WOLLONGONG CITY COUNCIL

HEWITTS CREEK FLOOD STUDY, FLOODPLAIN RISK MANAGEMENT STUDY AND PLAN

VOLUME 1
PUBLIC EXHIBITION DRAFT REPORT



JUNE 2025

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HEWITTS CREEK FLOOD STUDY, FLOODPLAIN RISK MANAGEMENT STUDY AND PLAN

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PUBLIC EXHIBITION DRAFT REPORT
JANUARY 2024

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LIST OF ACRONYMS

AEP	Annual Exceedance Probability
ARI	Average Recurrence Interval
ALS	Airborne Laser Scanning
ARR	Australian Rainfall and Runoff
BOM	Bureau of Meteorology
DCCEEW	Department of Climate Change, Energy, the Environment and Water
DECC	Department of Environment and Climate Change (now DCCEEW)
DNR	Department of Natural Resources (now DCCEEW)
DPE	Department of Planning and Environment
DPIE	Department of Planning, Industry and Environment (now DCCEEW)
DRM	Direct Rainfall Method
DTM	Digital Terrain Model
GIS	Geographic Information System
GPS	Global Positioning System
IFD	Intensity, Frequency and Duration (Rainfall)
LiDAR	Light Detection and Ranging
LFC	Layered Flow Constriction
mAHD	meters above Australian Height Datum
OEH	Office of Environment and Heritage (now DCCEEW)
PMF	Probable Maximum Flood
SRMT	Shuttle Radar Mission Topography
SCIMS	Survey Control Information Management System
TUFLOW	one-dimensional (1D) and two-dimensional (2D) flood and tide simulation software (hydraulic model)
WBNM	Watershed Bounded Network Model (hydrologic model)

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ACKNOWLEDGEMENTS

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Wollongong City Council would further like to acknowledge the community of the Hewitts Creek catchment who have given their time in responding to calls for information relating to flooding, attending information sessions and providing feedback on reports and study outcomes.

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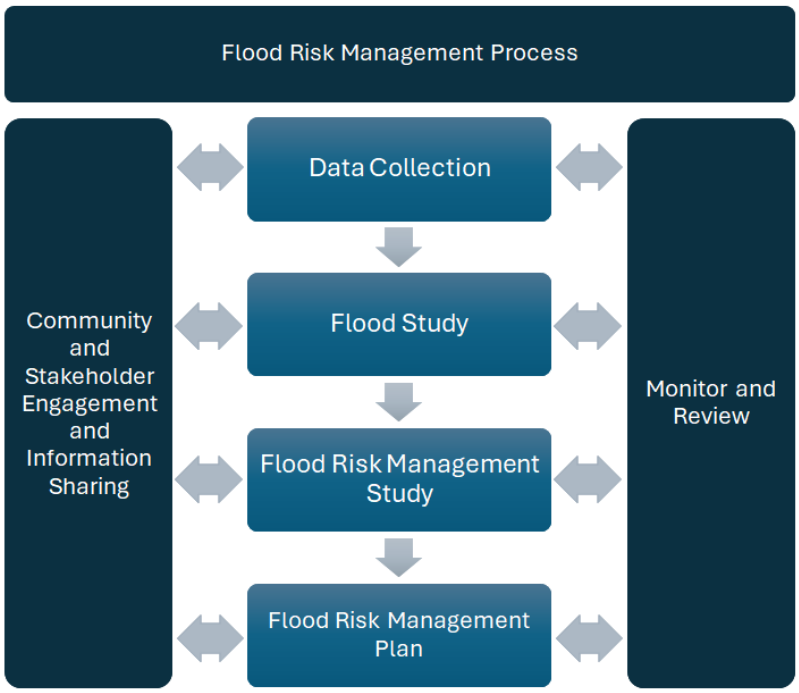
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FOREWORD

The NSW State Government's Flood Prone Land Policy, contained in the Flood Risk Management Manual provides a framework to ensure the sustainable use of floodplain environments. 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 to reduce private and public losses resulting from floods using ecologically sustainable methods, where possible. At the same time, the Policy recognises the benefits flowing from the use, occupation, and development of flood prone land. 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. The State Government 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 Government through the Flood Risk Management Process:



This document constitutes the third and fourth stages of the management process for the study area. The Study aims to identify, quantify and weigh the relevant risks to the community and the potential for different options to manage these risks. Options are assessed against a range of performance criteria related to their effectiveness, efficiency, practicality, feasibility, and community and environmental impacts. The Plan provides recommendations for a range of measures and outlines how Council will effectively manage flood risk in the study area into the future.

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This study was commissioned under the 2005 NSW Floodplain Development Manual; however, it is recognised that the 2023 Flood Risk Management Manual was gazetted during the latter stages of the project. While the study was undertaken in accordance with the 2005 Manual, there are elements that are consistent to both the 2005 and 2023 Manuals. Where appropriate, the 2023 Manual is referenced where project methodology or outputs are consistent with the new 2023 Manual.

REPORT STRUCTURE

The reporting for the Hewitts Creek Floodplain Risk Management Study and Plan has been presented in two documents:

- The Floodplain Risk Management Study and Plan – details the assessments undertaken as part of the study and presents an implementation strategy for Council to prioritise recommended floodplain management options.
- The Map Compendium – a set of A3 maps as referenced in the Study and Plan.

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EXECUTIVE SUMMARY

The Hewitts Creek Floodplain Risk Management Study and Plan (FRMS&P), which follows on from the previous Hewitts Creek Flood Study (2019) and Floodplain Risk Management Study and Plan completed in 2002 and builds on the updated flood modelling developed as part of the Review of Hewitts Creek Flood Study, completed in 2015 and the Hewitts Creek Flood Study (2019). The study has been undertaken in accordance with the NSW Government's Flood Prone Land Policy. This study provides recommendations for reducing flood risk due to flooding in the Hewitts Creek catchment. The flood behaviour was defined in the Review of Hewitts Creek Flood Study (2015) and the Hewitts Creek Flood Study (2019) which developed a suite of models that have been thoroughly reviewed and revised in accordance with best practice.

In this study, a full assessment of the existing flood risk in the catchment has been carried out, including hydraulic hazard across the study area, over floor flooding of residential, commercial, and industrial properties, identification of known flooding issues and hotspots, and emergency response during a flood event. Various measures aimed at managing this flood risk were assessed for their efficacy across a range of criteria. The options were rated according to a detailed matrix of possible impacts. Those rated highest have been recommended in the Floodplain Risk Management Plan, and prioritised based upon how readily the management measures can be implemented, their capital cost, what constraints exist and how effective the measures are. Measures with little cost that can readily be implemented, and which are effective in reducing damage or personal danger would have high priority.

Flood Prone Land Policy Framework

The NSW Government Flood Prone Land Policy supported by the Flood Risk Management Manual, provides a framework for the assessment and management of flood risk across the state. Specifically, the Flood Risk Management Manual guides Councils in the development and implementation of detailed local floodplain risk management plans in order to plan for and manage flood risk. The Flood Risk Management Manual outlines the process and the roles and responsibilities of the various stakeholders involved in the process.

Council (both elected members and Council staff) are primarily responsible for managing flood prone land through the implementation of floodplain risk management strategies. The Floodplain Risk Management Committee assists Council in the development and implementation of these strategies by providing a forum for discussion of the differing viewpoints within the study area, identifying management options and considering and making recommendations to Council on appropriate measures and controls with the primary objective of achieving a beneficial but equitable result for the study area. The committee is the driving force behind the study and plan. The committee includes elected local government officials, Council staff, emergency managers, state government representatives and members of the local community. In addition to the local community committee members, the broader local community, who live and work in the floodplain, have been given the opportunity to contribute to the plan development through community consultation periods at various stages of the study.

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State Government agencies provide funding and technical support to assist Council and the committee in developing a robust Floodplain Risk Management Plan. In most cases a specialist consultant is engaged by Council to undertake the required technical investigations and assessment. The committee directs the consultant through this investigation and receives this information from the consultants to assist with their deliberations.

WMAwater has undertaken the investigation and assessment for this Hewitts Creek Floodplain Risk Management Study under the guidance and direction of the Floodplain Risk Management Committee and developed the Hewitts Creek Floodplain Risk Management Plan.

Key End Users

The FRMS&P and its outputs, inform decision making and investment in the floodplain, and assist in managing flood risk through prevention, preparedness, response and recovery activities, including informing and educating the public about the risks of flooding. Each of these areas has different user groups, whose needs vary and therefore the study and its outputs aim to support the following end users:

- Decision makers at a strategic level.
- The local community.
- Professionals engaged in flood risk management.
- Engineers responsible for designing, building, and maintaining mitigation structures.
- Planners focused on emergency management.
- Urban planning specialists.
- Hydrologists and meteorologists contributing to flood forecasting and protection.

Background

Hewitts Creek is located within the Wollongong City Council Local Government Area (LGA). The combined 7.8km^2 catchment incorporates the northern Wollongong suburbs of Bulli and Thirroul (Figure 1), and extends from the Illawarra Escarpment in the west, discharging into the Thirroul and Sandon Point Beaches in the east.

Hewitts Creek catchment includes several smaller tributaries:

- Slacky Creek;
- Tramway Creek;
- Woodlands Creek;
- Hewitts Creek; and,
- Thomas Gibson Creek.

The upper half of the catchment, forming a section of the Illawarra Escarpment, is heavily vegetated, falling steeply from 500m to 250m AHD. The lower half of the catchment is generally flatter with a mixture of land uses including, residential, commercial, industrial and open space. The catchment land use is shown on Figure 2.

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Existing Flood Behaviour

A number of historical flood events have occurred in the Hewitts Creek floodplain, including flooding in April 1988 and June 1991, with the largest and most significant flood event occurring in August 1998. This August 1998 event resulted in damage to private and public property.

During events as frequent as the 20% AEP flow is not contained to the main creek lines and shallow overland flow travels through developed areas, particularly roadways. Road inundation begins in relatively frequent events (20% AEP) at the following locations:

- Princes Highway, at Woodlands Creek and Slacky Creek,
- Beacon Avenue,
- Hobart Street,
- Cliff Parade,
- Bath Street,
- Station Street,
- Lawrence Hargrave Drive at the Thirroul Community Centre,
- Lachlan Street,
- Phillip Street,
- Deborah Avenue,
- Kanangra Drive and
- George Street.

Property inundation also occurs in relatively frequent events (20% AEP). The most significantly affected location is the Bath Street and Cliff Parade area. At this location depths increase to up to 0.5m in the 1% AEP event. Similarly, properties are impacted on the eastern side of Hewitts Avenue, where depths are up to 0.5m in the 1% AEP event. Property inundation is also shown to occurs with shallow depths of up to 0.3m in the 1% AEP event, on Corbett Avenue and the western side of Pass Avenue.

As larger events occur inundation tends to spread from these areas becoming deeper, with large developed areas being inundated to substantial depths in the 1% AEP event. Overflow occurs between Hewitts and Woodlands Creeks in the larger events.

Economic Impact of Flooding

A flood damages assessment was carried out for the inundation of residential and commercial properties in the study area. The internal damages assessment was based on estimated floor levels. The assessment identified 280 properties impacted by over floor flooding and 587 properties impacted externally across the Study Area up to the PMF. The annual average damages for residential and commercial/industrial properties was found to be $1,137,300. This represents the average cost of flooding each year.

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Flood Risk Management Measures

This Floodplain Risk Management Study process under the direction of the Floodplain Risk Management Committee has identified and assessed a range of risk management measures that would help mitigate flooding to reduce existing and future flood damages. The options were assessed using a multicriteria analysis, which considered not only flood impacts, but also construction feasibility, economic merits and the alleviation or exacerbation of property damages, risk to life and pressure on the SES.

These measures have been grouped into the following general categories:

Flood modification measures modify the flood's physical behaviour (depth, velocity etc) by undertaking structural works in particular areas of the floodplain. Among the flood modification options considered are upgrades to the stormwaters lines, and retarding or detention basins.

Property modification measures modify the existing land use or buildings as well as development controls for future development. These measures primarily involve updating policies and regulations which relate to development on the floodplain. Property modification measures including Voluntary Purchase and Voluntary House Raising were assessed, as well as a broad range of planning measures that aim to reduce flood risk to life, to proposed development and to the wider floodplain.

Response modification measures are aimed at changing and enhancing the community's response to the potential hazards of flooding. This is achieved by educating the property owners and the wider community about flooding, its behaviour and potential damages, so that they can make better informed decisions. The response modification measures considered in this FRMS are generally to 'continue and improve' on current flood emergency management systems and practices including improvements to driver safety.

Recommended Options

The outcomes of the analysis undertaken in this Floodplain Risk Management Study are presented in this report and from that information, the Floodplain Risk Management Committee has made recommendations which include property modification (for example, planning controls), flood modification (for example, drainage improvements) and response modification (for example, community education, flood emergency management planning), and are detailed in Table 1 overleaf. The Final Draft Floodplain Risk Management Study and Plan will be placed on public exhibition to allow the broader community and stakeholders to provide feedback on the recommendations. The Floodplain Risk Management Committee will then consider the submissions received and make any appropriate changes before finalisation and adoption of the Floodplain Risk Management Plan by Council.

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Table 1 - Draft Floodplain Risk Management Plan

	Option ID (Ref)	Option	Description	Benefits	Concerns	Responsibility	Funding	Cost	B/C Ratio	Time Frame	Priority
Property Modification Options	**PM01 (8.3.1)**	Adoption of Flood Planning Levels (FPL)	Council to adopt the following Flood Planning Levels: • Defined Flood Event + freeboard where the Defined Flood Event has been determined to be the 1% AEP (including envelope of blocked and unblocked scenarios) plus climate change rainfall increases (RCP8.5 2090) and 0.90 m SLR. Freeboard is 0.5m Adopt the Flood Planning Level, for sensitive, vulnerable or critical uses: • Probable Maximum Flood where Freeboard is 0.5m Amend LEP Dictionary definition for FPL	FPLs are effective tools to limit property damage to new development and redevelopment.	Developer may consider a FPL onerous. Education can help to mitigate this.	Council	N/A	In house, nominally $10,000	Typically shown to be economically viable	Short	High
	PM02 (8.3.2)	Adoption of Flood Planning Area (FPA)	The FPL, and other flood related development controls, are applied to properties within the Flood Planning Area (FPA). Adopt associated Flood Planning Area map developed in this FRMS&P, which delineates the FPA. Adopt the Flood Planning Area for residential development as the area defined by the extent of: • Defined Flood Event + Freeboard where the Defined Flood Event has been determined to be the 1% AEP (including envelope of blocked and unblocked scenarios) plus climate change rainfall increases (RCP8.5 2090) and 0.90 m SLR. Freeboard is 0.5 m. Adopt the extent of the Probable Maximum Flood for planning purposes on land with a significant risk to life, sensitive, vulnerable or critical uses, or land with hazardous materials or industry.	The FPA will provide clear guidance on the properties subject to flood related development controls.	A planning proposal may be required to amend the LEP and implement the new FPA definition. Consultation would be required.	Council	N/A	In house, nominally $10,000	N/A	Short	High
	PM03 (8.3.3)	Provision of Flood Information to Residents via Section 10.7 Planning Certificates.	Increase resolution of flood information to be provided on s10.7(2) and (5) certificates to identify the property's flood hazard, hydraulic category and whether or not flood related development controls apply using high resolution outputs from this study.	The more informed a home owner is, the greater the understanding of their flood risk. During a flood event this information can help prepare residents to evacuate and reduces the number of residents that elect to take shelter in high hazard areas.	Limited - s10.7(2) certificates already contain basic information, Council to provide further detail from current FRMS results. May increase demand on Council staff, however GIS systems can be established to provide this information efficiently.	Council	NA	In house, nominally $15,000	Typically shown to be economically viable	Short	High
Property Modification Options	**PM04 (8.3.4)**	Managing Development in Flood Prone Areas	Adopt the DFE as the 1% AEP (including envelope of blocked and unblocked scenarios) plus climate change rainfall increases (RCP8.5 2090) and 0.90 m SLR for planning related matters. Adopt the Flood Risk Precinct Definition and Mapping as defined by Figure 13 from this study for the purposes of flood related planning controls. Adopt a consistent set of flood related planning controls across the LGA with guidance from the example matrix and controls from this study. Adopt Major/Minor Overland Flow definition and mapping as defined by Figure 5 from this study. Adopt a revised clause within Council's DCP to better achieve Chapter E13 Objective 3(1)(i): Ensure new development (with the exception of waterway crossings) does not encroach within areas susceptible to channel erosion, migration, bank failure and slumping. Consider Flood Risk Precincts and Flood Emergency Response Classifications in land use planning decisions.	Ensure developments are designed, constructed and managed in such a way as to minimise flood risk to the structure and (if relevant) its occupants, in addition to minimising the impacts of flooding.	There may be resistance from developers who consider new controls to be onerous or likely to reduce the development yield.	Council	Council	In house, nominally $15,000	N/A	Short	High

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	Option ID (Ref)	Option	Description	Benefits	Concerns	Responsibility	Funding	Cost	B/C Ratio	Time Frame	Priority
Response Modification Options	**PM05 (8.3.5)**	Voluntary House Raising	Undertake a feasibility investigation for the 10 identified properties (including to confirm structural compatibility of the identified buildings, owner interest and a more accurate cost estimate of raising to at least the DFE + 0.5 m flood level), and if found viable, prepare the documentation for funding applications.	Seeks to reduce the frequency of exposure to flood damage of the house and its contents by raising the house above the Flood Planning Level (FPL), resulting in a reduction in the frequency of household disruption and associated trauma and anxiety.	External flood risk remains, and evacuation is required before inundation in cases where the property becomes isolated. Community appetite may be a challenge. VHR schemes are long term options and may take approximately a decade to implement.	Council/ Landholder	Landholder/ May be eligible for NSW Government funding assistance	Approximately $100,000 (Dependent on quotes) Feasibility Investigation $50,000	0.39 – 1.71	Mid (Further Investigation) Long (Implementation)	High (Feasibility Study)
	PM06 (8.3.6)	Voluntary Purchase	Undertake further investigation to determine inclusion of the additional 15 properties in the ongoing VP scheme, including consultation with the identified properties, prioritisation and if appropriate, prepare the documentation for funding applications.	Voluntary Purchase (VP) schemes are a long-term option to remove residential properties from areas of high flood hazard.	Community appetite for or acceptance of VP may be a challenge. VP schemes are long term options and may take approximately a decade to implement.	Council	Council/May be eligible for NSW Government funding assistance	Dependent on property purchase price Further Investigation $50,000	N/A	Mid (Further Investigation) Long (Implementation)	High (Further Investigation)
	PM07 (8.3.7)	Flood Proofing/Flood Resilient Buildings	Allow flood proofing within Council's DCP enabling new and existing buildings to be developed with due consideration given to their flood risk and minimisation of internal flood damages and recovery time.	Flood proofing reduces damage and recovery costs and time following flood events.	Retrofitting to existing buildings can have challenges.	Council/ Landholder	Council/ Landholder	Varies for Implentation Guideline development $20,000	N/A	Short	High
	RM01 (8.4.1)	Amend Local Flood Plans with Flood Information Derived from this Study	Develop local flood plans and operational plans to include information on flood risk due to overland flow, drawing on modelling and information provided in this FRMS&P	Detailed information will allow for better management and recovery of overland flow flood risk and will increase understanding of the different levels and types of risk present in the study area.	Modelled results should be used as a guide only, as real flood behaviour may vary from modelled design results.	SES	SES	In house, nominally, $15,000	N/A	Mid	High
	RM02 (8.4.2)	Facilitation of Communication with Emergency Services and Response Agencies	Ongoing facilitation of communication between Council and emergency service agencies. Improvements to volunteer coordination. Identify vulnerable occupants.	Improved understanding of roles and responsibilities for more effective, efficient, and safe actions during and following flood events.	Challenges include change of personnel, difficulty in organising meetings and exercises between flood events.	All response agencies, including but not limited to the SES, Council, RFS, Fire and Rescue, and community organisations.	May be eligible for NSW Government funding assistance	Minimal - In house	N/A	Short	High
	RM03 (8.4.3)	Improve Community Flood Education and Awareness	Council to implement a flood education program to improve ongoing flood awareness in study area using a range of approaches and engagement strategies.	Flood awareness significantly improves preparedness for and recovery from flood events, building a more flood resilient community.	Ongoing efforts to ensure information is not forgotten. Potential for residents to become bored or complacent with messaging.	Council in collaboration with other response agencies and community organisations.	May be eligible for NSW Government funding assistance	Annual Budget to be determined and allocated.	Typically shown to be economically viable	Mid	High
	RM04 (8.4.4)	Flood Warning Improvements	Utilise Severe Weather Warnings from the BOM to prepare for potential flash flooding events, look at utilising innovative gauge technologies following review of the Fairy Creek pilot program, couple with community awareness campaigns and utilise information from the FRMS&P to understand the consequences of the warning (SES and Council).	Improve current system understanding by using outputs from the FRMS&P to inform interpretation. Potentially to increase warning time of possible event for the community.	May not be possible to significantly increase warning time in overland catchments due to short catchment response time. Communication needs to be at the correct level to avoid false alarms and complacency.	Council, SES	May be eligible for NSW Government funding assistance	$250,000 Upfront $40,000 ongoing	N/A	Mid	Medium

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	Option ID (Ref)	Option	Description	Benefits	Concerns	Responsibility	Funding	Cost	B/C Ratio	Time Frame	Priority
Flood Modification Options	**LV01 (8.5.2.1)**	Woodlands Creek North Bank Levee	A 170m levee along the north bank of Woodlands Creek with the aim of preventing property inundation along Hewitts Avenue. Parts of the levee (110m) would be set at 18.5mAHD with the remainder at 16mAHD.	Removes property inundation in frequent events, improved flood levels for some properties in less frequent events, the land is vacant and likely without services, low cost and positive BC ratio	Worsens flood behaviour for some properties, visual amenity impacts, impede local drainage	Council	May be eligible for NSW Government funding assistance	$216,000	0.77	Mid	Medium
	DB02 (8.5.3.1)	Former Bulli Mine Basin	Undertake embankment stability works to formalise existing basin near the Old Bulli Mine (south of 16-22 Hobart Street) with the aim to reduce the peak flow and transfer of flows between Tramway and Slacky Creeks. The bank stability works will allow the construction of an embankment to increase the floodplain storage.	Reduces flood levels in frequent events (0.4m in the 5% AEP), reduced flood volume along Hobart Street, utilises existing culvert structure as outlet, straight forward design, low cost and significant economic benefit.	Worsens flood behaviour for some properties and along Slacky Creek, visual amenity impacts, land ownership, minimal benefit in larger events.	Council	May be eligible for NSW Government funding assistance	$246,000	2.67	Mid	High
	CM10 (8.5.4.4)	South Arm Diversion	Create a lowered section between Cliff Parade and the ocean for Thomas Gibson Creek floodwater that overtop Cliff Parade	Improved flood behaviour, reduced property impacts.	Excavation up to 2m required, Existing cycle path likely to be impacted, existing services.	Council	May be eligible for NSW Government funding assistance	$560,000	0.83	Mid	Medium
	DM03 (8.5.5.3)	Additional Culvert to the Ocean at Cliff Parade	New drainage structure (3 x 1.5m by 0.8m) under Tingara Park and outlet to ocean.	Improved flood behaviour.	Existing services, additional outlet on the beach, a number of considerations required through the design process, traffic disruption during construction, reduced hydraulic efficiency	Council	May be eligible for NSW Government funding assistance	$1,011,000	0.85	Mid	Medium
	DM07 (8.5.5.5)	Cliff Parade Culvert Upgrade	New drainage structure (3 x 1.5m by 0.8m) under Cliff Parade creating an outlet to the ocean through Tingara Park.	Improved flood behaviour, improved property impacts Cliff Parade no longer overtopped in events up to the 5% AEP.	Existing services, land ownership, creek may need widening	Council	May be eligible for NSW Government funding assistance	$831,000	0.87	Mid	Medium
	VM01/VM02 (8.5.6.1)	Vegetation Management	Continuation of existing and extension of Council's vegetation management program to maintain vegetation density.	The current vegetation management practices have been shown to be reducing flood levels by between 0.1 – 0.3m at various locations throughout the catchment.	Community may perceive that current works are insufficient. Education required to communicate the importance of vegetation to bank stability, and that further removal of riparian vegetation would not achieve significant reductions in flood levels, may cause erosion and sedimentation and require artificial bank stabilisation or reducing the bank slope.	Council	May be eligible for NSW Government funding assistance	$40,000 - $60,000	N/A	Mid	High

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	Option ID (Ref)	Option	Description	Benefits	Concerns	Responsibility	Funding	Cost	B/C Ratio	Time Frame	Priority
	DCM (8.5.6.2)	Debris Control Measures	Consider the installation of debris control measures at locations identified to be sensitive to blockage.	Flood levels at the identified locations can potentially increase by up to 2.5m if blockage is not appropriately managed.	Management of blockage requires catchment wide approach to reduce potential debris load. Structures may still become blocked.	Council	May be eligible for NSW Government funding assistance	From $370,000	0.33 – 0.83	Mid	High

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1. INTRODUCTION

1.1. Overview

A Floodplain Risk Management Study and Plan for the Hewitts Creek catchment is being undertaken by Wollongong City Council (Council). This current study aims to provide an update to the previous Hewitts Creek Flood Study (2019) and Floodplain Risk Management Study and Plan completed in 2002 and builds on the updated flood modelling developed as part of the Review of Hewitts Creek Flood Study, completed in 2015 and the Hewitts Creek Flood Study completed in December 2019.

