

Section 9.3.6 presents results of the damages assessment undertaken for the potential mitigation options which were compared against the existing scenario so that the feasibility of the options can be determined.

5.1.1. Residential Properties

The flood damages assessment for residential development was undertaken in accordance with OEH guidelines (Reference 10). For residential properties, external damages (damages caused by flooding below the floor level) were set at \$6,700 and additional costs for clean-up as \$4,000. For additional accommodation costs or loss of rent a value of \$220 per week was allowed assuming that the property would have to be unoccupied for up to three weeks. Internal (contents) damages were allocated a maximum value of \$33,750 occurring at a depth of 0.5 m above the building floor level (and linearly proportioned between the depths of 0 to 0.5 m). Structural damages vary on whether the property is slab/low set or high set. For the purpose of this study, any property with a floor level of 0.5 m or more above ground level was assumed to be high set. For two storey properties, damages (apart from external damages) are reduced by a factor of 70% where only the ground floor is flooded as it is assumed some contents will be on the upper floor and unaffected and that structural damage costs will be less. In some instances external damage may occur even where the property is not inundated above floor level and therefore tangible damages include external damages which may occur with or without house floor inundation.

A summary of the residential flood damages for the Centennial Park catchment is provided in Table 5. Overall, for residential properties in the catchment there is little difference in the average tangible damages per property for all the design events analysis up to the 1% AEP event. This is reflective of the relatively small differences in flood levels between the design flood events. Average damage per property increases at events larger than the 1% AEP when more properties become flooded above floor level. Note that the terminology used refers to a property or lot being the land within the ownership boundary. Flooding of a property does not necessarily mean flooding above floor level of a building on that property/lot.

Table 5: Estimated Residential Flood Damages for Centennial Park Catchment

Event	Number of Properties Flood Affected	No. of Properties Flooded Above Floor Level	Total Tangible Flood Damages	Average Tangible Damages Per Flood Affected Property
PMF	86	57	\$ 3,532,400	\$ 41,100
0.2%	83	37	\$ 2,422,200	\$ 29,200
1.0%	81	28	\$ 1,844,800	\$ 22,800
2.0%	77	25	\$ 1,663,600	\$ 21,600
5.0%	75	23	\$ 1,506,300	\$ 20,100
10.0%	69	19	\$ 1,282,600	\$ 18,600
20.0%	62	13	\$ 910,100	\$ 14,700
50.0%	53	9	\$ 608,700	\$ 11,500
Average Annual Damages (AAD)			\$ 647,400	\$ 7,800

5.1.2. Commercial and Industrial Properties

The tangible flood damage to commercial and industrial properties is more difficult to assess. Commercial and industrial damage estimates are more uncertain and larger than residential damages. Commercial and industrial damage estimates can vary significantly depending on:

- Type of business – stock based or not;
- Duration of flooding – affects how long a business may be closed for not just whether the business itself is closed but when access to it becomes available;
- Ability to move stock or assets before onset of flooding - some large machinery will not be able to be moved and in other instances there may be no sufficient warning time to move stock to dry locations; and
- Ability to transfer business to a temporary location.

Costs to business can occur for a range of reasons, some of which will affect some businesses more than others dependent on the magnitude of flooding and the type of businesses. Common flood costs to businesses are:

- Removal and storage of stock before a flood if warning is given;
- Loss of production – caused by damaged stock, assets and availability of staff;
- Loss of stock and/or assets;
- Reduced stock through reduced or no supplies;
- Trade loss – by customers not being able to access the business or through business closure;
- Cost of replacing damages or lost stock or assets; and
- Clean-up costs.

No specific guidance is available for assessing flood damages to non-residential properties. Therefore for this Study, commercial and industrial damages were calculated using the methodology for residential properties but with the costs/damages increased to a value which is consistent with commercial/industrial development. For example, the maximum value of internal (contents) damages was increased to \$95,625 since the building contents are of higher value whilst loss of rent was set at \$1,000 per week to account for the loss of business through having to close for a period. Flooding below floor level uses the same damages curve as the residential properties.

Though the original OEH guidelines for flood damages calculations are not applicable to non-residential properties, they can still be used to create comparable damage figures. The damages value figure should not be taken as an actual likely cost rather it is useful when comparing potential management options and for benefit-cost analysis.

A summary of the commercial/industrial flood damages for the Centennial Park catchment is provided in Table 6. AAD for the surveyed commercial/industrial properties is less than that for

residential properties but there are no flood affected properties above floor level for the commercial/industrial properties.

Table 6: Estimated Commercial and Industrial Flood Damages for Centennial Park Catchment

Event	Number of Properties Flood Affected	No. of Properties Flooded Above Floor Level	Total Tangible Flood Damages	Average Tangible Damages Per Flood Affected Property
PMF	4	0	\$ 8,100	\$ 2,000
0.2%	3	0	\$ 5,700	\$ 1,900
1.0%	3	0	\$ 5,300	\$ 1,800
2.0%	3	0	\$ 5,100	\$ 1,700
5.0%	2	0	\$ 4,900	\$ 2,400
10.0%	2	0	\$ 4,700	\$ 2,300
20.0%	2	0	\$ 4,500	\$ 2,300
50.0%	2	0	\$ 4,300	\$ 2,100
Average Annual Damages (AAD)			\$ 3,300	\$ 1,100

5.1.3. Climate Change

A damages assessment was carried out for a climate change scenario to estimate the potential increase in flood damages. This scenario entails producing the range of design flood results under one of the rainfall increase scenarios (+10% increase). It should be noted that large uncertainty exists in the estimation of climate change effects on extreme rainfall, and so the scenario is only an example of one possible climate change scenario. For this reason, it should be used as an indication of general sensitivity of the economic damages to changes in rainfall, and not an accurate estimate of what damages will be in the future. Table 7 lists the damages estimate.

Table 7: Estimated Combined Flood Damages Under Climate Change Scenario

Event	Number of Properties Flood Affected	No. of Properties Flooded Above Floor Level	Total Tangible Flood Damages	Average Tangible Damages Per Flood Affected Property
PMF	90	61	\$ 3,790,600	\$ 42,100
0.2%	88	39	\$ 2,549,300	\$ 29,000
1.0%	85	29	\$ 1,944,900	\$ 22,900
2.0%	83	28	\$ 1,842,300	\$ 22,200
5.0%	79	25	\$ 1,655,900	\$ 21,000
10.0%	73	23	\$ 1,488,800	\$ 20,400
20.0%	69	15	\$ 1,022,700	\$ 14,800
50.0%	60	9	\$ 654,800	\$ 10,900
Average Annual Damages (AAD)			\$ 715,300	\$ 8,500

5.2. Intangible Flood Damages

The intangible damages associated with flooding, by their nature, are inherently more difficult to estimate in monetary terms. In addition to the tangible damages discussed previously,

additional costs/damages are incurred by residents affected by flooding, such as stress, risk/loss to life, injury, loss of sentimental items etc. It is not possible to put a monetary value on the intangible damages as they are likely to vary dramatically between each flood (from a negligible amount to several hundred times greater than the tangible damages) and depend on a range of factors such as the size of flood, the individuals affected, and community preparedness. However, it is still important that the consideration of intangible damages is included when considering the impacts of flooding on a community.

