage

MOST LIKELY DEISGN INLET BLOCKAGE LEVEL (B_{des}%) for the selected debris type/size

Control Dimension Inlet Width (W) (m)	AEP Adjusted Debris Potential At Structure		
	High	Medium	Low
$W < L_{10}$	100%	50%	25%
$L_{10} \leq W \leq 3*L_{10}$	20%	10%	0%
$W > 3*L_{10}$	10%	0%	0%
B_{des} %	AEP<0.5%	AEP 0.5% - AEP 5%	AEP>5%

Barrel Blockage

LIKELIHOOD OF SEDIMENT BEING DROPPED IN THE BARREL OR WATERWAY (HML)

Peak Velocity Through Structure (m/s)	Mean Sediment Size Present				
	Clay/Silt 0.001 to 0.04 mm	Sand 0.04 to 2 mm	Gravel 2 to 63 mm	Cobbles 63 to 200 mm	Boulders >200 mm
>= 3	L	L	L	L	M
1.0 to < 3.0	L	L	L	M	M
0.5 to < 1.0	L	L	L	M	H
0.1 to < 0.5	L	L	M	H	H
< 0.1	L	M	H	H	H

MOST LIKELY DESIGN BARREL BLOCKAGES (B_{des}%) for sediment of a particular mean size is then;

Likelihood that Deposition will Occur	AEP Adjusted Sediment Potential		
	High	Medium	Low
High	100%	60%	25%
Medium	60%	40%	15%
Low	25%	15%	0%

Event AEP	B_{des} %
AEP > 5%	0%
AEP 5% - AEP 0.5%	15%
AEP < 0.5%	25%

PROJECT: LITHGOW FLOODPLAIN RISK MANAGEMENT STUDY & PLAN

DESCRIPTION: BLOCKAGE ASSESSMENT FORM - URBANISED AREAS

DEBRIS TYPE / MATERIAL / L_{10} / SOURCE AREA - There may be more than one material type to consider!

Debris Type/Material	L_{10}	Source Area	Assessment Method
Floating	1.5	Urbanised Areas	StreetView and Site Photos

DEBRIS AVAILABILITY (HML) - for the selected debris type/size and its source area

Classification	Typical Source Area Characteristics (1% AEP Event)	Notes
High	Dense forest with thick vegetation, extensive canopy cover, difficult to walk through with considerable fallen limbs, leaves and high levels of floor litter.	
	Streams with boulder/cobble beds and steep bed slopes and steep banks showing signs of substantial past bed/bank movements.	
	Arid areas, where loose vegetation and exposed loose soils occur and vegetation is sparse.	
	Urban areas that are not well maintained and/or old paling fences, sheds, cars and/or stored loose material etc., are present on the floodplain close to the water course.	
Medium	State forest areas with clear understory, grazing land with stands of trees.	
	Source areas generally falling between the High and Low categories.	✓
Low	Well maintained rural lands and paddocks with minimal outbuildings or stored materials in the source area.	
	Streams with moderate to flat slopes and stable bed and banks.	
	Arid areas where vegetation is deep rooted and soils are resistant to scour.	
	Urban areas that are well maintained with limited debris present in the source area.	

DEBRIS MOBILITY (HML) - for the selected type/size and its source are

Classification	Typical Source Area Characteristics (1% AEP Event)	Notes
High	Steep source area with fast response times and high annual rainfall and/or storm intensities and/or source areas subject to high rainfall intensities with sparse vegetation cover.	✓
	Receiving streams that frequently overtop their banks.	
	Main debris source areas close to streams.	
Medium	Source areas generally falling between the High and Low mobility categories.	
Low	Low rainfall intensities and large, flat source areas.	
	Receiving streams infrequently overtops their banks.	
	Main debris source areas well away from streams.	

DEBRIS TRANSPORTABILITY (HML) - for the selected debris type/size and its stream characteristics

Transportability	Typical Transporting Stream Characteristics (1% AEP Event)	Notes
High	Steep bed slopes (> 3%) and/or high stream velocity (V > 2.5 m/s)	
	Deep stream relative to vertical debris dimension ($D > 0.5L_{10}$)	
	Wide streams relative to horizontal debris dimension.($W > L_{10}$)	
	Streams relatively straight and free of major constrictions/snag points.	
	High temporal variability in maximum stream flows.	
Medium	Streams generally falling between High and Low categories.	
Low	Flat bed slopes (< 1%) and/or low stream velocity (V<1m/s).	
	Shallow stream relative to vertical debris dimension ($D < 0.5L_{10}$).	✓
	Narrow streams relative to horizontal debris dimension ($W < L_{10}$).	
	Streams meanders with frequent constrictions/snag points.	✓
	Low temporal variability in maximum stream flows.	

PROJECT: LITHGOW FLOODPLAIN RISK MANAGEMENT STUDY & PLAN
DESCRIPTION: BLOCKAGE ASSESSMENT FORM - URBANISED AREAS

SITE BASED DEBRIS POTENTIAL 1% AEP (HML) - for the selected debris type/size arriving at size

Debris Potential	Combinations of the Above (any order)	Notes
DP_{High}	HHH or HHM	
DP_{Medium}	MMM or HML or HMM or HLL	MHL
DP_{Low}	LLL or MML or MLL	

AEP ADJUSTED SITE DEBRIS POTENTIAL (HML) - for selected debris type/size

Event AEP	(1% AEP) Debris Potential at Structure			AEP Adjusted At Site Debris Potential
	DP_{High}	DP_{Medium}	DP_{Low}	
AEP > 5%	Medium	Low	Low	
AEP 5% - AEP 0.5%	High	Medium	Low	
AEP < 0.5%	High	High	Medium	

Debris Blockage

MOST LIKELY DEISGN INLET BLOCKAGE LEVEL (B_{des}%) for the selected debris type/size

Control Dimension Inlet Width (W) (m)	AEP Adjusted Debris Potential At Structure		
	High	Medium	Low
$W < L_{10}$	100%	50%	25%
$L_{10} \leq W \leq 3*L_{10}$	20%	10%	0%
$W > 3*L_{10}$	10%	0%	0%
B_{des} %	AEP<0.5%	AEP 0.5% - AEP 5%	AEP>5%

Barrel Blockage

LIKELIHOOD OF SEDIMENT BEING DROPPED IN THE BARREL OR WATERWAY (HML)

Peak Velocity Through Structure (m/s)	Mean Sediment Size Present				
	Clay/Silt 0.001 to 0.04 mm	Sand 0.04 to 2 mm	Gravel 2 to 63 mm	Cobbles 63 to 200 mm	Boulders >200 mm
>= 3	L	L	L	L	M
1.0 to < 3.0	L	L	L	M	M
0.5 to < 1.0	L	L	L	M	H
0.1 to < 0.5	L	L	M	H	H
< 0.1	L	M	H	H	H

MOST LIKELY DESIGN BARREL BLOCKAGES (B_{des}%) for sediment of a particular mean size is then;

Likelihood that Deposition will Occur	AEP Adjusted Sediment Potential		
	High	Medium	Low
High	100%	60%	25%
Medium	60%	40%	15%
Low	25%	15%	0%

Event AEP	B_{des} %
AEP > 5%	0%
AEP 5% - AEP 0.5%	15%
AEP < 0.5%	25%

ATTACHMENT B4
DESIGN PEAK FLOWS

TABLE B1
DESIGN PEAK FLOWS(1)

Peak Flow Location Identifier(2)	Tributary/Catchment	Location	Design Flood Events																						
			20% AEP			10% AEP			5% AEP			2% AEP			1% AEP			0.5% AEP			0.2% AEP			PMF	
			Peak Flow (m^3/s)	Critical Storm Duration(3) (minutes)	Critical Storm Burst(4)	Peak Flow (m^3/s)	Critical Storm Duration(3) (minutes)	Critical Storm Burst(4)	Peak Flow (m^3/s)	Critical Storm Duration(3) (minutes)	Critical Storm Burst(4)	Peak Flow (m^3/s)	Critical Storm Duration(3) (minutes)	Critical Storm Burst(4)	Peak Flow (m^3/s)	Critical Storm Duration(3) (minutes)	Critical Storm Burst(4)	Peak Flow (m^3/s)	Critical Storm Duration(3) (minutes)	Critical Storm Burst(4)	Peak Flow (m^3/s)	Critical Storm Duration(3) (minutes)	Critical Storm Burst(4)	Peak Flow (m^3/s)	Critical Storm Duration(3) (minutes)
[A]	[B]	[C]	[D]	[E]	[F]	[G]	[H]	[I]	[J]	[K]	[L]	[M]	[N]	[O]	[P]	[Q]	[R]	[S]	[T]	[U]	[V]	[W]	[X]	[Y]	[Z]
Q01		Upstream extent of TUFLOW model	35.3	120	10	48.3	180	4	62.2	90	6	91.3	120	6	118	120	2	133	120	2	154	120	2	987	90
Q02		Brewery Lane	44.6	120	3	61.7	180	4	79.6	180	4	116	120	2	148	120	2	166	120	2	192	120	1	-	-
Q03		Mills Street Causeway	47.6	120	3	65.2	180	4	82.9	180	4	119	120	2	154	180	9	174	180	2	200	120	1	-	-
Q04		Victoria Avenue	47.5	120	3	65.8	180	4	84.3	180	4	120	120	2	154	180	9	172	180	9	191	120	7	-	-
Q05		Lithgow State Mine Railway	48.6	120	3	67.7	180	4	86.1	180	4	121	120	2	157	180	9	175	180	9	199	180	9	-	-
Q06		Atkinson Street	62.5	120	3	85.0	180	4	108	180	4	155	120	2	196	120	9	218	120	9	242	120	9	-	-
Q07	Farmers Creek	Tank Street	72.6	120	3	100	180	4	128	180	4	180	120	2	230	180	9	255	180	9	291	180	9	-	-
Q08		Sandford Avenue	85.1	120	3	112	180	4	142	180	4	190	120	2	242	180	9	293	180	9	310	180	2	-	-
Q09		Albert Street	96.5	120	3	127	180	4	161	180	4	214	120	2	277	180	9	320	180	9	346	180	9	-	-
Q10		Geordie Street	102	120	3	133	180	4	164	180	4	221	180	9	288	180	9	330	120	9	362	120	9	2,260	120
Q11		Cooerwull Road	107	120	3	141	180	4	170	180	4	227	180	9	298	180	9	337	180	9	376	180	2	-	-
Q12		Great Western Highway	106	120	3	141	180	4	171	180	4	227	180	9	296	180	9	334	180	9	372	180	2	2,380	150
Q13		Downstream extent of TUFLOW model	110	120	3	150	180	4	181	180	4	241	180	9	319	180	9	357	180	9	402	180	2	2,616	180
Q14	Lithgow Valley Gully	Bells Road	4.5	120	10	7.0	180	6	9.0	180	6	13.0	120	2	17.4	120	2	19.8	120	2	22.2	90	4	164	90
Q15	Ida Falls Creek	Main Western Railway	5.8	120	10	7.8	90	6	10.4	90	6	15.2	90	9	16.0	90	2	21.9	90	10	25.5	90	10	155	90
Q16	Oakey Park Creek	Upstream Farmers Creek Confluence	7.4	60	8	10.1	60	3	13.6	60	3	17.0	30	5	21.5	30	5	24.3	30	5	28.5	30	5	138	90
Q17	Overland Flow	Main Western Railway Corridor(5)	0.8	120	8	0.8	60	6	0.8	60	3	0.8	30	5	0.8	30	5	0.8	30	5	0.8	30	5	-	-
Q18	Vale of Clwydd Creek	Inflow to TUFLOW Model	5.7	120	10	8.9	180	6	11.7	180	6	16.8	120	2	22.1	120	2	25.0	120	2	30.1	120	2	209	90
Q19	Overland Flow	Upstream Redgate Street	5.3	60	8	7.2	60	3	9.5	60	3	12.0	30	6	15.3	30	6	17.4	30	6	20.5	30	6	95	30
Q20	Vale of Clwydd Creek	Mort Street	11.3	120	7	15.1	90	6	18.0	60	3	26.1	120	6	33.6	120	6	38.5	120	6	44.3	120	8	-	-

TABLE B1 (Cont'd)
DESIGN PEAK FLOWS[1]