The overall objective of this study is to review Council's current Floodplain Risk Management Study and develop an updated Floodplain Risk Management Plan for the Hewitts Creek catchment to be based on the Review of Hewitts Creek Flood Study (2015) and the Hewitts Creek Flood Study (2019). The updated plan will develop flood risk mitigation strategies that address existing, future and continuing flood risks in the Hewitts Creek catchment.

The Hewitts Creek Flood Study (2019) updated design flood behaviour based on Council's Revised Conduit Blockage Policy (2016), in addition to catchment changes since 2015 and recommendations coming out of review of the models including the inclusion of the pit and pipe network.

The Hewitts Creek Flood Study (2019) was undertaken in accordance with the methodologies outlined in Australian Rainfall and Runoff 1987 (ARR 1987). In late 2016, a first release of a revised Australian Rainfall and Runoff guideline became available, a later revision was subsequently released in mid 2019. The current methodologies and their impact on design flood behaviour has been considered as part of this Floodplain Risk Management Study stage.

1.2. Study Area

The study area is located within the Wollongong City Council Local Government Area (LGA) and incorporates Slacky, Tramway, Woodlands, Hewitts and Thomas Gibson Creeks. The combined catchment is approximately 7.8km^2 and incorporates the northern Wollongong suburbs of Bulli and Thirroul (Figure 1). The catchment extends from the Illawarra Escarpment in the west, discharging into the Thirroul and Sandon Point Beaches in the east.

The upper half of the catchment, forming a section of the Illawarra Escarpment, is heavily vegetated, falling steeply from 500m to 250m AHD. The lower half of the catchment is generally flatter with a mixture of land uses including, residential, commercial, industrial and open space. The catchment land use is shown on Figure 2.

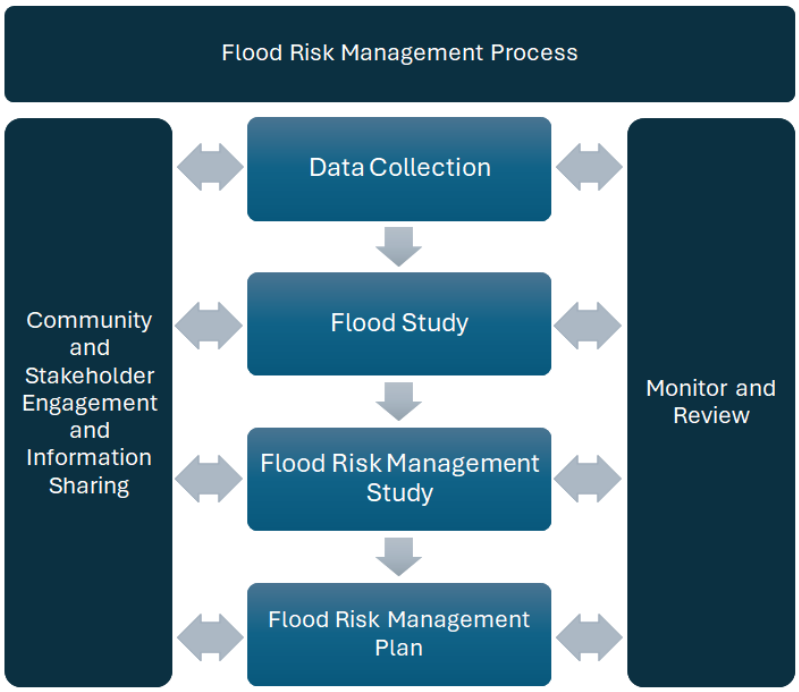
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The flood behaviour in the catchment is influenced by catchment runoff, in addition to the interaction with ocean conditions, particularly in the lower catchment. Significant flooding was experienced in August 1998 when vast areas of the Illawarra region were impacted. Within the Hewitts Creek catchment both public and private property were damaged in that event. Anecdotal and surveyed flood levels exist for the 1998 event in addition to the 1988, 1991 and 2013 events, these events were used for calibration in the Flood Study Review (2015).

1.3. The Floodplain Risk Management Process

As described in the Flood Risk Management Manual (2023) the floodplain risk management process is formed by sequential stages as shown in Diagram 1:

Diagram 1: Floodplain Risk Management Process



The Hewitts Creek Flood Study was completed in 2002 and the outcomes of this assessment formed the basis for the subsequent Hewitts Creek Floodplain Risk Management Study and Plan, completed in 2002. In 2015, the Flood Study was reviewed and updated, allowing current best practice to be applied to the adopted modelling tools. In 2019, the design flood behaviour was updated based on Council's Revised Conduit Blockage Policy (2016), in addition to catchment changes since 2015 and recommendations coming out of review of the modelling tools including the inclusion of the pit and pipe network (Hewitts Creek Flood Study (2019). Wollongong City Council wish to ensure the Floodplain Risk Management Study and Plan for the catchment remain current and informed from best practice.

The revised Hewitts Creek Floodplain Risk Management Study and Plan (FRMS&P – this project) are being undertaken in two phases:

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Phase I – Floodplain Risk Management Study in which the floodplain management issues confronting the study areas are assessed, management options investigated, and recommendations made. Specific objectives for this phase include:

- Update the Hewitts Creek Flood Study (2019) using the methodology and data outlined in Australian Rainfall and Runoff (2019);
- Undertake a review of the current Floodplain Risk Management Study and Plan (2002) and reassess outstanding recommended measures for consideration in this study;
- Review existing planning policies with particular consideration given to climate change and provide Council with planning information required to ensure sound development in the future including residential flood planning levels and flood planning area, flood hazard, hydraulic categorisation, emergency response categorisation and flood risk precincts;
- Identifying innovative solutions to the management of flood hazards within the study area under current and future conditions including an assessment of any adverse environmental, social and economic impacts;
- Review the current local flood plan and provide information to address issues;
- Provide emergency management planning measures for existing and future development; and
- Review and discuss strategies enhancing community knowledge/awareness in regard to flooding.

Phase II – Draft Floodplain Risk Management Plan which is developed from the floodplain risk management study details how flood prone land within the study areas is to be managed moving forward. The primary aim of the Plan is to reduce the flood hazard and risk to people and property in the existing community and to ensure future development is controlled in a manner consistent with the flood hazard and risk at this time and ensuring that such plans are informed to a degree by climate change sensitivity.

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2. DATA COLLECTION AND REVIEW

2.1. Overview

A range of data exists for the Hewitts Creek catchment including topographic information, previous reports and previously established hydrologic and hydraulic models. The following section provides an overview of the data available to the current study.

2.2. Topographic Information

2.2.1. LiDAR

Light Detection and Ranging (LiDAR) survey is aerial survey data that provides a detailed topographic representation of the ground with a survey mark approximately every square metre. LiDAR provides the primary source of terrain information for the modelling tools. LiDAR capture methods often provide less survey marks in heavily vegetated or inundated areas, for this reason the model terrain information is often supplemented with field survey in these areas.

LiDAR captured in May 2005 by AAM Hatch was utilised over the study area in the Flood Study Review (2015). The accuracy of the ground information obtained from LiDAR survey can be adversely affected by the nature and density of vegetation, the presence of steeply varying terrain, the vicinity of buildings and/or the presence of water. The 2005 LiDAR has a stated vertical accuracy of +/-0.15m @ 68% confidence and horizontal accuracy of +/-0.55m @ 68% confidence.

The Flood Study Review (2015) states that the filtered ground data was used to produce a regular 1m resolution digital elevation model (DEM) of the study area.

An updated LiDAR survey of the study area and its immediate surroundings was undertaken in 2013 and provided by LPI. The 2013 LiDAR was not utilised in the Flood Study Review (2015), as it is understood that the study had commenced prior to the LiDAR being available.

The Hewitts Creek Flood Study (2019) included the more recent LiDAR in the TUFLOW model.

2.2.2. Other Survey

Field survey can be used to supplement the LiDAR in defining the model terrain, particularly in areas that are heavily vegetated or have substantially changed since the LiDAR was captured. A comprehensive survey of the creek channels and structures was captured by NSW Public Works as part of the Floodplain Risk Management Study and Plan (2002). The Flood Study Review (2015) obtained survey for 8 cross sections throughout Hewitts and Slacky Creeks and undertook a comparison between the two datasets.

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This comparison confirmed that the survey captured in the Floodplain Risk Management Study and Plan (2002) still provided an appropriate representation of the creek channels through the catchment and was therefore adopted for use in the TUFLOW model developed in the Flood Study Review (2015). These cross sections represent the best available representation of the creek channels and the in-bank representation will be adopted for the current modelling as part of this study.

2.2.3. Recent Catchment Changes

Since the completion of the Flood Study Review (2015), a number of significant developments have occurred or are being undertaken in the catchment, namely:

- Bulli Brickworks subdivision – Stages 1 and 2 are complete with Stage 3 currently under construction.
- Armagh Parade subdivision, Thirroul.

These catchment changes are not included in the Flood Study TUFLOW model and would not be shown in the 2013 LiDAR (Section 2.2.1). Plans including site contour information were provided by Council for inclusion in the updated modelling as part of the Hewitts Creek Flood Study and will also be included as part of this study.

2.2.4. Hydraulic Structures

Details of key hydraulic structures within the Study Area, are required within the hydraulic model to appropriately represent flood behaviour. The Flood Study Review (2015) captured the details via survey at thirteen structures including culverts and bridges. This information has also been supplemented where needed by information provided by Council, in the form of structure drawings, the Floodplain Risk Management Study and Plan (2002) and field inspections undertaken by WMAwater.

2.2.5. Pit and Pipe Database

The TUFLOW model established as part of the Flood Study Review (2015) contained only major hydraulic structures located along the main creek lines, the smaller trunk drainage system was not included. The trunk drainage system captures runoff and can reduce inundation in smaller flood events. This is particularly important in the model representation through more urbanised catchments where these systems tend to replace the former creek lines. The inclusion of this information also allows for potential mitigation strategies on these systems to be identified.

A revised database was provided by Council in January 2018. As part of the Hewitts Creek Flood Study (2019), the revised database was supplemented where needed, including additional details that were gathered via visual inspection or assumed based on location, surrounding pipes, available LiDAR data and reasonable pipe cover depths. Pit inverts were assumed to be 1-1.5m below the ground level (from LiDAR), and were manually adjusted where needed to ensure no negative grades were assigned to pipes. In addition, pit inlets were assumed to be 2.5m by 0.15m, this is a representative pit that combines the typical dimension of a lintel and grate inlet.

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The sensitivity of design flood behaviour to this pit size assumption was tested and the impact found to be insignificant. The results of the sensitivity test are discussed in Hewitts Creek Flood Study (2019).

2.3. Geographic Information System (GIS) Data

GIS layers assist in providing context to the study inputs and outcomes. Council has provided a range of GIS layers to assist with the study, which include:

- Aerial imagery,
- Cadastral boundaries and DP numbers,
- Roadways,
- Contours,
- LEP zoning,
- Council owned land,
- Watercourses,
- Stormwater details (pits, pipes, basins, etc),
- Flood risk precincts, and
- Historical flood levels.

2.4. Previous Reports

2.4.1. Hewitts Creek (incorporating Slacky, Tramway, Woodlands and Thomas Gibson Creeks) Flood Study (2002)

This report investigated and quantified existing flood behaviour in the Slacky, Tramway, Woodlands, Hewitts and Thomas Gibson Creek catchments for the 5%, 2%, 1% AEP and PMF events. The study undertook comprehensive data collection and drew on information about the significant flood event in August 1998 to improve the performance of the modelling tools. Information from the April 1988 and June 1991 flood events was also considered.

A suite of modelling tools were developed to describe flood behaviour in the catchment including WBNM and PSxRM hydrologic models and a HEC-RAS hydraulic model.

The study used a range of data to build the modelling tools, including mapping, photography, creek survey, rainfall and tide information.

The study concluded that catchment flood behaviour can be adversely impacted by many culverts and bridges, in addition to development in the area upstream of the Illawarra Railway.

Data from the Flood Study (2002), particularly the creek survey was used in the development of the TUFLOW model as part of the Flood Study Review (2015). The TUFLOW model subsequently formed the basis for the current model updates.

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2.4.2. Hewitts Creek Floodplain Risk Management Study and Plan (2002)

Following the Hewitts Creek Flood Study also completed in 2002, a Floodplain Risk Management Study and Plan was prepared for the catchment and completed in 2002. The broad aim of the study and plan was to investigate and make recommendations to assist in minimising the effects of flooding in the catchment. A range of options were considered and the most promising assessed for their benefits to flood behaviour in addition to costs/benefits. The Plan recommended a range of different elements for each system including 15 combined schemes, including:

- Land use planning,
- Development controls,
- Formalised overland flow diversions,
- Drainage and culvert upgrades,
- Small levee,
- Voluntary purchase,
- Debris control structures,
- Riparian Management Study,
- Further development of the SES Local Flood Plan,
- Flood awareness.

A number of these recommendations have been implemented by Council since the completion of the study (Table 4). The complete list of recommended mitigation options has been included in Table 4.

Data from the study and plan was used in the development of the TUFLOW model as part of the Flood Study Review (2015) and updated as part of the Hewitts Creek Flood Study (2019). The recommendations made will help in identifying potential mitigation strategies for investigation considering current flood behaviour.

2.4.3. Review of Hewitts Creek Flood Study (2015)

The Review of Hewitts Creek Flood Study was completed in August 2015 and undertaken in accordance with NSW Government's Flood Prone Land Policy. The study provided an update to the assessment undertaken in Floodplain Risk Management Study and Plan (2002), updating the modelling tools. The Flood Study aimed to determine design flood behaviour in the study area, to achieve this, a WBNM hydrologic model and a 1D/2D TUFLOW hydraulic model were established.

To ensure the established models were able to reproduce historical flood behaviour the models were calibrated and validated to storm events of August 1998, January 2013 and April 1988.

The study determined design flood behaviour for the 20%, 10%, 5%, 2%, 1%, 0.5% and 0.2% AEP and PMF events and considered the sensitivity of design flood behaviour to model parameter selection and climate change.

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The study also developed mapping of a range of metrics which aim to identify flood risk in the catchment including, provisional flood hazard, hydraulic categories, flood emergency response classification and preliminary flood planning levels.

The project undertook a community consultation program which gathered useful information about flood behaviour within the catchment. This information was used in the model build process and will be very useful when identifying appropriate mitigation strategies.

The modelling tools and outputs developed in this study form the basis of the assessment undertaken in the current study.

2.4.4. Hewitts Creek Flood Study (2019)

Following the completion of the 2015 Flood Study Review, Council developed a revised Conduit Blockage Policy in 2016. The 2015 Flood Study Review was based on Council's previous Conduit Blockage Policy (2002) as documented in Council's 2009 Development Control Plan.

The Hewitts Creek Flood Study outlines the revised design flood behaviour considering Council's Revised blockage policy, in addition to catchment changes since 2015 and recommendations coming out of review of the models. The WBNM hydrologic model and TUFLOW hydraulic model established as part of the 2015 Flood Study Review were generally considered appropriate. Some minor updates were required to ensure the models produce an improved representation of design flood behaviour. These updates included updating the terrain information to a more recent dataset, refinement of the models in the new development areas, improved representation at a number of hydraulic structures, and inclusion of the drainage network. These updated models formed the basis for assessment of a range of scenarios including Council's Revised Conduit Blockage Policy (2016).

Updated design flood behaviour for current Hewitts Creek catchment conditions has been defined for the 5 year ARI, 10%, 5%, 2%, 1%, 0.5%, 0.2% AEP and PMF events. Potential increases to rainfall intensity and sea level due to climate change and a combination of both have been considered as part of the Hewitts Creek Flood Study for the 1% AEP event. All climate change scenarios were based on the scenario reflective of 2018 catchment conditions and the revised Conduit Blockage Policy (2016). Rainfall increases of 20% and sea level rise increases of 0.4m and 0.9m were assessed.

The draft Flood Study was placed on Public Exhibition for the period 9 September to 8 October 2019, to allow the community and other stakeholders to review and comment on the report prior to finalisation and adoption by Council. An information session was held at Bulli Senior Citizens Centre on the 18 September 2019. The information session was attended by 27 community members.

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Feedback on the study was gathered during the information session, via the Feedback form, Council's website and through the Customer Service Centre during the exhibition period. A total of 15 submissions were received. The key themes of the feedback included:

- Australian Rainfall and Runoff: Appropriateness of using the methodologies and data described in Australian Rainfall and Runoff 1987.
- Flood Modelling: Concerns that the flood modelling results were overly conservative particularly in the more frequent events.
- Blockage: Appropriateness of Council's Blockage Policy (2016) and its application to catchment wide studies.
- Mapping: Clarification of the hazard mapping was requested.
- Rainfall Intensity: Concern that the applied percentage increase in rainfall intensity used to test the sensitivity of flood behaviour to climate change was overly conservative, particularly when applied to the data derived in Australian Rainfall and Runoff 1987.
- Report Presentation: Suggestions to improve report clarity were made.
- Overland Flooding: Consideration of the impacts of new developments, such as recent land clearing and vegetation removal as part of the development at Armagh Parade and the impact of these changes further downstream at Turnbull Gully and Deborah Ave culvert.
- Flood Mitigation: A number of submissions included suggestions to reduce flooding and items to investigate as part of the Floodplain Risk Management Study. Endeavour Energy's focus was on the future Floodplain Risk Management Study and mitigating risks to the electricity distribution network.
- Floodplain Risk Management Process: Frustration over the ongoing floodplain risk management process and perceived lack of action.
- Perceived Causes of Flooding: The contribution of, new developments and a seeming lack of culvert maintenance, to increased flood risk.
- Maintenance: More regular clearing of vegetation and debris from various creek, culverts and pipes due to current and ongoing build-up, or overgrown weeds was identified.
- Impact on Individual Properties: A request was made for property level information.
- Insurance: The impact of Council flood information on how insurers set their premiums.

Council provided responses to all submissions received. The outcomes of the Public Exhibition and how they will be considered as part of the study was reported to the Northern Floodplain Risk Management Committee and Council prior to adoption of the study.

This study was undertaken in accordance with the methodologies outlined in Australian Rainfall and Runoff 1987 (ARR 1987). In late 2016, a first release of a revised Australian Rainfall and Runoff guideline became available, a later revision was subsequently released in mid 2019. The current methodologies and their impact on design flood behaviour has been considered as part of the current study.

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2.5. Existing Flood Behaviour

A number of historical flood events have occurred in the Hewitts Creek floodplain, including flooding in April 1988 and June 1991, with the largest and most significant flood event occurring in August 1998. The August 1998 event resulted in damage to private and public property.

More recently in April 2024, the catchment experienced a significant flood event approaching the size of the August 1998 event. The event resulted in property inundation and damages. On the 5th April between 12pm and 4pm, the catchment experienced continuous rainfall with a total of 45mm recorded at the Rixon Pass rainfall gauge (No. 568317). A similar pattern occurred on the 6th April between 12am and 3am with a total rainfall of 43mm recorded at Rixon Pass. A final larger burst occurred between 4am and 5:30am on the 6th April with 94mm of rainfall recorded at Rixon Pass. Council received 26 reports of impacts associated with the event within the Hewitts Creek catchment. These were primarily focused in the north west of the catchment. All impacts reported by the community appear to be replicated by the design 1% AEP extend, verifying that the design modelling provides a reliable representation of flood behaviour across the study area and can be used to identify areas subject to flood risk. The feedback and mitigation measures assessed as part of this report were reviewed to identify any additional options that should be reviewed as part of the report. The details of the analysis of the April 2024 are provided in Appendix E.

During events as frequent as the 20% AEP flow is not contained to the main creek lines and shallow overland flow travels through developed areas, particularly roadways. Road inundation begins in relatively frequent events (20% AEP) at the following locations:

- Princes Highway, at Woodlands Creek and Slacky Creek,
- Beacon Avenue,
- Hobart Street,
- Cliff Parade,
- Bath Street,
- Station Street,
- Lawrence Hargrave Drive at the Thirroul Community Centre,
- Lachlan Street,
- Phillip Street,
- Deborah Avenue,
- Kanangra Drive and
- George Street.

Property inundation also occurs in relatively frequent events (20% AEP). The most significantly affected location is the Bath Street and Cliff Parade area. At this location depths increase to up to 0.5m in the 1% AEP event. Similarly, properties are impacted on the eastern side of Hewitts Avenue, where depths are up to 0.5m in the 1% AEP event. Property inundation is also shown to occurs with shallow depths of up to 0.3m in the 1% AEP event, on Corbett Avenue and the western side of Pass Avenue.

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As larger events occur, inundation tends to spread from these areas becoming deeper, with large developed areas being inundated to substantial depths in the 1% AEP event. Overflow occurs between Hewitts and Woodlands Creeks in the larger events.

These flooding locations will help to inform the Floodplain Risk Management Study and Plan by identifying locations to potentially target flood mitigation strategies.

2.6. Social Characteristics

Information is available from the 2016 census (http://www.abs.gov.au/) for each of the localities in the study area. This is used to help define social characteristics of this study area. Understanding the social characteristics of the area can be used to inform the risk assessment process through providing metrics for some of the aspects which influence the vulnerability of a community. These include:

- **physical vulnerability:** measured through age demographics with the young (<14) and the elderly (>65 as defined by the United Nations) considered the more vulnerable in a community.
- **flood awareness:** measured through years lived in current location, mortgage or home owners, ability to speak English, and having access to the internet at home.
- **mobility**: measured through having access to a car at home, and the number of people per dwelling
- **financial resilience:** measured through average incomes and proportion of low income earners.

Table 2 below shows the 2016 census statistical for the available State Suburbs (SSCs) compared to the NSW average. Figure 3 shows the suburb boundaries for the suburbs included in the demographics analysis.