Post flood damages surveys have linked flooding to stress, ill-health and trauma for the residents. For example the loss of memorabilia, pets, insurance papers and other items without fixed costs and of sentimental value may cause stress and subsequent ill-health. In addition flooding may affect personal relationships and lead to stress in domestic and work situations. In addition to the stress caused during an event (from concern over property damage, risk to life for the individuals or their family, clean up etc.) many residents who have experienced a major flood are fearful of the occurrence of another flood event and the associated damage. The extent of the stress depends on the individual and although the majority of flood victims recover, these effects can lead to a reduction in quality of life for the flood victims.

During any flood event there is the potential for injury as well as loss of life due to causes such as drowning, floating debris or illness from polluted water. Generally, the higher the flood velocities and depths the higher the risk. Within the Centennial Park catchment area, the high hazard areas include Driver Avenue and trapped low points with high flood depths, i.e. at Lang Road, Poate Road, Leinster and Stewart Street. However, there will always be local high risk (high hazard) areas where flows may be concentrated around buildings or other structures within low hazard areas.

6. FLOOD EMERGENCY RESPONSE ARRANGEMENTS

6.1. Flood Emergency Response

The majority of flooding within the Centennial Park catchment is characterised by overland flow. The critical duration is between 30 and 60 minutes across the catchment, with the peak of the flood reached approximately 1 hour after the start of the storm. This is considered short duration “flash” flooding.

Due to the short interval between the start of the storm and the peak of the flood, there is little in the way of warning that can be provided. Any warning provided would be for immediate safety precautions such as temporary refuge (if available nearby or onsite), raising of items off the ground and accounting for people on site.

The short duration until flooding occurs does not allow sufficient time to evacuate residents from their properties. In these situations, evacuation is generally not recommended as the response during a flood event as it is likely to be hurried and uncoordinated, which can expose evacuees to a hazardous situation. As such, the preferred response to flooding in flash flooding catchments is for people to remain within the property, preferably within the upper levels if available. The suitability of the shelter-in-place approach should be considered in consultation with the State Emergency Service (SES) for the preparation of a Local Flood Plan. Assessment of evacuation and emergency response arrangements is given in Sections 9.4.2 and 9.4.4.

It is important that residents are aware of signs that will signal an approaching flood, and are aware of the correct response such that the small time period before the flood arrives may be used as effectively as possible to move people and belongings to a close, safe location.

The nature of the flood problem in the study area does not lend itself to a managed flood response. The issues undermining a planned response are as follows:

- Lack of effective warning time;
- Flood issue is distributed rather than aggregated;
- Difficulty with vehicle movement during an event; and finally
- The flash nature of the flooding. Note that where rainfall exceeds 5 year ARI intensity generally speaking vehicle movement will be limited by visibility.

As such, and given the lack of a specific response plan at this time, it is reasonable to suggest that SES response will be ad hoc and demand based. Arguably then the most critical element of SES response will be flexibility.

The largest impediment to operational flexibility is likely to be vehicle movement. As such in looking at improving flood risk via enhanced flood emergency response the study has focussed on the roads that may be cut in the event of flooding.

Given the relatively low risk nature of most property flooding it is reasonable to assume that

flooded roads will be one of the highest risk areas during flooding. As such road locations subject to inundation must be a priority for management.

6.2. Flood Emergency Responses Documentation

Flood emergency measures are an effective means of reducing the costs of flooding and managing the continuing and residual risks to the area. Current flood emergency response arrangements for managing flooding in the Centennial Park catchment are discussed as follows.

6.2.1. DISPLAN

The Centennial Park catchment is located within the Sydney East Emergency Management District. Flood emergency management for the study area is organised under the NSW Disaster Plan (2010) (DISPLAN). No district DISPLAN has been prepared for this district.

The DISPLAN details emergency preparedness, response and recovery arrangement for NSW to ensure the coordinated response to emergencies by all agencies having responsibilities and functions in emergencies.

The DISPLAN has been prepared to coordinate the emergency management measures necessary at State level when an emergency occurs, and to provide direction at District and Local level.

The plan is consistent with district plans prepared for areas across NSW and covers the following aspects at a state level:

- Roles and strategies for prevention of disasters;
- Planning and preparation measures;
- Control, coordination and communication arrangements;
- Roles and responsibilities of agencies and officers;
- Conduct of response operations; and
- Co-ordination of immediate recovery measures.

The DISPLAN states that:

“Each District and Local Emergency Management Committee is to develop and maintain its own District / Local Disaster Plan, with appropriate Supporting Plans and Sub Plans, as required by Functional Area Coordinators and Combat Agency Controllers at the appropriate level. Supporting plans are to be the exception at local level and their development must be approved by District Functional Area Coordinators.”

It is recommended that a DISPLAN be prepared for the Sydney East Emergency Management District to outline emergency response arrangement specific to the district. In particular the purpose of a District DISPLAN is to:

- Identify responsibilities at a District and Local level in regards to the prevention, preparation, response and recovery for each type of emergency situation likely to affect the district;
- Detail arrangements for coordinating resource support during emergency operations at both a District and Local level;
- Outline the tasks to be performed in the event of an emergency at a District and Local level;
- Specifies the responsibilities of the East Metropolitan District Emergency Operations Controller and Local Emergency Operations Controllers within the East Metro EM District;
- Detail the responsibilities for the identification, development and implementation of prevention and mitigation strategies;
- Detail the responsibilities of the District and Local Emergency Management Committees within the District;
- Detail agreed Agency and Functional Area roles and responsibilities in preparation for, response to and recovery from, emergencies;
- Outline the control, coordination and liaison arrangements at District and Local levels;
- Detail arrangements for the acquisition and coordination of resources;
- Detail public warning systems and responsibility for implementation;
- Detail public information arrangements and public education responsibilities;
- Specifies arrangements for reporting before, during and after an operation; and
- Detail the arrangements for the review, testing, evaluation and maintenance of the Plan.

6.2.2. Local Flood Plan

A local flood plan has not been prepared for the local area containing the Centennial Park catchment. As such, the New South Wales State Flood Sub-plan (2008) is used to set out the arrangements for the emergency management of flooding.

The State Flood Sub-plan is a sub-plan to the state DISPLAN. The Sub-plan sets out the emergency management aspects of prevention, preparation, response and initial recovery arrangements for flooding and the responsibilities of agencies and organisations with regards to these functions.

There is a requirement for the development and maintenance of a Flood Sub-plan for:

- The State of New South Wales;
- Each SES Region; and
- Each council area with a significant flood problem. In some cases the flood problems of more than one council area may be addressed in a single plan or the problems of a single council area may be addressed in more than one.

Annex B of the Sub-plan lists the Local Flood Sub Plans that exist or are to be prepared in New South Wales and indicates which river, creek and/or lake systems are to be covered in each

plan.

The City of Sydney is not listed in Annex B. However, it may be useful for the City of Sydney to prepare a Local Flood Plan in conjunction with the SES to outline the following details:

- Evacuation centres in close proximity to the floodplain which allow flood free access to the centres and are flood free sites;
- Inclusion of a description of local flooding conditions;
- Identification of potentially flood affected vulnerable facilities; and
- Identification of key access roads subject to flooding.