Peak Flow Location Identifier[2]	Tributary/Catchment	Location	Design Flood Events																						
			20% AEP			10% AEP			5% AEP			2% AEP			1% AEP			0.5% AEP			0.2% AEP			PMF	
			Peak Flow (m^3/s)	Critical Storm Duration[3] (minutes)	Critical Storm Burst[4]	Peak Flow (m^3/s)	Critical Storm Duration[3] (minutes)	Critical Storm Burst[4]	Peak Flow (m^3/s)	Critical Storm Duration[3] (minutes)	Critical Storm Burst[4]	Peak Flow (m^3/s)	Critical Storm Duration[3] (minutes)	Critical Storm Burst[4]	Peak Flow (m^3/s)	Critical Storm Duration[3] (minutes)	Critical Storm Burst[4]	Peak Flow (m^3/s)	Critical Storm Duration[3] (minutes)	Critical Storm Burst[4]	Peak Flow (m^3/s)	Critical Storm Duration[3] (minutes)	Critical Storm Burst[4]	Peak Flow (m^3/s)	Critical Storm Duration[3] (minutes)
[A]	[B]	[C]	[D]	[E]	[F]	[G]	[H]	[I]	[J]	[K]	[L]	[M]	[N]	[O]	[P]	[Q]	[R]	[S]	[T]	[U]	[V]	[W]	[X]	[Y]	[Z]
Q21	Vale of Clwydd Creek	Chifley Road	13.4	120	7	18.2	90	6	23.7	60	3	32.9	120	9	42.4	120	4	48.2	120	4	55.4	120	9	334	90
Q22		Main Western Railway	14.5	120	7	19.6	90	7	25.5	60	6	35.7	120	9	42.7	120	9	45.7	120	9	43.6	120	9	-	-
Q23	Overland Flow	Main Western Railway[5]	0.5	30	7	0.5	60	10	0.5	30	4	0.5	30	5	0.5	60	2	0.5	60	2	0.5	60	5	-	-
Q24	State Mine Creek	State Mine Gully Road	6.6	120	10	10.1	180	6	13.2	180	6	19.2	120	2	25.2	120	2	28.6	120	2	33.8	90	8	236	90
Q25		Downstream State Mine Gully Road	11.8	120	7	16.5	90	6	21.4	60	6	31.2	120	6	38.8	120	6	44.3	120	9	52.0	120	9	317	90
Q26		Laidley Street	14.7	60	8	20.4	60	3	26.9	60	3	36.5	120	4	45.4	120	9	51.7	120	9	59.0	120	9	-	-
Q27	Overland Flow	Lithgow High School	4.3	60	6	6.0	60	7	7.8	60	3	9.7	30	5	11.8	30	5	13.3	30	5	15.4	30	5	80	15
Q28		Main Western Railway[5]	3.2	120	3	3.7	60	7	2.7	60	4	4.0	90	2	4.2	90	9	4.4	90	9	4.6	90	9	7	45
Q29		Main Western Railway[5]	1.3	120	3	1.4	60	7	1.4	60	4	1.9	90	2	1.7	90	9	1.8	90	9	2.0	90	9	5	45
Q30	McKellars Park Tributary	Downstream Gell Street	6.3	60	8	8.5	60	3	10.9	60	3	13.6	60	1	16.9	60	8	18.8	60	8	22.0	30	5	101	45
Q31		Upstream Sandford Avenue	13.6	60	8	18.7	60	3	24.4	60	3	29.8	60	1	38.5	60	1	44.2	60	1	52.0	60	8	-	-
Q32	Overland Flow	Main Western Railway[5]	0.4	60	6	0.4	60	6	0.4	30	4	0.4	30	5	0.4	30	5	0.4	30	5	0.4	30	5	-	-
Q33	Sheedys Gully Tributary	Upstream Valley Drive	5.1	120	3	7.2	90	6	9.7	90	6	14.8	90	7	18.6	120	6	21.0	120	6	23.6	120	7	171	90
Q34		Queen Elizabeth Park	9.6	120	7	13.1	180	6	17.3	90	6	25.3	90	7	32.8	120	6	37.8	120	6	44.7	120	2	299	90
Q35		Main Western Railway[6] (James Street Underpass)	9.8	120	3	13.4	180	4	18.4	90	6	26.6	90	7	34.1	120	6	39.0	120	6	44.5	120	10	264	150
Q36	Overland Flow	Main Western Railway[5]	1.6	30	5	1.7	60	7	1.7	60	7	1.7	60	7	1.8	60	3	1.8	60	3	1.8	60	2	2	120
Q37		Main Western Railway[6] (George Coates Street Underpass)	3.7	30	5	5.1	30	8	6.3	30	8	7.9	30	5	9.5	30	5	10.8	30	8	12.7	30	8	63	120
Q38		Finlay Avenue	3.6	120	7	5.0	90	6	6.4	90	6	8.4	60	2	10.4	60	7	11.7	60	7	13.3	60	7	54	60
Q39		Upstream Amiens Street[6]	2.1	60	8	2.9	60	3	3.8	60	6	4.7	30	6	5.9	30	6	6.8	30	6	8.4	30	6	40	30
Q40		Endeavour Park[6]	4.0	60	8	5.3	60	6	6.2	60	3	7.3	60	8	8.7	60	8	9.6	30	6	11.0	30	6	67	45

TABLE B1 (Cont'd)
DESIGN PEAK FLOWS(1)

Peak Flow Location Identifier(2)	Tributary/Catchment	Location	Design Flood Events																					
			20% AEP			10% AEP			5% AEP			2% AEP			1% AEP			0.5% AEP			0.2% AEP			PMF	
			Peak Flow (m^3/s)	Critical Storm Duration(3) (minutes)	Critical Storm Burst(4)	Peak Flow (m^3/s)	Critical Storm Duration(3) (minutes)	Critical Storm Burst(4)	Peak Flow (m^3/s)	Critical Storm Duration(3) (minutes)	Critical Storm Burst(4)	Peak Flow (m^3/s)	Critical Storm Duration(3) (minutes)	Critical Storm Burst(4)	Peak Flow (m^3/s)	Critical Storm Duration(3) (minutes)	Critical Storm Burst(4)	Peak Flow (m^3/s)	Critical Storm Duration(3) (minutes)	Critical Storm Burst(4)	Peak Flow (m^3/s)	Critical Storm Duration(3) (minutes)	Critical Storm Burst(4)	Peak Flow (m^3/s)	Critical Storm Duration(3) (minutes)
[A]	[B]	[C]	[D]	[E]	[F]	[G]	[H]	[I]	[J]	[K]	[L]	[M]	[N]	[O]	[P]	[Q]	[R]	[S]	[T]	[U]	[V]	[W]	[X]	[Y]	[Z]
Q41	Overland Flow	Downstream Martini Parade(6)	2.1	120	4	5.2	90	5	6.6	90	4	8.0	90	9	9.0	90	5	9.7	120	1	11.7	90	5	-	-
Q42		Enfield Avenue(6)	5.5	30	7	6.4	30	8	8.0	60	10	10.3	120	2	12.7	60	7	14.4	60	7	17.3	60	7	-	-
Q43		Main Western Railway(5)	9.1	120	6	11.1	60	10	13.5	90	9	15.7	90	2	20.2	60	2	23.0	60	7	27.4	60	7	-	-
Q44		Downstream Great Western Highway	8.7	60	8	11.5	60	3	13.9	60	7	17.1	30	6	22.9	30	5	26.9	30	5	32.0	30	8	99	180
Q45	Good Luck Hollow	James O'Donnell Drive	2.6	60	1	2.9	60	3	3.5	60	6	5.3	90	1	7.6	90	2	9.1	90	2	9.8	60	2	46	60
Q46		Upstream Confluence with Farmers Creek	5.8	60	6	8.3	60	7	10.5	30	8	12.6	30	5	15.0	30	5	16.6	30	5	19.0	30	5	95	180
Q47	South Bowenfells Tributary	Upstream Confluence with Farmers Creek	2.0	30	5	2.8	30	4	3.5	30	4	3.9	30	5	4.1	30	5	4.3	30	5	4.5	30	5	28	15
Q48	Marrangaroo Creek	Upstream extent of TUFLOW Model	62.0	120	10	87.9	180	4	113	180	4	156	120	2	211	180	9	235	120	2	275	120	2	2,043	120
Q49		-	67.7	120	10	94.8	180	4	120	180	4	159	180	9	224	180	9	250	180	9	288	120	2	-	-
Q50		Disused Railway Line	69.8	120	10	98.1	180	4	125	180	4	166	180	9	233	180	9	261	180	9	296	120	2	-	-
Q51		-	87.1	120	3	117	180	4	146	180	4	190	120	2	257	180	9	287	180	9	320	120	2	-	-
Q52		Great Western Highway	92.3	120	3	123	180	4	156	180	4	204	180	9	265	180	9	292	180	9	312	120	2	-	-
Q53		Downstream extent of TUFLOW Model	92.1	120	3	123	180	4	157	180	4	207	180	9	279	180	9	314	180	9	342	120	2	2,445	180
Q54	Overland Flow	-	4.7	120	7	6.6	90	6	8.4	90	6	11.8	60	7	15.0	60	7	17.0	60	7	19.8	60	7	106	60
Q55		-	1.9	60	8	2.7	60	3	3.5	60	7	4.5	30	7	5.7	30	5	6.5	30	5	7.7	30	5	36	30
Q56		-	7.4	60	8	10.7	60	3	14.6	60	3	18.9	120	2	23.5	60	2	26.7	60	2	31.4	30	5	162	45
Q57		-	8.2	120	7	11.7	60	6	15.9	60	3	20.7	120	2	25.7	60	2	29.2	60	2	34.3	30	5	183	45
Q58		-	3.4	120	7	5.1	60	6	6.8	60	6	8.5	60	2	10.9	30	5	12.6	30	5	14.9	30	5	81	45
Q59		-	3.8	120	7	5.6	60	6	7.5	60	6	9.5	60	2	12.0	30	5	13.9	30	5	16.5	30	5	92	45
Q60		-	2.3	120	7	3.2	60	6	4.4	60	6	5.7	60	2	7.2	60	2	8.2	60	2	9.4	60	2	68	45

TABLE B1 (Cont'd)
DESIGN PEAK FLOWS(1)

Peak Flow Location Identifier(2)	Tributary/Catchment	Location	Design Flood Events																						
			20% AEP			10% AEP			5% AEP			2% AEP			1% AEP			0.5% AEP			0.2% AEP			PMF	
			Peak Flow (m^3/s)	Critical Storm Duration(3) (minutes)	Critical Storm Burst(4)	Peak Flow (m^3/s)	Critical Storm Duration(3) (minutes)	Critical Storm Burst(4)	Peak Flow (m^3/s)	Critical Storm Duration(3) (minutes)	Critical Storm Burst(4)	Peak Flow (m^3/s)	Critical Storm Duration(3) (minutes)	Critical Storm Burst(4)	Peak Flow (m^3/s)	Critical Storm Duration(3) (minutes)	Critical Storm Burst(4)	Peak Flow (m^3/s)	Critical Storm Duration(3) (minutes)	Critical Storm Burst(4)	Peak Flow (m^3/s)	Critical Storm Duration(3) (minutes)	Critical Storm Burst(4)	Peak Flow (m^3/s)	Critical Storm Duration(3) (minutes)
[A]	[B]	[C]	[D]	[E]	[F]	[G]	[H]	[I]	[J]	[K]	[L]	[M]	[N]	[O]	[P]	[Q]	[R]	[S]	[T]	[U]	[V]	[W]	[X]	[Y]	[Z]
Q61	Overland Flow	Reserve Road	14.0	120	7	19.3	90	7	26.6	90	7	37.0	60	7	46.7	60	7	52.9	60	7	61.5	60	7	361	45
Q62	Overland Flow	Reserve Road	2.6	120	7	3.7	60	6	4.9	60	6	6.5	60	7	8.2	60	2	9.2	60	2	10.7	60	2	70	45
Q63	Overland Flow	Confluence with Marrangaroo Creek	16.8	120	3	22.7	90	7	31.6	90	7	43.7	60	7	56.0	60	7	63.9	60	7	75.1	60	7	463	45
Q64	Overland Flow	-	2.4	60	8	3.3	60	3	4.2	60	7	5.1	30	6	6.3	30	6	7.0	30	6	8.1	30	6	37	30
Q65	Overland Flow	-	8.4	60	6	12.5	60	6	16.3	60	6	20.0	120	5	24.6	120	5	27.1	60	5	30.3	30	5	-	-
Q66	Overland Flow	-	9.9	60	6	15.0	60	6	20.2	60	3	24.3	60	5	30.3	120	5	33.9	60	5	38.7	60	5	220	45
Q67	Overland Flow	Reserve Road	10.2	120	7	13.7	90	7	15.7	90	7	23.9	120	7	29.8	90	7	33.5	60	7	39.9	60	7	-	-
Q68	Overland Flow	Parallel to Great Western Highway	1.9	60	6	2.6	60	3	3.3	60	3	4.1	30	5	5.0	30	5	5.6	30	5	6.5	30	5	-	-
Q69	Overland Flow	-	0.8	120	3	1.0	60	6	1.2	60	6	1.6	60	7	2.0	60	7	2.2	30	5	2.7	60	5	19	45

1. Peak flows less than 100 m^3/s have been quoted to one decimal place in order to show minor differences.
2. Refer to relevant figures in **Volume 2** for location of Peak Flow Identifier.
3. Relates to storm duration that is critical for maximising the peak flood level at each location, not necessarily the peak flow.
4. Relates to temporal pattern that is critical for generating the median peak flood level for a given storm duration, not necessarily the median peak flow.
5. Relates to flow in pipe only.
6. Refers to total piped and overland flow at location.