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Table 2: 2016 Census Data

	NSW	Thirroul	Bulli
Population demographics: **Median age** **0 – 14 years** **15 - 64 years** **> 65 years**	 38 18.5% 65.1% 16.2%	 42 20.5% 63.1% 16.4%	 38 22.7% 64.7% 12.6%
Average people per dwelling **Average children per family**	2.6 1.9	2.7 1.9	2.8 1.9
Own/mortgage property **Rent property**	64.5% 31.8%	77.0% 19.9%	74.6% 22.0%
Moved into area: **- within last year** **- within last five years**	 19.4% 38.9%	 11.0% 37.6%	 11.7% 33.8%
No vehicles at dwelling **Ave vehicles per dwelling**	9.2% 1.7	5.3% 1.8	6.6% 1.9
Speak only English at home **Households where non-English is spoken** **Other languages spoken**	68.5% 26.5%	89.7% 9.5% French, Spanish, Italian, German and Thai	90.3% 8.8% German, Spanish, Italian, Arabic and Greek
Internet not accessed at home	14.7%	11.1%	12.8%
Median weekly income **< $650 gross per week**	$1,486 19.7%	$1,947 15.2%	$1,896 17.2%

The key variance from NSW averages are discussed below.

Metric	Trends	Impact[1]
Physical Vulnerability	Generally all suburbs have a comparable median age or just slightly higher median age than NSW average	Unchanged
	All suburbs have a comparable proportion of over 65s and only a slightly higher proportion of under 14 years old	Unchanged
Flood Awareness	All suburbs have lower proportions of renters.	Decreased vulnerability (all suburbs)
	Increased percentages homeowners / mortgage, for all suburbs.	Decreased vulnerability (all suburbs)
	Consistently lower percentages of new residents in both the <1 year and <5 year metrics	Decreased vulnerability (all suburbs)
	All areas have a higher than average prevalence of English, with fewer residents speaking any other languages	Decreased vulnerability (all suburbs)
	All suburbs have decreased proportion of residents without internet at home	Decreased vulnerability (all suburbs)
Mobility	All suburbs have a slightly lower rate of households with no vehicles.	Decreased vulnerability (all suburbs)
	Slightly higher than average number of people per property	Slightly increased vulnerability (all suburbs)

[1] This is a generalised qualitative indication of the impact on community vulnerability at a catchment scale.

Financial resilience	All areas had a slightly lower proportion of lower income earners, and a higher median weekly income.	Decreased vulnerability (all suburbs)

Generally, the vulnerability for the Hewitts Creek floodplain is slightly decreased compared to the NSW average. Overall, the community has a slightly higher flood awareness and financial resilience than the NSW average community. The physical and mobility vulnerability of the Hewitts Creek community is considered to be comparable to the NSW average.

2.7. Environmental Features and Built Environment

The Hewitts Creek floodplain is largely comprised low density and medium density residential development with some small areas of commercial and mixed use development. The land use zoning for the study area can be seen in Figure 2. The study area is situated on the Illawarra escarpment and includes a number of vegetation communities that have been declared Endangered Ecological Communities (EEC) and must be protected under the Threatened Species Conservation Act 1995.

The vegetation communities located along Sandon Point and McCauley's Beach include:

- Alluvial Swamp Mahogany Forest (EEC – Swamp Sclerophyll Forest);
- Coastal Swamp Oak Forest (EEC - Swamp Oak Floodplain Forest);
- Coastal Sand Scrub (not an EEC);
- Coastal Headland Banksia Scrub (not an EEC);
- Beach Sands Spinifex (not an EEC);
- Coastal Headland Grassland (EEC – Themeda Grassland on Seacliffs and Coastal Headlands);
- Estuarine Alluvial Wetland (EEC – Sydney Freshwater Wetlands); and
- Floodplain Wetland (EEC – Floodplain Wetland).

The Illawarra escarpment and foothills were home to a dense sub-tropical rainforest prior to European settlement. Over time with increased development there has been substantial tree clearing of the escarpment including of the cedar trees in the early 1800's and clearing of Blackbutt and Turpentine for agricultural lands. However, the escarpment is still heavily vegetated with dense forest with some areas inaccessible.

2.8. Property Database

A key element of an FRMS is the economic assessment of the impacts of flooding. This informs the understanding of flood risk across the catchment and provides a mechanism to assess potential mitigation options and the economic impact of climate change. An important dataset required to complete an economic assessment is the property database, including floor level estimates.

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While the assessment uses floor level data for individual properties, the results are not an indicator of individual flood risk exposure but part of a regional assessment of flood risk exposure and a tool to identify the benefits of mitigation strategies being investigated.

The floor level database was developed from a combination of surveyed properties provided by Council and floor level estimates, undertaken as part of this study. The methodology to capture floor levels for this study used a combination of LiDAR and google earth street view. The ground level was estimated from the LiDAR and relevant building details were determined from google earth street view. The floor rise is estimated from google earth from which an assumed floor level can be derived.

For each property, the following descriptors were captured:

- Ground Level at dwelling (in mAHD);
- Estimated Floor Level (in mAHD);
- Indication of house size (number of storeys);
- Location of the front entrance to the property; and
- Local Environmental Plans (LEP) land use (residential, commercial, industrial, primary production, or public recreation and infrastructure).

The floor level database includes all properties within the PMF extent defined in the Hewitts Creek Flood Study (2019).

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3. COMMUNITY CONSULTATION

3.1. Northern Floodplain Risk Management Committee

The Floodplain Risk Management Study are being overseen by Council's Northern Floodplain Risk Management Committee. The committee includes representatives from a number of stakeholders, including:

- Wollongong City Council,
- Department of Planning and Environment,
- NSW State Emergency Service,
- Transport for NSW,
- Sydney Water,
- Roads and Maritime Services,
- Councillors and
- Community.

The committee has received project updates throughout the project and endorsed the draft Hewitts Creek Floodplain Risk Management Study and Plan for Public Exhibition.

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4. FLOODPLAIN MANAGEMENT POLICY CONTEXT

Wollongong City Council (Council) is responsible for local planning and land management in the Wollongong LGA, including the management of the floodplain and drainage systems. The planning policies held and used by Council in their management of the floodplain are underpinned and bound by national and State planning legislation. It is important to understand the national and state context prior to making recommendations for Council to amend its own local planning policies to ensure that any changes are consistent with the requirements of State and national legislation.

An overview of the national and State planning instruments that influence planning in relation to flood risk at the local government level is provided below to provide this background.

4.1. National Planning Provisions - Building Code of Australia

The Building Code of Australia (BCA) is part of the National Construction Code Series, an initiative of the Council of Australian Government's developed to incorporate all on-site construction requirements into a single code. The BCA is produced and maintained by the Australian Building Codes Board on behalf of the Australian Government and each State and Territory Government.

The BCA is a uniform set of technical provisions for the design and construction of buildings and other structures throughout Australia. The goals of the BCA are to enable the achievement and maintenance of acceptable standards of structural sufficiency, safety, health and amenity for the benefit of the community now and in the future.

The BCA contains requirements to ensure new buildings and structures and, subject to State and Territory legislation, alterations and additions to existing buildings located in flood hazard areas do not collapse during a flood when subjected to flood actions resulting from the 'defined flood event'. The 'Defined flood event is "*the flood event selected for the management of flood hazard for the location of specific development as determined by the appropriate authority."*

Flood hazard areas are identified by the relevant State/Territory or Local Government authority (such as via a Floodplain Risk Management Study). The BCA is produced and maintained by the Australian Building Codes Board and given legal effect through the *Building Act 1975,* which in turn is given legal effect by building regulatory legislation in each State and Territory. Any provision of the BCA may be overridden by, or subject to, State or Territory legislation. The BCA must, therefore, be read in conjunction with that legislation.

The BCA provides general requirements for measures to keep water out of the building structure and foundations, such as setting minimum heights above ground, and minimum paved apron requirements graded to direct runoff away from the building. Section 3.1.2.3 of the BCA refers specifically to drainage of surface water and finished slab heights, and contains the requirements shown below.

Additional requirements for buildings in flood hazard areas, consistent with the objectives of the BCA, primarily aim to protect the lives of occupants of those buildings in events up to and including the defined flood event.

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Building Code of Australia 3.1.3.3 Surface water drainage

Surface water must be diverted away from Class 1 buildings as follows:

(a) Slab-on-ground — finished ground level adjacent to buildings:
the external finished surface surrounding the slab must be drained to move surface water away from the building and graded to give a slope of not less than (see Figure 3.1.2.2):
- (i) 25 mm over the first 1 m from the building in low rainfall intensity areas for surfaces that are reasonably impermeable (such as concrete or clay paving); or
- (ii) 50 mm over the first 1 m from the building in any other case.

(b) Slab-on-ground — finished slab heights:
the height of the slab-on-ground above external finished surfaces must be not less than (see Figure 3.1.2.2):
- (i) 100 mm above the finished ground level in low rainfall intensity areas or sandy, well-drained areas; or
- (ii) 50 mm above impermeable (paved or concreted areas) that slope away from the building in accordance with (a); or
- (iii) 150 mm in any other case.

4.2. State Planning Provisions

4.2.1. State Provisions – NSW Environmental Planning and Assessment Act 1979

The NSW Environmental Planning and Assessment Act 1979 (EP&A Act) provides the framework for regulating and protecting the environment and controlling the impact of development. Pursuant to Section 9.1(2) of the EP&A Act, the Minister has directed that councils have the responsibility to facilitate the implementation of the NSW Government's Flood Prone Land Policy. The policies and guidelines described in this Section fall under the EP&A Act. The objects of the Act are set out below.

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Environmental Planning and Assessment Act 1979 No 203

1.3 Objects of Act

The objects of this Act are as follows:

(a) to promote the social and economic welfare of the community and a better environment by the proper management, development and conservation of the State's natural and other resources,

(b) to facilitate ecologically sustainable development by integrating relevant economic, environmental and social considerations in decision-making about environmental planning and assessment,

(c) to promote the orderly and economic use and development of land,

(d) to promote the delivery and maintenance of affordable housing,

(e) to protect the environment, including the conservation of threatened and other species of native animals and plants, ecological communities and their habitats,

(f) to promote the sustainable management of built and cultural heritage (including Aboriginal cultural heritage),

(g) to promote good design and amenity of the built environment,

(h) to promote the proper construction and maintenance of buildings, including the protection of the health and safety of their occupants,

(i) to promote the sharing of the responsibility for environmental planning and assessment between the different levels of government in the State,

(j) to provide increased opportunity for community participation in environmental planning and assessment.

4.2.2. NSW Flood Prone Land Policy

The primary objectives of the NSW Government's Flood Prone Land Policy are:

(a) to reduce the impact of flooding and flood liability on individual owners and occupiers of flood prone land, and

(b) to reduce public and private losses resulting from floods whilst utilising ecologically positive methods wherever possible.

The NSW Flood Risk Management Manual 2023 relates to the development of flood prone land for the purposes of Section 733 of the Local Government Act 1993 and incorporates the NSW Flood Prone Land Policy. Section 733 of the Local Government Act 1993 provides councils with statutory indemnity for decisions made and information provided in good faith from the outcomes of the management process (undertaken in accordance with the Manual).

The Manual outlines a merits approach based on floodplain management and recognises differences between urban and rural floodplain issues. 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.

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4.2.3. Flood Prone Land Package

On the 14th July 2021, the Department of Planning and Environment (DPE) implemented updates to the Flood Prone Land Package. The purpose of the package is to increase flood resilience in New South Wales, reduce loss of life and property damage. The package provides councils additional land use planning tools to manage flood risk beyond the 1% AEP flood event and strengthen evacuation consideration in land use planning.

The changes include:

- A revised Ministerial Direction 4.1 regarding flooding issued under Section 9.1 of the Environmental Planning and Assessment Act 1979,
- a revised planning circular on flooding
- a new guideline: Considering Flooding in Land Use Planning
- Revised Local Environmental Plan flood clauses (Clause 5.21 and 5.22 of the Wollongong Local Environmental Plan 2009),
- Amendments to Schedule 2, Section 9 of the Environmental Planning and Assessment Regulation 2001,
- State Environmental Planning Policy Amendment (Flood Planning) 2021.

The key changes and implications are outlined below:

- Amendments to Schedule 2 of EP&A Regulation including changes to Clause 9(1), Clause 9(2). These amendments now require councils to note on Section 10.7 certificates if any flood related development controls apply to the land relating to either the Flood Planning Area, hazardous materials / industry, sensitive, vulnerable or critical uses.
- The Ministerial Direction 4.3 (now Direction 4.1) has been amended to remove the requirement for councils to seek exceptional circumstances to apply residential development controls to land outside the 1% AEP flood event (previously included in Clause 7 of Direction 4.3).
- Two proposed LEP clauses relating to the Flood Planning Area, and Special Flood Consideration.
    - The Flood Planning Area clause allows council to extend the FPA to include more extreme flood events where the flood risk requires land use planning tools.
    - The clause relating to Special Flood Consideration provides councils the mechanism to apply development controls to land outside the FPA but within the PMF. This clause is specific to land with a significant risk to life, sensitive, vulnerable or critical uses, or land with hazardous materials or industry.

4.2.4. Ministerial Direction 4.1

Direction 4.1 was issued on 1st March 2022 to replace the previous Direction 4.3. Directions are issued by the Minister for Planning to relevant planning authorities under Section 9.1(2) of the *Environmental Planning and Assessment Act 1979.* Direction 4 pertains to “Resilience and Hazards”, with Direction 4.1 relating specifically to Flood Prone Land, the clause is shown below.

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Objectives

The objectives of this direction are to:

(a) ensure that development of flood prone land is consistent with the NSW Government's Flood Prone Land Policy and the principles of the Floodplain Development Manual 2005,

(b) ensure that the provisions of an LEP that apply to flood prone land are commensurate with flood behaviour and includes consideration of the potential flood impacts on and off the subject land.

Application

This direction applies to all relevant planning authorities that are responsible for flood prone land when preparing a planning proposal that creates, removes or alters a zone or a provision that affects flood prone land.

Clauses (1)-(5) of Direction 4.1 state:

(1) A planning proposal must include provisions that give effect to and are consistent with:

(a) The NSW Flood Prone Land Policy, and

(b) The principles of the Floodplain Development Manual 2005,

(c) The Considering flooding land use planning guideline 2021, and

(d) any adopted flood study and/or floodplain risk management plan prepared in accordance with the principles of the Floodplain Development Manual 2005 and adopted by the relevant council.

(2)A planning proposal must not rezone land within the Flood Planning Area from Recreation, Rural, Special purpose or Conservation Zones to a Residential, Employment, Mixed Use, W4 Working Waterfront, or Special Purpose Zones.

(3) A planning proposal must not contain provisions that apply to the Flood Planning Area which:

(a) permit development in a floodway,

(b) permit development that will result in significant flood impacts to other properties,

(c) permit development for the purposes of residential accommodation in high hazard areas,

(d) permit a significant increase in the development and/or dwelling density of that land,

(e) permit development for the purpose of centre-based child care facilities, hostels, boarding houses, group homes, hospitals, residential care facilities, respite day care centres and seniors housing in areas where the occupants of the development cannot effectively evacuate,

(f) permit development to be carried out without development consent except for the purposes of exempt development or agriculture. Dams, drainage canals, levees, still require development consent,

(g) are likely to result in a significantly increased requirement for government spending on emergency management services, flood mitigation and emergency response measures, which can include but not limited to the provision of road infrastructure, flood mitigation infrastructure and utilities or

(h) permit hazardous industries or hazardous storage establishments where hazardous materials cannot be effectively contained during the occurrence of a flood event.

(4) A planning proposal must not contain provisions that apply to areas between the Flood Planning Area and probable maximum flood to which Special Flood Considerations apply which:

(a) permit development in floodway areas,

(b) permit development that will result in significant flood impacts to other properties,

(c) permit a significant increase in the dwelling density of that land,

(d) permit the development of centre-based childcare facilities, hostels, boarding houses, group homes, hospitals, residential care facilities, respite day care centres and seniors housing in areas where the occupants of the development cannot effectively evacuate,

(e) are likely to affect the safe occupation of and efficient evacuation of the lot, or

(f) are likely to result in a significantly increased requirement for government spending on emergency management services, and flood mitigation and emergency response measures, which can include but not limited to road infrastructure, flood mitigation infrastructure and utilities.

(5) For the purposes of preparing a planning proposal, the flood planning area must be consistent with the principles of the Floodplain Development Manual 2005 or as otherwise determined by a Floodplain Risk Management Study or Plan adopted by the relevant council.

A planning proposal may be inconsistent with this direction only if the planning proposal authority can satisfy the Planning Secretary (or their nominee) that:

(a) the planning proposal is in accordance with a floodplain risk management study or plan adopted by the relevant council in accordance with the principles and guidelines of the Floodplain Development Manual 2005, or

(b) where there is no council adopted floodplain risk management study or plan, the planning proposal is consistent with the flood study adopted by the council prepared in accordance with the principles of the Floodplain Development Manual 2005 or

(c) the planning proposal is supported by a flood and risk impact assessment accepted by the relevant planning authority and is prepared in accordance with the principles of the Floodplain Development Manual 2005 and consistent with the relevant planning authorities' requirements, or

(d) the provisions of the planning proposal that are inconsistent are of minor significance as determined by the relevant planning authority.

Note: In this direction:

(a) "flood prone land" "flood storage" "floodway" and "high hazard" have the same meaning as in the Floodplain Development Manual 2005.

(b) "flood planning level" "flood behaviour" and "flood planning area" has the same meaning as in the Considering flooding in land use planning guideline 2021.

(c) Special flood considerations are outlined in the Considering flooding in land use planning guideline 2021 and an optional clause in the Standard Instrument (Local Environmental Plans) Order 2006.

(d) Under the floodplain risk management process outlined in the NSW Government's Floodplain Development Manual 2005, councils may produce a flood study followed by a floodplain risk management study and floodplain risk management plan.

4.2.5. Planning Circular PS 21-006 and PS 24-001

A planning circular '*Considering flooding in land use planning: guidance and statutory requirements'* PS 21-006 was released with the recent changes to the Flood Prone Land Package on 14th July 2021. The revised circular provides advice on a package of changes regarding how land use planning considers flooding and flood-related constraints, including Section 10.7 Planning Certificates, local planning direction 4.1, LEP clauses and associated guidelines.

In Planning Circular PS21-006 it is noted that: *"Section 733 of the* Local Government Act 1993 *(the LG Act) protects councils from liability if they have followed the requirements of the Manual".*

In March 2024, PS 24-001 was released *'Update on addressing flood risk in planning decisions'* which supplements PS 21-006 providing additional information and advice to planning authorities in relation to addressing flood risk in land use planning and development assessment considering the *Environmental Planning and Assessment Act 1979* as well as the outcomes of the 2022 Flood Inquiry.

4.2.6. Considering flooding in land use planning guideline

The guideline aims to provide councils with mechanisms to manage flood risk for the full range of flooding up to the Probable Maximum Flood (PMF) and give further consideration to evacuation constraints. Within the proposed Flood Prone Land package, there are two main categories council can use to address flooding impacts namely, flood planning areas or special considerations.

The Flood Prone Land Package aims to provide councils the ability to apply development controls to areas where the flood risk requires it. The FDM identifies either the 1% AEP flood event or an equivalent historic event as an appropriate starting point when selecting the Defined Flood Event (DFE). However, it recommends considering selecting a more extreme flood event where there are significant economic, social, environmental or cultural risks associated with a larger event.

The Special Flood Considerations category provides council the ability to apply controls to land outside FPA but within the PMF flood event where there is a significant risk to life or risk of hazardous material impacting the community or environment.

4.2.7. Section 10.7 Planning Certificates

Formerly known as Section 149 Planning Certificates, Section 10.7 Planning Certificates describe how a property may be used and the development controls applicable to that property. The Planning Certificate is issued under Section 10.7 of the Environmental Planning and Assessment Act 1979.

When land is bought or sold, the Conveyancing Act 1919 and Conveyancing (Sale of Land) Regulation 2010 requires that a Section 10.7 Planning Certificate be attached to the contract of sale for the land.

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Section 10.7 of the EP&A Act states:

(1) A person may, on payment of the prescribed fee, apply to a council for a certificate under this section (a planning certificate) with respect to any land within the area of the council.
(2) On application made to it under subsection (1), the council shall, as soon as practicable, issue a planning certificate specifying such matters relating to the land to which the certificate relates as may be prescribed (whether arising under or connected with this or any other Act or otherwise).
(3) (Repealed)
(4) The regulations may provide that information to be furnished in a planning certificate shall be set out in the prescribed form and manner.
(5) A council may, in a planning certificate, include advice on such other relevant matters affecting the land of which it may be aware.
(6) A council shall not incur any liability in respect of any advice provided in good faith pursuant to subsection (5). However, this subsection does not apply to advice provided in relation to contaminated land (including the likelihood of land being contaminated land) or to the nature or extent of contamination of land within the meaning of Schedule 6.
(7) For the purpose of any proceedings for an offence against this Act or the regulations which may be taken against a person who has obtained a planning certificate or who might reasonably be expected to rely on that certificate, that certificate shall, in favour of that person, be conclusively presumed to be true and correct.

The Environmental Planning and Assessment Regulation 2001, Schedule 2 specifies the information to be disclosed on a Section 10.7 (2) Planning Certificate. In particular, Schedule 2, refers to flood related development control information and requires councils to provide the following information:

(1) If the land or part of the land is within the flood planning area and subject to flood related development controls.
(2) If the land or part of the land is between the flood planning area and the probable maximum flood and subject to flood related development controls.
(3) In this clause—
flood planning area has the same meaning as in the Flood Risk Management Manual.
Floodplain Development Manual means the *Flood Risk Management Manual,* ISBN 978-1-923076-17-4, published by the NSW Government in June 2023.
probable maximum flood has the same meaning as in the Flood Risk Management Manual.

Section 10.7 (2) and (5) certificates contain the information prescribed in Schedule 2 described above and additional information relating to the property. In a flooding context, additional information may include notations on flood hazard, percentage of the lot affected by flooding, or peak flood depths and levels on the property, or *"advice on other such relevant matters affecting the land of which it may be aware" (EP&A Act, 10.7 (5)).*

4.2.8. State Environmental Planning Policy (Exempt and Complying Development Codes (2008))

The aims of the State Environmental Planning Policy (Exempt and Complying Development Codes) (SEPP) 2008 are presented below.

This Policy aims to provide streamlined assessment processes for development that complies with specified development standards by:

(a) providing exempt and complying development codes that have State-wide application, and
(b) identifying, in the exempt development codes, types of development that are of minimal environmental impact that may be carried out without the need for development consent, and
(c) identifying, in the complying development codes, types of complying development that may be carried out in accordance with a complying development certificate as defined in the Act, and
(d) enabling the progressive extension of the types of development in this Policy, and
(e) providing transitional arrangements for the introduction of the State-wide codes, including the amendment of other environmental planning instruments.

Part 3 of the SEPP contains standards relating to development in flood control lots. This is described below.

4.2.9. State Environmental Planning Policy (Exempt and Complying Development Codes) Amendment (Housing Code) 2017

Part 3 of the SEPP relates to the *"Housing Code".* This section replaces the former *"General Housing Code",* which was repealed in June 2017. Part 3 is divided into 5 "Divisions", with Division 2 containing General standards relating to land type. Part 3.5 specifically relates to Complying Development on flood control lots and is reproduced below.

3.5 *Complying development on flood control lots*

1) Development under this code must not be carried out on any part of a flood control lot, other than a part of the lot that the council or a professional engineer who specialises in hydraulic engineering has certified, for the purposes of the issue of the relevant complying development certificate, as not being any of the following:
   a) a flood storage area,
   b) a floodway area,
   c) a flow path,
   d) a high hazard area,
   e) a high risk area.