6.2.3. Emergency Service Operators

The emergency response to any flooding of the Centennial Park catchment will be coordinated by the lead combat agency, the SES, from their Local Command Centre located at Erskineville. However, the City of Sydney Security and Emergency Management Centre located at Town Hall is on the notification list for SES flood warning alerts and direct liaison between the SES and the Security and Emergency Management Centre may be conducted via a dedicated radio frequency.

The Manager - Security and Emergency Management may then pass on the flood warnings to any affected Council or Community Building within the Centennial Park catchment.

The Security and Emergency Management Centre will continue to receive regular updates from the SES throughout a flood event.

The relevant flood information from the draft Centennial Park Flood Study (Reference 2) should be transferred to the Security and Emergency Management Centre.

6.2.3.1. Sydney Cricket Ground and Sydney Football Stadium

There is a separate emergency response arrangement for the Sydney Cricket Ground and Sydney Football Stadium, which are operated by the Sydney Cricket and Sports Ground Trust. In the event of a flood in the catchment, the grounds' Emergency Control Organisation will assess the risk to patrons and determine whether it is safe for people to leave. The risk is concentrated to patrons who may attempt to cross floodwaters in the Driver Road hotspot (described in Section 3.3.3). If there is an evacuation path available, the route will be regulated by emergency wardens. There is no hazardous inundation in the stadiums themselves, meaning they can be used as refuges if need be.

6.2.4. Flood Warning Systems

The critical duration and response times for the catchment limit the implementation of a flood warning system. The short duration flooding experienced in local systems is not well suited to flood warning systems. However, for areas prone to flash flood within the catchment, the BoM

provides general warning services, including:

- Severe Thunderstorm Warnings
- Severe Weather Warnings
- Flood Watches

These services are typically issued for a much larger region, or catchment, that includes the local flash flood site. This information can sometime be used at a local level as discussed below.

6.2.4.1. Flood Warnings Issued by BOM

The Centennial Park catchment is affected by flash flooding (i.e. floods where the warning time is less than 6 hours). As such it is difficult to provide any flood warning in advance of floods. Where possible, the Bureau of Meteorology (BoM) will issue a severe weather / flood warning to the Regional SES headquarters in Bankstown. Where that alert is relevant to the Centennial Park catchment, the SES Regional Command will pass the BoM's warning on to the Local Command based in Erskineville. In some cases, 2-3 days advanced notice may be available (e.g. where an East Coast Low develops off Sydney). However, at other times it may only be possible to issue a flood warning a few hours in advance, if at all.

6.2.4.2. Activation of Local SES Command

SES staff are advised and placed on alert when the SES Local Command has been issued with a flood warning by the BoM. The BoM's flood warning is also forwarded by SMS to the relevant individuals and organisations, including the City of Sydney Security and Emergency Management Centre located at Town Hall.

It is noted that the SES is the designated lead combat agency in an emergency such as a flood event. However, local authorities may wish to act on the advice provided by the SES to minimize the level of risk in the lead up to the flood event. Depending on the amount of lead time provided, Council may undertake any relevant priority works, such as cleaning out storm water pits to reduce the risk of blockage. In addition, Council's Rangers are placed on standby and report any issue directly to the SES (e.g. cars parked in overland flow paths, etc.).

6.3. Access and Movement During Flood Events

Any flood response suggested for the study area must take into account the availability of flood free access, and the ease with which movement may be accomplished. Movement may be evacuation from flood affected areas, medical personnel attempting to provide aid, or SES personnel installing flood defences.

6.3.1. Access Road Flooding

The catchment area has two arterial roads (Moore Park Road and Anzac Parade) and one main

road (Lang Road) that are flood affected, and a smaller road (Driver Avenue) where traffic will be impeded in a flood event. Both arterial roads connect the CBD to the eastern suburbs and convey a significant volume of vehicle traffic. Moore Park Road has little upstream catchment and, in frequent events, only has significant inundation in the gutters and adjoining area, the depths of which are listed in Table 8. As shown in the table, the Anzac Parade bus lane has around 0.3 m in frequent events and up to 0.5 m in the 1% AEP event. On Lang Road, there is up to 1 m of water in frequent events, while Driver Avenue has around the same depth.

Table 9 lists the rate of rise in metres per hour for the same locations listed in Table 8, for the 1 hour duration storm. It should be noted that the rate of rise will vary with other event durations, and therefore the values presented are only to give a general approximation of rate of rise and how it varies in the catchment. Also, the five locations (except for Driver Avenue) reach their peak depth within one hour of the event occurring, hence the rates of rise are greater than the peak flood depths. Rate of rise is around 1 m/hour in frequent events, except for on Anzac Parade which is around 0.4 m/hour.

Table 8: Major Road Peak Flood Depths (m) for Various Events

ID	Road Location	2 year ARI	5 year ARI	10% AEP	5% AEP	2% AEP	1% AEP	0.2% AEP	PMF
1	Lang Road near Driver Avenue	1.0	1.0	1.1	1.1	1.1	1.2	1.3	1.6
2	Driver Avenue near SCG	1.0	1.3	1.4	1.5	1.6	1.7	1.7	2.8
3	Lang Road near Darvall Street	0.3	0.5	0.5	0.6	0.6	0.7	0.7	0.9
4	Anzac Parade bus lane near Robertson Road Fields	0.2	0.3	0.3	0.4	0.4	0.5	0.5	1.0
5	Moore Park Road near Driver Avenue	0.5	0.5	0.5	0.6	0.6	0.6	0.6	0.7

Table 9: Major Road Flooding Rate of Rise (m/hour) for Various Events (1 hour duration event)

ID	Road Location	2 year ARI	5 year ARI	10% AEP	5% AEP	2% AEP	1% AEP	PMF
1	Lang Road near Driver Avenue	1.2	1.6	1.7	1.9	1.9	2.0	2.2
2	Driver Avenue near SCG	1.0	1.3	1.4	1.5	1.5	1.6	3.4
3	Lang Road near Darvall Street	0.7	1.0	1.1	1.2	1.4	1.5	1.9
4	Anzac Parade bus lane near Robertson Road Fields	0.4	0.3	0.4	0.5	0.6	0.7	1.4
5	Moore Park Road near Driver Avenue	1.1	1.2	1.3	1.3	1.4	1.3	1.9

For the 1% AEP flood event, roads cut (as per Figure 20) are shown in Table 10.

Table 10: Major Roads Cut in the 1% AEP Event

Road Location	Description
Lang Road near Driver Avenue	Flood depths are up to 2 m and a depth of greater than 0.3 m will persist for up to 4 hours given the critical storm modelled (1 hour)
Driver Avenue near SCG	Flood depths are up to 1.6 m and a depth of greater than 0.3 m will persist for up to 4 hours given the critical storm modelled (1 hour)
Lang Road near Darvall Street	Flood depths of up to 1.5 m and persist for up to 1 hour for the critical storm modelled (1 hour)
Anzac Parade bus lane near Robertson Road Fields	Flood depths of up to 0.7 m and persist for up to 1 hour for the critical storm modelled (1 hour)
Moore Park Road near Driver Avenue	Flood depths of up to 0.6 m and persist for up to 30 minutes for the critical storm modelled (1 hour)

Following a review of this information revised SES plans might allot responsibility for management of these road closures. Note SES involvement is likely to be required given the presumable limited mobility of Council employees in the event of a severe flood event.