ATTACHMENT B5
FLOOD DATA FOR INDIVDUAL ROAD CROSSINGS AT LITHGOW

TABLE B2
MAXIMUM DEPTH OF INUNDATION AT INDIVDUAL ROAD CROSSINGS AT LITHGOW[1,2]
(m)

ID[3]	Tributary	Location	Road Level (m AHD)	20% AEP	10% AEP	5% AEP	2% AEP	1% AEP	0.5% AEP	0.2% AEP	PMF
Q02	Farmers Creek	Brewery Lane	931.7	NF	NF	NF	NF	0.2	0.4	0.6	3.3
Q03		Mills Street Causeway	927.9	1.5	1.7	1.9	2.2	2.4	2.5	2.9	6.1
Q04		Victoria Avenue	927.5	NF	0.5	0.8	1	1.2	1.3	1.4	4.1
Q06		Atkinson Street	919.7	NF	NF	0.1	0.5	0.8	0.9	1.0	4.0
Q07		Tank Street	914.7	NF	NF	0.4	0.9	1.2	1.4	1.6	5.4
Q08		Sandford Avenue	914.3	NF	NF	NF	NF	NF	NF	NF	0.9
Q09		Albert Street	908.4	NF	NF	NF	NF	NF	NF	0.2	4.4
Q10		Geordie Street	901.1	1.7	1.9	2.1	2.5	2.8	2.9	3	5.8
Q11		Cooerwull Road	897.6	NF	NF	NF	NF	NF	NF	NF	4.1
Q12		Great Western Highway	894.5	NF	NF	NF	NF	NF	NF	NF	3.1
Q20	Vale of Clwydd Creek	Mort Street	941.1	NF	NF	NF	NF	NF	NF	NF	1.1
Q21		Chifley Road	931.2	NF	NF	0.5	0.7	0.8	0.9	1	1.9
Q22		Main Western Railway	930.4	NF	NF	NF	NF	NF	NF	NF	1.9
Q24	State Mine Creek	State Mine Gully Road	951.9	NF	NF	NF	0.2	0.4	0.5	0.5	1.5
Q26		Laidley Street	919	NF	NF	NF	NF	0.3	0.4	0.5	3.2
Q31	McKellars Park Tributary	Sandford Avenue	913.7	0.1	0.2	0.3	0.4	0.5	0.5	0.6	3.5
Q52	Marrangaroo Creek	Great Western Highway	910.4	NF	NF	NF	0.3	0.6	0.7	1	7.8
Q61	Unnamed Tributary	Reserve Road	921.8	NF	<0.1	0.2	0.3	0.4	0.5	0.5	1.5
Q62		Reserve Road	923.7	NF	NF	NF	NF	NF	NF	<0.1	0.8
Q67		Reserve Road	912.5	NF	NF	0.1	0.2	0.3	0.3	0.5	5.7

1. Depths rounded to nearest 0.1 m.
2. NF = Not Flooded.
3. Refer to relevant figures in **Volume 2** for location of Peak Flow Identifier.

APPENDIX C
FLOOD DAMAGES

TABLE OF CONTENTS

Page No.

FIGURES
(BOUND IN VOLUME 2)

C1. INTRODUCTION AND SCOPE

C1.1 Introduction

Damages from flooding belong to two categories:

- **Tangible Damages**
- **Intangible Damages**

Tangible damages are defined as those to which monetary values may be assigned, and may be subdivided into direct and indirect damages. Direct damages are those caused by physical contact of floodwater with damageable property. They include damages to commercial and residential building structures and contents as well as damages to infrastructure services such as electricity and water supply. Indirect damages result from the interruption of community activities, including traffic flows, trade, industrial production, costs to relief agencies, evacuation of people and contents and clean up after the flood.

Generally, tangible damages are estimated in dollar values using survey procedures, interpretation of data from actual floods and research of government files.

The various factors included in the **intangible damage** category may be significant. However, these effects are difficult to quantify due to lack of data and the absence of an accepted method. Such factors may include:

- inconvenience
- isolation
- disruption of family and social activities
- anxiety, pain and suffering, trauma
- physical ill-health
- psychological ill-health.

C1.2 Scope of Investigation

In the following sections, tangible damages to residential, commercial and industrial properties, and public buildings have been estimated resulting from flooding in the two study catchments. Intangible damages have not been quantified. The threshold floods at which damages may commence to infrastructure and community assets have also been estimated, mainly from site inspection and interpretation of flood level data. However, there are no data available to allow a quantitative assessment of damages to be made to this category.

C1.3 Terminology

Definitions of the terms used in this Appendix are presented in **Section C8** which also summarises the value of Tangible Flood Damages.

C2. DESCRIPTION OF APPROACH

The damage caused by a flood to a particular property is a function of the depth of flooding above floor level and the value of the property and its contents. The warning time available for residents to take action to lift property above floor level also influences damages actually experienced. A spreadsheet model which has been developed by DPE for estimating residential damages and an in-house spreadsheet model which has been developed for previous investigations of this nature for estimating commercial, industrial and public building damages were used to estimate damages on a property by property basis according to the type of development, the location of the property and the depth of inundation.

Using the results of the hydraulic modelling, a peak flood elevation was derived for each event at each property. The property flood levels were input to the spreadsheet model which also contained property characteristics and depth-damage relationships. The depth of flooding was computed as the difference between the interpolated flood level and the floor elevation at each property.

The floor levels of individual dwellings/buildings were derived from Kinhill, 1991 where available, else they were assessed by adding the height of floor above a representative natural surface within the allotment (as estimated by visual inspection) to the natural surface elevation determined from LiDAR survey. The type of structure and potential for property damage were also assessed during the visual inspection. If a property was not accessible to undertake a visual inspection, the height of the floor was assumed to be 300 mm above the adjacent natural surface level.

The depth-damage curves for residential damages were determined using procedures described in *Floodplain Management Guideline No 4. Residential Flood Damage Calculation*, *2007* (**Guideline No. 4**) published by the Department of Environment and Climate Change (**DECC**) (now DPE). Damage curves for other categories of development (commercial and industrial, public buildings) were derived from previous floodplain management investigations.

It should be understood that this approach is not intended to identify individual properties liable to flood damages and the values of damages in individual properties, even though it appears to be capable of doing so. The reason for this caveat lies in the various assumptions used in the procedure, the main ones being:

- the assumption that computed water levels and topographic data used to define flood extents are exact and without any error;
- the assumption that the water levels as computed by the hydraulic model are not subject to localised influences;
- the estimation of property floor levels by visual inspection rather than by formal field survey;
- the use of "average" stage-damage relationships, rather than a unique relationship for each property;
- the uncertainties associated with assessing appropriate factors to convert *potential damages* to *actual flood damages* experienced for each property after residents have taken action to mitigate damages to contents.

The consequence of these assumptions is that some individual properties may be inappropriately classified as flood liable, while others may be excluded. Nevertheless, when applied over a broad area these effects would tend to cancel, and the resulting estimates of overall damages, would be expected to be reasonably accurate.

For the above reasons, the information contained in the spreadsheets used to prepare the estimates of flood damages for the catchments should not be used to provide information on the depths of above-floor inundation of individual properties.

C3. SOURCES OF DATA

C3.1 General

To estimate A*verage Annual Flood Damages* for a specific area it is necessary to estimate the damages for several floods of different magnitudes, i.e., of different frequencies, and then to integrate the area beneath the damage – frequency curve over the whole range of frequencies. To do this it is necessary to have data on the damages sustained by all types of property over the likely range of inundation. There are several ways of doing this:

- The ideal way would be to conduct specific damage surveys in the aftermath of a range of floods, preferably immediately after each. An example approaching this ideal is the case of Nyngan where surveys were conducted in May 1990 following the disastrous flood of a month earlier (DWR, 1990). This approach is not possible in the study catchments as specific damage surveys have not been conducted following the historic flood events.
- The second best way is for experienced loss adjusters to conduct a survey to estimate likely losses that would arise due to various depths of inundation. This approach is used from time to time, but it can add significantly to the cost of a floodplain management study (LMJ, 1985). It was not used for the present investigation.
- The third way is to use generalised data such as that published by CRES (Centre for Resource & Economic Studies, Canberra) and used in the Floodplain Management Study for Forbes (SKM, 1994). These kinds of data are considered to be suitable for generalised studies, such as broad regional studies. They are not considered to be suitable for use in specific areas unless none of the other approaches can be satisfactorily applied.
- The fourth way is to adapt or transpose data from other flood liable areas. This was the approach used for the present study. As mentioned, the *Guideline No 4* procedure was adopted for the assessment of residential damages. The approach was based on data collected following major flooding in Katherine in 1998, with adjustments to account for changes in values due to inflation, and after taking into account the nature of development and flooding patterns in the study area. The data collected during site inspection in the flood liable areas assisted in providing the necessary adjustments. Commercial and industrial damages were assessed via reference to recent floodplain management investigations of a similar nature to the present study (L&A, 2019).

C3.2 Property Data

The properties were divided into three categories: residential, commercial/industrial and public buildings.

For residential properties, the data used in the damages estimation included:

- the location/address of each property
- an assessment of the type of structure
- representative natural surface level of the allotment
- floor level of the residence

For commercial/industrial properties, the Property Survey obtained information regarding:

- the location of each property
- the nature of each enterprise
- an estimation of the floor area
- natural surface level
- floor level

The property descriptions were used to classify the commercial and public developments into categories (i.e., high, medium or low value properties) which relate to the magnitude of likely flood damages.

The total number of residential properties, commercial / industrial and public buildings in the study catchments is shown in **Table C3.1**.

TABLE C3.1
NUMBER OF PROPERTIES INCLUDED IN DAMAGES DATABASE

Development Type	Number of Properties	
	Farmers Creek Catchment	**Marrangaroo Creek Catchment**
Residential	3,507	127
Commercial / Industrial	260	9
Public	47	3
Total	**3,814**	**139**

C3.3 Flood Levels Used in the Analysis

Damages were computed for the design flood levels determined from the hydraulic models that were developed as part of the present investigation and incorporate provision for the impact that a partial blockage of major hydraulic structures would have on flood behaviour at Lithgow.

C4. RESIDENTIAL DAMAGES

C4.1 Damage Functions

The procedures identified in *Guideline No 4* allow for the preparation of a depth versus damage relationship which incorporates structural damage to the building, damage to internals and contents, external damages and clean-up costs. In addition, there is the facility for including allowance for accommodation costs and loss of rent. Separate curves are computed for three residential categories:

- Single storey slab on ground construction
- Single storey elevated floor
- Two storey residence

The level of flood awareness and available warning time are taken into account by factors which are used to reduce “potential” damages to contents to “actual” damages. “Potential” damages represent losses likely to be experienced if no action were taken by residents to mitigate impacts. A reduction in the potential damages to "actual" damages is usually made to allow for property evacuation and raising valuables above floor level, which would reduce the damages actually experienced. The ability of residents to take action to reduce flood losses is mainly limited to reductions in damages to contents, as damages to the structure and clean-up costs are not usually capable of significant mitigation.

The reduction in damages to contents is site specific, being dependent on a number of factors related to the time of rise of floodwaters, the recent flood history and flood awareness of residents and emergency planning by the various Government Agencies (BoM and NSW SES).

Flooding in the two study catchments is “flash flooding” in nature, with surcharge of the watercourses and various drainage lines occurring less than one hour after the onset of flood producing rain. Consequently, there would be very limited time in advance of a flood event in which to warn residents located along the various flow paths and for them to take action to mitigate flood losses.

Provided adequate warning were available, house contents may be raised above floor level to about 0.9 m, which corresponds with the height of a typical table/bench height. The spreadsheet provides two factors for assessing damages to contents, one for above and one for below the typical bench height. The reduction in damages is also dependent on the likely duration of inundation of contents, which would be limited to no more than an hour for most flooded properties. **Table C4.1** over sets out the parameters and resulting factors that were adopted for converting potential to actual damages in the two study catchments.

Table C4.2 over shows total flood damages estimated for the three classes of residential property using the procedures identified in *Guideline No. 4*, for typical depths of above-floor inundation of 0.3 m and 0.6 m. A typical ground floor area of 240 m^2 was adopted for the assessment. The values in **Table C4.2** allow for damages to buildings and contents, as well as external damages and provision for alternative accommodation.

TABLE C4.1
DAMAGE ADJUSTMENT FACTORS/PARAMETERS FOR RESIDENTIAL DEVELOPMENT

Property Damage	Parameter/Factor	Adopted Value
Building	Typical Duration of Immersion (hours)	2
	Building Damage Repair Limitation Factor	0.85
	Total Building Adjustment Factor	2.41
Contents	Contents Damage Repair Limitation Factor	0.75
	Level of Flood Awareness	Low
	Effective Warning Time	0
	Typical Table/Bench Height (TTBH) (m)	0.9
	Total Contents Adjustment Factor (Above-Floor Depth <= TTBH)	1.45
	Total Contents Adjustment Factor (Above-Floor Depth > TTBH)	1.45

1. Maximum value permitted in damages spreadsheet.

TABLE C4.2
DAMAGES TO RESIDENTIAL PROPERTIES

Type of Residential Construction	0.3 m Depth of Inundation Above Floor Level	0.6 m Depth of Inundation Above Floor Level
Single Storey Slab on Ground	$82,322	$94,531
Single Storey High Set	$92,443	$106,520
Double Storey	$57,625	$66,172

Note: These values allow for damages to buildings and contents, as well as external damages and provision for alternative accommodation.

C4.2 Total Residential Damages

Table C4.3 over summarises the residential damages for the range of floods in the study catchments, while **Tables C1** to **C10** in **Annexure C1** set out the residential damages in the ten damage centres. The damage estimates were carried out for floods between the 20% AEP and the PMF which were modelled hydraulically as part of the present study. **Figures 2.2** and **2.3** of **the** Main Report show the plan location and indicative depth of above-floor inundation in the 1% AEP storm event and PMF, while **Figures B4.1**, **B4.2**, **B4.3**, **B4.4**, **B4.5** and **B4.6** shows similar results for the 20%, 10%, 5%, 2%, 0.5% and 0.2% AEP storm events.

The key findings as they relate to residential flood damages are as follows:

- At total of 33 dwellings are inundated above-floor level in a 20% AEP storm event in the Farmers Creek catchment, increasing to 265 dwellings in a 1% AEP storm event. The total residential flood damages in the Farmers Creek catchment increases from $5.31 Million in a 20% AEP storm event, to $32.9 Million in a 1% AEP event.