2) If complying development under this code is carried out on any part of a flood control lot, the following development standards also apply in addition to any other development standards:

   a) if there is a minimum floor level adopted in a development control plan by the relevant council for the lot, the development must not cause any habitable room in the dwelling house to have a floor level lower than that floor level,

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b) any part of the dwelling house or any attached development or detached development that is erected at or below the flood planning level is constructed of flood compatible material,

c) any part of the dwelling house and any attached development or detached development that is erected is able to withstand the forces exerted during a flood by water, debris and buoyancy up to the flood planning level (or if an on-site refuge is provided on the lot, the probable maximum flood level),

d) the development must not result in increased flooding elsewhere in the floodplain,

e) the lot must have pedestrian and vehicular access to a readily accessible refuge at a level equal to or higher than the lowest habitable floor level of the dwelling house,

f) vehicular access to the dwelling house will not be inundated by water to a level of more than 0.3m during a 1:100 ARI (average recurrent interval) flood event,

g) the lot must not have any open car parking spaces or carports lower than the level of a 1:20 ARI (average recurrent interval) flood event.

3) The requirements under subclause (2) (c) and (d) are satisfied if a joint report by a professional engineer specialising in hydraulic engineering and a professional engineer specialising in civil engineering states that the requirements are satisfied.

4) *A word or expression used in this clause has the same meaning as it has in the* Flood Risk Management Manual*, unless it is otherwise defined in this Policy.*

4.3. Summary of State Legislative and Planning Policies

From the above discussion of the Housing Code, it is clear that, unless a lot affected by flooding is included as a *"flood control lot"*, an s.10.7 notification is not applied and, as a result, planning controls relating to flooding do not apply and Exempt Development can be undertaken. This highlights the importance of Council undertaking Flood Studies (such as this FRMS) to ensure appropriate properties are tagged and planning controls applied to reduce the risk and impact of flooding for current and future occupants.

4.4. Local Planning Provisions

Updated and relevant planning controls are important in flood risk management. Appropriate planning restrictions, ensuring that development is compatible with flood risk, can significantly reduce flood damages. Planning instruments can be used as tools to guide new development away from high flood risk locations and ensure that new development does not increase flood risk elsewhere. They can also be used to develop appropriate evacuation and disaster management plans to better reduce flood risks to the existing population. Councils use Local Environmental Plans (LEPs) and Development Control Plans (DCPs) to govern control on development with regards to flooding.

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Environmental Planning Instruments such as LEPs guide land use and development by zoning all land, identifying appropriate land uses that are allowed in each zone, and controlling development through other planning standards and DCPs. LEPs are made under the EP&A Act 1979 which contains mandatory provisions on what they must contain and the steps a Council must go through to prepare them. In 2006 the NSW Government initiated the Standard Instrument LEP program and produced a new standard format which all LEPs should conform to. LEPs are used as tools to guide new development away from high flood risk locations and ensure that new development does not adversely affect flood behaviour. LEPs can also be used to develop appropriate evacuation and disaster management plans to better reduce flood risks to the existing population.

4.4.1. Wollongong Local Environmental Plan 2009

The Wollongong LEP 2009 was prepared under the Standard Instrument LEP program. Clause 5.21 of the WLEP relates to flood planning, and states:

(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

(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 Flood Risk Management Manual.*

***Flood Risk Management Manual** means the Flood Risk Management Manual, ISBN 978-1-923076-17-4, published by the NSW Government in June 2023.*

The Flood Prone Land Package included a second optional clause 'Special Flood Consideration' which provides councils the mechanism to apply development controls to land outside the FPA but within the PMF. This clause is specific to land with a significant risk to life, sensitive, vulnerable or critical uses, or land with hazardous materials or industry. Clause 5.22 of the WLEP states:

(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 has considered whether the development—

(a) will 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 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).*

***Flood Risk Management Manual**—see clause 5.21(5).*

***probable maximum flood** has the same meaning as it has in the Flood Risk Management Manual.*

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

(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.

4.4.2. Wollongong Development Control Plan (DCP) 2009

The purpose of the Wollongong DCP is to provide more detailed guidance and provisions for implementing the broader development control objectives outlined in the LEP. The Wollongong DCP 2009 contains prescriptive planning controls relating to floodplain and stormwater management, primarily outlined in *Chapter E13* and *Chapter E14*. *Chapter E13* and *Chapter E14* were recently updated in March 2020 and the following sections, Section 4.4.2.1 and Section 4.4.2.2, were summarised from the March 2020 version.

4.4.2.1. Chapter E13: Floodplain Management

The key objectives of *Chapter E13: Floodplain Management* are to:

a) Maintain the existing flood regime and flow conveyance capacity;
b) Maintain the function of floodway and flood storage areas;
c) Reduce the impact of flooding and flood liability on individual owners and occupiers of flood prone land;
d) Reduce private and public losses from flooding;
e) Improve public safety with respect to flooding;
f) Minimise the potential impact of development and other activity upon the aesthetic, recreational and environmental value of the waterway corridors;
g) Increase public awareness of the hazard and extent of land affected by the full range of potential floods;
h) Ensure new development must, as far as practical, reduce the existing flood risk, and in no circumstances should the flood risk be worsened;
i) Ensure new development (with the exception of waterway crossings) does not encroach within areas susceptible to channel erosion, migration, bank failure and slumping; and
j) Deal equitably and consistently with all matters requiring Council approval on flood affected land, in accordance with the principles within the latest version of the NSW Floodplain Development Manual or its update.

The flood-related provisions of the DCP are extensive. While most provisions apply to the entire LGA, there is a framework for implementing different controls for specific floodplain areas based on special characteristics of those floodplains. These catchment-specific provisions are only implemented where a Floodplain Risk Management Study and Plan have been completed for the catchment. The following section summarises the most critical floodplain management requirements.

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Section 6.3 Flood Risk Precincts details how each of the floodplains in the Wollongong LGA have been classified based on their levels of potential flood risk. The flood risk precincts for the Hewitts floodplain are currently noted as under review on the Wollongong online planning mapping website. Where a floodplain risk management study has not been undertaken, this section specifies that an individual study may be required for a development application.

(3) Council has adopted a three tier FRP classification as follows:
(a) High Flood Risk Precinct – [...] The High FRP includes:
(i) Areas greater than H3 hazard conditions during a 1% AEP flood from Figure 3;
(ii) Land within 10 m from the top of a watercourse bank; and
(iii) Floodway.
(b) Medium Flood Risk Precinct – [...] The Medium FRP includes:
(i) Includes land below the 1% AEP level plus 0.5 m that is not within the High FRP area inundated in a 1% AEP plus freeboard and not classified as High FRP.
(c) Low Flood Risk Precinct – [...] The Low FRP:
(i) All areas within the floodplain (i.e. within the extent of the PMF) but not identified within either the High FRP or the Medium FRP; and
(ii) All areas within the 2100 Coastal Zone Inundation Extent not classified Medium Flood Risk or High Flood Risk Precinct.

Section 6.4.2 of Chapter E13 outlines the required performance criteria for proposed development including:

(a) The proposed development should not result in any increased risk to life;
(b) Development should not detrimentally increase the potential flood affectation on other development or properties either individually or in combination with the cumulative impact of development that is likely to occur in the same floodplain;
(c) Development should not result in 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;
(d) The proposal must not have an adverse impact upon the ecological value of the waterway corridors, and where possible, should provide for their enhancement. Proposed development must be consistent with ESD principles; and
(e) The geomorphic stability of a waterway corridor does not impose additional risk to human life or property

Permissible impacts for different development types are described in Section 6.4.3 of Chapter E13.

c) Flood impacts in the PMF will be assessed on merit and will consider:

i. Impacts to evacuation routes and onsite refuge service levels;
ii. Additional flood affected allotments;
iii. Flood warning times; and
iv. Changes to above yard and above floor flooding.

Table 2: Permissible Flood Impacts (extracted from the Wollongong Development Control Plan (DCP), 2009)

Development / Project Type	*Allowable Impact (mm)*					
	Critical Uses and Facilities	*Sensitive Uses and Facilities*	*Residential*	*Commercial or Industrial*	*Tourist Related Development*	*Recreation or Non-urban Uses*
Individual Property	*10*	*10*	*20*	*20*	*20*	*20*
Multi Lot Subdivision	*10*	*10*	*20*	*50*	*50*	*50*
Government Infrastructure Projects	*20*	*20*	*100*	*150*	*150*	*150*

A requirement outlined in Section 6.4.3 is *that 'new development must not increase the frequency of over floor flooding for residential, commercial or industrial buildings in a 20%, 1% or PMF event. Additionally, new development must not cause additional lots to be impacted by the 1% or PMF event.'*

Section 7 outlines the restrictions on fill in the floodplain. An extract is provided below.

(1) Filling in flood prone areas is not permitted unless:
- *A FRMP for the catchment has been adopted which allows filling to occur; or*
- *A report from a suitably qualified engineer is submitted to Council that satisfies the requirements of items 2 and 3 below and certifies that the development, in combination with similar filling of developable sites in the area, will not increase flood affectation elsewhere.*

(2) Filling of individual sites in isolation without consideration of the cumulative effects is not permitted. A case by case decision making approach cannot take into account the cumulative impact on flooding behaviour and associated risks caused by individual developments. Any proposal to fill a site must be accompanied by an analysis of the effect on flood levels of similar filling of developable sites in the area.

(3) This analysis would form part of a flood study prepared in accordance with Chapters E13 and E14 of this DCP.

(4) Generally, there is to be no net increase in fill in the floodplain. Compensatory excavation may be used to offset fill; however the compensatory excavation must be taken from an adjacent area of similar flood function that is lower in the floodplain (i.e. at a lower AEP inundation extent) than the proposed fill areas. Cut and fill drawings and volume calculations must be supplied to Council.

(5) Filling above the 1% event may be permitted if can be demonstrated there are no adverse impacts in rare events (e.g. 0.2%, 0.5%, PMF).

Other sections included in Chapter E13 include requirements relating to carparks, fencing, house raising, and information when preparing a development application to meet requirements of this Chapter.

Schedule 2 provides prescriptive standards specific to the Hewitts and other floodplains across the Wollongong LGA.

Included in Schedule 2 is a flood planning matrix for Hewitts Creek that details the prescriptive controls for each of the flood risk precincts. These precincts were defined in Section 6.3 of Chapter E13 as described above. This has been extracted and included below. Prescriptive controls for Hewitts Creek floodplain include the following:

- Flood Planning Levels (FPLs) and minimum floor levels;
- Building components and methods;
- Structural soundness;
- Flood affectation including development impacts,
- Evacuation; and
- Flood management and design.

	Flood Risk Precincts (FRP's)																							
	Low Flood Risk								Medium Flood Risk								High Flood Risk (& Interim Riverine Corridor)							
Planning Consideration	Essential Community Facilities	Critical Utilities	Subdivision	Residential	Commercial & Industrial	Tourist Related Development	Recreation & Non-Urban	Concessional Development	Essential Community Facilities	Critical Utilities	Subdivision	Residential	Commercial & Industrial	Tourist Related Development	Recreation & Non-Urban	Concessional Development	Essential Community Facilities	Critical Utilities	Subdivision	Residential	Commercial & Industrial	Tourist Related Development	Recreation & Non-Urban	Concessional Development
Floor Level		3										2, 7	2 or 5	2, 7	1	2,4 ,6							1	2,4 6
Building Components		2										1	1	1	1	1							1	1
Structural Soundness		3		3		3						3	2	3	2	2							1	1
Flood Affectation		2	2		2	2					1	1 or 2	2	2	2	2							1	1
Evacuation		2 , 4	5	3, 4	4	3, 4					5	3,4	1,4	3 , 4	1								1	
Management & Design		4 , 5	1								1		2,3 5	2 , 3 5	2 , 3 5	2,3 5							2 , 3 5	2,3 5
	Not Relevant			Unsuitable Land Use																				

Note:

a. Filling of the site, where acceptable to Council, may change the FRP considered to determine the controls applied in the circumstances of individual applications.

b. For the Hewitts Catchments it is recommended that filling in floodplain areas east of the South Coast Railway Line embankment be permitted, if the applicant can demonstrate there are no local hydraulic impacts on adjoining property as a result of this filling. Filling in floodplain areas west of the Main South Coast Railway is not to be permitted unless an Engineer's report is provided that certifies that the development will not increase flood affectation elsewhere.

c. Terms in italics are defined in the glossary of this plan and Schedule 2 specifies development types included in each land use category. These development types are generally as defined within Environmental Planning Instruments applying to the local government area.

d. Freeboard equals an additional height of 500 mm.

4.4.2.2. Chapter E14: Stormwater Management

Chapter E14: Stormwater Management of the Wollongong DCP 2009 outlines the requirements for stormwater drainage design and on-site stormwater detention within the LGA. Objectives of the Chapter are to:

> *a) Achieve a uniform standard of stormwater drainage design for all developments;*
> *b) Reduce peak flows from sites into Council's stormwater drainage system;*
> *c) Reduce the probability of downstream flooding;*
> *d) Minimise the potential impacts of new development and redevelopment in areas affected by local overland stormwater run-off or flooding, such that no increase in stormwater peak flows occurs downstream;*
> *e) Minimise stormwater run-off volumes;*
> *f) Reduce peak run-off flows from urban developments and minimising impervious areas, wherever practicable;*
> *g) Minimise the drainage infrastructure cost of development; and*
> *h) Increase public convenience and public safety as well as protection of property.*

4.4.3. Wollongong Local Strategic Planning Statement 2020

The Wollongong Local Strategic Planning Statement sets out Council's 20 year vision for the future of land use and housing development in Wollongong, drawing on the findings, recommendations and conclusions of many existing strategies and plans. The statement demonstrates how Council will continue to implement existing strategies and plans to address key challenges, such as:

- Employment opportunities,
- Climate change,
- Projected housing needs,
- Creating great places,
- Supporting the population with culture, recreation and social activities,
- Enabling infrastructure and transport, and
- Protecting the environment.

The statement will be reviewed every 7 years.

4.4.4. 2002 Conduit Blockage Policy

Blockage of bridges, culverts and other stormwater conduits is a key consideration for Council in fulfilling its floodplain management responsibilities. Flood levels can be significantly influenced by the degree of blockage at a particular culvert or bridge. The policy was initially established in 2002, primarily in response to major flooding that occurred in the LGA in August 1998 and October 1999.

The catchments in Wollongong exhibit a range of conditions which contribute to a higher likelihood of debris blockage, including:

- Orographic influenced extreme rainfall due to the Illawarra escarpment,
- Multiple parallel catchments running from the escarpment to the coast,
- Development in the flatter lower parts of the catchment on flood prone land,

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- Most of the upper catchment areas are forested, so there is a relatively high availability of debris, and
- Several major arterial roads and railway lines along the coast, with structures and embankments aligned perpendicular to the flow direction in the majority of catchments.

The policy is implemented as part of Council's Development Control Plan (DCP) and was updated in 2016 as described in the following section. The 2002 Conduit Blockage Policy was applied in the Flood Study Review (2015).

4.4.5. 2016 Conduit Blockage Policy

Since the implementation of the DCP (2009) there has been advancements in a number of areas, which meant that a review of the Conduit Blockage Policy was appropriate, to ensure that the policy meets the current and future requirements of Council and the community in a fair and reasonable way.
These advancements included:

- data techniques and modelling tools used for flood estimation and floodplain management, particularly in modelling flow behaviour in and around culverts and bridges.
- Wollongong faces significant development pressures for both "greenfield" urban release areas and infill development of existing urban areas. The policy must facilitate best practice flood risk management both for existing flood affected communities and future development areas.
- Guidelines for blockage have been released as part of the Project 11 work for the Australian Rainfall & Runoff revision.
- Council has accrued years of experience with the operation of the existing policy, and additional insight has been gathered from this experience.

While the previous 2002 policy had been effective in identifying and managing flood risks at locations potentially sensitive to blockage, it used a relatively broad-brush approach. The revised 2016 policy is based on the detailed probabilistic analysis of blockage data and provides the following:

- Clarification of policy wording to clarify the intent and improve consistency with current modelling and design practice.
- Refinement of culvert and bridge size categories.
- Revised blockage factors based on the data analysis and modelling undertaken.

The 2016 Conduit Blockage Policy was applied in the Flood Study (2019). The Wollongong DCP was updated in March 2020 to include the revised conduit blockage policy (Risk Management Blockage Factors). This policy has been applied in this study.

Table 3 below provides a summary of the Conduit Blockage Policy. Blockage factors have been determined for a range of design AEP and pipe classifications. The following extract from the DCP provides the definitions for each pipe class.

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- *Class 1 - Pipes 1.2 m internal diameter or smaller. Box culverts or bridges with a diagonal opening less than 1.5 m, and a width or height less than 0.9 m.*
- *Class 2 - Pipes greater than 1.2 m internal diameter. Box culverts or bridges with a diagonal opening of more than or equal to 1.5 m, less than 3 m and minimum dimension of 0.9 m for both width and height.*
- *Class 3 - Box culverts or bridges with a diagonal opening of more than or equal to 3 m, less than 6 m, and a minimum dimension of 1.2 m for both width and height.*
- *Class 4 - Box culverts or bridges with a diagonal opening greater than or equal to 6 m, and a minimum dimension of 2.5 m for both width and height.*

Table 3: Blockage Factors - Conduit Blockage Policy

Design AEP	**Bridge / Culvert Classification**				**Debris Blockage of Overtopping Flows**
	Class 1	**Class 2**	**Class 3**	**Class 4**	
20% AEP or more frequent (e.g. 50% AEP, 20% AEP)	60%	50%	35%	5%	Must appropriately represent obstructions to flow such as bridge decks, fences, handrails, buildings noise barriers etc. Modelling of pervious structures such as fences and railings above the structure should assume a 75% debris blockage of the unblocked flow area through the obstruction, plus associated energy losses.
Rarer than 20% AEP and more frequent than 2% AEP (e.g. 10% AEP, 5% AEP)	75%	65%	50%	10%	
2% AEP or greater (e.g. 2% AEP, 1% AEP, PMF)	95%	75%	60%	15%	

4.4.6. Riparian Corridor Management Study, 2004

The Riparian Corridor Management Study was delivered in 2004 and was developed in response to the 1999 Commission of Inquiry – *'Long Term Planning and Management of the Illawarra Escarpment.'* The study includes the entirety of the Wollongong local government area including Hewitts Creek catchment.

The study sets out objectives for natural resource management, of which floodplain risk management is one.

The identified desired floodplain risk management objectives of the study are:

- *Floodplain risk management studies and plans need to consider both existing and proposed long term development and changes to the catchment, floodplain and riparian corridors to assess the associated impacts and consider these in the management of flood risk.*
- *Any proposed flood risk management measures need to be considered in terms of social, environmental and economic issues including the integration of riparian and ecological enhancement opportunities wherever possible.*

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- *Proposed changes to the riparian corridor need to consider any potential impact upon flood risk and ensure there is no adverse impact to the flood liability of existing development.*
- *Encourage flood compatible use of the floodplains (particularly high hazard areas) that are outside the areas reserved for riparian vegetation through strategic environmental planning instruments.*
- *Ensure that natural stream functions are not compromised by flood risk management measures such as "channelisation" of watercourses to support new development.*
- *Support a stream rehabilitation and ecological enhancement philosophy wherever possible in the development of flood risk management measures.*

Relating to floodplain management options, the study calls for environmental impacts need to be considered, including channel stability, riverine habitat and ecological function. Other factors to be considered are:

- vegetation impacts (changes in hydraulic roughness);
- downstream tailwater conditions/greenhouse effect;
- debris loads and blockage of waterway openings;
- watercourse and flow diversions;
- dynamics of the stream geomorphology (erosion/sedimentation);
- accretion of floodplains;
- cumulative impacts of future development; and
- major infrastructure crossing floodplains.

4.4.7. Climate Change Adaptation Strategy, 2022

The Climate Change Adaptation Plan outlines Council's long-term and staged approach to adaptation under a changing climate. The Plan's objectives are to:

1. *Demonbstrate leadership in climate change adaptation planning and action.*
2. *Identify and understand the risks to council infrastructure, services and operations.*
3. *Acknowledge the work that Council is already doing to adapt to climate change.*
4. *Set out what Council can do in coming years and decades to prepare for and adapt to climate change.*

The Plan acknowledges that climate change poses a number of challenges for Wollongong Council and for the Plan to be effective Council must work with all those with adaptation responsibility, including all spheres of Government, businesses, the community and individuals.

Adaptation actions relating to flooding include:

- *Continue managing flood risk through floodplain risk management plans, incorporating climate predictions.*
- *Continue and monitor maintenance schedules to reduce the risk of drainage network blockages. Ensure new developments consider climate change projections including rainfall intensity and sea level rise.*
- *Undertake community education to increase awareness of the dangers of floodwaters and precautions to minimize risks to people and property.*

This FRMS will provide necessary information and data requirements to feed into a number of the actions listed above.

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5. EXISTING FLOOD ENVIRONMENT

5.1. Existing Flood Management Measures

Flooding has occurred in the Hewitts Creek floodplain a number of times in the past and the area has been subject to previous investigations, as summarised in Section 2.4.

Following the completion of the previous Floodplain Risk Management Study and Plan in 2002 a number of recommendations have been implemented across the catchment. Table 4 provides a summary.

Table 4: Floodplain Risk Management Measures Implemented

Management Measure	Location	Measure
Flood Modification	Black Diamond Place, Bulli	Modifications to detention basin adjacent to Slacky Creek
Flood Modification	Old Bulli Mine Dam, Bulli	Embankment upgrade works and creek rehabilitation on a tributary of Slacky Creek
Flood Modification	Lachlan Street, Thirroul	Improvements to existing culvert on Hewitts Creek
Flood Modification	The Esplanade, Thirroul	New overland flow path adjacent to Flanagan's Creek
Flood Modification	Various locations	Natural Area Restoration including control of weeds, clearance of blockages and debris and revegetation.
Property Modification	Princes Highway, Bulli	Voluntary purchase of two properties adjacent to Tramway Creek
Property Modification	Hewitts Creek Catchment	Planning Matrix
Response Modification	51 George Street, Thirroul	New footbridge over Hewitts Creek
Response Modification	Princes Highway and Lawrence Hargrave Drive, Thirroul	Construction of a bridge and associated road works on/adjacent to Woodlands Creek
Response Modification	Blackhall Street, Bulli	New footbridge at Blackhall Street on Slacky Creek

5.2. Australian Rainfall and Runoff 2019 Assessment

The Hewitts Creek Flood Study (2019) presented revised design flood behaviour considering Council's blockage policy (2016), in addition to catchment changes since the 2015 Flood Study and recommendations coming out of the review of the models as part of the Flood Study including the inclusion of the pit and pipe network. The design flood behaviour produced as part of the Flood Study Update was developed using the methodologies described in Australian Rainfall and Runoff 1987 (ARR 1987).

As part of the current study, the design flood behaviour has been updated in accordance with the methodologies outlined in Australian Rainfall and Runoff 2019 (ARR 2019). Further details of the applied assessment are provided in Appendix B.

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5.3. Discussion of Design Flood Behaviour

The hydrologic and hydraulic modelling suite updated as part of the Hewitts Creek Flood Study (2019) were revised to incorporate the changes in design flood methodology described above. Updated design flood mapping is provided for the 20% AEP, 10%, 5%, 2%, 1%, 0.5% and 0.2% AEP and PMF events (Figure B1 to Figure B17).