6.4. Flood Emergency Response Classifications

To assist in the planning and implementation of response strategies, the SES in conjunction with OEH has developed guidelines to classify communities according to the impact that flooding has upon them. These Emergency Response Planning (ERP) classifications (Reference 8) consider flood affected communities as those in which the normal functioning of services is altered, either directly or indirectly, because a flood results in the need for external assistance. This impact relates directly to the operational issues of evacuation, resupply and rescue. Based on the guidelines, communities are classified as either; Flood Islands; Road Access Areas; Overland Access Areas; Trapped Perimeter Areas or Indirectly Affected Areas and when used with the SES Requirements Guideline (Reference 8). The ERP classification can identify the type and scale of information needed by the SES to assist in emergency response planning (refer to Table 11).

Table 11: Emergency Response Planning Classifications of Communities

Classification	Response Required		
	Resupply	Rescue/Medivac	Evacuation
High flood island	Yes	Possibly	Possibly
Low flood island	No	Yes	Yes
Area with rising road access	No	Possibly	Yes
Area with overland escape routes	No	Possibly	Yes
Low trapped perimeter	No	Yes	Yes
High trapped perimeter	Yes	Possibly	Possibly
Indirectly affected areas	Possibly	Possibly	Possibly

Key considerations for flood emergency response planning in these areas include:

- Cutting of external access isolating an area;
- Key internal roads being cut;
- Transport infrastructure being shut down or unable to operate at maximum efficiency;
- Flooding of any key response infrastructure such as hospitals, evacuation centres,

- emergency services sites;
- Risk of flooding to key public utilities such as gas, power, sewerage; and
 - The extent of the area flooded.

Flood liable areas within the study area have been classified according to the ERP classification above, with the additional criteria of flood depths being greater than 0.1 m. If only the flood extent was used in the Centennial Park catchment, areas surrounded by less than 0.1 m would be classified as flood islands, when in reality, people could move through this water without concern. Therefore, all flood depths of less than 0.1 m were removed from the PMF flood extents prior to classification. The ERP classifications for the study area are shown in Figure 5.

This figure shows that a large proportion of the study area has been classified as high flood island due to the reasonably high depths that would occur in road reserves surrounding properties, prior to inundation of the properties themselves. Adjacent to this are several rising road access areas which allow access out of the flood affected area.

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7. POLICIES AND PLANNING

7.1. Legislative and Planning Context

The NSW State Government's Flood Policy provides a framework to ensure the sustainable use of floodplain environments. The Policy is specifically structured to provide solutions to existing flooding problems in rural and urban areas. In addition, the Policy provides a means of ensuring that any 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. Furthermore, Section 117(2) of the 1979 Environmental Planning and Assessment Act Direction 15 states that Council must ensure development is appropriate in regard to flood risk and that furthermore it does not cause impacts on adjoining property.

Councils have a number of planning tools available to them in order to fulfil this role, including the Local Environment Plan (LEP) and Development Control Plans (DCPs). Detail of the specific planning documents relevant to Centennial Park is provided below.

7.1.1. NSW Flood Prone Land Policy

The primary objective of the NSW Government's Flood Prone Land Policy is to reduce the impact of flooding and flood liability on individual owners and occupiers of flood prone property and reduce public and private losses resulting from floods whilst utilising ecologically positive methods wherever possible.

The NSW Floodplain Development Manual (Reference 1) relates to the development of flood liable land for the purposes of Section 733 of the Local Government Act 1993 and incorporates the NSW Flood Prone Land Policy.

The Manual outlines a merits based approach to floodplain management. At the strategic level this allows for the consideration of social, economic, cultural, ecological and flooding issues to determine strategies for the management of flood risk. The Manual recognises differences between urban and rural floodplain issues. Although it maintains that the same overall floodplain management approach should apply to both, it recognises that a different emphasis is required for each type of floodplain.

7.1.2. Existing Council Policy

With regards to flood risk management, Councils use Local Environment Plans (LEP) and Development Control Plans (DCP) to set policies and development controls. City of Sydney recently adopted the Sydney Local Environmental Plan 2012 and Sydney Development Control Plan 2012 and these are discussed in the following sections in relation to flood risk and management. Council has also prepared an Interim Floodplain Management Policy that will operate until Council completes floodplain risk management plans for its entire LGA and then

integrates these outcomes into planning controls.

Sydney LEP 2012

This planning instrument provides overall objectives, zones and core development standards, including provisions related to “flood planning” applicable to land at or below the flood planning level. Clause 7.15 of the Plan states the following objectives in relation to flood planning:

- To minimise the flood risk to life and property associated with the use of land;
- To allow development on land that is compatible with the land’s flood hazard, taking into consideration projected changes as a result of climate change; and
- To avoid significant adverse impacts on flood behaviour and the environment.

The Clause stipulates that consent will not be granted to development on land to which this Clause applies unless Council is satisfied that the development:

- Is compatible with the flood hazard of the land;
- Is not likely to significantly adversely affect flood behaviour resulting in detrimental increases in the potential flood affectation of other development or properties;
- Incorporates appropriate measures to manage risk to life from flood;
- Is not likely to significantly adversely affect the environment or cause avoidable erosion, siltation, destruction of riparian vegetation or a reduction in the stability of river banks or watercourses; and
- Is not likely to result in unsustainable social and economic costs to the community as a consequence of flooding.

Under this Clause, the flood planning level is defined as the level of a 1% AEP flood event plus 0.5 metres freeboard.

Sydney DCP 2012

The purpose of this plan is to supplement the LEP and provide more detailed provisions to guide development. It came into effect on the same day as the LEP and must be read in conjunction with the provision of the LEP.

Prescriptive planning controls are provided in Section 3.7 of the document. The objectives of these planning controls are to:

- Ensure an integrated approach to water management across the City through the use of water sensitive urban design principles;
- Encourage sustainable water use practices;
- Assist in the management of stormwater to minimise flooding and reduce the effects of stormwater pollution on receiving waterways;
- Ensure that development manages and mitigates flood risk, and does not exacerbate the potential for flood damage or hazard to existing development and to the public domain; and

- Ensure that development above the flood planning level as defined in the Sydney LEP 2012 will minimise the impact of stormwater and flooding on other developments and the public domain both during and after the event.

Interim Floodplain Management Policy

This interim Policy (Reference 7) was adopted in May 2014 and provides direction with respect to how floodplains are managed within the LGA of the City of Sydney. This Policy has been prepared having regard to the provisions of the NSW Flood Policy and NSW Floodplain Development Manual (Reference 1) and is to be read in conjunction with the provisions of the LEP and DCP.

The Policy outlines Council responsibilities in managing floodplains and it provides controls to facilitate a consistent, technically sound and best practice approach for the management of flood risk within the LGA. This interim policy will be withdrawn once Council complete Floodplain Risk Management Plans for the entire LGA and then integrate outcomes from these plans into planning controls.