TABLE C4.3
TOTAL RESIDENTIAL FLOOD DAMAGES

Design Flood Event (%AEP)	Farmers Creek Catchment			Marrangaroo Creek Catchment		
	No. of Allotments Flood Affected	No. of Dwellings Flooded Above Floor Level	Damages $ Million	No. of Allotments Flood Affected	No. of Dwellings Flooded Above Floor Level	Damages $ Million
20	162	33	5.31	1	0	0.02
10	225	49	7.59	4	0	0.08
5	319	89	12.2	7	1	0.18
2	498	165	21.3	10	1	0.24
1	648	265	32.9	11	2	0.36
0.5	739	332	40.7	14	5	0.51
0.2	835	399	48.7	17	6	0.66
PMF	1,932	1,486	216	52	33	4.42

- A total of two dwellings in the Marangaroo Creek catchment are inundated above-floor level in a 1% AEP storm event, resulting in flood damages of about $0.36 Million.
- The total number of dwellings inundated above-floor level in the Farmers Creek catchment in a 0.5% AEP (i.e. 332 dwellings) and 0.2% AEP (i.e. 399 dwellings) storm events, respectively are 25% and 50% higher than the number of dwellings inundated in the 1% AEP storm event.
- A total of 1,486 dwellings in the Farmers Creek catchment and 33 dwellings in the Marangaroo Creek catchment would be inundated above-floor level in a PMF event.
- Floodwater commences to inundate dwellings in the Oakey Park Damage Centre in a 2% AEP storm event, while a total of 38 dwellings are inundated above-floor level in a 1% AEP storm event, resulting in flood damages of about $2.56 Million (refer **Table C1** in **Annexure C**).
- A total of 18 dwellings in the Morts Estate Damage Centre are inundated above-floor level in a 1% AEP storm event, resulting in flood damages of about $2.38 Million (refer **Table C2** in **Annexure C**).
- Floodwater commences to surcharge Farmers Creek and inundate dwellings in the Tank Street Damage Centre in a 5% AEP storm event, while a total of 22 dwellings are inundated above-floor level in a 1% AEP storm event, resulting in flood damages of about $2.38 Million (refer **Table C3** in **Annexure C**).
- The 2% AEP storm event is the threshold at which a significant number of dwellings commence to become inundated above-floor level in the Hermitage Flat Damage Centre, while a total of 90 dwellings are inundated above-floor level in a 1% AEP storm event, resulting in flood damages of about $9.32 Million (refer **Table C4** in **Annexure C**).

- Eight dwellings in the Vale of Clwydd Damage Centre are inundated in a 20% AEP storm event resulting in flood damages of about $0.79 Million, while in a 1% AEP storm event, 29 dwellings in the Vale of Clwydd Damage Centre would be inundated above-floor level resulting in flood damages of about $2.99 Million (refer **Table C5** in **Annexure C**).
- Eleven dwellings in the Gas Works Lane Damage Centre are inundated above-floor level in a 1% AEP storm event, resulting in flood damages of about $1.47 Million (refer **Table C6** in **Annexure C**).
- A single dwelling would be inundated above-floor level in a 1% AEP storm event in each of the Lithgow CBD and Sheedys Gully Damage Centres (refer **Tables C7** and **C8** in **Annexure C**).
- Four dwellings in the Cupro Street Damage Centre are inundated in a 20% AEP storm event resulting in flood damages of about $0.73 Million, while in a 1% AEP storm event, a total of nine dwellings are inundated above-floor level resulting in flood damages of about $2.28 Million (refer **Table C9** in **Annexure C**).
- Eighteen dwellings in the Enfield Avenue Damage Centre are inundated above-floor level in a 1% AEP storm event, resulting in flood damages of about $2.76 Million (refer **Table C10** in **Annexure C**).

C5. COMMERCIAL AND INDUSTRIAL DAMAGES

C5.1 Direct Commercial and Industrial Damages

The method used to calculate damages requires each property to be categorised in terms of the following:

- damage category;
- floor area; and
- floor elevation.

The damage category assigned to each enterprise may vary between "low", "medium" or "high", depending on the nature of the enterprise and the likely effects of flooding. Damages also depend on the floor area.

It has recently been recognised following the 1998 flood in Katherine that previous investigations using stage damage curves contained in proprietary software tend to seriously underestimate true damage costs (*Guideline No 4*). DPE are currently researching appropriate damage functions which could be adopted in the estimation of commercial and industrial categories as they have already done with residential damages. However, these data were not available for the two study catchments.

On the basis of previous investigations, the following typical damage rates are considered appropriate for potential external and internal damages and clean-up costs for both commercial and industrial properties. They are indexed to a depth of inundation of 2 metres. At floor level and 1.2 m inundation, zero and 70% of these values respectively were assumed to occur:

Low value enterprise	\$280/m^2	(e.g., Commercial: small shops, cafes, joinery, public halls. Industrial: auto workshop with concrete floor and minimal goods at floor level, Council or Government Depots, storage areas.)
Medium value enterprise	\$420/m^2	(e.g., Commercial: food shops, hardware, banks, professional offices, retail enterprises, with furniture/fixtures at floor level which would suffer damage if inundated. Industrial: warehouses, equipment hires.)
High value enterprise	\$650/m^2	(e.g., Commercial : electrical shops, clothing stores, bookshops, newsagents, restaurants, schools, showrooms and retailers with goods and furniture, or other high value items at ground or lower floor level. Industrial: service stations, vehicle showrooms, smash repairs.)

The factor for converting potential to actual damages depends on a range of variables such as the available warning time, flood awareness and the depth of inundation. Given sufficient warning time a well prepared business will be able to temporarily lift property above floor level. However, unless property is actually moved to flood free areas, floods which result in a large depth of inundation, will cause considerable damage to stock and contents.

For the present study, the above potential damages were converted to actual damages using a multiplier which ranged between 0.5 and 0.8 depending on the depth of inundation above the floor. At relatively shallow depths it would be expected that owners may be able to take significant action to mitigate damages, even when allowing for the flash flooding nature of inundation. Consequently, a multiplier of 0.5 was adopted to convert potential to actual damages for depths of inundation up to 1.2 m, and a multiplier of 0.8 for greater depths.

C5.2 Indirect Commercial and Industrial Damages

Indirect commercial and industrial damages comprise costs of removal of goods and storage, loss of trading profit and loss of business confidence.

Disruption to trade takes the following forms:

- The loss through isolation at the time of the flood when water is in the business premises or separating clients and customers. The total loss of trade is influenced by the opportunity for trade to divert to an alternative source. There may be significant local loss but due to the trade transfer this may be considerably reduced at the regional or state level.
- In the case of major flooding, a downturn in business can occur within the flood affected region due to the cancellation of contracts and loss of business confidence. This is in addition to the actual loss of trading caused by closure of the business by flooding.

Loss of trading profit is a difficult value to assess, and the magnitude of damages can vary depending on whether the assessment is made at the local, regional or national level. Differences between regional and national economic effects arise because of transfers between the sectors, such as taxes, and subsidies such as flood relief returned to the region.

Some investigations have lumped this loss with indirect damages and have adopted total damage as a percentage of the direct damage. In other cases, loss of profit has been related to the gross margin of the business, i.e., turnover less average wages. The former approach has been adopted in this present study. Indirect damages have been taken as 50% of direct actual damages. A clean-up cost of \$15/m^2 of floor area of each flooded property was also included.

C5.3 Total Commercial and Industrial Damages

Table C5.1 over summarises the estimated commercial and industrial damages in the study catchments, while **Tables C1** to **C10** in **Annexure C1** set out similar information for the ten damage centres. **Figures 2.2** and **2.3** of **the** Main Report show the plan location and indicative depth of above-floor inundation in the 1% AEP storm event and PMF, while **Figures B4.1**, **B4.2**, **B4.3**, **B4.4**, **B4.5** and **B4.6** shows similar results for the 20%, 10%, 5%, 2%, 0.5% and 0.2% AEP storm events.

The key findings as they relate to flood damages in commercial / industrial development are as follows:

- At total of 23 commercial/industrial buildings are inundated above-floor level in a 20% AEP storm event in the Farmers Creek catchment, twelve of which are located within the Lithgow CBD Damage Centre (refer **Table C7**), four in the Sheedys Gully Damage Centre (refer **Table C8**) and two each in the Gas Works Lane and Cupro Street Damage Centres (refer **Tables C6** and **C9**).

TABLE C5.1
COMMERCIAL / INDUSTRIAL FLOOD DAMAGES

Design Flood Event (%AEP)	Farmers Creek Catchment			Marrangaroo Creek Catchment		
	No of Allotments Flood Affected	No. of Buildings Flooded Above Floor Level	Damages $ Million	No. of Allotments Flood Affected	No. of Buildings Flooded Above Floor Level	Damages $ Million
20	26	23	1.24	0	0	0
10	32	27	1.62	0	0	0
5	41	36	3.92	0	0	0
2	48	43	5.82	0	0	0
1	52	48	8.39	0	0	0
0.5	64	54	9.85	0	0	0
0.2	69	58	12.2	1	0	0.02
PMF	149	143	74.6	3	3	0.62

- The total commercial and industrial flood damages increase significantly at the 5% AEP level of flooding as The Lithgow Valley Plaza (which is located in the Sheedys Gully Damage Centre) commences to be inundated above-floor level during an event of this magnitude.
- A total of 48 commercial/industrial buildings are inundated in the Farmers Creek catchment in a 1% AEP storm event, resulting in flood damages of about $8.39 Million.
- **C**ommercial and industrial buildings in the Marangaroo Creek catchment remain flood free for all storms up to 0.2% AEP in intensity.
- A total of 143 commercial/industrial type buildings in the Farmers Creek and three commercial/industrial type buildings in the Marrangaroo Creek catchment would be inundated above-floor level in a PMF event.
- Seven commercial/industrial type buildings in the Morts Estate Damage Centre are inundated above-floor level in a 1% AEP storm event, resulting in flood damages of about $2.86 Million (refer **Table C2** in **Annexure C**).
- **T**wo commercial/industrial type buildings in the Hermitage Flat Damage Centre are inundated above-floor level in a 1% AEP storm event, resulting in flood damages of about $0.24 Million (refer **Table C4** in **Annexure C**).
- There are no commercial/industrial type properties located in tbe Vale of Clwydd Damage Centre (refer **Table C5** in **Annexure C**).
- Three commercial/industrial type buildings in the Gas Works Lane Damage Centre are inundated above-floor level in a 1% AEP storm event, resulting in flood damages of about $0.42 Million (refer **Table C6** in **Annexure C**).

- Seventeen commercial/industrial type buildings in the Lithgow CBD Damage Centre are inundated above-floor level in a 1% AEP storm event, resulting in flood damages of about $0.59 Million (refer **Table C7** in **Annexure C**).
- Eight commercial/industrial type buildings in the Sheedys Gully Damage Centre are inundated above-floor level in a 1% AEP storm event, resulting in flood damages of about $3.43 Million (refer **Table C8** in **Annexure C**).
- Three commercial/industrial type buildings in the Cupro Street Damage Centre are inundated above-floor level in a 1% AEP storm event, resulting in flood damages of about $0.1 Million (refer **Table C9** in **Annexure C**).
- Four commercial/industrial type buildings in the Enfield Avenue Damage Centre are inundated above-floor level in a 1% AEP storm event, resulting in flood damages of about $0.43 Million (refer **Table C10** in **Annexure C**).

C6. DAMAGES TO PUBLIC BUILDINGS

C6.1 Direct Damages – Public Buildings

Included under this heading are government buildings, churches, swimming pools and parks. Damages were estimated individually on an areal basis according to the perceived value of the property. Potential internal damages were indexed to a depth of above floor inundation of 2 m as shown below. At floor level and 1.2 m depth of inundation, zero and 70% of these values respectively were assumed to occur.

Low value	\$280/m^2	
Medium value	\$420/m^2	(e.g. council buildings, SES HQ, fire station)
High value	\$650/m^2	(e.g. schools)

These values were obtained from the Nyngan Study (DWR, 1990) as well as commercial data presented in the Forbes Water Studies report (WS, 1992). External and structural damages were taken as 4 and 10% of internal damages, respectively.

C6.2 Indirect Damages – Public Buildings

A value of \$15/m^2 was adopted for the clean-up of each property. This value is based on results presented in the Nyngan Study and adjusted for inflation. Total "welfare and disaster" relief costs were assessed as 50% of the actual direct costs.

C6.3 Total Damages – Public Buildings

Table C6.1 summarises the estimated damages to public buildings in the study catchments, while **Tables C1** to **C10** in **Annexure C1** set out similar information for the ten damage centres. **Figures 2.2** and **2.3** of **the** Main Report show the plan location and indicative depth of above-floor inundation in the 1% AEP storm event and PMF, while **Figures B4.1**, **B4.2**, **B4.3**, **B4.4**, **B4.5** and **B4.6** shows similar results for the 20%, 10%, 5%, 2%, 0.5% and 0.2% AEP storm events.

The key findings as they relate to flood damages in commercial / industrial development are as follows:

- One public building which is located in the Hermitage Flat Damage Centre is inundated above-floor level in a 1% AEP storm event, resulting in flood damages of about \$0.04 Million.
- One public building which is located in the Marangaroo Creek catchment is inundated above-floor level in a 1% AEP storm event, resulting in flood damages of about \$0.1 Million.
- **T**en public buildings that are located in the Farmers Creek catchment and two public buildings that are located in the Marangaroo Creek catchment would be inundated above-floor level in a PMF event.