Design envelope flood results have been filtered for mapping purposes to exclude areas of very shallow inundation or runoff, that would typically not be considered flooding. The following criteria have been applied to the mapping:

- Peak flood depths less than 0.15m were excluded, removing very shallow inundation and catchment runoff,
- Velocity x Depth greater than 0.025m^2/s were reinstated, including shallow areas where greater velocity and therefore hazard exists. These areas are typically part of overland flowpaths or located in the steep sections of the upper catchment. This criteria ensures continuity of mapping along these paths,
- Areas of inundation less than 100m^2 were excluded, removing isolated puddles formed as a result of shallow depressions in the ground terrain representation within the hydraulic model.

During events as frequent as the 0.2 EY flow is not contained to the main creek lines and shallow overland flow travels through developed areas, particularly roadways. Road inundation begins in relatively frequent events (0.2 EY) at the following locations:

- Princes Highway, at Woodlands Creek and Slacky Creek,
- Beacon Avenue,
- Hobart Street,
- Cliff Parade,
- Bath Street,
- Station Street,
- Lawrence Hargrave Drive at the Thirroul Community Centre,
- Lachlan Street,
- Phillip Street,
- Deborah Avenue,
- Kanangra Drive and
- George Street.

The most significantly affected location is the Bath Street and Cliff Parade area. At this location depths increase to up to 0.5m in the 1% AEP event. Similarly, properties are impacted on the eastern side of Hewitts Avenue, where depths are up to 0.5m in the 1% AEP event. Property inundation is also shown to occurs with shallow depths of up to 0.3m in the 1% AEP event, on Corbett Avenue and the western side of Pass Avenue.

As larger events occur inundation tends to spread from these areas becoming deeper, with large, developed areas being inundated to substantial depths in the 1% AEP event. Overflow occurs between Hewitts and Woodlands Creeks in the larger events.

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5.4. Overland Flow

Current flow modelling techniques allow for mapping of flow mechanisms very early in the runoff process and in some cases, as rainfall hits the ground. While this information is useful to understand how drainage paths develop, it is important to differentiate this behaviour into what might be referred to as local drainage or runoff, overland flow (concentration of runoff flowing overland towards a watercourse) and mainstream flooding. This ensures that appropriate controls can be applied to each mechanism to manage the associated risk.

The mapping of flow behaviour produced by the hydrologic and hydraulic modelling has been mapped using the following criteria to allow for a differentiation between mainstream flooding, major overland flow, and minor overland flow.

1. The Defined Flood Event (DFE) flood extent is defined (Refer to Section 8.3.1.1) as the extent of the 1% AEP event plus an allowance for future climatic conditions, including projected sea level rise (2090 ~ 0.9m) and rainfall increases (RCP8.5 2090)
2. The DFE flood extent was filtered to remove areas with depth less than 0.15 m and areas of low conveyance (defined as areas where the velocity x depth product is less than $0.3m^2/s$)
3. Areas removed in Step 2 but identified as Floodway in the PMF event were retained to ensure that continuous flowpaths formed part of the mainstream extent.
4. Overland flow was then separated into Major and Minor Overland Flow using the following criteria:
    a. Major Overland Flow – Depth greater than 0.3 m in the DFE OR identified as Floodway in the DFE OR where the depth increases by more than 0.3 m between the DFE and the PMF.
    b. Minor Overland Flow – Remaining areas.
5. Isolated patches removed based on judgement.

The resulting categorisation of mainstream, major overland and minor overland is shown on Figure 6.

5.5. Hydraulic Hazard Categorisation

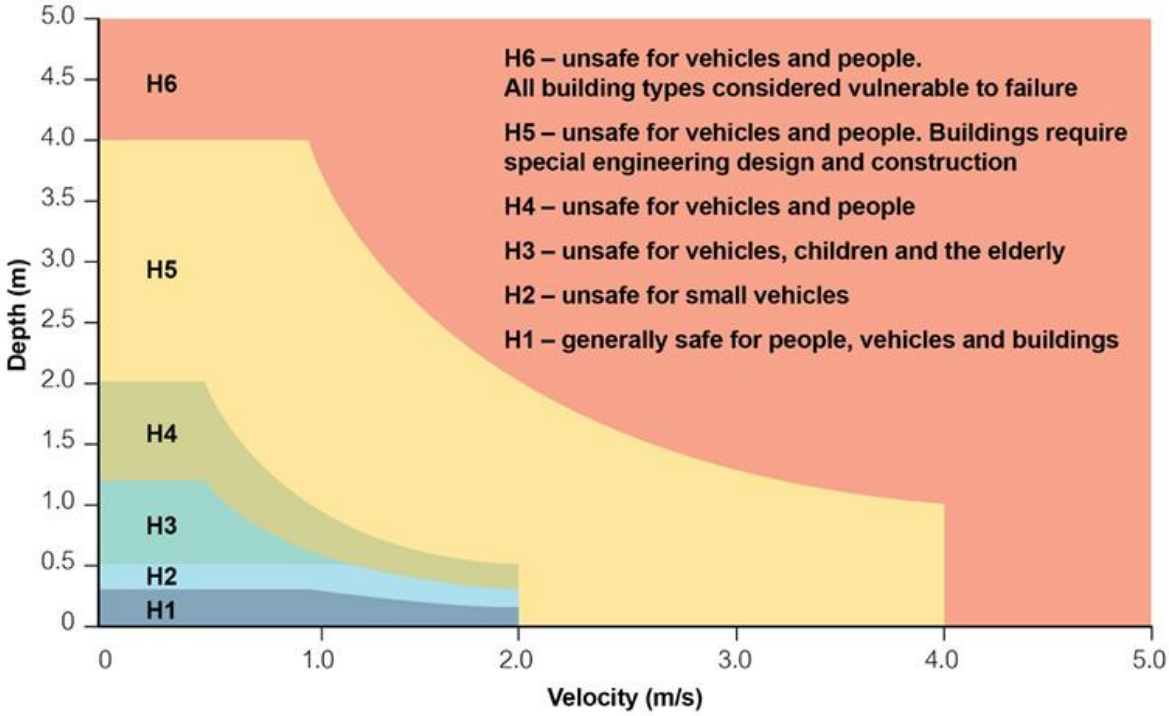
Hazard classification plays an important role in informing flood risk management. It reflects the likely impact of flooding on development and people, providing a measure of potential risk to life and property damage, from a flood event. Hydraulic hazard is typically determined by considering the depth and velocity of floodwaters. In recent years, there have been a number of developments in the classification of hazards. Research has been undertaken to assess the hazard to people, vehicles and buildings based on flood depth, velocity and velocity depth product.

Hydraulic hazard categories have been determined for the study area in accordance with the NSW Flood Risk Management Manual (Department of Planning and Environment , 2023) and its accompanying guideline FB03 – Flood Hazard (Department of Planning and Environment, 2023). FB03 provides a best practice approach for understanding of the potential vulnerabilities as a result of hydraulic hazard of flood water.

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The accompanying guideline FB03 contains information relating to the categorisation of flood hazard. A summary of this categorisation is provided in Diagram 2.

Diagram 2: General flood hazard vulnerability curves



It should be noted that these classifications are based on the physical flood behaviour in design flood events and do not account for other hazards that may exist (such as, road surface failure, loss of access) or the variability in real storm events.

Mapping of hydraulic hazard has been prepared across the floodplain based on the methodology outlined in the NSW Flood Risk Management Manual. The classification is divided into 6 categories (H1-H6), listed in Table 5, which indicate constraints and vulnerabilities of hazard on people, buildings and vehicles within each zone. The criteria and threshold values (vulnerability curves) for each of the hazard categories are reproduced in Table 5.

Table 5 – Hazard Categories

Category	Constraint to people/vehicles	Building Constraints
H1	Generally safe for people, vehicles and buildings	*No constraints*
H2	Unsafe for small vehicles	*No constraints*
H3	Unsafe for vehicles, children and the elderly	*No constraints*
H4	Unsafe for vehicles and people	*No constraints*
H5	Unsafe for vehicles and people	Buildings require special engineering design and construction.
H6	Unsafe for vehicles and people	All building types considered vulnerable to failure.

The hydraulic hazard maps are presented in Figure 7 and Figure B18 for the 1% AEP event.

The mapping of hydraulic hazard for the 1% AEP events shows classifications H5 and H6, those areas considered unsafe for buildings, are generally contained to the creek lines and immediately adjacent riparian areas. However, the following roads are also affected by classifications H5 and H6:

- Kanangra Drive,
- George Street,
- Hewitts Avenue, Princes Highway at Woodlands Creek and
- Hobart Street.

Some areas of the catchment are subject to hazard classification H4 which is considered unsafe for people and vehicles, including south side of Lachlan Street, backyards of properties on High Street, Lawrence Hargrave Drive near Hewitts Avenue, Allenby Parade, Corbett Avenue and the intersection of Cliff Parade and Bath Street.

The hydraulic hazard across most developed areas of the catchment is category H3 or less. While category H3 has the potential to be unsafe for children and the elderly and pose a potential mobilisation hazard for vehicles, the flood behaviour across most of the remaining study area is unlikely to pose a significant threat to people.

Hazard classification H3 is considered unsafe for vehicles, and more vulnerable people. This classification occurs in similar areas to classification H4 with the addition of the Princes Highway near the Point Road intersection.

The remaining inundated areas are generally classified as H1 “generally safe for people, vehicles and buildings” and H2 “unsafe for small vehicles”.

5.6. Flood Function

Hydraulic categorisation of the floodplain is used in the Floodplain Risk Management process to assist in the assessment of the suitability of future types of land use and development, and the formulation of floodplain risk management plans. The Flood Risk Management Manual defines land inundated in a particular event as falling into one of the three hydraulic categories, listed in Table 6, based on their function during that flood event. The flood function of an area may change with the magnitude of the event, the most extreme example being areas which are flood free during a smaller more frequent flood event, forming part of a floodway in larger less frequent events. Hydraulic categorisation mapping has therefore been developed for a range of event magnitudes.

There are no discrete criteria or parameters which explicitly break down the floodplain into the three categories of flood function that would be suitable for all catchments. Different approaches are used in different studies and by different authorities, based on the specific features of the catchment in question. These approaches aim to validate the areas of the floodplain falling into each hydraulic category.

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Table 6: Hydraulic Categorisation Definitions (Floodplain Development Manual (2005))

Category	Definition
Floodway	• Those areas where a significant volume of water flows during floods; • Often aligned with obvious natural channels; • Areas that, even if only partially blocked, would cause a significant increase in flood levels and/or a significant redistribution of flood flow, which my adversely affect other areas; and • Often, but not necessarily, areas with deeper flow or areas where higher velocities occur.
Flood Storage	• 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, for example by the construction of levees or by landfill, flood levels in nearby areas may rise and the peak discharge downstream may be increased; and • Substantial reduction of the capacity of a flood storage area can also cause a significant redistribution of flood flows.
Flood Fringe	• 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.

To define the floodway, the Howells et al. (Defining the Floodway Paper (2003)) methodology was applied, which differentiates the floodway from other hydraulic categories by selecting a velocity-depth product criteria that exceeds a specific threshold. The parameters applied as part of the Flood Study, 2015 were used as a starting point and then confirmed iteratively through encroachment analysis, in which all areas not defined as 'floodway' were totally excluded from the modelling domain, and the subsequent impact on flood levels examined. If the reduction in conveyance area resulted in an increase greater than 0.1 m to existing flood levels, the floodway area was increased.

This approach is informed by Section L4 of the Floodplain Development Manual (Floodplain Development Manual (2005)), which defines Flood Storage areas as *"those areas outside floodways which, if completely filled with solid material, would cause peak flood levels to increase anywhere by more than 0.1 m and/or would cause the peak discharge anywhere downstream to increase by more than 10%."* The resulting parameters are provided in Table 7, where V = Velocity (m/s) and D= Depth (m). Following application of these criteria, the resulting floodway areas were examined to ensure continuity of flowpaths, and to remove any isolated grid cells inappropriately classified as floodway (for example as an artefact of the modelling).

Table 7: Hydraulic Category Definition Parameters

Category	Definition Parameters
Floodway	VD > 0.25 m^2/s **AND** V > 0.25 m/s; **OR** V > 1.0 m/s **AND** D > 0.01m
Flood Storage	Areas outside floodway where D > 0.25 m
Flood Fringe	Areas outside floodway where D < 0.25 m

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The hydraulic categories have been mapped on Figure 8, Figure B20 and Figure B21 for the DFE, 1% AEP and PMF events, respectively.

The mapping of flood function for the DFE and 1% AEP events shows floodways are generally contained to the creek lines and immediately adjacent riparian areas. A floodway is also shown to form across parts of a number of roadways including Beacon Avenue, Hobart Street, Hewitts Avenue, Lachlan Street, George Street, Kanangra Drive, Deborah Avenue, Station Street and Bath Street.

Flood storage areas are limited across the catchment. The remaining flood extent is identified as flood fringe.

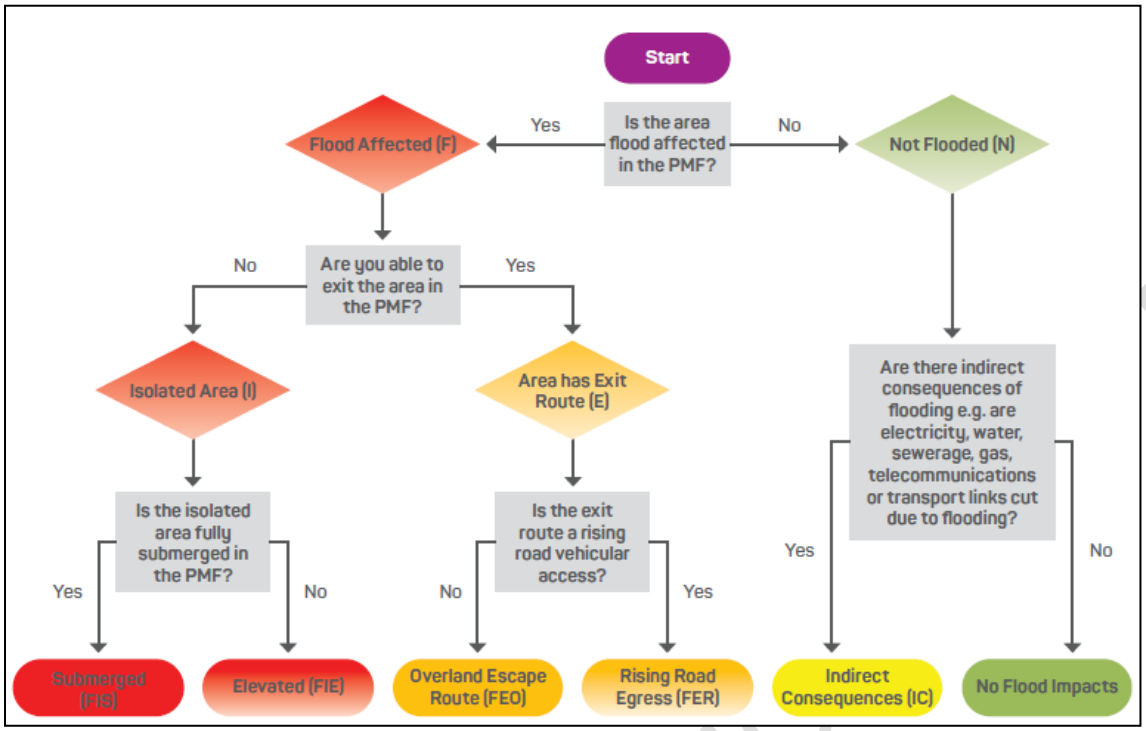
5.7. Flood Emergency Response Classification

Flooding can result in the isolation of the landscape and the subsequent obstruction of evacuation routes and access to medical/emergency facilities. The Flood Emergency Response Classification (FERC) provides a basis for understanding the varying nature, seriousness and scale of these issues, particularly isolation, across the floodplain. The FERC for the study area was undertaken in accordance with the *Australian Disaster Resilience Handbook 7 Managing the Floodplain: A guide to best practice in flood risk management in Australia (AIDR 2017)* (AIDR Handbook 7 (2017)). The methodology (refer to Diagram 3) was applied to the PMF design event and the classification results are presented on Figure 10, Figure 11 and Figure 12. This information will be provided to the SES upon completion of this project.

It is important to note that the FERC classification has been prepared based on existing development within the catchment and does not consider the classification that may pertain to new development on currently vacant land.

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Diagram 3: Flow chart for determining flood emergency response classifications (AIDR Handbook 7 (2017))



Outcomes of the FERC Classification are summarised below:

Mapping of the flood emergency response classification for the Hewitts Creek catchment is shown on Figure 10, Figure 11 and Figure 12. The areas with the greatest risk of isolation classified as FIS (Submerged) are Ocean Street/Cliff Parade, Hewitts Avenue, Lachlan Street, and Hobart Street. These areas can be described as low flood island as the practical access is cut and the area is fully inundated in rarer events. It is important that residents in these locations are aware of their flood risk and the impacts of flooding on their property. Other inundated properties in the PMF event are classified as FER (Rising Road). This is due to parts of the property (although not necessarily the house or building on the property) being subject to inundation in the PMF event but flood free access roads provide a retreat to flood free land.

Classification of FIE (Elevated) applies to portions of Bath Street, Bath Street, George Street and Deborah Avenue, a high trapped perimeter area as the practical access roads are inundated during rarer flood events but there is enough flood free land to retreat and the direct risk to life is limited.

5.8. Flood Risk Precincts

Flood maps produced as part of a flood investigation provide information on a range of flood metrics, including, depth, velocity, hazard etc, for specific flood events, such as the 1% AEP. Flood related planning controls aim to manage overall flood risk, that is across all metrics and many events. In order to simplify the identification of areas of flood risk for the purposes of applying planning controls, areas of similar consequence or similar degree of constraint, have been combined to develop a set of flood risk precincts.

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These precincts are defined as follows:

- **High Flood Risk** – Areas classified with greater than H3 hazard in the Defined Flood Event (DFE)* and floodways in the DFE,
- **Medium Flood Risk** – Areas within the Flood Planning Area and not identified as High Flood Risk,
- **Low Flood Risk** – All other areas within the floodplain (that is, within the extent of the PMF) and not identified as either High or Medium Flood Risk.

* The Defined Flood Event (DFE) is outlined in Section 8.3.1.1.

Mapping of the Flood Risk Precincts is provided on Figure 13.

The above flood risk precinct definition differs from that currently within Council's DCP Chapter E13. The existing definition for the High Flood Risk Precinct includes land within 10m from the top of the watercourse banks. The nature of the creeks within the Hewitts Creek catchment means that the application of this 10 m area may result in an overly conservative High Flood Risk Precinct.

The intent of the inclusion of the 10m top of bank offset was to reduce the risk of channel erosion and bank instability when development is proposed near watercourses or overland flowpaths, however the High Risk Precinct controls do not directly achieve this. Setback controls outlined in Council's DCP Chapter E23 partially address this, however, do not apply to all development types.

A revised clause within Council's DCP should be developed to better achieve Chapter E13 Objective 3(1)(i): Ensure new development (with the exception of waterway crossings) does not encroach within areas susceptible to channel erosion, migration, bank failure and slumping.

Recommended controls for each flood risk precinct are outlined in Section 8.3.4.

5.9. Vulnerable Facilities

A high level investigation highlighted a number of potentially vulnerable properties in the study area including four schools, five health facilities, six child and aged care facilities and one emergency service. Two of these properties are within the PMF flood extent including Bulli Public School, and Thirroul District Community Centre. Both Physical Edge Healthcare and Seacliff Healthcare Medical Centre are within the 5% AEP flood extent. The Thirroul District Community Centre and Bulli Public School are inundated by depths of up to 0.7m and 1.0m, respectively in the PMF event. The Physical Edge Healthcare and Seacliff Healthcare Medical Centre are inundated by up to 0.4 m and 0.7 m, respectively in the 5% AEP event. Figure 14 shows these locations throughout the study area.

5.10. Road Inundation

The catchment presents a number of challenges for emergency response as local and major roads can become inundated and blocked to traffic during an event. Appendix D provides tables of depth and velocity in addition to graphs of road inundation for the locations shown on Figure 16.

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6. FUTURE FLOOD ENVIRONMENT

The Flood Risk Management Manual (2023) places an emphasis on the importance of developing floodplain risk management plans that address existing, future, and continuing flood risk for flood prone land on a strategic, rather than an ad hoc or individual, proposal basis. As well as considering the current flood risk in the study area, consideration must be given to the potential future land use scenarios, projected lot sizes, and occupancy rates that may occur. An assessment is then required on how these future scenarios may be impacted by flood risk. Consideration of future development enables Council to ensure that the management of flood prone land is consistent with flood risk and that such development does not cause undue future distress to individuals, nor unduly increase potential flood liability to them or the community.

The Floodplain Risk Management Study examines not only the current flood risk but takes into account flood management into the future by considering elements such as climate change, future development areas and the impacts of cumulative development across the floodplain.

6.1. Future Development and Growth Areas

The following sections consider the potential changes to the flood environment as a result of potential development in the catchment.

Development in the floodplain will inevitably, and unavoidably, result in some change to flood behaviour. The wide scale adoption of two-dimensional hydraulic models has provided a tool for assessing the impacts of, floodplain management measures, development proposals, and infrastructure projects, on adjoining properties and communities.

As development within a catchment increases, the relatively minor impacts from each development individually can accumulate and cause a much larger impact on a broader regional scale, particularly if this development (including the use of fill to achieve flood planning levels) occurs in areas of the floodplain that are sensitive to landform changes. It is therefore important to understand the floodplains sensitivity to increased development, specifically the cumulative impact of future potential development on the flood risk, conveyance and flood damages. This will provide an understanding of how development may impact flood behaviour and can then be used to inform development controls and land use responses to ensure flood risk is not exacerbated in the future.

This section considers current council zoning and proposed future development to identify a potential future development scenario for assessment. The following section describes the development of this scenario and the proposed assessment methodology.

Figure 14 illustrates locations for proposed development or rezoning for the purpose of development. The following section describes the changes and proposed development in more detail.

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6.1.1. Bulli and Thirroul Road Improvements

Transport for NSW is looking at improving the road network along the Princes Highway at Bulli and Lawrence Hargrave Drive at Thirroul. This project is still at the options identification and assessment phase.

The current proposal includes an extension from Molloy Street to the intersection of Lawrence Hargrave Drive and Wrexham Road. The screenshot below, Image 1, provides the indicative draft plan and is subject to change.



Image 1: Proposed new road corridor from Molloy Street to the intersection of Lawrence Hargrave Drive and Wrexham Road.

The current route is significantly impacted during flood events with overtopping occurring at all creek crossings in the 20% AEP.

Hydraulic Hazard categories of H4 (Unsafe for people and vehicles) and H5 (Unsafe for people or vehicles. All buildings vulnerable to structural damage) occur at these crossings. These aspects will need consideration through the design process to develop solutions which assist in the management of flood risk.

6.1.2. Tramway Creek Bridge

Proposal to construct a bridge over Tramway Creek for the purpose of connecting Geraghy Street. The proposed location is indicated in Image 2 below. The proposal was only at the conceptual planning phase and it is unclear if detailed design has been undertaken.



Image 2: Proposed bridge over Tramway Creek connecting Geraghy Street.

The inundation at the crossing location has a broad span in the 1% AEP event, as the floodwater spills over the railway and spread into Geraghy Street. The location is classified as a floodway and H4 (Unsafe for people and vehicles). These aspects will need consideration through the design process to develop solutions which assist in the management of flood risk.

6.1.3. Bulli Bowling Club Planning Proposal

A planning proposal was submitted to Council to rezone the former Bulli Bowling Club for mixed use development. This proposal has not been approved for development however, would comprise approximately 100 residential dwellings, a childcare centre, café and a co-working space. The proposed Master Plan is provided in the screenshot below, Image 3.