The document provides general requirements for proposed development on flood prone land, Flood Planning Level requirements for different development types and guidelines on flood compatible materials. It makes the following requirements of new development on flood prone land in the area:

- It stipulates the information that is to be provided with a development application relevant to the various controls, for example building layouts and floor plans;
- It gives a criterion that must be satisfied in the case of a development not meeting the relevant Prescriptive Provisions in Sydney DCP 2012. These criteria include the development being compatible with established flood hazard of the land, not impacting flood behaviour so that other properties' affectation is worsened and incorporating appropriate measures to manage risk to life from flood;
- Concession is made to minor additions being made to existing properties, as these additions are acknowledged to not present an unmanageable risk to life. The concession can be given to dwelling additions of up to 40 m² and commercial industrial/commercial additions of up to 100 m² or 20% of Gross Floor Area. The concession is granted no more than once per development;
- It gives general requirements for development on flood prone land, including design requirements for fencing, minimum floor level, car parking, filling of flood prone land and the impact of climate change;
- It sets flood planning levels to be adhered to by various types of development. For example habitable rooms affected by mainstream flooding are to be at or above the 1% AEP flood level + 0.5 m. Other levels are given for properties affected by local drainage flooding (as per the Policy's definition), industrial/commercial development, car parks and critical facilities; and
- It specifies flood compatible materials for various components of a development, for example use of concrete slab-on-ground monolith construction or suspended reinforced concrete slab for flooring.

7.2. Planning Recommendations

Based on the review of the planning documents presented in the previous sections, the following recommendations have been made:

- There is a lack of consistency between the Sydney LEP 2012 and the Sydney DCP 2012. It is recommended that either the LEP or the DCP or both are updated to ensure accurate cross referencing between the two documents. Also the requirements for a site specific flood study are provided in the Sydney DCP 2012. Though the DCP notes that the Sydney LEP 2012 outlines when a site specific flood study is required, the LEP does not contain this information. Either the LEP or the DCP or both should be updated to ensure this information is provided;
- Flood related development controls and requirements are provided in the Interim Floodplain Management Policy (Reference 7). Reference to this policy should be included in the DCP or the key controls outlined in the Policy could also be included in the DCP. Council's current position on climate change requirements should also be informed in the DCP as outlined in the Policy;
- Consideration of emergency response provisions in new development with regards to short duration flooding in the catchment should also be included in the Interim Floodplain Management Policy (Reference 7); and
- There may be opportunities to incorporate flood management measures into new developments as a condition of consent, Section 94 contribution offsets or government related funding. The nature of the flood controls implemented will be dependent on the location of the development, the flooding behaviour and the type of development. However, allowance and / or requirements for these works could be identified through amendments to the Sydney DCP 2012 or the Interim Floodplain Management Policy (Reference 7).

8. FLOOD PLANNING

8.1. Flood Planning Level (FPL)

The FPL is the height at which new building floor levels should be built. Due to the mixture of residential and commercial development in the Centennial Park catchment, a variety of FPLs may be applicable depending on where in the catchment development is being considered and also based on the type of development being proposed.

A variety of factors need to be considered when calculating the FPL for an area. A key consideration is the flood behaviour and resultant risk to life and property. The Floodplain Development Manual (Reference 1) identifies the following issues to be considered:

- Risk to life;
- Long term strategic plan for land use near and on the floodplain;
- Existing and potential land use;
- Current flood level used for planning purposes;
- Land availability and its needs;
- FPL for flood modification measures (levee banks etc);
- Changes in potential flood damages caused by selecting a particular flood planning level;
- Consequences of floods larger than that selected for the FPL;
- Environmental issues along the flood corridor;
- Flood warning, emergency response and evacuation issues;
- Flood readiness of the community (both present and future);
- Possibility of creating a false sense of security within the community;
- Land values and social equity;
- Potential impact of future development on flooding;
- Duty of care.

8.1.1. Likelihood of Flooding

As a guide, Table 12 has been reproduced from the NSW Floodplain Development Manual 2005 to indicate the likelihood of the occurrence of an event in an average lifetime to indicate the potential risk to life.

Analysis of the data presented in Table 12 gives a perspective on the flood risk over an average lifetime. The data indicates that there is a 50% chance of a 100 Year ARI (1% AEP) event occurring at least once in a 70 year period. Given this potential, it is reasonable from a risk management perspective to give further consideration to the adoption of the 1% AEP flood event as the basis for the FPL. Given the social issues associated with a flood event, and the non-tangible effects such as stress and trauma, it is appropriate to limit the exposure of people to floods.

Note that there still remains a 30% chance of exposure to at least one flood of a 200 Year ARI (0.5% AEP) magnitude over a 70 year period. This gives rise to the consideration of the

adoption of a rarer flood event (such as the PMF) as the flood planning level for some types of development.

Table 12: Likelihood of given design events occurring in a period of 70 years

Likelihood of Occurrence in Any Year (ARI)	Probability of Experiencing At Least One Event in 70 Years (%)	Probability of Experiencing At Least Two Events in 70 Years (%)
10	99.9	99.3
20	97	86
50	75	41
100	50	16
200	30	5

8.1.2. Land Use and Planning

The hydrological regime of the catchment can change as a result of changes to the land-use, particularly with an increase in the density of development. The removal of pervious areas in the catchment can increase the peak flow arriving at various locations, and hence the flood levels and flood hazards can be increased.

A potential impact on flooding can arise through the intensification of development on the floodplain, which may either remove flood storage or impact on the conveyance of flows. The Sydney DCP 2012 currently outlined controls relating to the installation of onsite detention to manage increased impervious area. No provisions exist within the current DCP 2012 or LEP 2012 to limit development within floodway or areas or limit filling in storage areas. Provisions to these issues, however, have been included in the Interim Floodplain Management Policy (Reference 7).

8.1.3. Freeboard Selection

A freeboard ranging from 0.3 – 0.5 metres is commonly adopted in determining the FPL. The freeboard accounts for uncertainties in deriving the design flood levels and as such should be used as a safety margin for the adopted FPL. The freeboard may account for factors such as:

- Changes in the catchment;
- Changes in flowpath vegetation;
- Accuracy of the model inputs (e.g. ground survey, design rainfall inputs for the area);
- Model sensitivity:
 - Local flood behaviour (due to local obstructions);
 - Wave action (e.g. wind induced waves or waves from vehicles);
 - Blockage of drainage network; and
 - Climate change (affecting rainfall).

The various elements factored into a freeboard can be summarised as follows:

- Afflux (local increase in flood levels due to small local obstructions not accounted for in

the modelling) (+0.1 m);

- Local wave action (trucks and other vehicles) (allowance of +0.1 m is typical);
- Climate change impacts on rainfall (0.02 m to 0.24 m, mean 0.08 m, as per Centennial Park Flood Study (2013))
- Sensitivity of the model +/-0.05 m.

Based on this analysis, the total sum of the likely variations is between 250 mm and 500 mm, depending on climate change, which has a varying effect across the catchment. Based on this range, the freeboard recommended in the Interim Floodplain Management Policy (Reference 7) is suitable for the catchment. The policy specifies a freeboard of 500 mm, except for in areas with local drainage flooding. In the policy, local drainage flooding refers to where there the 1% AEP depth is less than 0.25 m and the area is not in, or influenced by, a trapped low point. In these areas, the flood planning level is two times the depth of flow with a minimum of 0.3 m. Given the difference in flood depth between the 1% AEP and the PMF in the catchment, this freeboard is suitable for local drainage flooding.