TABLE C6.1
PUBLIC FLOOD DAMAGES

Design Flood Event (%AEP)	Farmers Creek Catchment			Marrangaroo Creek Catchment		
	No. of Allotments Flood Affected	No. of Buildings Flooded Above Floor Level	Damages $ Million	No. of Allotments Flood Affected	No. of Buildings Flooded Above Floor Level	Damages $ Million
20	1	0	0.02	0	0	0
10	2	0	0.04	1	0	0.02
5	3	0	0.06	1	1	0.04
2	3	0	0.06	1	1	0.06
1	4	1	0.1	1	1	0.1
0.5	5	1	0.14	1	1	0.12
0.2	6	3	0.23	1	1	0.16
PMF	16	10	5.83	2	2	15.1

C7. DAMAGES TO INFRASTRUCTURE AND COMMUNITY ASSETS

No data are available on damages experienced to infrastructure and community assets during historic flood events. However, a qualitative matrix of the effects of flooding on important assets in the two study catchments is presented in **Table C7.1**.

TABLE C7.1
QUALITATIVE EFFECTS OF FLOODING ON
INFRASTRUCTURE AND COMMUNITY ASSETS IN LITHGOW

Catchment	Damage Sector	Design Flood Event (AEP)							
		20%	10%	5%	2%	1%	0.5%	0.2%	PMF
Farmers Creek	Roads	X	X	X	X	X	X	X	X
	Parks and Gardens	O	X	X	X	X	X	X	X
	Electricity	O	O	O	O	O	O	O	O
	Water Supply	O	O	O	O	O	O	O	X
	Telephone	O	O	O	O	O	O	O	O
Marrangaroo Creek	Roads	O	X	X	X	X	X	X	X
	Parks and Gardens	X	X	X	X	X	X	X	X

Notes: O = No significant damages likely to be incurred.
X = Some damages likely to be incurred.

C8. SUMMARY OF TANGIBLE DAMAGES

C8.1 Tangible Damages

Flood damages have been computed for a range of flood frequencies from 20% AEP up to the PMF. For the purposes of assessing damages, the 50% AEP was adopted as the "threshold" flood at which damages commence in the drainage system. From **Table C8.1** over, about $41.4 Million of damages would be incurred at the 1% AEP level of flooding in the Farmers Creek catchment and about $0.46 Million in the Marangaroo Creek catchment. **Tables C1** to **C10** in **Annexure C1** set out the total flood damages that would be incurred in the ten damage centres **Figure C8.1** shows the damage frequency curves for residential, commercial / industrial and public buildings in the study catchments.

C8.2 Definition of Terms

Average Annual Damages (also termed "expected damages") are determined by integrating the area under the damage-frequency curve. They represent the time stream of annual damages, which would be expected to occur on a year by year basis over a long duration.

Using an appropriate discount rate, average annual damages may be expressed as an equivalent "*Present Worth Value"* of damages and used in the economic analysis of potential flood management measures.

A flood management scheme which has a design 1% AEP level of protection, by definition, will eliminate damages up to this level of flooding. If the scheme has no mitigating effect on larger floods then these damages represent the benefits of the scheme expressed on an average annual basis and converted to the *Present Worth Value* via the discount rate.

Using the procedures outlined in *Guideline No. 4*, as well as current NSW Treasury guidelines, economic analyses were carried out assuming a 50 year economic life for projects and discount rates of 7% pa. (best estimate) and 11% and 4% pa (sensitivity analyses).

C8.3 Average Annual Damages

The average annual damages in the study catchments for all flood events up to the PMF are shown below in **Table C8.2**, while **Table C8.3** sets out the total average annual damages for all flood events up to the PMF for the ten Damage Centres. Note that values have been quoted to two decimal places to highlight the relatively small recurring damages.

C8.4 Present Worth of Damages

The *Present Worth Value* of damages likely to be experienced for all flood events up to the 1% AEP and PMF, for a 50 year economic life and discount rates of 4, 7 and 11 per cent are shown in **Table C8.3**. **Table C8.4** shows similar information for the ten damage centres.

For a discount rate of 7% pa, the *Present Worth Value* of total damages for all flood events up to the 1% AEP flood in the Farmers Creek and Marrangaroo Creek catchments are $46.9 Million and $0.4 Million, respectively. In terms of the *Present Worth Value* of total flood damages in the Farmers Creek catchment, this value can be further subdivided into the ten damage centres as follows:[1]

[1] Note that there is a residual amount of $16.3 Million that is spread throughout the Farmers Creek catchment.

- Oakey Park Damage Centre - $1.0 Million
- Morts Estate Damage Centre - $3.2 Million
- Tank Street Damage Centre - $1.0 Million
- Hermitage Flat Damage Centre - $2.3 Million
- Vale of Clwydd Damage Centre - $5.7 Million
- Gas Works Lane Damage Centre - $3.3 Million
- Lithgow CBD Damage Centre - $2.5 Million
- Sheedys Gully Damage Centre - $3.3 Million
- Cupro Street Damage Centre - $5.1 Million
- Endfield Avenue Damage Centre - $3.2 Million

Therefore, one or more schemes costing up to these amounts could be economically justified if they eliminated damages in the individual damage centres for all flood events up to this level. While schemes costing more than this value would have a benefit/cost ratio less than 1, they may still be justified according to a multi-objective approach which considers other criteria in addition to economic feasibility.

TABLE C8.1
TOTAL FLOOD DAMAGES
$ MILLION

Design Flood Event (%AEP)	Farmers Creek Catchment				Marrangaroo Creek Catchment			
	Residential	Commercial/ Industrial	Public	Total	Residential	Commercial/ Industrial	Public	Total
20	5.31	1.24	0.02	6.57	0.02	0	0	0.02
10	7.59	1.62	0.04	9.25	0.08	0	0.02	0.10
5	12.2	3.92	0.06	16.2	0.18	0	0.04	0.22
2	21.3	5.82	0.06	27.2	0.24	0	0.06	0.30
1	32.9	8.39	0.10	41.4	0.36	0	0.10	0.46
0.5	40.7	9.85	0.14	50.7	0.51	0	0.12	0.63
0.2	48.7	12.2	0.23	61.1	0.66	0.02	0.16	0.84
PMF	216	74.6	5.83	296	4.42	0.62	15.1	20.1

TABLE C8.2
AVERAGE ANNUAL DAMAGES
$ MILLION

Design Flood Event (%AEP)	Farmers Creek Catchment				Marrangaroo Creek Catchment			
	Residential	Commercial/ Industrial	Public	Total	Residential	Commercial/ Industrial	Public	Total
20	0.80	0.19	0.00	0.99	0.00	0.00	0.00	0.00
10	1.44	0.33	0.01	1.78	0.01	0.00	0.00	0.01
5	1.94	0.47	0.01	2.42	0.01	0.00	0.00	0.01
2	2.44	0.61	0.01	3.06	0.02	0.00	0.00	0.02
1	2.71	0.68	0.01	3.40	0.02	0.00	0.01	0.03
0.5	2.89	0.73	0.01	3.63	0.03	0.00	0.01	0.04
0.2	3.03	0.76	0.01	3.80	0.03	0.00	0.01	0.04
PMF	3.29	0.85	0.02	4.16	0.03	0.00	0.02	0.05

TABLE C8.3
TOTAL AVERAGE ANNUAL DAMAGES
IN INDIVIDUAL DAMAGE CENTRES
$ MILLION

Design Flood Event (%AEP)	Oakey Park	Morts Estate	Tank Street	Hermitage Flat	Vale of Clwydd	Gas Works Lane	Lithgow CBD	Sheedys Gully	Cupro Street	Enfield Avenue
20	0.01	0.05	0	0.01	0.12	0.08	0.07	0.03	0.12	0.05
10	0.02	0.1	0.01	0.02	0.22	0.14	0.13	0.06	0.22	0.09
5	0.03	0.14	0.03	0.04	0.31	0.18	0.15	0.13	0.28	0.14
2	0.05	0.19	0.05	0.1	0.38	0.22	0.18	0.21	0.35	0.2
1	0.07	0.23	0.07	0.17	0.41	0.24	0.18	0.24	0.37	0.23
0.5	0.08	0.26	0.08	0.24	0.43	0.25	0.18	0.26	0.38	0.24
0.2	0.09	0.28	0.09	0.27	0.44	0.26	0.19	0.27	0.39	0.26
PMF	0.12	0.36	0.12	0.34	0.44	0.27	0.19	0.29	0.41	0.28

TABLE C8.4
PRESENT WORTH VALUE OF DAMAGES
$ MILLION

Catchment	Discount Rate (%)	Nominal Flood Level Case	
		All Floods up to 1% AEP	All Floods up to PMF
Farmers Creek	4	73.1	89.4
	7	46.9	57.4
	11	30.6	37.4
Marrangaroo Creek	4	0.6	1.1
	7	0.4	0.7
	11	0.3	0.5

TABLE C8.5
PRESENT WORTH VALUE OF DAMAGES
IN INDIVIDUAL DAMAGE CENTRES
$ MILLION

Damage Centre	Discount Rate (%)	Nominal Flood Level Case	
		All Floods up to 1% AEP	All Floods up to PMF
Oakey Park	4	1.5	2.6
	7	1.0	1.7
	11	0.6	1.1
Morts Estate	4	4.9	7.7
	7	3.2	5.0
	11	2.1	3.2
Tank Street	4	1.5	2.6
	7	1.0	1.7
	11	0.6	1.1
Hermitage Flat	4	3.7	7.3
	7	2.3	4.7
	11	1.5	3.1
Vale of Clwydd	4	8.8	9.5
	7	5.7	6.1
	11	3.7	4.0
Gas Works Lane	4	5.2	5.8
	7	3.3	3.7
	11	2.2	2.4
Lithgow CBD	4	3.9	4.1
	7	2.5	2.6
	11	1.6	1.7
Sheedys Gully	4	5.2	6.2
	7	3.3	4.0
	11	2.2	2.6
Cupro Street	4	8.0	8.8
	7	5.1	5.7
	11	3.3	3.7
Enfield Avenue	4	4.9	6.0
	7	3.2	3.9
	11	2.1	2.5

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ANNEXURE C1
FLOOD DAMAGES IN INDIVIDUAL DAMAGE CENTRES

TABLE C1
FLOOD DAMAGES
OAKEY PARK DAMAGE CENTRE

Design Flood Event (% AEP)	Residential			Commercial/Industrial			Public			Total Damage ($ Million)
	Number of Properties		Damage ($Million)	Number of Properties		Damage ($Million)	Number of Properties		Damage ($Million)	
	Flood Affected	Flood Above Floor Level		Flood Affected	Flood Above Floor Level		Flood Affected	Flood Above Floor Level		
20	4	0	0.08	0	0	0	No Public Buildings Located in this Damage Centre			0.08
10	6	0	0.12	0	0	0				0.12
5	8	0	0.17	0	0	0				0.17
2	26	9	1.05	0	0	0				1.05
1	38	23	2.56	0	0	0				2.56
0.5	47	30	3.38	0	0	0				3.38
0.2	55	35	4.22	0	0	0				4.22
PMF	144	139	22.5	6	6	0.9				23.4

TABLE C2
FLOOD DAMAGES
MORTS ESTATE DAMAGE CENTRE

Design Flood Event (% AEP)	Residential			Commercial/Industrial			Public			Total Damage ($ Million)
	Number of Properties		Damage ($Million)	Number of Properties		Damage ($Million)	Number of Properties		Damage ($Million)	
	Flood Affected	Flood Above Floor Level		Flood Affected	Flood Above Floor Level		Flood Affected	Flood Above Floor Level		
20	4	0	0.08	1	1	0.24	No Public Buildings Located in this Damage Centre			0.32
10	6	1	0.20	3	3	0.35				0.55
5	17	4	0.57	4	3	0.44				1.01
2	37	13	1.54	6	6	1.39				2.93
1	47	18	2.38	7	7	2.86				5.24
0.5	63	29	3.47	8	8	3.69				7.16
0.2	72	33	4.16	9	8	4.57				8.73
PMF	223	221	36.1	14	14	35.3				71.4

TABLE C3
FLOOD DAMAGES
TANK STREET DAMAGE CENTRE

Design Flood Event (% AEP)	Residential			Commercial/Industrial			Public			Total Damage ($ Million)
	Number of Properties		Damage ($Million)	Number of Properties		Damage ($Million)	Number of Properties		Damage ($Million)	
	Flood Affected	Flood Above Floor Level		Flood Affected	Flood Above Floor Level		Flood Affected	Flood Above Floor Level		
20	1	0	0.02	No Commercial/Industrial Type Buildings Located in this Damage Centre			0	0	0	0.02
10	4	0	0.08				0	0	0	0.08
5	9	5	0.59				0	0	0	0.59
2	18	9	1.10				0	0	0	1.10
1	32	22	2.38				0	0	0	2.38
0.5	44	28	3.31				0	0	0	3.31
0.2	49	33	3.87				0	0	0	3.87
PMF	144	139	24.3				1	1	0.1	24.4