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Image 3: Proposed Master Plan for the Bulli Bowling Club.

This area is subject to significant flood risk, a tributary of Slacky Creek flows down Grevillia Park Road before crossing the Princes Highway, resulting in flood depths of up to 1m during the 20% AEP.

The area is also classified as FIS (submerged) as the practical access is cut and the area is fully inundated in rarer events. Hydraulic Hazard categories of H3 (Unsafe for vehicles, children and the elderly occur on the road and part of the site. These aspects will need consideration through the design process to develop solutions which assist in the management of flood risk.

6.1.4. Bulli Showgrounds

The former Bulli Showgrounds has been identified by Council for future development. A master plan for Bulli Showground is currently in development. The study has been divided into two stages namely, Stage 1: Needs Assessment and Stage 2: Master Plan. Stage 1 has been completed however, Stage 2 has not yet commenced.

The Bulli Showground is located on Lot 33 DP 1182831 and is zoned as Community land: General Community Use. Options considered in the Stage 1 report include the following:

1. *'Development primarily for an events centre,*
2. *Develop primarily for sport,*
3. *Develop primarily as a park,*
4. *Develop to better accommodate events, markets as well as retain regional and local sport.'*

Of these options, development that may have an impact on the flood behaviour include:

- Changes to the current greyhound facilities for either development to support an events centre, and
- Development to support a sports centre including an indoor centre, an area and motor sports track.

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This area is subject to significant flood risk, Slacky Creek flows past the site and overland catchment flows move through the site, resulting in flood depths of up to 1m during the 10% AEP event.

The creek is classified as floodway and should be avoided during developed. Hydraulic Hazard categories of H3 (Unsafe for vehicles, children and the elderly) and H4 (Unsafe for people and vehicles) occur across the site. These aspects will need consideration through the design process to develop solutions which assist in the management of flood risk.

6.1.5. Sandon Point Stockland Residential and Anglicare Retirement Village

This development concept has been approved and is largely already developed. Originally, the proposal was for a retirement village (Anglicare), however has since been modified to include both an area for seniors living (Anglicare) and a residential development (Stocklands).

The development concept includes:

- Residential aged care facility comprising 80 beds,
- 140 independent living units, and
- 51 dwellings for the purpose of senior living or general residential.

The site is flood prone and a stormwater and flood management measures designed for the site include:

- A swale along the western barrier to mitigate flood impacts to adjoining properties,
- Planned easement on an adjoining site for drainage over that land (subject to owners' consent),
- Additional stormwater pits along the proposed roadway to resolve conflict with existing pit, and
- A new culvert under Geraghty Street.

The current concept plan is detailed in Image 4 below.

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Image 4: Concept plan for Sandon Point Stockland Residential and Anglicare Retirement Village.

This area is subject to some flood risk, with a small tributary of Tramway Creek passing through the site. The tributary is not classified as floodway and the hazard is fairly low, however the most significant risk results from isolation due to road inundation. These aspects will need consideration through the design process to develop solutions which assist in the management of flood risk.

6.1.6. Proposed Ultimate Development Scenarios

The *Ultimate Development* represents the maximum potential development under the current land use zoning and flood function constraints. This for potential consolidation and expansion as per the land use zoning. Areas identified as having future development potential were categorised based on current land use zones identified in the Wollongong Local Environmental Plan 2009 and areas identified for possible new development. This development scenario represents the maximum *potential* development that could in theory occur based on current land use zoning.

This scenario has been used to understand the impact from filling in flood fringe zones. A desired outcome of this development scenario is to identify the extent where filling to the PMF produces an acceptable impact.

For the purposes of representation in the model, the areas were categorised as either:

- Low density urban,
- Medium density urban,
- Commercial / industrial, and
- Other (not identified as developable land).

The proposed zoning categorisation is outlined in Table 8.

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Table 8: Zoning categorisation and proposed modelling approach

Development Category	Zones	Proposed modelling approach
Low density urban	R1 General Residential R2 Low Density Residential	Increased roughness to represent low density development. 300m^2 pad added with high Manning's 'n' roughness for lots within the 1% AEP flood fringe. Imperviousness set to 60% for R1 and R2
Medium density urban	R3 Medium Density Residential	Increased roughness to represent medium density development. 300m^2 pad added with high Manning's 'n' roughness for lots within the 1% AEP flood fringe. Imperviousness set to 80%
Commercial / industrial	E1 Local Centre E2 Commercial Centre E3 Productivity Support E4 General Industrial E5 Heavy Industrial SP1 Special Activities SP2 Infrastructure SP3 Tourist	Increased roughness to represent commercial / industrial development. Imperviousness set to 100%. 300m^2 pad added with high Manning's 'n' roughness for lots within the 1% AEP flood fringe.
Other (not identified as developable land)	C1 National Parks and Nature Reserve C2 Environmental Conservation C3 Environmental Management C4 Environmental Living RE1 Public Recreation RE2 Private Recreation RU1 Primary Production RU2 Rural Landscape RU4 Primary Production Small Lots W1 Natural Waterways W2 Recreational Waterways	No change.

Figure B27 shows the results of this assessment which identifies a number of locations across the catchment that are particularly sensitive to development intensification, including:

- The area around Station Street,
- The upstream reaches of Hewitts Creek,
- To the north of Thirroul Railway Station.

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6.2. Future Climate Conditions

Climate change is expected to have adverse impacts upon sea levels and rainfall intensities into the future. Intensive scientific investigation is ongoing to estimate the effects that increasing amounts of greenhouse gases (water vapour, carbon dioxide, methane, nitrous oxide, ozone) may be having on the average earth surface temperature. Changes to surface and atmospheric temperatures may affect climate and sea levels. The extent of any permanent climatic or sea level change can only be established through scientific observations over several decades.

Both increases in sea levels and rainfall intensities have the potential to impact on flood behaviour. Considering and understanding the sensitivity of the current catchment flood behaviour to these influences is crucial in the management of future flood risk, feeding into planning decisions. While the primary factor influencing future changes to flood behaviour in coastal areas is changes to sea levels, potential increases in rainfall intensity could potentially influence flood behaviour in the catchment. As such both increases to rainfall intensity and sea level due to climate change, and a combination of both, have been considered for the 1% AEP event, assuming current catchment conditions.

6.2.1. Sea Level Rise

The former policy statement of the NSW Government set out a series of state-wide sea level rise planning benchmarks, including an increase of 0.4m by 2050 and 0.9m by 2100. In 2012, the NSW Government released the first stage of the Coastal Management Reforms which no longer recommended state-wide sea level rise benchmarks for use by local councils. Council's now have the flexibility to consider local conditions when determining future hazards.

In setting their adopted sea level rise projections in 2013, Council have considered a range of scientific research including the NSW Chief Scientist and Engineer's Report (2012). The report considers the science behind the previous NSW Government state-wide planning benchmarks. Council's adopted sea level rise policy sets projections of 0.4m for 2050 and 0.9m for 2100.

In order to understand the impacts increases in sea level rise will have on flood behaviour within the catchment, increases of 0.4m and 0.9m have been assessed for the 1% AEP event.

In both cases (Figure B22 and Figure B23) the area of impact is limited to the very downstream reaches of Hewitts, Tramway and Slacky Creeks in the 2050 scenario. Flood levels for the 1% AEP under a 2050 projection are shown to increase by up to 0.3m. Under the 2100 projection, 1% AEP flood levels are shown to increase by up to 1m through the same areas.

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6.2.2. 2090 Projection – Combined Sea Level Rise and Increase in Rainfall Intensity

Any change in design flood rainfall intensities will increase the frequency, depth and extent of inundation across the catchment. It has also been suggested that the cyclone belt may move further southwards. Projected increases to evaporation are also an important consideration because increased evaporation would lead to generally dryer catchment conditions, resulting in lower runoff from rainfall. The combination of uncertainty about projected changes in rainfall and evaporation makes it extremely difficult to predict with confidence the likely changes to peak flows for large flood events within the catchments under warmer climate scenarios.

In light of this uncertainty, the NSW Government released *Practical Consideration of Climate Change* in 2007 which recommends sensitivity analysis on flood modelling should be undertaken to develop an understanding of the effect of various levels of change in the hydrologic regime. Specifically, it has suggested that a range of percentage increases to rainfall intensity be analysed.

ARR (2016) considered a range of research sources to develop a best practice methodology for considering the impact of climate change on rainfall as part of design flood estimation. The methodology includes the application of IFD curve adjustment factors derived from the temperature predictions available from the Australian Climate Futures web tool. The Australian Climate Futures web tool provides temperature predictions under a range of Representative Concentration Pathways (RCP), predicted future greenhouse gas concentration scenarios. ARR (2016) recommends the consideration of RCP 4.5 (low) and RCP 8.5 (high). IFD curve adjustment factors for both RCP 4.5 and RCP 8.5, as a percentage increase, for the study catchment are available from the Australian Rainfall and Runoff Data Hub. Current research suggests that greenhouse gas concentrations are tracking closer to RCP 8.5.

The effect of increasing the design rainfalls for a RCP 8.5 2090 scenario have been evaluated for the 1% AEP event in combination with an approximate 0.9m sea level rise to provide a projection for 2090 for the combined influences of climate change.

Figure B24 provides the outcomes of the assessment and indicates that the influence of sea level rise is fairly consistent to the projection presented previously, where flood levels for the 1% AEP increase by up to 1.0m through the very lower reaches of Hewitts, Tramway and Slacky Creeks. This combined with increased rainfall intensity, shows increased flood levels across the Cliff Parade/Ocean Street area, Hewitts Creek to upstream of the railway line, Tramway Creek (including near Allenby Parade and Hobart Street) and Slacky Creek to just upstream of the railway line. Flood levels are generally increased by up to 0.3m with pockets of increases up to 0.5m in Hewitts Creek upstream of the railway line.

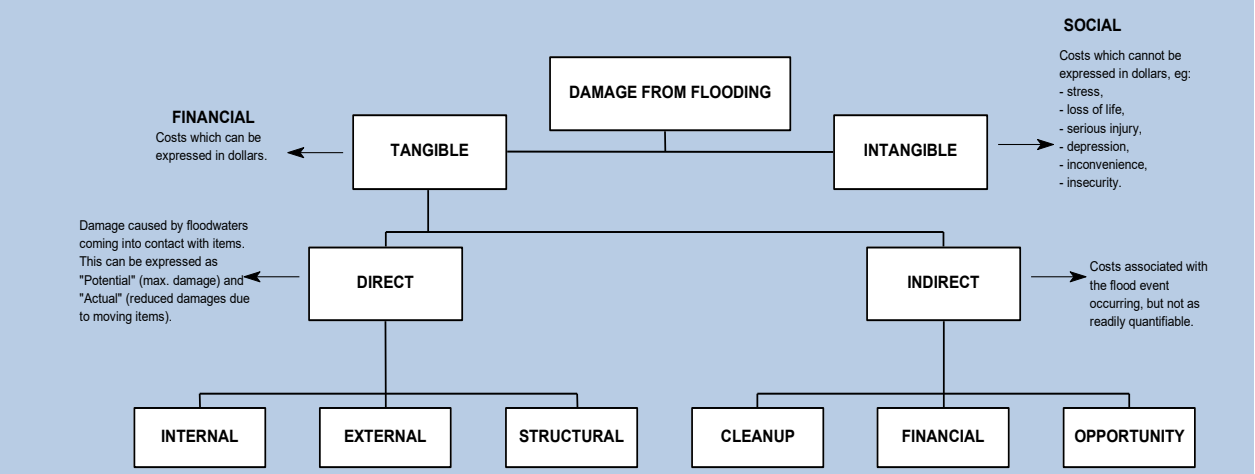
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7. ECONOMIC IMPACT OF FLOODING

7.1. Overview

Economic assessments of flooding consider the economic costs resulting from damage to communities as a result of flood events. This damage can be defined as either tangible or intangible. Tangible damages are those for which a monetary value can be easily assigned, while intangible damages are those to which a monetary value cannot easily be attributed. Damages are further categorised as being either direct or indirect. Direct damages are caused by direct contact with flood water, for example damage to buildings and their contents. Indirect damages refer to the knock-on effects of flood events, such as loss of wages, traffic disruption and loss of community welfare.

The common categories of flood damages are shown in Diagram 4.



RESIDENTIAL	Contents of Buildings: Clothes, Carpets, Furniture, Valuables, Fittings, Appliances	External Items: Vehicles, Laundries, Caravans, Sheds, Tools, Gardens, Fences	Physical Damage to Buildings: Gyprock, Cupboards, Scour of Footings, Houses becoming buoyant (floating off footings)	Clean Carpets, Walls, Clothes; Re-instate Furniture; Remove Mud and Debris	Loss of wages, Living costs (temporary accomodation and food), Time to repair/replace damaged items	Not Applicable
RURAL	Contents of Buildings: Clothes, Carpets, Furniture, Valuables, Fittings, Appliances	External Items: Vehicles, Sheds (stables/barns), Machinery, Tools, Fences, Feed storage, Saddles, Crops &/or Stock, Irrigation Systems	Physical Damage to Structures: Damage to Homestead, Sheds, Access tracks, Protection levees	Clean Homestead and Out-buildings; Remove Debris; Dispose of affected crops &/or stock	Loss of Farm Production and Income, Re-instatement of Pastures, Supplementary feeding of stock (by hand or outside agistment), Stock movement/ transport, Living costs (temporary accomodation and food)	Sowing or harvesting of Crops, Sale of Stock (at depreciated value or dependent on market influences)
COMMERCIAL	Contents of Buildings: Products, Stock, Fittings, Tools, Machinery, Raw Materials	External Items: Vehicles, Machinery, Display, Raw Materials/Stockpiles, Fences	Physical Damage to Buildings	Dispose of damaged products, stock, materials; Cleaning and Re-instatement	Loss of Productivity and Income, Bank Interest Charges	Loss of existing &/or Potential Trade
PUBLIC AUTHORITIES	Contents of Public Buildings and Facilities	Public Property and Facilities: Parks, Signs, Machinery, Equipment	Physical Damage to Infrastructure: Electricity, Water, Telephone, Gas, Road & Rail Transport Links	Remove Mud & Debris from Facilities, Public & Private Property Repairs (temporary & permanent)	Disruption of Services, Community Service Relief Grants	Provision of Public Service

Diagram 4: Flood Damages Categories

The cost of damage and the degree of disruption to the community caused by flooding depends upon many factors including:

- The magnitude (depth, velocity and duration) of the flood;
- Land use and susceptibility to damages;
- Awareness of the community to flooding;
- Effective warning time;
- The availability of an evacuation plan or damage minimisation program;
- Physical factors such as failure of services (sewerage), flood borne debris, sedimentation; and
- The types of asset and infrastructure affected.

Flood damage assessments attempt to quantify this wide range of impacts to provide an assessment of the economic loss caused by flooding. This can then be used to determine the benefits of proposed mitigation strategies, whereby the reduction in damage is considered the benefit of the mitigation option. When compared to the cost of implementing the measure, this results in the determination of a benefit cost ratio, with anything over one considered economically viable, or delivering value for money. Analysis of other tangible damages, and intangible aspects, is captured via a multi-criteria matrix assessment in the option investigation process.

The observations obtained from the damage analysis can be used to develop a targeted approach to investigating suitable flood risk mitigation options. To have the most impact in reducing flood risk to properties in the study area, options need to a, be effective in flood events greater than the 1% AEP event and b, assist in the reduction of damages to commercial properties. Mitigation options that meet these two criteria are identified and assessed further in Section 8.

The results are not an indicator of individual flood risk exposure, but part of a regional assessment of flood risk. Furthermore, the purpose of the damages assessment amount is not to calculate the actual damage that would be incurred in a flood, but to forms a basis of comparison with other flood prone communities throughout NSW, and a baseline against which mitigation options can be assessed.

The standard way of expressing flood damages is in terms of average annual damages (AAD). AAD represents the equivalent average damages that would be experienced by the community on an annual basis, by taking into account the probability of a flood occurrence. This means the smaller floods, which occur more frequently, are given a greater weighting than the rare catastrophic floods.

The below assessment focuses on the direct tangible damages caused by flooding in the Hewitts Creek catchment and forms the basis of quantifying the tangible benefits of certain mitigation measures investigated later in this study. The methodology and results have been summarised below.

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7.2. Flood Damages Assessment

Damage calculations were carried out for all properties within the PMF extent, using the survey data and modelled flood level information. The damages were calculated using height-damage curves which relate the depth of water above the floor with tangible damages. Each component of tangible damages is allocated a maximum value and a maximum depth at which this value occurs. Any flood depths greater than this allocated value do not incur additional damages as it is assumed that, by this level, all potential damages have already occurred. The damages assessment methodology is based on DPE guidelines. These values have been calculated using the design flood behaviour defined as part of this study.

The total estimated damages from both residential and non-residential properties are provided in Table 9. Damages were calculated for residential and commercial/industrial properties separately as discussed in the following sections.

The flood damages estimates do not include the cost of restoring or maintaining public services and infrastructure. It should also be noted that damages calculations do not take into account flood damages to any basements or cellars, hence where properties have basements, damages can be underestimated.

The damage calculations are based on the property survey, described in Section 2.8. The classification of a "habitable" floor was based on visual inspection only. As such, properties which may have created habitable spaces in under croft areas which do not meet Building Code or Council's planning requirements will still be recorded as habitable in this survey. As such, some of the above floor inundation determined below may include damages associated with illegal building structures.

Table 9: Estimated Total Flood Damages (residential & non-residential) for Hewitts Creek Floodplain

Event	Number of Properties Flood Affected	No. of Properties Flooded Above Floor Level	Total Tangible Flood Damages	% Contribution to AAD	Average Tangible Damages Per Flood Affected Property
20% AEP	160	25	$ 1,817,250	26	$ 11,358
10% AEP	187	30	$ 2,925,659	22	$ 15,645
5% AEP	249	42	$ 4,009,914	16	$ 16,104
2% AEP	315	88	$ 7,699,012	17	$ 24,441
1% AEP	353	104	$ 9,017,893	8	$ 25,546
0.5% AEP	371	111	$ 9,761,584	4	$ 26,312
0.2%PMF	403	120	$ 10,577,647	4	$ 26,247
PMF	587	280	$ 24,574,030	3	$ 41,864
Average Annual Damages (AAD)			**$ 1,054,774**		**$ 2,000**

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7.2.1. Residential Properties

Table 10 provides the calculation of damages for residential properties only in the catchment. Residential property damage contributes 64% of the average annual damage in the Hewitts Creek floodplain. Residential properties account for 91% of the total number of properties flood affected and 89% of the total flooded above floor. For the 1% AEP flood event, the total tangible damages for residential contribute 72% to the total tangible damages.

Table 10: Estimated Total Flood Damages (residential) for Hewitts Creek Floodplain.

Event	Number of Properties Flood Affected	No. of Properties Flooded Above Floor Level	Total Tangible Flood Damages	% Contribution to AAD	Average Tangible Damages Per Flood Affected Property
20% AEP	137	17	$ 1,192,000	27	$ 9,000
10% AEP	160	18	$ 1,534,000	20	$ 10,000
5% AEP	216	29	$ 2,356,000	14	$ 11,000
2% AEP	278	72	$ 5,503,000	18	$ 20,000
1% AEP	313	85	$ 6,497,000	9	$ 21,000
0.5% AEP	330	92	$ 7,087,000	5	$ 21,000
0.2%PMF	359	100	$ 7,805,000	3	$ 22,000
PMF	535	249	$ 19,366,000	4	$ 36,000
Average Annual Damages (AAD)			**$ 673,100**		**$ 1,000**

7.2.2. Non-residential – Commercial and Industrial

The total non-residential damages for the Hewitts Creek floodplain are shown in Table 11. Commercial property damage contributes only 46% to the total tangible damages for the floodplain. However, commercial properties account for only 9% of the total properties affected and 11% of total properties flooded above floor. For the 1% AEP flood event, commercial damages account for 28% of the total tangible damages.

Table 11: Estimated Total Flood Damages (commercial and industrial) for Hewitts Creek Floodplain.

Event	Number of Properties Flood Affected	No. of Properties Flooded Above Floor Level	Total Tangible Flood Damages	% Contribution to AAD	Average Tangible Damages Per Flood Affected Property
20% AEP	23	8	$ 624,900	25	$ 27,000
10% AEP	27	12	$1,391,200	26	$ 52,000
5% AEP	33	13	$ 1,653,400	20	$ 50,000
2% AEP	37	16	$ 2,195,400	15	$ 59,000
1% AEP	40	19	$ 2,520,400	6	$ 63,000
0.5% AEP	41	19	$ 2,674,900	3	$ 65,000
0.2%PMF	44	20	$ 2,772,500	3	$ 63,000
PMF	52	31	$ 5,207,500	2	$ 100,000
Average Annual Damages (AAD)			**$ 464,200**		**$ 7,000**

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7.2.3. Average Annual Damages

Depending on its size (or severity), each flood will cause a different amount of flood damage within a flood prone area. Annual Average Damage (AAD) is the average damage per year that would occur in a nominated development situation (i.e. current catchment conditions in the study area) from flooding over a very long period of time. That is, the AAD is equal to the total damage caused by all floods over a long period of time divided by the number of years in that period. Note that it is assumed that the development situation is constant over the analysis period.

The AAD in the Hewitts Creek catchment due to flooding is summarised in Table 12.

Table 12 Annual Average Damages

Property Type	Average Annual Damages(1)	% Contribution to total AAD
Residential	$ 673,700	63.9%
Commercial	$ 381,000	46.1%
Total	**$1,054,700**	**100%**

(1) 2022 dollar value

7.3. First Event Flooded

The property database described above in Section 2.8, provides useful information to better understand the flood risk and can inform the development of management measures and prioritisation of hot spot areas. In addition to assessing potential costs due to flooding, the damages assessment is useful in identifying the frequency of event in which residential and commercial properties are likely to be first flooded above floor level. Mapping showing the first event properties become inundated above floor has been developed and is shown Figure 9.

Mapping shows there is a pocket of properties adjacent to the Tramway Creek crossing of the Princes Highway inundated as frequently as the 20% AEP flood event. Other properties in the area become inundated in larger, less frequent events such as the 2% AEP.

Other locations with properties inundated as frequently as the 20% AEP include, Hewitts Avenue, George Street, Philip Street, McCauley Street and Cliff Parade.

A cluster of properties in the vicinity of Ocean Street and along Cliff Parade are shown to be inundated in the 2% AEP event.

In total, there are 587 properties impacted by flooding across the study area in the PMF flood event. 280 of these experience flooding above floor. In the 1% AEP flood event, there are 103 properties flooded above floor and of these 84 are residential properties. Property affectation across the study area catchments is shown in Table 13.

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Table 13 Over Floor Property Affectation

Event	No. Properties Flood Affected (Yard Inundation)	No. Properties Flooded Above Floor Level
20% AEP	160	25
10% AEP	187	30
5% AEP	249	42
2% AEP	315	88
1% AEP	353	104
0.5% AEP	371	111
0.2% AEP	403	120
PMF	587	280

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8. FLOODPLAIN RISK MANAGEMENT MEASURES

This FRMS&P aims to identify and assess risk management measures which could be put in place to mitigate areas of unacceptable flood risk. Initially, looking at the recommended mitigation options from the FRMS&P completed in 2002 and identifying any relevant mitigation options for consideration again as part of this assessment given the context of updated modelling tools and design flood behaviour. In addition to this, additional options have been identified to assess their potential to mitigate flood risk and reduce flood damages.