When applied to design events less than the PMF, the freeboard may still result in the FPL being higher than the PMF in certain cases.

8.1.4. Current FPL as Adopted by Council

FPL requirements have been outlined by Council in their Interim Floodplain Management Policy (Reference 7). This policy was tested each time a development application was received. The policy provides further details regarding flood planning levels for various types of development within the floodplain and these are outlined in Table 13.

Table 13: Adopted Flood Planning Levels in CoS Interim Floodplain Management Policy (Reference 7)

Development		Type of flooding	Flood Planning Level
Residential	Habitable rooms	Mainstream flooding	1% AEP flood level + 0.5 m
		Local drainage flooding	1% AEP flood level + 0.5 m or Two times the depth of flow with a minimum of 0.3 m above the surrounding surface if the depth of flow in the 1% AEP flood is less than 0.25 m
		Outside floodplain	0.3 m above surrounding ground
	Non-habitable rooms such as a laundry or garage (excluding below-ground car parks)	Mainstream or local drainage flooding	1% AEP flood level
Industrial or	Business	Mainstream or local drainage flooding	Merits approach presented by the applicant with a minimum

Commercial			of 1% AEP flood level
	Schools and child care facilities	Mainstream or local drainage flooding	Merits approach presented by the applicant with a minimum of 1% AEP flood level + 0.5m
	Residential floors within tourist establishments	Mainstream or local drainage flooding	1% AEP floor level + 0.5 m
	Housing for older people or people with disabilities	Mainstream or local drainage flooding	1% AEP flood level + 0.5 m or a the PMF, whichever is the higher
	On-site sewer management (sewer mining)	Mainstream or local drainage flooding	1% AEP floor level
	Retail Floor Levels	Mainstream or local drainage flooding	Merits approach presented by the applicant with a minimum of the 1% AEP flood. The proposal must demonstrate a reasonable balance between flood protection and urban design outcomes for street level activation.
Below-ground garage/ car park	Single property owner with not more than 2 car spaces.	Mainstream or local drainage flooding	1% AEP floor level + 0.5 m
	All other below-ground car parks	Mainstream or local drainage flooding	1% AEP flood level + 0.5 m or the PMF (whichever is the higher)
	Below-ground car park outside floodplain	Outside floodplain	0.3 m above the surrounding surface
Above ground car park	Car parks	Mainstream or local drainage flooding	1% AEP flood level
	Open car parks	Mainstream or local drainage	5% AEP flood level
Critical Facilities	Floor level	Mainstream or local drainage flooding	1% AEP flood level + 0.5m or the PMF (whichever is higher)
	Access to and from critical facility within development site	Mainstream or local drainage flooding	1% AEP flood level

In the policy, Council also provided clarity in the definition of local drainage flooding as opposed to mainstream flooding as follows:

1. Local drainage flooding occurs where:
 - The maximum cross sectional depth of flooding in the local overland flow path through and upstream of the site is less than 0.25 m for the 1% AEP flood; and
 - The development is at least 0.5 m above the 1% AEP flood level at the nearest downstream trapped low point; and
 - The development does not adjoin the nearest upstream trapped low point; and

- Blockage of an upstream trapped low point is unlikely to increase the depth of flow past the property to greater than 0.25 m in the 1% AEP flood.
2. Mainstream flooding occurs where the local drainage flooding criteria cannot be satisfied.
 3. A property is considered to be outside the floodplain where it is above the mainstream and local drainage flood planning levels including freeboard.

The establishment of the flood planning levels in conjunction with the publication of the Interim Floodplain Management Policy is a positive step forward for Council in setting development controls for new developments within the Centennial Park catchment. Nevertheless, it could be helpful to provide several case studies to illustrate how these levels could be applied to individual developments to assist in development applications.

DRAFT

9. FLOODPLAIN RISK MANAGEMENT MEASURES

9.1. General

The NSW Government's Floodplain Development Manual (2005) separates floodplain management measures into three broad categories:

Flood modification measures modify the flood's physical behaviour (depth, velocity) and include flood mitigation dams, retarding basins and levees.

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

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

A number of methods are available for judging the relative merits of competing measures. The benefit/cost (B/C) approach has long been used to quantify the economic worth of each option enabling the ranking against similar projects in other areas. The B/C is the ratio of the net present worth of the reduction in flood damages (benefit) compared to the cost of the works. Generally, the ratio only expresses the reduction in tangible damages as it is difficult to accurately include intangibles (such as anxiety, risk to life, ill health, etc.).

The potential environmental or social impacts of any proposed flood mitigation measure are of great concern to society and these cannot be evaluated using the classic B/C approach. For this reason, a matrix type assessment has been used which enables a value (including non-economic worth) to be assigned to each measure. The public consultation program has ensured that identifiable social and environmental factors were considered in the decision making process for the Centennial Park catchment.

A summary of the measures considered for the catchment and at the specific hotspot locations is provided in Table 14 below and discussed in the following sections.

Table 14: Flood Affected Areas and Investigated Management Options

Hotspot	Flooding issues	Investigated Measures	Measures Reference
Poate Road	Inundation with high depth or velocity, flooding of major roads, many properties flooded above floor	Trunk drainage upgrade from corner of Poate Road to SCG under Fox Studios	FM - CP01

Leinster Street	Localised inundation with high depth, many properties flooded above floor	Trunk drainage upgrade on Leinster and Stewart to Oatley Road and down to More Park Road.	FM - CP02
Lang Road near Darvall Street	Localised inundation with moderate depth, flooding of major roads	Drainage upgrade on Lang road for pipes into Centennial Park.	FM - CP03
Driver Avenue outside the SCG	Localised inundation with high depth, flooding of major roads	Regrade Driver Avenue to allow water to flow down the road rather than pooling in the low point	FM - CP04
Lang Road at Driver Avenue intersection	Localised inundation with high depth, flooding of major roads	Trunk drainage upgrade from Lang Road through a park down Anzac parade to the outlet in Centennial Park.	FM - CP05
Catchment-wide	General flood risk, inundation of major roads	Variable Message Display on Major Roads	RM-CP01
		Evacuation Planning	RM-CP02
		Public Information and Raising Flood Awareness	RM-CP03
		Local Flood Plan and DISPLAN	RM-CP04
		Flood Planning Levels	PM-CP01
		Flood Proofing of Affected Properties	PM-CP02
		Voluntary Purchase	PM-CP03
		Development Control Planning	PM-CP04

9.2. Measures Not Considered Further

During the early phase of this study a review of all possible floodplain management measures and their application in the Centennial Park catchment was undertaken. The measures not taken forward for further consideration, and the reasons for their exclusion, are summarised in the following sections.

9.2.1. Flood Modification - Dams and Retarding Basins

Flood mitigation dams and their smaller urban counterparts termed retarding basins have frequently been used in NSW to reduce peak flows downstream. However, dams are rarely used as a flood mitigation measure for existing development on account of the:

- high cost of construction,
- high cost of land purchase,
- risk of failure of the dam wall,
- likely low B/C ratio,
- lack of suitable sites as a considerable volume of water needs to be impounded by the dam in order to provide a significant reduction in flood level downstream.

This measure was not considered further for the above reasons.