TABLE C4
FLOOD DAMAGES
HERMITAGE FLAT DAMAGE CENTRE

Design Flood Event (% AEP)	Residential			Commercial/Industrial			Public			Total Damage ($ Million)
	Number of Properties		Damage ($Million)	Number of Properties		Damage ($Million)	Number of Properties		Damage ($Million)	
	Flood Affected	Flood Above Floor Level		Flood Affected	Flood Above Floor Level		Flood Affected	Flood Above Floor Level		
20	3	1	0.09	0	0	0	0	0	0	0.09
10	3	1	0.09	0	0	0	0	0	0	0.09
5	10	4	0.47	1	1	0.02	1	0	0.02	0.51
2	67	39	4.03	3	2	0.14	1	0	0.02	4.19
1	119	90	9.32	3	2	0.24	1	1	0.04	9.60
0.5	131	114	12.2	3	2	0.29	2	1	0.08	12.6
0.2	136	121	13.5	3	2	0.35	2	2	0.15	14.0
PMF	178	172	32.4	4	4	8.1	4	4	5.15	45.7

TABLE C5
FLOOD DAMAGES
VALE OF CLWYDD DAMAGE CENTRE

Design Flood Event (% AEP)	Residential			Commercial/Industrial			Public			Total Damage ($ Million)
	Number of Properties		Damage ($Million)	Number of Properties		Damage ($Million)	Number of Properties		Damage ($Million)	
	Flood Affected	Flood Above Floor Level		Flood Affected	Flood Above Floor Level		Flood Affected	Flood Above Floor Level		
20	17	8	0.79	No Commercial/Industrial Type Buildings Located in this Damage Centre			0	0	0	0.79
10	24	13	1.32				0	0	0	1.32
5	35	21	2.18				0	0	0	2.18
2	35	24	2.56				0	0	0	2.56
1	41	29	2.99				0	0	0	2.99
0.5	41	31	3.13				0	0	0	3.13
0.2	40	30	3.19				0	0	0	3.19
PMF	67	50	6.24				1	1	0.04	6.28

TABLE C6
FLOOD DAMAGES
GAS WORKS LANE DAMAGE CENTRE

Design Flood Event (% AEP)	Residential			Commercial/Industrial			Public			Total Damage ($ Million)
	Number of Properties		Damage ($Million)	Number of Properties		Damage ($Million)	Number of Properties		Damage ($Million)	
	Flood Affected	Flood Above Floor Level		Flood Affected	Flood Above Floor Level		Flood Affected	Flood Above Floor Level		
20	15	0	0.31	2	2	0.22	0	0	0	0.53
10	17	3	0.45	2	2	0.25	0	0	0	0.70
5	17	8	0.78	3	3	0.31	0	0	0	1.09
2	25	10	1.14	3	3	0.35	0	0	0	1.49
1	30	11	1.47	3	3	0.42	0	0	0	1.89
0.5	35	14	1.82	3	3	0.40	0	0	0	2.22
0.2	36	17	2.08	3	3	0.47	0	0	0	2.55
PMF	71	50	5.87	7	6	1.63	0	0	0	7.50

TABLE C7
FLOOD DAMAGES
LITHGOW CBD DAMAGE CENTRE

Design Flood Event (% AEP)	Residential			Commercial/Industrial			Public			Total Damage ($ Million)
	Number of Properties		Damage ($Million)	Number of Properties		Damage ($Million)	Number of Properties		Damage ($Million)	
	Flood Affected	Flood Above Floor Level		Flood Affected	Flood Above Floor Level		Flood Affected	Flood Above Floor Level		
20	3	0	0.06	13	12	0.42	0	0	0	0.48
10	4	1	0.11	14	13	0.45	0	0	0	0.56
5	4	1	0.16	15	14	0.49	0	0	0	0.65
2	4	1	0.16	16	15	0.53	0	0	0	0.69
1	7	1	0.22	18	17	0.59	0	0	0	0.81
0.5	7	1	0.22	21	19	0.69	0	0	0	0.91
0.2	8	1	0.24	23	21	0.74	0	0	0	0.98
PMF	21	12	1.40	46	46	2.17	2	1	0.11	3.68

TABLE C8
FLOOD DAMAGES
SHEEDYS GULLY DAMAGE CENTRE

Design Flood Event (% AEP)	Residential			Commercial/Industrial			Public			Total Damage ($ Million)
	Number of Properties		Damage ($Million)	Number of Properties		Damage ($Million)	Number of Properties		Damage ($Million)	
	Flood Affected	Flood Above Floor Level		Flood Affected	Flood Above Floor Level		Flood Affected	Flood Above Floor Level		
20	0	0	0	4	4	0.21	No Public Buildings Located in this Damage Centre			0.21
10	1	1	0.04	4	4	0.33				0.37
5	1	1	0.08	7	7	2.24				2.32
2	1	1	0.09	7	7	2.80				2.89
1	3	1	0.13	8	8	3.43				3.56
0.5	4	1	0.16	10	9	3.54				3.70
0.2	4	4	0.34	10	9	4.11				4.45
PMF	10	9	1.45	14	13	15.4				16.9

TABLE C9
FLOOD DAMAGES
CUPRO STREET DAMAGE CENTRE

Design Flood Event (% AEP)	Residential			Commercial/Industrial			Public			Total Damage ($ Million)
	Number of Properties		Damage ($Million)	Number of Properties		Damage ($Million)	Number of Properties		Damage ($Million)	
	Flood Affected	Flood Above Floor Level		Flood Affected	Flood Above Floor Level		Flood Affected	Flood Above Floor Level		
20	25	4	0.73	3	2	0.07	No Public Buildings Located in this Damage Centre			0.80
10	37	5	1.06	3	2	0.08				1.14
5	56	6	1.53	3	2	0.08				1.61
2	73	8	1.99	3	3	0.09				2.08
1	81	9	2.28	3	3	0.10				2.38
0.5	90	20	2.85	4	3	0.13				2.98
0.2	100	26	3.52	4	3	0.13				3.65
PMF	245	165	18.7	10	9	1.25				20.0

TABLE C10
FLOOD DAMAGES
ENFIELD AVENUE DAMAGE CENTRE

Design Flood Event (% AEP)	Residential			Commercial/Industrial			Public			Total Damage ($ Million)
	Number of Properties		Damage ($Million)	Number of Properties		Damage ($Million)	Number of Properties		Damage ($Million)	
	Flood Affected	Flood Above Floor Level		Flood Affected	Flood Above Floor Level		Flood Affected	Flood Above Floor Level		
20	13	1	0.30	0	0	0	0	0	0	0.30
10	22	2	0.56	1	1	0.06	0	0	0	0.62
5	38	9	1.19	3	3	0.19	0	0	0	1.38
2	58	16	2.11	4	4	0.34	0	0	0	2.45
1	75	18	2.76	4	4	0.43	0	0	0	3.19
0.5	80	17	2.91	7	6	0.64	0	0	0	3.55
0.2	102	24	3.64	8	7	1.24	0	0	0	4.88
PMF	234	172	19.7	8	8	5.01	1	0	0.02	24.7

APPENDIX D

SUGGESTED WORDING FOR INCLUSION IN LITHGOW DEVELOPMENT CONTROL PLAN

TABLE OF CONTENTS

FIGURES
(BOUND IN VOLUME 2)

D1.1 Introduction

This section of the Plan sets out specific controls to guide development of flood liable land in the Lithgow City LGA. The approach to managing future development that is subject to flooding supports the findings of a series of location specific floodplain risk management studies and plans that have been prepared as part of the NSW Government's program to mitigate the impact of major floods and reduce the associated hazards in the floodplain.

D1.2 Objectives in Relation to Flood Risk Management

a) To minimise the potential impact of development and other activity upon the aesthetic, recreational and ecological value of the waterway corridors.

b) Increase public awareness of the hazard and extent of land affected by all potential floods, including floods greater than the 1% Annual Exceedance Probability (AEP) flood and to ensure essential services and land uses are planned in recognition of all potential floods.

c) Inform the community of Council's controls and policy for the use and development of flood prone land.

d) Reduce the risk to human life and damage to property caused by flooding through controlling development on land affected by potential floods.

e) Provide detailed controls for the assessment of applications lodged in accordance with the *Environmental Planning and Assessment Act 1979* on land affected by potential floods.

f) Provide different guidelines, for the use and development of land subject to all potential floods in the floodplain, which reflect the probability of the flood occurring and the potential hazard within different areas.

g) Apply a "merit-based approach" to all development decisions which takes account of social, economic and ecological considerations.

h) To control development and other activity within each of the individual floodplains within the LGA having regard to the characteristics and level of information available for each of the floodplains, in particular the availability of floodplain risk management studies and plans prepared in accordance with the *Floodplain Development Manual*, issued by the NSW Government.

i) Deal equitably and consistently with applications for development on land affected by potential floods, in accordance with the principles contained in the *Floodplain Development Manual*.

D1.3 Procedure for Determining What Controls Apply to Proposed Development

The procedure Council will apply for determining the specific controls applying to proposed development in flood liable areas is set out below. Upon enquiry by a prospective applicant, Council will make an initial assessment of the flood affectation and flood levels at the site using the following procedure:

- Assess whether the development is located on flood liable land from the **Flood Planning Map**.
- Determine which set of prescriptive flood related planning controls apply to the development from the **Flood Planning Map** (i.e. Main Stream Flooding or Major Overland Flow).

- Identify the category of the development from **Schedule1: Land Use Categories.**
- Determine the appropriate flood level at the site from the results of the location specific flood or floodplain risk management study.
- Determine which part of the floodplain the development is located in from the **Flood Planning Constraint Category Map**.
- Confirm that the development conforms with the relevant performance criteria, as well as the prescriptive controls set out in either **Schedule 2A** for Main Stream Flooding affected areas and **Schedule 2B** for Major Overland Flow affected areas.

With the benefit of this initial information from Council, the applicant will:

- Prepare the documentation to support the Development Application according to the requirements of **Section D1.9**.

A survey plan showing natural surface levels over the site will be required as part of the Development Application documentation. Provision of this plan by the applicant at the initial enquiry stage will assist Council in providing flood related information.

D1.4 Land Use Categories

The policy recognises twelve different types of land use for which a graded set of flood related controls apply. They are included in **Schedule 1: Land Use Categories**.

D1.5 Flood Planning Constraint Categories

For those floodplains where Council has adopted a flood or floodplain risk management study, the identified flood liable land has been divided into the following four *Flood Planning Constraint Categories* (**FPCCs**):

- **Flood Planning Constraint Category 1 (FPCC 1)**, which comprises areas where factors such as the depth and velocity of flow, time of rise, and evacuation problems mean that the land is unsuitable for most types of development. The majority of new development types are excluded from this zone due to its potential impact on flood behaviour and the hazardous nature of flooding.
- **Flood Planning Constraint Category 2 (FPCC 2)**, which comprises areas which lie within the extent of the *Flood Planning Area* where the existing flood risk warrants careful consideration and the application of significant flood related controls on future development.
- **Flood Planning Constraint Category 3 (FPCC 3)**, which comprises areas which lie within the extent of the *Flood Planning Area* but outside areas designated FPCC1 and FPCC2. Areas designated FPCC3 are more suitable for new development and expansion of existing development provided it is carried out in accordance with the controls set out in this document.
- **Flood Planning Constraint Category 4 (FPCC 4)**, which comprises the area which lies between the extent of the *Flood Planning Area* and the Probable Maximum Flood (**PMF**). Flood related controls in areas designated FPCC4 are typically limited to flood evacuation and emergency response, although additional controls apply to essential community facilities and utilities that are critical for response and recovery, as well as community hospitals, residential care facilities and group homes. This area is identical to the *Special Flood Considerations Zone* shown on the **Flood Planning Map**.

D1.6 Development Controls

The development controls have been graded relative to the severity and frequency of potential floods, having regard to the FPCCs determined by the relevant Floodplain Risk Management Study and Plan or, if no such study or plan exists, Council's interim considerations.

The objectives of the development controls are:

a) To require developments with high sensitivity to flood risk to be designed so that they are subject to minimal risk.

b) To allow development with a lower sensitivity to the flood hazard to be located within the floodplain, provided the risk of harm and damage to property is minimised.

c) To minimise the intensification of the high flood risk areas, and if possible, allow for their conversion to natural waterway corridors.

d) To ensure design and siting controls required to address the flood hazard do not result in unreasonable social, economic or environmental impacts.

e) To minimise the risk to life by ensuring the provision of reliable access from areas affected by flooding.

f) To minimise the damage to property arising from flooding.

g) To ensure the proposed development does not expose existing development to increased risks associated with flooding.

The performance criteria which are to be applied when assessing a proposed development are:

a) The proposed development should not result in any significant increase in risk to human life, or in a significant increase in economic or social costs as a result of flooding.

b) The proposal should only be permitted where effective warning time and reliable access is available to an area free of risk from flooding, consistent with any relevant Flood Plan or flood evacuation strategy.

c) Development should not significantly increase the potential for damage or risk other properties either individually or in combination with the cumulative impact of development that is likely to occur in the same floodplain.

d) Procedures would be in place, if necessary, (such as warning systems, signage or evacuation drills) so that people are aware of the need to evacuate are capable of identifying the appropriate evacuation route.

e) Development should not result in significant impacts upon the amenity of an area by way of unacceptable overshadowing of adjoining properties, privacy impacts (e.g. by unsympathetic house–raising) or by being incompatible with the streetscape or character of the locality.

The prescriptive controls which apply to development that is proposed on land affected by Main Stream Flooding and Major Overland Flow are set out in **Schedules 2A** and **2B**, respectively.