8.1. Categories of Floodplain Risk Management Measures

The 2023 NSW Government's Floodplain Development Manual (2005)separates risk management measures into three broad categories;



Property modification measures modify existing properties, and land use and development controls for future new development or redevelopment. This is generally accomplished through such means as flood proofing, house raising or sealing entrances, strategic planning such as land use zoning, building regulations such as flood-related development controls, or voluntary purchase/voluntary house raising.



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



Flood Modification Measures modify the physical behaviour of a flood including depth, velocity and redirection of flow paths. Typical measures include flood mitigation dams, retarding basins, channel improvements, levees or defined floodways. Pit and pipe improvement and even pumps may be considered where practical.

8.2. Assessment Methodology

The Hewitt's Creek Floodplain Risk Management Study has assessed a range of potential options for the management of flooding. Options investigated were identified through four main methods: review of previously recommended options, consideration of improving "flooding hotspots" using modelled flood results (i.e. areas of significant depth, velocity or hazard), inspection of property affectation via the property damages assessment, and via discussions with the local community via the consultation period, as well as discussions with Council, Emergency Services. Community members provided valuable insight into problematic flooding hotspots and suggested a range of possible solutions. The inclusion of community suggestions in the subsequent option assessment is critical to identifying useful and effective flood risk mitigation options, as well as engendering a sense of ownership of the Floodplain Risk Management Study in the community.

An initial assessment of identified options was undertaken to determine its effectiveness in reducing flood risk, and to facilitate a general assessment of the option. Options were then shortlisted for hydraulic or further assessment, and if effective, proceeded to detailed assessment and multicriteria analysis. Options that are scored positively in the multicriteria analysis are typically included in the Draft Floodplain Risk Management Plan for implementation.

8.3. Property Modification Measures

Property modification measures aim to reduce flood risk to existing properties and future developments. Options such as voluntary house raising and flood proofing can be implemented to reduce damage to existing properties, while voluntary purchase schemes can be implemented to remove dwellings from areas of high flood hazard, thereby reducing the number of residents at risk and potentially improving flood conveyance. Flood risk to future developments can be managed via land use planning, and flood related development controls which regulate where and how various types of developments are constructed. The key tools Council uses to regulate development are the Local Environmental Plan and Development Control Plan. The following provides a summary of the recommendations.

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8.3.1. Option PM01: Flood Planning Level

☑	**PM01: Flood Planning Level**
Description	Adopt the following Flood Planning Level: • Defined Flood Event + Freeboard where the Defined Flood Event has been determined to be the 1% AEP (including envelope of blocked and unblocked scenarios) plus climate change rainfall increases (RCP8.5 2090) and 0.90 m SLR. Freeboard is 0.5m Adopt the Flood Planning Level, for sensitive, vulnerable or critical uses: • Probable Maximum Flood + Freeboard where Freeboard is 0.5m Amend LEP Dictionary definition for FPL
Outcome	Recommended to be considered in Council's Floodplain Management Program.

Flood Planning Levels (FPLs) are an important tool in floodplain risk management. Appendix K of the Floodplain Development Manual (the Manual, Floodplain Development Manual (2005)) provides a comprehensive guide to the purpose and determination of FPLs. The FPL is derived from a combination of a defined flood event and a freeboard and provides a development control measure for managing future flood risk (e.g. by elevating floors above a particular flood level), reducing potential damage, and setting minimum levels for floodplain mitigation works. Typically, this level would be the 1% AEP flood level plus a freeboard of typically 500 mm for residential or commercial development.

The FPL for planning purposes is generally the height at which new (or redeveloped) building floor levels should be built to minimise frequency of inundation and associated damage. It may also refer to the height to which flood proofing could be applied to reduce damages to commercial properties, required levels for evacuation or height of storage for hazardous goods. FPLs can vary for different types of land use categories depending on the level of risk, consequences of inoperability or vulnerability of occupants. For example, residential development could be considered more vulnerable due to people being present, whilst commercial development may be considered less vulnerable, as there are times when people are not likely to be present, this coupled with businesses being better placed to implement flood protection/mitigation measures, through business policies, compared to residents.

Less vulnerable development could therefore be prescribed lower floor levels but may then be subject to other controls, such as flood proofing, up to the level of the FPL. This allows a decision around the acceptable level of risk to be a business decision, allowing a trade-off of responsibility between Council and present and future business owners. For developments more vulnerable to flooding (hospitals, schools, electricity substations, seniors housing, etc.) consideration should be given to events rarer than the 1% AEP when determining their FPL or situating those developments outside the floodplain where possible.

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Until recently the NSW Government planning framework allowed for the FPL to be initially defined within the LEP and supported through subsequent controls in the DCP. Changes to the NSW Government planning framework in relation to flooding came into effect on the 14th July 2021. These changes removed the definition of the FPL from the LEP. Flood planning controls including FPLs are defined via the DCP, which is consistent with the changes that came into effect on 14th July 2021.

8.3.1.1. Defined Flood Event

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. Selecting the appropriate FPL involves trading off the social and economic benefits of a reduction in the frequency, inconvenience, damage and risk to life caused by flooding against the social, economic and environmental costs of restricting land use in flood prone areas and of implementing management measures.

The Floodplain Development Manual (Floodplain Development Manual (2005)) 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 FPL;
- 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; and
- Duty of care.

As detailed in Section 1.1.2 of the Manual, the NSW Flood Prone Land Policy provides for a merit-based approach to selection of appropriate flood planning levels (FPLs). This recognises the need to consider the full range of flood sizes, up to and including the PMF and the corresponding risks associated with each flood, whilst noting that with few exceptions, it is neither feasible nor socially or economically justifiable to adopt the PMF as the basis for FPLs [for residential purposes]. FPLs for typical residential development would generally be based on the 1% AEP event plus an appropriate freeboard. Justification for the use of the 1% AEP event, and discussion on the determination of appropriate freeboard is provided below.

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As a guide, Table 14 has been reproduced from the NSW Floodplain Development Manual to indicate the likelihood of the occurrence of an event in an average lifetime or during the design life of a structure, to indicate the potential impact that may be experienced. The table shows that there is a 50% chance of a 100 year Annual Recurrence Interval (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 residential 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 property 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 more vulnerable development.

Table 14: Likelihood of given design events occurring in a period of 70 years (Floodplain Development Manual (2005))

Size of Flood (Chance of occurrence in any year) ARI (AEP)	Probability of Experiencing the Given Flood in a Period of 70 years	
	At least once (%)	At least twice (%)
1 in 10 (10%)	99.9	99.3
1 in 20 (5%)	97.0	86.4
1 in 50 (2%)	75.3	40.8
1 in 100 (1%)	50.3	15.6
1 in 200 (0.5%)	29.5	4.9

Consideration of more or less frequent events can be appropriate for different land uses, with considerations around level of risk, consequences of inoperability or vulnerability of occupants. In the case of sensitive and hazardous uses and the available land within this zone, it is appropriate for the PMF to be considered. Additionally, it is appropriate to consider a more frequent risk of exposure such as the 5% AEP for recreational and non urban uses, such as recreation facilities.

The sensitivity of flood levels in the catchment to future climatic conditions have been assessed (Section 6.2) and it has been determined that flood levels are relatively sensitive to the influences of increased rainfall intensity and increases in sea level. The sensitivity of flood levels has the potential to significantly increase the number of properties at risk in addition to shifting the frequency at which properties and floor levels become impacted. For example, the influences of climate change has been shown to increase levels in the upper reaches by up to 0.3m, 0.5m through the middle reaches and up to 1.0m in the tidal influenced zones. These increases are equivalent to a 0.2% AEP event in the upper and middle reaches and in excess of the 0.2% AEP event in the lower reaches. This would indicate that to ensure appropriate ongoing management of flood risk and reduced property damage via the application of flood planning levels, that the appropriate defined flood event should account for future climatic conditions.

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8.3.1.2. Freeboard Selection

As noted above, the Flood Planning Level is typically derived from a defined flood event (usually the 1% AEP) plus a freeboard allowance. The Manual states that, in general, the FPL for a standard residential development would be the based on the 1% AEP event plus a freeboard which is typically 0.5 m. The freeboard may be varied where the consequences to people and property vary in less frequent events.

The freeboard can be considered as a compulsory 'safety factor' used to provide reasonable certainty that the reduced flood risk exposure provided by selection of a particular flood as the basis of an FPL, is actually provided given the following factors:

- Uncertainty in estimating flood levels, this results from the degree of uncertainty associated with each element used in determining design flood levels, such as model inputs, parameter assumptions, etc;
- Differences in water level because of local factors, such as local water surge due to localised blockages or vehicles moving through flood water;
- Increases due to wave action as a result of vehicles moving through flood waters or the influences of wind; and
- The cumulative effect of subsequent infill development.

The completed flood modelling provides the opportunity to understand the influence and magnitude of each of these factors by assessing the sensitivity of model results to changes to model parameters, blockage assumptions or potential future development. In this case the impacts of climate change have been incorporated separately into the defined flood event, rather than the freeboard, due to the significant change in risk under future climatic conditions.

The sensitivity of flood levels to a range of factors was considered as part of the Flood Study Review (2015) with the general range of 0.1 m – 0.3 m (average 0.1 m), for hydrologic lag, scale of flood behaviour, and hydraulic roughness.
The Flood Study (2019) considered the influence of blockage, with the general range again of 0.1 m – 0.3 m (average 0.2 m). The current study considered the potential influence of future development as generally within the same range of 0.1 m – 0.3 m.

The analysis also recognises that design flood characteristics could result from many combinations of flood-producing factors, and that in reality not all freeboard components would occur concurrently, however it is likely that some would. Consideration of the other factors that freeboard accounts for, it is appropriate to adopt a 0.5 m freeboard.

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8.3.2. Option PM02: Flood Planning Area (FPA)

☑	**PM02: Flood Planning Area**
Description	Adopt the Flood Planning Area for residential development as the area defined by the extent of: • Defined Flood Event + Freeboard where the Defined Flood Event has been determined to be the 1% AEP (including envelope of blocked and unblocked scenarios) plus climate change rainfall increases (RCP8.5 2090) and 0.90 m SLR. Freeboard is 0.5m. Adopt the extent of the Probable Maximum Flood for planning purposes on land with a significant risk to life, sensitive, vulnerable or critical uses, or land with hazardous materials or industry.
Outcome	Recommended to be considered in Council's Floodplain Management Program.

The FPL, and other flood related development controls, are applied to properties within the Flood Planning Area (FPA). The FPA is defined in the Manual (Floodplain Development Manual (2005)) as the land at or below the FPL. It is important to define the boundaries of the FPA to ensure flood related planning controls are applied where necessary and not to those lots unaffected by flood risk. It is also important to define the FPA on criteria set out in the Manual. The FPA map has been produced as an output of this study.

The NSW Standard Instrument LEP does not include a specific land use zone for flood prone land, rather it permits a Flood Planning Area map to impose flood related development controls across all land use zones. The Flood Planning Area map can be placed in the DCP or a Floodplain Risk Management Study.

The Flood Planning Area map, provided on Figure B1 is recommended to be adopted by Council.

8.3.3. Option PM03: Provision of Flood Information to Residents via Section 10.7 Planning Certificates

☑	**PM03: Provision of Flood Information to Residents via Section 10.7 Planning Certificates**
Description	Utilise mapping developed as part of this study to identify lots where flood related development controls apply and update Section 10.7(2) certificates
Outcome	Recommended to be considered in Council's Floodplain Management Program.

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Section 10.7 Planning Certificates (formerly S149 Planning Certificates) are issued in accordance with the Environmental Planning & Assessment Act 1979. They contain information on how a property may be used and the restrictions on development that apply. A person may request a Section 10.7 Planning Certificate at any time to obtain information about his or her own property, but generally the certificate will be requested when a property is to be redeveloped or sold. When land is bought or sold the Conveyancing Act 1919 requires that a Section 10.7 Planning Certificate be attached to the Contract for Sale.

Schedule 2 of the Environmental Planning and Assessment Regulations 2001 gives requirements for inclusion on Section 10.7 Planning Certificates under Section 10.7(2) of the Act. In particular Schedule 2, Clause 9 refers to flood related development control information and requires that Council include whether or not development on the land or part of the land is subject to flood related development controls. For the purposes of the State Environmental Planning Policy (Exempt and Complying Development Codes) Amendment (Housing Code) 2017, a *Flood Control Lots* is also a lot to which flood related development controls apply. Council applies flood related development control up to the PMF, these controls vary based on the vulnerability of the land use and the flood risk present. Examples include emergency management and structural stability considerations for properties up to the PMF. This notification is also consistent with the recent changes to the flood prone land package (refer Section 4.2.3).

It is recommended that the high-resolution flood information developed in this study is used by Council to improve community flood awareness, by providing information to residents (upon application) via Section 10.7 Planning Certificates. Section 17.2 and 17.3 of Appendix I to the FDM (Reference 2) detail typical examples of information for inclusion in Section 10.7 (2) and (5) Planning Certificates, and include the following:

- Whether the land is within the FPA (overland, riverine, or both) and if flood related development controls apply, (10.7(2));
- Design flood levels/depths specific to the property for the 1% AEP, 5% AEP and PMF events, (10.7 (2) and (5));
- Percentages of lots affected by the FPA(s) if not 100%, (10.7 (2) and (5));
- Likelihood of flooding and mechanism (riverine/ overland flow/ both) (10.7 (2) and (5));
- Flood hazard (10.7 (2) and (5));
- Hydraulic categorisation (e.g. floodway) (10.7 (2) and (5));
- Evacuation routes/ constraints (10.7(2) and (5)); and
- Associated Mapping for the above items (10.7 (2) and (5)).

The more informed a home owner is, the greater the understanding of their flood risk. During a flood event, having this understanding helps prepare residents for evacuation, and improves the ability of residents to recover following an event. Improved flood risk awareness may also reduce the number of residents that elect to shelter in place in high hazard areas, which can increase pressure on the SES if they are isolated or their homes inundated.

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Land owners can be concerned as to how a notification may impact on their property value or insurance, for example. The Insurance Council of Australia provides detailed fact sheets on how flood information is used for insurance pricing. This should be taken into account when developing a consultation strategy for notification of any changes related to S10.7 Planning Certificates.

8.3.4. Option PM04: Managing Development in Flood Prone Areas

☑	**PM04: Managing Development in Flood Prone Areas**
Description	Adopt the DFE as the 1% AEP (including envelope of blocked and unblocked scenarios) plus climate change rainfall increases (RCP8.5 2090) and 0.90 m SLR for planning related matters. Adopt the Flood Risk Precinct Definition and Mapping as defined by Figure 13 from this study for the purposes of flood related planning controls. Adopt a consistent set of flood related planning controls across the LGA with guidance from the example matrix and controls from this study. Adopt Major/Minor Overland Flow definition and mapping as defined by Figure 5 from this study. Adopt a revised clause within Council's DCP to better achieve Chapter E13 Objective 3(1)(i): Ensure new development (with the exception of waterway crossings) does not encroach within areas susceptible to channel erosion, migration, bank failure and slumping. Consider Flood Risk Precincts and Flood Emergency Response Classifications in land use planning decisions.
Outcome	Recommended to be considered in Council's Floodplain Management Program.

Appropriate planning instruments ensure that development can be undertaken considering compatibility with the flood risk. Effective planning instruments have the ability to reduce residual flood risk over time as redevelopment occurs. Planning instruments can be used as tools to:

- Reduce risk to life;
- Reduce damage to the proposed development itself; and
- Reduce damage to the broader floodplain and existing development.

Development Control Plans (DCPs) are used by councils to regulate development on flood prone land in support of the objectives set out in the LEP. They provide more detailed guidance and provisions for implementing the broader development control objectives outlined in the LEP. The Wollongong DCP 2009 contains prescriptive planning controls relating to floodplain and stormwater management, primarily outlined in *Chapter E13* and *Chapter E14*. The flood-related provisions of the DCP are extensive. While most provisions apply to the entire LGA, there is a framework for implementing different controls for specific floodplain areas based on special characteristics of those floodplains.

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These catchment-specific provisions are only implemented where a Floodplain Risk Management Study and Plan have been completed for the catchment. Prescriptive controls across a range of areas including floor level, building components, structural soundness, flood affectation, evacuation and flood management and design are provided for each flood risk precincts across different land use types. Flood risk precincts are defined within the DCP and as shown on Figure 13 has been developed based on the outputs from this study.

Currently there are some slight variations in controls between catchments, an LGA wide strategy for the revision and update of the applied flood related development controls should be developed.

Additionally, a number of the catchments in the LGA are also subject to shallower overland flow, rainfall runoff that runs across the land towards a watercourse, generally in the upper reaches of a catchment. Development controls relating to overland flow typically vary depending on the flood behaviour.

To assist the development of an LGA wide approach for both mainstream and overland flooding, the following recommendations are made in relation to appropriate prescriptive controls for the Hewitts Creek catchment.

Table 15: Recommended Prescriptive Controls

Precinct	Land-use category	Planning Consideration					
		Floor Level	**Building Components**	**Structural Soundness**	**Flood Affectation**	**Emergency Response**	**Management and Design**
High Flood Risk	**Critical Use and Facilities**	**U**	**U**	**U**	**U**	**U**	**U**
	Essential Community Facilities	**U**	**U**	**U**	**U**	**U**	**U**
	Subdivision	**U**	**U**	**U**	**U**	**U**	**U**
	Residential	**U**	**U**	**U**	**U**	**U**	**U**
	Commercial & Industrial	**U**	**U**	**U**	**U**	**U**	**U**
	Tourist Related	**U**	**U**	**U**	**U**	**U**	**U**
	Recreational & Non-urban	**F1**	**B1**	**S1**	**FA1**	**E1, E4**	**M2, M3, M4**
	Concessional Development	**F2, F4, F6**	**B1**	**S1**	**FA1**	**E4**	**M2, M3, M4**
Medium Flood Risk	**Critical Use and Facilities**	**U**	**U**	**U**	**U**	**U**	**U**
	Essential Community Facilities	**U**	**U**	**U**	**U**	**U**	**U**
	Subdivision	**N/A**	**N/A**	**N/A**	**FA1**	**E4, E5**	**M1**
	Residential	**F2, F6 or F7**	**B1**	**S2**	**FA1**	**E3, E4**	**N/A**

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	Commercial & Industrial	**F2 or F5**	**B1**	**S2**	**FA1**	**E1, E4**	**M2, M3, M4**
	Tourist Related	**F2, F6**	**B1**	**S3**	**FA1**	**E3, E4**	**M2, M3, M4**
	Recreational & Non-urban	**F1, F6**	**B1**	**S2**	**FA1**	**E1, E4**	**M2, M3, M4**
	Concessional Development	**F2, F4**	**B1**	**S1**	**FA2**	**E4**	**M2, M3, M4**
Low Flood Risk	**Critical Use and Facilities**	**F3**	**B2**	**S3**	**FA2**	**E2 or E3, E4**	**M2, M3, M4**
	Essential Community Facilities	**U**	**U**	**U**	**U**	**U**	**U**
	Subdivision	**N/A**	**N/A**	**N/A**	**FA2**	**E4, E5**	**M1**
	Residential	**N/A**	**N/A**	**S2**	**N/A**	**E3, E4**	**N/A**
	Commercial & Industrial	**N/A**	**N/A**	**N/A**	**FA2**	**E4**	**N/A**
	Tourist Related	**N/A**	**N/A**	**S3**	**FA2**	**E3, E4**	**N/A**
	Recreational & Non-urban	**N/A**	**N/A**	**N/A**	**N/A**	**N/A**	**N/A**
	Concessional Development	**N/A**	**N/A**	**N/A**	**N/A**	**N/A**	**N/A**

Planning Consideration	No.	Control
Floor Level	**F1**	All floor levels to be equal to or greater than the 5% AEP flood level plus freeboard (FB1) unless justified by site-specific assessment
	F2	Habitable floor levels to be equal to or greater than the DFE flood level plus freeboard (FB1)
	F3	All floor levels to be greater than the PMF level plus freeboard (FB1)
	F4	Floor levels to be as close to the FPL as practical and no lower than the existing floor level when undertaking alterations or additions
	F5	Floor levels of commercial premises to be as close to the FPL as practical. Where below the FPL the premises to be flood proofed below the FPL. The floor level must be above the DFE.
	F6	Garage floor level to be above finished adjacent ground (except where an integral retaining wall is provided and waterproofed to prevent the ingress of runoff)
	F7	Garage and all other non-habitable internal floor levels to be no lower than the DFE flood level minus 300 mm or 300 mm above finished adjacent ground (whichever is greater)
	F8	Habitable floor levels to be equal to or greater than the DFE flood level plus freeboard (FB2)
	F9	All floor levels to be equal to or greater than the 5% AEP flood level plus freeboard (FB2) unless justified by site-specific assessment
Building Components	**B1**	All structures to have flood compatible building components up to and including the DFE flood level plus freeboard (FB1)
	B2	All structures to have flood compatible building components up to and including the PMF level
	B3	All structures to have flood compatible building components up to and including the DFE flood level plus freeboard (FB2).
Structural Soundness	**S1**	FIRA required that includes certification that any structure can withstand the forces of floodwater, debris and buoyancy up to and including the DFE flood level and applied to the DFE flood level plus freeboard (FB1)

	S2	Applicant to demonstrate that any structure can withstand the forces of floodwater, debris and buoyancy up to and including the DFE flood level (and applied to the DFE flood level plus freeboard (FB1)) or PMF if required to satisfy emergency response criteria (see below)
	S3	Applicant to demonstrate that any structure can withstand the forces of floodwater, debris and buoyancy up to and including a PMF flood
	S4	Applicant to demonstrate that any structure can withstand the forces of floodwater, debris and buoyancy up to and including a DFE flood level (and applied to the DFE flood level plus freeboard (FB2)), PMF if required to satisfy emergency response criteria (see below).
Flood Affectation	**FA1**	FIRA required to certify the development will not increase flood affectation elsewhere considering the permissible impacts outlined in the DCP.
	FA2	The impacts of the development on flooding are to be addressed considering the permissible impacts outlined in the DCP.
Emergency Response	**E1**	Reliable access and egress for pedestrians required during the DFE flood
	E2	Reliable access and egress for pedestrians and vehicles required during a PMF
	E3	Reliable egress for pedestrians or vehicles is required from the lowest habitable floor of the building to an area of refuge above the PMF level, or a minimum of 20 sqm of the building to be above the PMF level.
	E4	The emergency response strategy of the development is consistent with any relevant local or state flood plan developed by the flood combat and flood emergency management lead agency
	E5	Applicant to demonstrate that evacuation of any proposed development proposal can be undertaken in accordance with this DCP
Management and Design	**M1**	Applicant to demonstrate that potential development as a consequence of a subdivision or development proposal can be undertaken in accordance with this DCP and / or FIRA
	M2	Site Flood Safe plan (home or business) to address safety and property damage issues (including goods storage) considering the full range of flood risk
	M3	Materials that may cause pollution or be potentially hazardous during a flood should be contained or not be stored below the PMF flood level
	M4	Applicant to demonstrate that area is available to store goods above the DFE flood level plus freeboard (FB1) or above the PMF if the development is a critical utility.
	M5	Applicant to demonstrate that area is available to store goods above the DFE flood level plus freeboard (FB2) or above the PMF if the development is a critical utility.
Notes	**FPL**	Flood Planning Level [DFE + freeboard]
	DFE	'Defined Flood Event' [1% AEP + sea level rise (SLR) + increase in rainfall intensity (+RI) + envelope of blockage]
	FB1	500 mm freeboard
	FB2	300 mm freeboard
	FIRA	Flood Impact and Risk Assessment: prepared by a suitably qualified engineer experienced in hydrological and hydraulic analysis for flood risk management.
	N/A	Not applicable
	U	Unsuitable use

8.3.5. Option PM05: Voluntary House Raising

☑	PM05: Voluntary House Raising
Description	Undertake a feasibility investigation (including to confirm structural compatibility of the identified buildings, owner interest and a more accurate cost estimate of raising to at least the DFE + 0.5 m flood level), and if found viable, prepare the documentation for funding applications.
Outcome	Recommended to be considered in Council's Floodplain Management Program.