9.2.2. Flood Modification - Levees, Flood Gates and Pumps

Levees are built to exclude previously inundated areas of the floodplain from the river up to a certain design events, and are commonly used on large river systems (e.g. Hunter and Macleay Rivers), but can also be found on small creek systems in urban areas.

Flood gates allow local waters to be drained from the leveed area when the external level is low, but when the river is elevated, the gates prevents floodwaters from entering.

Pumps are also generally associated with levee designs. They are installed to remove local floodwaters from behind levees when flood gates are closed or there are no flood gates.

These measures were not considered further due to the absence of a defined channel or river in the catchment area.

9.2.3. Response Modification – Catchment-Wide Flood Warning

During a major flood it may be necessary for some residents to evacuate their homes. Whilst not all will have their house floors inundated, it is possible that their power, water and sewerage systems could be affected. The amount of evacuation time depends on the available warning time. Providing sufficient warning time has the potential to reduce the social impacts of the flood as well as reducing the strain on emergency services.

The effectiveness of a flood warning systems depends on:

- the maximum potential warning time before the onset of flooding,
- the actual warning time provided before the onset of flooding. This depends on the adequacy of the information gathering network and the skill and knowledge of the operators,
- the flood awareness of the community responding to a warning.

At present there is no flood warning system in place for the Centennial Park catchment area. This is a result of the short time from the start of the rainfall to the flood peak (around 1 hour for the critical storm duration), which would not allow sufficient time for evacuation to occur prior to the flood event. Furthermore, flood risk in the catchment is concentrated at several separate locations, meaning a warning system would not benefit the majority of the area. This option was not considered further for these reasons.

9.2.4. Property modification - House raising

House raising has been widely used throughout NSW to eliminate inundation from habitable floors. However, it has limited application as it is not suitable for all building types. It is also more common in areas where there is a greater depth of inundation than in the Centennial Park catchment.

House raising is suitable for most non-brick, single storey buildings on piers and is particularly

relevant to those houses situated in low hazard areas of the floodplain. The benefit of house raising is that it eliminates inundation to the height of the floor, and consequently reduces the flood damages.

Due to the nature of development and the heavily urbanised city catchment, it is considered highly unlikely that any of the flood affected buildings would be suitable for house raising. As such, this measure has not been considered further.

9.3. Site Specific Management Options

Site specific management options involve specific works aimed at managing the flood risk in a particular part of the catchment. Modifying the flood behaviour at a particular location involves either detaining runoff or improving the drainage capacity. Retarding basins were considered for the area around Lang Road but were discarded after producing limited benefit (see Section 9.3.7).

Measures to increase the capacity or efficiency of the existing piped drainage network include upgrading pipe capacity; re-profiling the pipe network; removing fixed blockages or impediments to flow and improved maintenance. This type of measure was assessed in detail for a number of flood affected areas within the catchment. An overview of the flood affected areas and assessed mitigation options are provided in Table 15 and shown in Figure 21. These options are discussed in detail in Sections 9.3.1 to 9.3.5.

Table 15: Flood Modification Measures

Suburb	Flood Affected Streets/Areas	Proposed Mitigation Options	Ref
Centennial Park	Poate Road adjacent to Fox Studios	Trunk drainage upgrade from corner of Poate Road to SCG under Fox Studios	FM - CP01
Paddington	Leinster and Stewart Street	Trunk drainage upgrade on Leinster and Stewart to Oatley Road up to Moore Park Road.	FM - CP02
Centennial Park	Lang Road near Darvall Street	Drainage upgrade on Lang road for pipes into Centennial Park.	FM - CP03
Moore Park	Driver Avenue outside the SCG	Regrade Driver Avenue to relieve topographic depression	FM - CP04
Moore Park	Lang Road at Driver Avenue intersection	Trunk drainage upgrade up to Centennial Park	FM - CP05

9.3.1. Trunk Drainage Upgrade – Poate Road (FM - CP01)

Option Description

Option FM – CP01 describes a trunk drainage upgrade of the pipe relieving the depression in Poate Road. The upgrade extends approximately 200 m from Poate Road to adjacent to the Sydney Football Stadium, and consists of a 1.5 m diameter replacing the current 525 mm diameter pipe. The upgrade would also involve upgrading the pits and feeder pipe on Poate Road to ensure the upgraded trunk element is at capacity in a 5% AEP event. It should be noted that the location of the existing pipe proposed for upgrade was based on incomplete survey, and that its size and location should be confirmed before any further work is carried out.

Modelled Impacts

The upgrade achieves a significant reduction in the peak flood level in the hotspot; however, it

also increases the peak flood level downstream, through the SCG precinct and on Errol Flynn Boulevard and Lang Road. Figure 23 shows the location of the upgrade and its impact on the 5% AEP peak flood level, while Figure 24 shows the change in hazard in the same event. The reduction in peak flood level is over 1 m in the event shown, and parts of the north side of the street are no longer flooded. Relieving the ponding in this area (via the upgraded pipe) transfers the runoff to the downstream area, where impacts are around 0.3 m around the stadiums, and less than 0.05 m on Lang Road and Driver Avenue. In a 5% AEP event, the option reduces the ponding on Poate Road to low hydraulic hazard, while there is a minimal area that is newly high hazard immediately downstream of the upgraded section.

Evaluation

The option is unlikely to be feasible, based on its significant downstream impact, however, it does demonstrate that the Poate Road flood issue can be largely resolved via a pit and pipe upgrade. The downstream impact affects parts of Fox Studios, the Entertainment Quarter and the SCG precinct, as well as an existing hotspot at Lang Road. These impacts are the direct result of the reduced flooding at Poate Road, and can only be managed with a detention basin in the area (of which there appears to be no opportunity for) or a much longer pipe upgrade, past the Lang Road/Driver Avenue hotspot, which would likely be prohibitively expensive.

9.3.2. Trunk Drainage Upgrade – Stewart and Leinster Street (FM - CP02)

Option Description

Option FM – CP02 describes a trunk drainage upgrade on Leinster Street, Stewart Street and Oatley Road. The upgrade consists of new pits and pipes on Leinster Street and Stewart Street, which drain to the network on Oatley Road, which has also been upgraded. The upgraded pipes have the following dimensions:

- Upgrade of Stewart Street pipes to one 1.2 m diameter pipe;
- Upgrade of Oatley Road pipes to one 2.4 m diameter pipe;
- Upgrade of Leinster Street pipes to two 3.0 m diameter pipes;

The upgraded pipe capacities are designed to transmit the 5% AEP flood. New pipes, rather than using the existing system, were used to avoid the high cost associated with upgrading pipes below properties; however, upgrading of the existing system could also produce similar reductions in flood level.

Modelled Impacts

The upgrade achieves a significant reduction in peak flood level at both Stewart Street and Leinster Street. Figure 26 shows the location of the upgraded and new pipes, and their impact on the 5% AEP peak flood level, while Figure 27 shows the change in hazard in the same event. The reduction in peak flood level is up to 1.2 m on Leinster Street and up to 0.9 m on Stewart Street, with many properties backyards on Leinster Street no longer flooded. As shown on Figure 26, the reduced flood level results in 11 properties no longer being flooded above floor in a 5% AEP event. The upgrade reduces the ponding on both streets to a depth that is categorised as low hazard, and under the option there are no areas of high hazard in the 5% AEP event.