D1.7 Proposals to Modify Flood Planning Constraint Categories

In certain situations it may be feasible to modify existing flood behaviour through engineering works which in turn would enable the extent of the FPCCs to be modified at a particular location. Proposals to modify an FPCC at a particular location would need to be supported by a detailed flooding investigation, further details of which are set out in **Section D1.9** below. Proposals would also need to demonstrate consistency with the flood related objectives and performance

criteria of both the *Lithgow Local Environmental Plan* and the *Lithgow Development Control Plan 2021*.

D1.8 Special Requirements for Fencing

The objectives are:

a) To ensure that fencing does not result in the undesirable obstruction of the free flow of floodwater.

b) To ensure that fencing does not become unsafe during floods so as to threaten the integrity of structures or the safety of people.

c) Fencing is to be constructed in a manner which does not significantly increase flood damage or risk on surrounding land.

The performance criterion which is to be applied when assessing proposed fencing are:

a) Fencing is to be constructed in a manner that does not affect the flow of floodwater so as to detrimentally increase flood affection on surrounding land.

b) Fencing shall be certified by an engineer specialising in hydraulic engineering, that the proposed fencing is adequately constructed so as to withstand the force of floodwater, or collapse in a controlled manner to prevent the undesirable impediment of floodwater.

The prescriptive controls which apply to any proposed fencing on land designated FPCC 1, FPCC 2 and FPCC 3 are:

a) An applicant will need to demonstrate that the fence (new or replacement fence) would create no impediment to the flow of floodwater. Appropriate fences must satisfy the following:

- an open collapsible hinged fence structure or pool type fence, or louvre fencing;
- must not be constructed of non-permeable materials; or
- must allow floodwaters to equalised on both sides and minimise entrapment of flood debris.

D1.9 Explanatory Notes on Lodging Applications

Follow these major steps to lodge the application:

a) Check the proposal is permissible in the zoning of the land by reference to any applicable environmental planning instruments.

b) Consider any other relevant planning controls of Council (e.g. controls in any other relevant part of the *Lithgow Development Control Plan 2021*).

c) Check whether your property is located either partially or wholly within the Flood Planning Area or Outer Floodplain, as defined on the **Flood Planning Map**.

d) Determine which set of prescriptive flood related planning controls apply to the development from the **Flood Planning Map**.

e) Determine which FPCC applies to the developable portion of your property by reference to the **Flood Planning Constraint Category Map**. Enquire with Council regarding existing flood risk mapping or whether a site–specific assessment may be warranted. A property may be located in more than one FPCC and the assessment must consider the

controls that apply in each. The flow diagram below summarises this consideration process.

f) Determine the land use category relevant to the development proposal, by firstly confirming how it is defined by the relevant environmental planning instrument and secondly by ascertaining the land use category from **Schedule 1: Land Use Categories**.

g) Assess and document how the proposal will achieve the performance criteria for proposed development and associated fencing set out in **Sections D1.6** and **D1.8**.

h) Check if the proposal will satisfy the prescriptive controls for different land use categories in different FPCCs, as specified in either **Schedule 2A** or **Schedule 2B**.

i) If the proposal does not comply with the prescriptive controls, determine whether the performance criteria are nonetheless achieved.

j) Illustrations provided in this plan to demonstrate the intent of development controls are diagrammatic only. Proposals must satisfy all relevant controls contained in this plan and associated legislation.

k) The assistance of Council staff or an experienced engineer or planner may be required at various steps in the process to ensure that the flood risk management related requirements of this Plan are fully and satisfactorily addressed.

Note that compliance with all the requirements of this plan does not guarantee that an application will be approved.

Information required with an application to address this plan is as follows:

a) Applications must include information which addresses all relevant controls listed above, and the following matters as applicable.

b) Applications for alterations and additions (see either **Schedule 2A** or **Schedule 2B**) to an existing dwelling on flood liable land shall be accompanied by documentation from a registered surveyor confirming existing floor levels.

c) Development applications affected by this plan shall be accompanied by a survey plan showing:

   i. The position of the existing building/s or proposed building/s;

   ii. The existing ground levels to Australian Height Datum around the perimeter of the building and contours of the site; and

   iii. The existing or proposed floor levels to Australian Height Datum.

d) Applications for earthworks, filling of land and subdivision shall be accompanied by a survey plan (with a contour interval of 0.25 m) showing relative levels to Australian Height Datum.

e) For large scale developments, or developments where an existing catchment based flood study is not available, a flood study using a fully dynamic one or two dimensional computer model may be required. For smaller developments the existing flood study may be used if available and suitable (e.g. it contains sufficient local detail), or otherwise a flood study prepared in a manner consistent with the latest edition of *Australian Rainfall and Runoff* and the *Floodplain Development Manual*, will be required. From this study, the following information shall be submitted in plan form:

   i. water surface contours;

   ii. velocity vectors;

iii. velocity and depth product contours;

iv. delineation of flood risk precincts relevant to individual floodplains; and

v. show both existing and proposed flood profiles for the full range of events for total development including all structures and works (such as revegetation/ enhancements).

This information is required for the pre–developed and post–developed scenarios.

f) Where the controls for a particular development proposal require an assessment of structural soundness during potential floods, the following impacts must be addressed:

i. hydrostatic pressure;

ii. hydrodynamic pressure;

iii. impact of debris; and

iv. buoyancy forces.

Foundations need to be included in the structural analysis.

D1.10 Glossary of Terms

Note: For expanded list of definitions, refer to Glossary contained within the NSW Government Floodplain Development Manual, 2005.

TERM	DEFINITION
Annual Exceedance Probability (AEP)	The chance of a flood of a given or larger size occurring in any one year, usually expressed as a percentage. For example, for a flood magnitude having five per cent AEP, there is a five per cent probability that there would be floods of greater magnitude each year.
Australian Height Datum (AHD)	A common national surface level datum corresponding approximately to mean sea level.
Floodplain	Area of land which is subject to inundation by floods up to and including the Probable Maximum Flood (**PMF**) event, that is, flood prone land.
Flood Planning Area	The area of land that is shown to be in the Flood Planning Area on the *Flood Planning Map*.
Flood Planning Map	The *Flood Planning Map* shows the extent of land on which flood related development controls apply in a given area, noting that other areas may exist which are not mapped but where flood related development controls apply.
Flood Planning Constraint Category 1 (FPCC 1)	Comprises areas where factors such as the depth and velocity of flow, time of rise, and evacuation problems mean that the land is unsuitable for most types of development. The majority of new development types are excluded from this zone due to its potential impact on flood behaviour and the hazardous nature of flooding
Flood Planning Constraint Category 2 (FPCC 2)	Comprises areas which lie below the *Flood Planning Level* where the existing flood risk warrants careful consideration and the application of significant flood related controls on future development.
Flood Planning Constraint Category 3 (FPCC 3)	Comprises areas which lie below the *Flood Planning Level* but outside areas designated FPCC1 and FPCC2. Areas designated FPCC3 are more suitable for new development and expansion of existing development provided it is carried out in accordance with the controls set out in this document.
Flood Planning Constraint Category 4 (FPCC 4)	Comprises the area which lies above the *Flood Planning Level* (**FPL**) but within the extent of the PMF. Flood related controls in areas designated FPCC4 are typically limited to flood evacuation and emergency response, although additional controls apply to essential community facilities and utilities that are critical for response and recovery, as well as community hospitals, residential care facilities and group homes. This area is identical to the *Special Flood Considerations Zone* shown on the **Flood Planning Map**.
Flood Planning Level (FPL)	Flood levels selected for planning purposes, as determined by the relevant adopted floodplain risk management study and plan, or as part of a site specific study In the absence of an adopted floodplain risk management study and plan for a particular location, the FPL is defined as the peak 1% AEP flood level plus the addition of a 0.5 m freeboard.

TERM	DEFINITION
Flood Prone/Flood Liable Land	Land susceptible to flooding by the PMF. Flood Prone land is synonymous with Flood Liable land.
Floodway	Those areas of the floodplain where a significant discharge of water occurs during floods. They are often aligned with naturally defined channels. Floodways are areas that, even if only partially blocked, would cause a significant redistribution of flood flow, or a significant increase in flood levels.
Flood Storage Area	Those parts of the floodplain that may be important for the temporary storage of floodwaters during the passage of a flood. Loss of flood storage can increase the severity of flood impacts by reducing natural flood attenuation.
Freeboard	Provides reasonable certainty that the risk exposure selected in deciding a particular flood chosen as the basis for the *Flood Planning Level* is actually provided. It is a factor of safety typically used in relation to the setting of floor levels, levee crest levels, etc. Freeboard is included in the *Flood Planning Level*.
Habitable Room	In a residential situation: a living or working area, such as a lounge room, dining room, kitchen, bedroom or workroom. In an industrial or commercial situation: an area used for offices or to store valuable possessions susceptible to flood damage in the event of a flood.
Local Drainage	Land on an overland flow path where the depth of inundation during the 1% AEP storm event is less than 0.1 m.
Main Stream Flooding	Inundation of normally dry land occurring when water overflows the natural or artificial banks of a stream, river, estuary, lake or dam.
Major Overland Flow	Where the depth of overland flow during the 1% AEP storm event is greater than 0.1 m.
Probable Maximum Flood (PMF)	The largest flood that could conceivably occur at a particular location. Generally, it is not physically or economically possible to provide complete protection against this event. The PMF defines the extent of flood prone land, that is, the floodplain.
Special Flood Consideration Zone	Comprises the area where the flood risk is considered to be high enough to require additional controls to be applied to future development that is located on land which lies above the FPL. The additional controls in this area relate to the safe and timely evacuation of people who would be occupying the floodplain at the time of a flood event and only apply in areas categorised as FPCC4.

SCHEDULE 1
LAND USE CATEGORIES

Land Use Category	Subdivision	LEP Land Uses
Critical Uses and Facilities	*Community facilities which may provide an important contribution to the notification or evacuation of the community during flood events.*	Health services facility; Electricity generating works; Emergency services facility.
Sensitive Uses and Facilities	*Uses which involve vulnerable members of the community;* *Uses which may cause pollution of a watercourse or town water supply;* *Uses which if affected, would significantly affect the ability of community to return to normal after flood event;*	Bio-solids treatment facility; Cemeteries; Child care centre; Correctional centre; Heavy industrial storage establishment; Heavy industries; Highway service centre; Group home; Passenger transport facilities; Respite day care centre; Schools; Seniors housing; Service Stations; Sewage treatment plant; Veterinary hospital; Waste or resource management facility; Water treatment facility.
Subdivision	*Subdivision of land which involves* *the creation of new allotments, with* *potential for further development;*	Camping grounds; Caravan parks; Eco-tourist facilities; Home business/ child care/occupations; Residential accommodation (excluding Group Home and Seniors housing); Tourist and visitor accommodation.
Residential		
Commercial and Industrial		Amusement centre; Commercial premises (excluding Market); Crematorium; Depots; Entertainment facility; Freight transport facilities; Function centre; General industries; Industrial retail outlet; Industrial training facility; Light industries; Mortuaries; Place of public worship; Public administration building; Recreation facility (indoor & major); Registered club; Research station;

		Restricted premises; Sex services premises; Storage premises; Transport depots; Truck depots; Warehouse or distribution centre; Wholesale suppliers; Vehicle body repair workshops; Vehicle repair stations;
Recreation and Non-Urban		Agriculture (excluding intensive livestock agriculture); Animal boarding and training establishment; Boat sheds; Charter & tourism boating facilities; Car park; Community facility; Extractive industry; Forestry; Jetties; Market; Open cut mining; Recreation area; Recreation facility (outdoor).
Alterations and additions		Residential development: i. An addition or alteration to an existing dwelling of not more than 50m² to the habitable floor area which existed at the date of commencement of this Plan; ii. The construction of an outbuilding with a maximum floor area of 30m² or Rebuilt dwellings which substantially reduce flood risk having regard to property damage and personal safety; or iii. A change of use which does not increase flood risk having regard to property damage and personal safety. iv. Alterations and additions: i. An addition to existing premises of not more than 10% of the floor area which existed at the date of commencement of this DCP; ii. Rebuilding of a development which substantially reduces the extent of flood effects to the existing development; iii. A change of use which does not increase flood risk having regard to property damage and personal safety; or iv. Subdivision which does not involve the creation of new allotments with potential for further development.