Evaluation

The option produces significant benefit with regards to overfloor flooding and reduction in high hazard flooding, as well having negligible downstream impacts; however, the required drainage elements are exceptionally large and may not be economically or technically feasible. As previously described, the benefit to the area is well defined, with 11 properties no longer being flooded overfloor in a 5% AEP event, and no high hazard inundation in the area in the same event. To achieve these benefits, pipes with a cross-sectional area of up to 14 m² are required, which are both very expensive to construct, and technically difficult to design. Section 9.3.6 has further assessment of the option's economic feasibility.

9.3.3. Drainage Upgrade – Lang Road North (FM - CP03)

Option Description

Option FM – CP03 describes a drainage upgrade on Lang Road near Darvall Street, discharging into Centennial Park. The upgrade consists of upgrading a single pipe beneath Lang Road to have a diameter of 900 mm (currently 450 mm), as well any pit upgrades to ensure they are not restricting flow into the pipe. The upgrade was designed to mitigate a 10% AEP flood event.

Modelled Impacts

The upgrade achieves a localised benefit to the depression on Lang Road, by increasing discharge from the area into Centennial Park. Figure 29 shows the location of the upgrade and its impact on the 5% AEP peak flood level. The figure shows that a large section of Lang Road is no longer flooded, while the remainder has a decrease of 0.2 – 0.5 m in peak flood level. The improved drainage of the area causes an impact of around 0.05 m in Centennial Park, which is considered acceptable.

Evaluation

The option relieves the existing flood issue on Lang Road near Darvall Street, but is difficult to justify due to the cost of works. The reduction in flood level is significant, with an associated reduction in the flood risk to vehicles and pedestrians along the road. In addition, the two properties on Lang Road that are adjacent to the hotspot are no longer flooded in their front yards. However, as these properties are not flooded above floor level in current conditions, there is minimal economic cost associated with the existing flood issue. As a result, the cost of the works will outweigh their limited economic benefit. It is not recommended that the option be carried out for this reason. Nuisance flooding of the properties' front yards may be better managed via flood proofing (see Section 9.4.6).

9.3.4. Trunk Drainage Upgrade – Driver Avenue (FM – CP04)

Option Description

Option FM – CP04 describes a regrading of Driver Avenue, between the Sydney Cricket Ground and Lang Road. The regrading removes the topographic depression on Driver Avenue, increasing the conveyance to the downstream area. As shown on Diagram 1, the option would lower Driver Avenue by up to 3 m, and would require large-scale earth works.

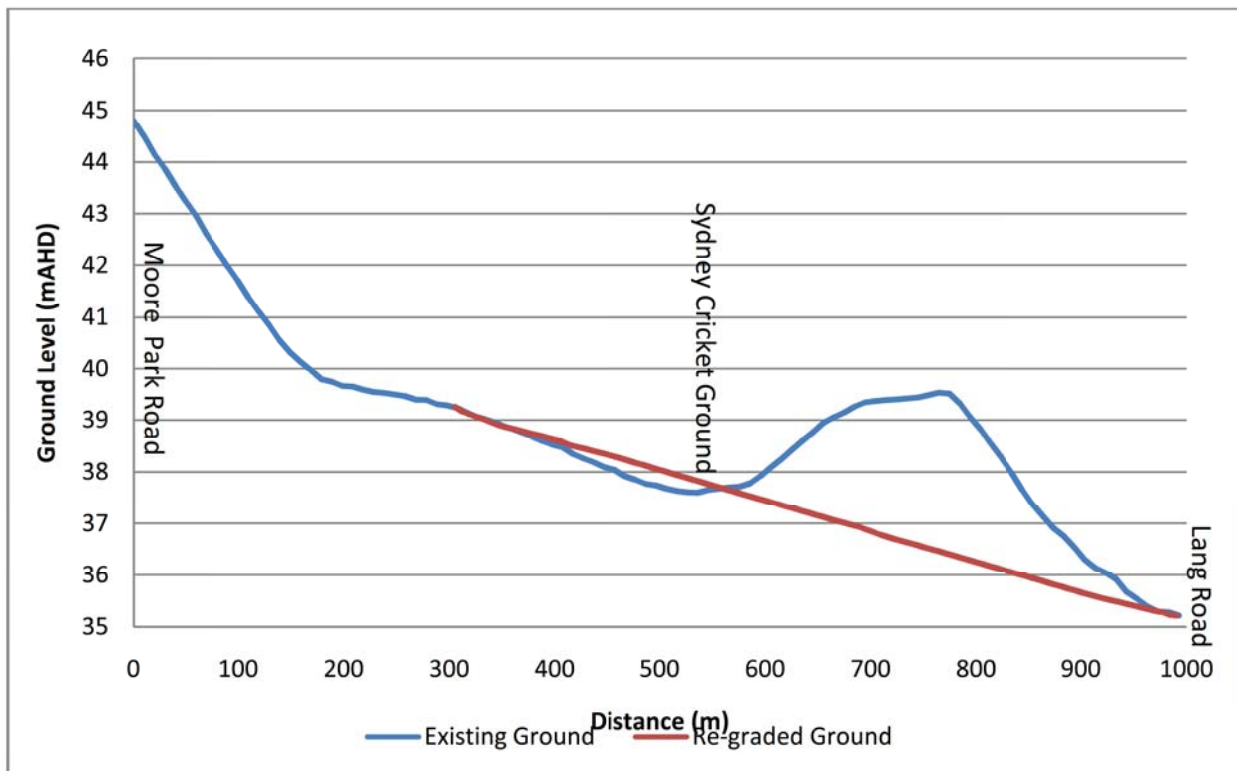


Diagram 1: FM - CP04 Driver Avenue Long Section

Modelled Impacts

The regrading results in a significant reduction of peak flood level on Driver Avenue; however, it also has adverse impacts downstream at Lang Road and Anzac Parade. Figure 31 shows the location of the regrading and its impact on the 10% AEP peak flood level, while Figure 32 shows the change in hazard in the same event. The reduction in flood level is up to 2.4 m on Driver Avenue, while the downstream has an increase of 0.06 m at the Lang Road hotspot, 0.1 m on the Robertson Road Sports Fields, and up to 0.16 m on Anzac Parade. The lowered flood level on Driver Avenue reduces the flooding adjacent to the SCG to low hazard; however, there are new areas of high hazard at the Lang Road hotspot, and on parts of Anzac Parade.

Evaluation

The reduction of flood affectation at the Driver Avenue hotspot directly impacts the downstream flood issue at Lang Road, making the option difficult to justify under most criteria. At present, the depression on Lang Road stores runoff that would otherwise pond at Lang Road. Given that Lang Road is a traffic thoroughfare and Driver Avenue is not, it is not desirable to pass the flood risk downstream to Lang Road. Under an economic assessment, the reduction at Driver Avenue has little economic benefit, as there are no flood affected properties in the hotspot. As the hotspot currently benefits the downstream area, it is recommended that no works be undertaken, and the existing flood hazard is warned of via a depth marker or similar signage (see Section 9.4.1)

9.3.5. Trunk Drainage Upgrade – Lang Road (FM - CP05)

Option Description