SCHEDULE 2A
PRESCRIPTIVE FLOOD RELATED DEVELOPMENT CONTROLS – MAIN STREAM FLOODING

Planning considerations	Flood Planning Constraint Category 1 (FPCC 1)							Flood Planning Constraint Category 2 (FPCC 2)							Flood Planning Constraint Category 3 (FPCC 3)							Flood Planning Constraint Category 4 (FPCC 4)						
	Critical Uses and Facilities	Sensitive Uses and Facilities	Subdivision	Residential	Commercial and Industrial	Recreational and Non-Urban	Alterations and Additions	Critical Uses and Facilities	Sensitive Uses and Facilities	Subdivision	Residential	Commercial and Industrial	Recreational and Non-Urban	Alterations and Additions	Critical Uses and Facilities	Sensitive Uses and Facilities	Subdivision	Residential	Commercial and Industrial	Recreational and Non-Urban	Alterations and Additions	Critical Uses and Facilities	Sensitive Uses and Facilities	Subdivision	Residential	Commercial and Industrial	Recreational and Non-Urban	Alterations and Additions
Minimum Habitable Floor Level						A1	A2 A4				A2	A5	A1	A2 A4				A2	A5	A1	A2 A4	A3	A3					
Building Components						B2	B2				B2	B2	B2	B2				B2	B2	B2	B2	B3	B3					
Structural Soundness						C2	C2				C2	C2	C3	C2				C2	C2	C3	C2	C4	C4					
Flood Affectation						D1	D1			D1	D1	D1	D1	D2			D1	D1	D1	D1	D2							
Emergency Response						E4	E2 or E3			E4 E5	E3 E4	E3 E4	E4	E2 or E3			E4 E5	E2 E4	E2 E4	E4	E2 or E3	E2 or E3	E2 E4	E4 E5	E2 E4	E2 E4		E2 E4
Management and Design						F2 F3	F2 F3			F1	F2	F2 F3 F4	F2 F3	F2 F3			F1	F2	F2 F3 F4	F2	F2 F3	F2 F3	F2 F3 F4	F1	F2	F2 F3 F4	F2	F2
Stormwater							G2			G1 G2	G1 G2	G1 G2		G2			G1 G2	G1 G2	G1 G2		G2	G1	G1					
Parking and Driveway Access						H2 H4 H6 H7	H6 H7 H8			H1 H3 H5 H6 H7	H1 H3 H5 H6 H7	H1 H3 H5 H6 H7	H2 H4 H6 H7	H6 H7 H8			H1 H3 H5 H6 H7	H1 H3 H5 H6 H7	H1 H3 H5 H6 H7	H2 H4 H6 H7	H6 H7 H8	H3	H3					

	Not Relevant		Unsuitable Land Use

SCHEDULE 2B
PRESCRIPTIVE FLOOD RELATED DEVELOPMENT CONTROLS – MAJOR OVERLAND FLOW

Planning considerations	Flood Planning Constraint Category 1 (FPCC 1)							Flood Planning Constraint Category 2 (FPCC 2)							Flood Planning Constraint Category 3 (FPCC 3)							Flood Planning Constraint Category 4 (FPCC 4)						
	Critical Uses and Facilities	Sensitive Uses and Facilities	Subdivision	Residential	Commercial and Industrial	Recreational and Non-Urban	Alterations and Additions	Critical Uses and Facilities	Sensitive Uses and Facilities	Subdivision	Residential	Commercial and Industrial	Recreational and Non-Urban	Alterations and Additions	Critical Uses and Facilities	Sensitive Uses and Facilities	Subdivision	Residential	Commercial and Industrial	Recreational and Non-Urban	Alterations and Additions	Critical Uses and Facilities	Sensitive Uses and Facilities	Subdivision	Residential	Commercial and Industrial	Recreational and Non-Urban	Alterations and Additions
Minimum Habitable Floor Level						A1	A2 A4				A2	A5	A1	A2 A4	A3	A3		A2	A5	A1	A2 A4	A3	A3					
Building Components						B1	B1				B1	B1	B1	B1	B3	B3		B1	B1	B1	B1	B3	B3					
Structural Soundness						C1	C1				C1	C1	C1	C1	C4	C4		C1	C1	C1	C1	C4	C4					
Flood Affectation						D1	D1			D1	D1	D1	D1	D2														
Emergency Response						E1	E1			E5					E2 orE 3	E2 E4	E5					E2 or E3	E2 E4					
Management and Design						F2	F2			F1 F3	F2	F2 F4	F2	F2	F2 F3	F2 F3 F4	F1 F3		F4			F2 F3	F2 F3 F4					
Stormwater										G1	G1	G1			G1	G1	G1	G1	G1			G1	G1					
Parking and Driveway Access						H2 H4 H6 H7	H6 H7 H8			H1 H3 H5 H6 H7	H1 H3 H5 H6 H7	H1 H3 H5 H6 H7	H2 H4 H6 H7	H6 H7 H8			H1 H3 H5 H6	H1 H3 H5 H6	H1 H3 H5 H6	H2 H4 H6	H6 H8	H3	H3					

	Not Relevant		Unsuitable Land Use

Prescriptive controls for associated planning considerations under each FPCC

Minimum Habitable Floor Level

A1 Habitable floor levels to be set no lower than the 5% AEP flood level plus freeboard[(1)] unless justified by site specific assessment.

A2 Habitable floor levels to be set no lower than the 1% AEP flood level plus freeboard[(1)].

A3 Habitable floor levels to be set no lower than the PMF flood level.

A4 Habitable floor levels to be as close to the Minimum Habitable Floor Level as practical and no lower than the existing floor level when undertaking concessional development.

A5 Habitable floor levels to be as close to the 1% AEP flood level plus freeboard[(1)] as practical, but no lower than the 5% AEP flood level plus freeboard[(1)]. In situations where the habitable floor level is set below the 1% AEP flood level plus freeboard[(1)], a mezzanine area equal to 30% of the total habitable floor area is to be provided, the elevation of which is to be set no lower than the 1% AEP flood level plus freeboard[(1)].

Building Components & Method

B1 All structures to have flood compatible building components below the 1% AEP flood level plus freeboard[(1)] (refer **Schedules 3A** and **3B**).

B2 All structures to have flood compatible building components below the 1% AEP flood level plus freeboard[(1)] or the 0.2% AEP flood level, whichever is the highest (refer **Schedules 3A** and **3B**).

B3 All structures to have flood compatible building components below the 1% AEP flood plus freeboard[(1)] or the PMF level, whichever is the highest (refer **Schedules 3A** and **3B**).

Structural Soundness

C1 Engineers report to certify that any structure can withstand the forces of floodwater, debris and buoyancy up to and including a 1% AEP flood plus freeboard[(1)].

C2 Engineers report to certify that any structure can withstand the forces of floodwater, debris and buoyancy up to and including a 1% AEP flood plus freeboard[(1)] or a 0.2% AEP flood, whichever is the greatest.

C3 Applicant to demonstrate that any structure can withstand the forces of floodwater, debris and buoyancy up to and including a 1% AEP flood plus freeboard[(1)] or a 0.2% AEP flood, whichever is the greatest, alternatively PMF if required to satisfy emergency response criteria (see below).

C4 Applicant to demonstrate that any structure can withstand the forces of floodwater, debris and buoyancy up to and including a 1% AEP flood plus freeboard[(1)] or a PMF, whichever is the greatest.

Flood Affectation

D1 Engineers report required to certify that the development will not increase flood affectation elsewhere.

D2 The impact of the development on flooding elsewhere to be considered.

Note: When assessing flood affectation the following must be considered:

1. Loss of storage in the floodplain (Only for development being assessed under Schedule 2A).

2. Changes in flood levels and flow velocities caused by alteration of conveyance of flood waters.

3. Impacts of urbanisation on peak flood flows and volumes.

Emergency Response

E1 Reliable egress for pedestrians and vehicles required during a 1% AEP flood.

E2 Reliable egress for pedestrians and vehicles required during a PMF.

E3 Reliable egress for pedestrians or vehicles is required from the building, commencing at a minimum level equal to the lowest habitable floor level to an area of refuge above the PMF level, or a minimum of 20 m^2 of the dwelling to be above the PMF level.

E4 The development is to be consistent with any relevant flood evacuation strategy or similar plan.

E5 Applicant to demonstrate that there is rising road egress/access from all allotments internal to the subdivision to land which lies above the PMF.

Management and Design

F1 Applicant to demonstrate that potential development as a consequence of a subdivision or development proposal can be undertaken in accord with this Plan.

F2 Flood Safe Plan (home or business or farm houses) to address safety and property damage issues (including goods storage and stock management) considering the full range of flood risk.

F3 Site Emergency Response Flood Plan required considering the full range of flood risk

F4 No external storage of materials below the Minimum Habitable Floor Level which may cause pollution or be potentially hazardous during any flood.

Stormwater

G1 Engineers report required to certify that the development will not affect stormwater drainage.

G2 The impact of the development on local overland flooding to be considered.

Parking and Driveway Access

H1 The minimum surface level of open car parking spaces or carports shall be as high as practical, but no lower than the 5% AEP flood or the level of the crest of the road at the location where the site has access. In the case of garages, minimum surface level shall be as high as practical but no lower than the 5% AEP flood.

H2 The minimum surface level of open car parking spaces, carports or garages shall be as high as practical

H3 Garages capable of accommodating more than three motor vehicles on land zoned for urban purposes, or enclosed car parking, must be protected from inundation by floods up to the 1% AEP flood plus freeboard[(1)].

H4 The driveway providing access between the road and parking space shall be as high as practical and generally rising in the egress direction.

H5 The level of the driveway providing access between the road and parking space shall be no lower than 0.3 m below the 1% AEP flood or such that the depth of inundation during a 1% AEP flood is not greater than either the depth at the road or the depth at the car parking space. A lesser standard may be accepted for single detached dwelling houses where it can be demonstrated that risk to human life would not be compromised.

H6 Enclosed car parking and car parking areas accommodating more than three vehicles (other than on Rural zoned land), with a floor level below the 5% AEP flood or more than 0.8 m below the 1% AEP flood level, shall have adequate warning systems, signage and exits.

H7 Restraints or vehicle barriers to be provided to prevent floating vehicles leaving the site during a 1% AEP flood.

H8 Driveway and parking space levels to be no lower than the design ground/floor levels. Where this is not practical, a lower level may be considered. In these circumstances, the level is to be as high as practical, and, when undertaking concessional development, no lower than existing levels.

H9 Flood related parking and access requirements to be advised by Council if necessary. Contact Council for advice as early as possible.

1. Unless stated otherwise in an adopted location specific Floodplain Risk Management Study and Plan, freeboard is equal to 0.5 m for development being assessed under Schedule 2A and 0.3 m for development being assessed under Schedule 2B.

SCHEDULE 3A
GENERAL BUILDING MATTERS

Electrical and Mechanical Equipment

For dwellings constructed on land to which this policy applies, the electrical and mechanical materials, equipment and installation should conform to the following requirements.

Main Power Supply

Subject to the approval of the relevant authority the incoming main commercial power service equipment, including all metering equipment, shall be located above the relevant elevation referred to in control B1 or B2 of **Schedules 2A** and **2B**. Means shall be available to easily isolate the dwelling from the main power supply.

Wiring

All wiring, power outlets, switches, etc, should be, to the maximum extent possible, located above the relevant elevation referred to in control B1 or B2 of **Schedules 2A** and **2B**. All electrical wiring installed below this level should be suitable for continuous underwater immersion and should contain no fibrous components. Earth leakage circuit breakers (core balance relays) must be installed. Only submersible type splices should be used below the relevant elevation referred to in control B1 or B2 of **Schedules 2A** and **2B**. All conduits located below the relevant designated flood level should be so installed that they will be self-draining if subjected to flooding.

Equipment

All equipment installed below or partially below the relevant elevation referred to in control B1 or B2 of **Schedules 2A** and **2B** should be capable of disconnection by a single plug and socket assembly.

Reconnection

Should any electrical device and/or part of the wiring be flooded it should be thoroughly cleaned or replaced and checked by an approved electrical contractor before reconnection.

Heating and Air Conditioning Systems

Where viable, heating and air conditioning systems should be installed in areas and spaces of the house above the relevant elevation referred to in control B1 or B2 of **Schedules 2A** and **2B**. When this is not feasible, every precaution should be taken to minimise the damage caused by submersion according to the following guidelines:

i) Fuel

Heating systems using gas or oil as a fuel should have a manually operated valve located in the fuel supply line to enable fuel cut-off.

ii) Installation

The heating equipment and fuel storage tanks should be mounted on and securely anchored to a foundation pad of sufficient mass to overcome buoyancy and prevent movement that could damage the fuel supply line. All storage tanks should be vented to the relevant elevation referred to in control B1 or B2 of **Schedules 2A** and **2B**.

iii) Ducting

All ductwork located below the relevant elevation referred to in control B1 or B2 of **Schedules 2A** and **2B** should be provided with openings for drainage and cleaning. Self-draining may be achieved by constructing the ductwork on a suitable grade. Where ductwork must pass through a watertight wall or floor below the relevant flood level, a closure assembly operated from above the relevant elevation set out under B1 or B2 of **Schedules 2A** and **2B** should protect the ductwork.

Sewer

All sewer connections to properties in flood prone areas are to be fitted with reflux valves.

SCHEDULE 3B
FLOOD COMPATIBLE MATERIALS

Building Component	Flood Compatible Material	Building Component	Flood Compatible Material
Flooring and Sub Floor Structure	• Concrete slab-on-ground monolith construction. Note: clay filling is not permitted beneath slab-on-ground construction which could be inundated. • Pier and beam construction or • Suspended reinforced concrete slab	**Doors**	• Solid panel with waterproof adhesives • Flush door with marine ply filled with closed cell foam • Painted material construction • Aluminium or galvanised steel frame
Floor Covering	• Clay tiles • Concrete, precast or in situ • Concrete tiles • Epoxy formed-in-place • Mastic flooring, formed-in-place • Rubber sheets or tiles with chemical set adhesive • Silicone floors formed-in-place • Vinyl sheets or tiles with chemical-set adhesive • Ceramic tiles, fixed with mortar or chemical set adhesive • Asphalt tiles, fixed with water resistant adhesive • Removable rubber-backed carpet	**Wall and Ceiling Linings**	• Brick, face or glazed • Clay tile glazed in waterproof mortar • Concrete • Concrete block • Steel with waterproof applications • Stone natural solid or veneer, waterproof grout • Glass blocks • Glass • Plastic sheeting or wall with waterproof adhesive
Wall Structure	Solid brickwork, blockwork, reinforced, concrete or mass concrete	**Insulation**	• Foam or closed cell types
Windows	Aluminium frame with stainless steel or brass rollers	**Nails, Bolts, Hinges and Fittings**	• Galvanised • Removable pin hinges