Voluntary house raising (VHR) seeks to reduce the frequency of exposure to flood damage of the house and its contents by raising the house above the Flood Planning Level (FPL). This results in a reduction in the frequency of household disruption and associated trauma and anxiety, however other external flood risks remain, such as the need to evacuate prior to properties being isolated by floodwaters.

VHR schemes are eligible for state government funding based on criteria set out in the *Guidelines for Voluntary House Raising Schemes*. In accordance with these guidelines, VHR is generally excluded for properties located within floodways; is limited to low hazard areas; and applies only to houses constructed before 1986. House raising is most suitable for non-brick single storey buildings on piers and is typically not feasible for slab-on-ground constructions.

However, advances in construction techniques and other alternatives may make house raising a viable option for slab-on-ground properties, and therefore individual assessments are required. Repurposing the ground floor for non-habitable use and constructing a second story (above the FPL) for habitable uses may also be a possibility. The VHR guideline states that "*VHR can be an effective strategy for existing properties in low flood hazard areas where mitigation works to reduce flood risk to properties are impractical or uneconomical*".

Outputs from the flood damages assessment and classification of the floodplain into hydraulic categories and hazard classifications have been used to identify residential dwellings that are located outside of the floodway and within low to moderate hazard areas only (H1 to H3) and are inundated over floor in events as frequent as the 20% AEP under current conditions. Ten properties met these criteria and would potentially be eligible for VHR, subject to further investigation including owner interest and construction type.

Costs of house raising is typically in the order of $100,000 although is highly variable and dependant on the specific property and building characteristics. An economic assessment of the option was undertaken and presented below, using a 70-year effective life of the house raising assuming the properties are raised to the DFE plus 500 mm level, and allowing for a 20% contingency factor. The option was tested for both 4%, 7% and 10% discount rates. Raising of individual properties was also assessed using a 7% discount rate only. Results are shown in Table 16.

Table 16: VHR economic assessment

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Option	NPV Costs	Change in AAD	NPV Benefits	Discount rate	BCR
Raising all properties	**$1,800,000**	**$102,136**	**$1,508,231**	**7%**	**0.84**
			$2,281,882	4%	1.27
			$1,113,932	10%	0.62
Raising individual properties					
Prop 257	$120,000	$10,170	$150,185	7%	0.83
Prop 473	$120,000	$20,873	$308,229	7%	1.71
Prop 1074	$120,000	$4,779	$70,578	7%	0.39
Prop 1226	$120,000	$10,170	$150,185	7%	0.83
Prop 1227	$120,000	$10,170	$150,185	7%	0.83
Prop 1233	$120,000	$15,947	$235,497	7%	1.31
Prop 1240	$120,000	$8,509	$125,658	7%	0.7
Prop 1251	$120,000	$8,509	$125,658	7%	0.7
Prop 1271	$120,000	$8,455	$67,189	7%	0.69
Prop 1334	$120,000	$102,136	$124,867	7%	0.84

This shows that a voluntary house raising scheme may be economically viable for some of the identified properties, with two properties shown to have BCRs greater than one. However, it will depend on the actual costs involved in raising, the interest of the owners and therefore further investigation is recommended.

8.3.6. Option PM06: Voluntary Purchase

☑	**PM06: Voluntary House Purchase**
Description	Undertake further investigation to determine inclusion of 15 properties in the ongoing VP scheme, including consultation with the identified properties, prioritisation and if appropriate, prepare the documentation for funding applications.
Outcome	Recommended to be considered in Council's Floodplain Management Program.

Voluntary Purchase (VP) schemes are a long-term option to remove residential properties from areas of high flood hazard. VP is recognised as an effective floodplain risk management measure for existing properties in areas where:

- There are highly hazardous flood conditions and the principle objective is to remove people living in these properties and reduce the risk to life of residents and potential rescuers;
- A property is located within a floodway and its removal may contribute to a floodway clearance program that aims to reduce significant impacts of flood behaviour elsewhere in the floodplain by improving the conveyance of the floodway; or
- Purchase of a property enables other flood mitigation works to be implemented (e.g. channel improvements of levee construction).

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In the NSW Government *Guidelines for Voluntary Purchase*, the eligibility criteria notes that VP will be considered only where no other feasible flood risk management options are available to address the risk to life at the property, and that subsidised funding is generally only available for residential properties. Once a dwelling is purchased it would be demolished, and a restriction placed upon the lot to prevent future residential or commercial development. The Guideline further sets out the way in which a VP scheme should be undertaken and how properties should be valued.

Council has previously purchased a number of high risk properties in the LGA and to understand the ongoing suitability of Voluntary Purchase in the catchment, an assessment was undertaken to identify the locations of dwellings in relation to the floodway and high hazard areas. Dwellings situated inside the 1% AEP floodway and high hazard areas may be eligible for voluntary purchase, as their removal would reduce the number of occupants in highly hazardous areas, as well as reduce obstruction to flow caused by the dwelling itself. This process identified 15 potential properties meeting the relevant criteria. Council should consider the inclusion of the further 15 properties in the ongoing VP scheme. The removal of properties from hazardous locations has greater benefits beyond just economic terms.

Further investigation is required, including considering these additional benefits, testing the community's ongoing appetite for such a scheme, the degree of risk at each property including the vulnerability of the occupants and to determine how best the purchased land could be integrated with the community.

8.3.7. Option PM07: Flood Proofing/Flood Resilient Buildings

☑	**PM07: Flood Proofing/Flood Resilient Buildings**
Description	Allow flood proofing within Council's DCP enabling new and existing buildings to be developed with due consideration given to their flood risk and minimisation of internal flood damages and recovery time.
Outcome	Recommended to be considered in Council's Floodplain Management Program.

Flood proofing or flood resilient building is a strategy applied to reduce the damage and recovery costs and time following flood events. It is often divided into two categories: wet proofing and dry proofing. Wet proofing assumes that water will enter a building and aims to minimise damages and/or reduce recovery times through use of water-resistant materials, locating electricals above the FPL, storage of possessions at higher levels, tie down of items that may float, and facilitation of drainage and ventilation after flooding. Dry proofing aims to totally prevent flood waters from entering a building and is typically best incorporated into a structure at the construction phase, though can also be retrofitted to existing buildings. Dry proofing measures are typically installed at doorways or garage entry points, however other openings (such as for ventilation) should also be considered. Dry proofing measure are often only effective if sufficient warning time is available for their placement at the onset of a flood event.

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Retrofitting some aspects of permanent flood proofing measures can be difficult and costly, and therefore permanent flood proofing is best implemented during construction and allowed under development controls. Elements such as flooring and lower wall protection is more easily retrofitted. As such, flood proofing can be stipulated within Council DCPs as an option for structures below the FPL, as a minimum.

Access to community facilities, shops, healthcare services, sporting facilities and pubs are key to a community's recovery from a flood event and contribute significantly to community resilience and emotional recovery. While such premises would still not be operational during a flood nor immediately afterwards (pending safe access, reconnection of utilities etc.), flood proofing would significantly decrease the duration of business closures after the event.

It is noted however that flood proofing individual buildings would not reduce external flood damages (e.g. to carparks, garages, sheds, fences or stock yards or to the external structure of buildings) nor does it reduce potential risk to life. Furthermore, if buildings are wet-proofed there would still be clean-up costs incurred, as well as days of business lost during the flood itself and the immediate recovery period.

Flood proofing can also be an option for sensitive and hazardous land uses, where controls would require, aspects to the essential operation, such as generators to be located at a higher level.

A range of existing guidance materials are available including the Blue Book – Reducing Vulnerability of Buildings to Flood Damage – Guidance on building in flood prone areas (2006), Queensland Reconstruction Authority – Flood Resilient building Guidance for Queensland Homes (2019) and NSW SES Business Flash Flood Tool Kit.

Flood proofing is currently not eligible for funding assistance through the NSW Government's Floodplain Management Program, however other funding sources may be available to landholders.

8.4. Response Modification Measures

The measures described in this section relate to how the community receives information about floods, and responds to and recovers from flood emergencies. Options are designed to improve emergency management procedures, and to improve the response of the community, for example by educating flood affected property owners about the nature of flooding so that they can make better informed decisions. Effective planning for emergency response assists in reducing risk to life and property, particularly for infrequent floods that are not managed through flood or property modification.

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8.4.1. Option RM01: Amend Local Flood Plans with Flood Information Derived from this Study

☑	RM01: Amend Local Flood Plans with Flood Information Derived from this Study
Description	• Amend local flood plans and operational plans to include information on flood risk, drawing on modelling and information provided in this FRMS&P • Significant risk to life exists during flash flood events, particularly where there is flow across roads; • Resources are likely to be limited during a regional storm event, so the consideration of efficient ways to manage flood risk without increasing the burden on the combat agencies is critical; • Allow for periodic review of plans: every 3-5 years, or following an event or exercise in which the plan(s) are implemented.
Outcome	Recommended to be considered in Council's Floodplain Management Program.

The NSW SES prepares a range of documents that cover preparedness, response and coordination measures that are essential to the management of storm and flood risk. These documents include FloodSafe brochures, Local Flood Plans, regionally based information webpages, StormSafe brochures in addition to information and brochures on preparedness strategies for urban areas. A Local Flood Plan and FloodSafe brochure exists for the Illawarra, however there are no specific documents for the study area. The Illawarra Local Flood Plan was updated in 2022.

It is recommended that flood information regarding flow risk in the study area is incorporated into these documents, for two main reasons.

- To allow SES and Council to better prepare for and respond to flood risk.
- To understand the areas and roads at risk when a local catchment event occurs.

In addition, the availability of these documents should be included as part of an ongoing flood education and awareness program.

This option improves community awareness and operations during a flood event, allowing preparedness. This can in turn reduce social disruption and anxiety resulting from experiencing a flood event.

Following completion of this study, Council and the SES will be provided with a range of outputs that can be used to develop plans relating to overland flow flood risk. Such outputs include:

- High resolution GIS results including peak flood depths and levels, hazard and hydraulic categories;
- Information pack with GIS layers that can be used to relate rainfall intensities and durations, to design flood events;
- Identification of parts of the study area at greatest risk; and
- Identification of roads that are prone to flooding.

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Importantly, the recommendations made in the subsequent sections of this report should also be considered when updating the various Flood Plans. The subsequent recommendations endeavour to reduce flood risk to the community without increasing the burden on SES and Council staff.

8.4.2. Option RM02: Facilitation of Communication with Emergency Services and Response Agencies

☑	**RM02: Facilitation of Communication with Emergency Services and Response Agencies**
Description	• Ongoing facilitation of communication between Council and emergency service agencies is recommended, for example via the following: • Regular meetings of all responders and 'peace time exercises' between flood events; • Continue to develop relationships between Council, SES and Fire & Rescue and other community groups; • Maintain an understanding of vulnerable occupants; • Improvement of volunteer coordination for more effective utilisation during clean-up and recovery.
Outcome	Recommended to be considered in Council's Floodplain Management Program.

The NSW SES is the legislated Combat Agency for floods and is responsible for the control of flood operations, including the coordination of evacuation and welfare of affected communities. The SES Local Controller is responsible for dealing with floods as detailed in the NSW State Flood Plan. The NSW State Storm Plan describes the framework within which evacuation orders are given and operations are carried out.

A key responsibility of the SES is the coordination of other agencies and organisations for flood management tasks. Effective communication, identification and prioritisation of vulnerable occupants, data sharing, and clarity of roles and responsibilities is essential for the efficient and safe execution of flood response actions.

The SES is able to respond to calls regarding private property, including storm damage, evacuations (if appropriate) and rescues (e.g. motorists or pedestrians who have entered floodwaters).

Council also plays a significant role in ensuring the safety of its community in times of emergency, including preparedness of the organisation in the lead up to an event such as a flood, its response, integration with other emergency services and recovery from the event. During a local storm or flash flood event, Council is responsible for responding to issues relating to public areas and infrastructure, for example, road closures, cleaning out drains, and pumps, and debris removal within road reserves or riparian corridors.

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It is important to share information about the typical roles of each agency with community members, to allow them to contact the appropriate agency in the event of a flood related emergency, to ensure their call is responded to without unnecessary delay, and not place additional burden on agencies that cannot assist directly.

Hosting meetings and exercises to improve plans at the strategic level, including a broader range of representatives from each agency in these meetings. In particular, the inclusion of Council engineering and outdoor staff, and SES volunteers and volunteer coordinators, would ensure that the individuals who are most likely to be active during the event would benefit from the training exercises, and could add input from their own experience. Not only will this help more responders prepare for flood events but increase familiarity between representatives of each agency.

Difficulties in achieving the above objectives stem from the logistics of gathering the relevant parties at a mutually convenient time, staff changeover within agencies, and location and availability of out-of-area volunteers. It may be more feasible to have regular, smaller meetings, where representatives from each agency can attend and report back to their teams, and perhaps aim to hold a larger scale gathering and training day once or twice a year to ensure individuals can plan their attendance well in advance.

The importance of volunteer coordination, particularly with the arrival of volunteers from outside the area can be an issue during events. To make the most of available volunteer resources, it is recommended that investment is made in developing a clear action guide with well-defined and clearly communicated roles and responsibilities.
The benefits include hazard response that is quick, efficient and safe and calls from the public can be directed to the appropriate agency and responded to effectively. This guide recommended to be developed during ‘peace time’, i.e. between floods (or other threats), and will be particularly beneficial for the recovery period immediately following a flood event.

The below suggestions are made to improve coordination between and within emergency service agencies.

- Regular Meetings of the Local Emergency Management Committee (Council), ensuring the inclusion and involvement of responders ‘on the ground,’ e.g. volunteers and Council outdoor staff, particularly for the benefit of new staff and;
- Hold ‘peace time exercises’ between flood events (or other threats) to maintain relationships and familiarity with roles and responsibilities, so that they are well defined and understood by each agency;
- Develop plans for the effective coordination of out-of-area volunteers who may travel to the area to assist during the recovery period immediately following a flood.

This option improves community and front line stakeholders awareness around responsibilities during a flood event with the aim of reducing frustration during an event. It also ensures that flood response activities can be undertaken effectively and efficiently.

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The below suggestions are made to improve coordination between and within emergency service agencies.

- Regular Meetings of the Local Emergency Management Committee, ensuring the inclusion and involvement of responders 'on the ground,' e.g. volunteers and Council outdoor staff, particularly for the benefit of new staff and;
- Hold 'peace time exercises' between flood events (or other threats) to maintain relationships and familiarity with roles and responsibilities, so that they are well defined and understood by each agency;
- Develop plans for the effective coordination of out-of-area volunteers who may travel to the area to assist during the recovery period immediately following a flood.

8.4.3. Option RM03: Improve Community Flood Education and Awareness

☑	**RM02: Improve Community Flood Education and Awareness**
Description	• Establish and implement an ongoing and collaborative education program to improve flood awareness within the Community. A range of potential strategies for engaging with the community are provided in this section
Outcome	Recommended to be considered in Council's Floodplain Management Program.

A key step towards modifying the community's response to a flood event is to ensure that the community is fully aware that floods are likely to interfere with normal activities in the floodplain. Flood awareness is a vital component of flood risk management for people residing and working in the floodplain, as well as for those reliant on services operated from within flood prone areas. Flood awareness can be developed through a range of strategies with varying levels of community participation. Strong flood awareness can significantly improve the way a community prepares for, and recovers from flooding.

While the NSW SES is the legislated Combat Agency for floods, responsible for the control of flood operations, including the coordination of evacuation and welfare of affected communities; during a flood events SES resources are often stretched. Improving community awareness and therefore readiness and preparedness can reduces losses during flood events.

Community Flood Education programs are useful management measures to raise awareness, community preparedness and overall resilience to flood events. Well developed flood education programs can reduce the risk to life and overall flood damages, and improve the communities understanding of floodplain management. This can in turn reduce social disruption and anxiety resulting from experiencing a flood event.

It is noted that ongoing flood awareness campaigns can be costly and can become ineffective over time with residents becoming bored or complacent around messaging, particularly in periods of little rainfall, unless messaging is targeted appropriately and continually evolving. However, it is key to keep flood awareness current, as awareness between events, particularly as residents move in and out of the area and flood awareness drops.

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To maintain a base level of flood awareness provision of basic flood information is recommended, for example to new residents or permanently on the Council website, to be supplemented with a range of events and other methods of engagement as described below.

The community's perception of flooding may be more driven by flood risk occurring in large river systems, and overland flow flood risk may be perceived as less important or hazardous in comparison. Overland flow events do occur, and bring with them their own risks, particularly relating to flash flooding of roads, and driver safety. It is key to keep overland flow flood awareness current, as flash floods can occur frequently and quickly.

Based on learnings from recent disasters, the focus of community disaster education has now turned from a concentration on raising awareness and preparedness to building community resilience through learning. Simply disseminating information to community does not necessarily trigger changed attitudes and behaviours. Flood education programs are most effective when they:

- Are participatory i.e. not only consisting of top-down provision of information but where the community has input to the development, implementation and evaluation of education activities;
- Involve a range of learning styles including experimental learning (e.g. field trips, flood commemorations), information provision (e.g. via pamphlets, the media), collaborative group learning (e.g. scenario role plays with community groups) and community discourse (e.g. forums, post-event debriefs);
- Are aligned with structural and other non-structural methods used in floodplain risk management and with emergency management measures such as operations and flooding; and
- Are ongoing programs rather than one-off, unintegrated 'campaigns', with activities varied for the learner.

It is difficult to accurately assess the benefits of a community flood education program, but the consensus is that the benefits far outweigh the costs. Nevertheless, sponsors must appreciate that ongoing funding is required to sustain the gain that has been made.

Key messages to be communicated to the community include:

- General information about how flooding in the study area is generated, where it is conveyed and typical durations of inundation;
- Specific information about flow paths and associated flood behaviour (for key areas at risk);
- Guidance on the roles and responsibilities of the SES and Council, and contact details of each agency;
- What to do when BoM issues a severe weather warning for the study area;
- General information regarding personal safety during a flash flood event, particularly, the risks of driving across flooded roads, even if flow is shallow.

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A community education program was recommended as part of the Floodplain Risk Management Study and Plan (2002) which included the following activities:

- Update of Council GIS data bases,
- Issuing of Flood Certificates,
- Production of book about August 1998 flood,
- Commemoration activities,
- Brochure on Flood Risk Precincts,
- Production of brochure on how the local community can care for the creek environment, and
- Installation of flood markers.

These methods both inform and prepare the community for future flood events, with a key objective being to build resilience. Available resilience building activities include:

- Use of Section 10.7 planning certificates to ensure residents have access to flood affectation information. This includes consultation activities to ensure the community are aware of what S10.7 certificates are and how to request one,
- Provision of flood awareness mapping and risk information at the property level through the Council website,
- A community champion program to identify trusted community members or groups within the community. A program like this provides a valuable two way conduit between the local residents and Council,
- Issuance of letters / certificates / pamphlets / social media platform updates from Council providing useful flood information to increase resilience (i.e. contacts, links to Council website, links to SES information, past historical flood levels, ground levels, information on climate change and its impacts on flood behaviour, information on implementation of FRMS&P recommendations etc.),
- Information packs for new residents,
- School projects to inform the younger generation about flooding. This method can also lead to information infiltration to parents,
- Library and mobile displays showing historical flood photos and stories,
- Historical flood depth and flood depth markers,
- NSW SES FloodSafe Guide,
- NSW SES Business Flood Safe Breakfast to promote completion of the FloodSafe Business templates and plans,
- ‘Meet the street’ events involving NSW SES and Council setting up a ‘stall’ at an appropriate time and visible location. The stall could consist of flood maps on boards, NSW SES banners, NSW SES materials to hand out,
- Identify and target awareness programs to vulnerable communities,
- Education on the impact structures such as fences and outbuildings can have on flood flow when they are built in locations and in a way that constrains the flow. Chapter E13 of the DCP already includes requirements to prevent household sheds and fences obstructing flood flow, however information on the consequences should be included in the community education program,

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- Information on drainage maintenance including responsibilities and the effectiveness of debris control measures (i.e. even with large scale and regular clearing of creeks and structures, it is not possible to completely prevent blockages), and
- Education on the maintenance of creeks on local properties including responsibilities.

Council already actively engages in a number of these methods. It is therefore recommended that Council invests in the ongoing improvement of community flood awareness in the study area, utilising a range of methods described above. This list is not exhaustive nor prescriptive, noting that innovative opportunities for the promotion of flood awareness may arise organically in conjunction with other Council projects and community events.
A collaborative community education program will maintain, improve (existing residents) and create (new residents) flood awareness in the study area.

A key aspect across all flood awareness programs requires consistency of the language used to describe flooding. Often technical language used in flood investigations is not readily understood by community members. Strategies include describing events in the context of experienced behaviour or relative to a known landmark.

8.4.4. Option RM04: Flood Warning Improvements

☑	**RM04: Flood Warning Improvements**
Description	• Use Severe Weather Warnings from the BoM to prepare for potential flash flooding events. • Monitor progress of pilot program in Fairy Creek and apply successful elements to Hewitts Creek, including the installation of additional rainfall and flow gauges. • Community awareness campaigns may assist residents in interpreting warnings from the BoM, and to prepare accordingly. • Information from this FRMS&P can be used internally by Council and the SES to relate forecast or recorded rainfall data to potential flood scenarios.
Outcome	Recommended to be considered in Council's Floodplain Management Program.

The purpose of a flood warning is to provide advice on impending flooding so people can take action to lessen its negative impacts. Where effective flood warnings are provided, risk to life and property can be significantly reduced. Studies have shown that flood warning systems generally have high benefit / cost ratios if sufficient warning time is provided and if the population at risk is aware of the threat and prepared to respond appropriately.

Due to the nature of storms and floods in the study area, flood warnings are difficult to prepare and disseminate. The quick catchment response time (within hours) does not allow time to interpret recorded rainfall data, construct and disseminate a flash flood warning, with enough time for the community to be able to take meaningful action to prepare.

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Flash floods are of a short duration and a relatively high flow that occurs within six hours of rain falling. While the BoM does not provide warnings for flash flood catchments, it does provide forecasts and warnings for severe weather conditions and potential heavy rainfall that can cause flash flooding. Flash flood warnings themselves are provided by State and local government where gauges and warning systems are available. In addition, there are currently limited rain gauges in the upper reaches of the local catchment, and the installation and operation of additional gauges would involve significant upfront and ongoing costs.

Decisions made on the basis of rainfall observations carry a significant degree of uncertainty. Forecast rainfall has an even greater degree of uncertainty associated with estimating flood affectation.
Evacuations or other response actions based on uncertain triggers may be theoretically defensible in a purely risk-avoidance context but are likely to be viewed as socially and economically unsustainable. There is also the issue that frequent 'false alarms' could lead to a situation where warnings are ignored by most of the community.

As an alternative to a flash flood warning system in the study area, severe weather warnings issued by the BoM can be used as a caution to the potential onset of flooding in overland flow areas coupled with education and awareness. Severe weather warnings are issued when severe weather or thunderstorms are expected – these are the types of storms that can cause flash flooding in the study area. The warning may also note the hazards associated with the storm including damaging wind gusts, large hail and flash flooding. These alerts can also be made available on Council's website and sent directly to residents through SMS alerts. A flood awareness campaign can assist in providing guidance to residents on how to interpret BoM weather warnings and how to manage flooding.

Council is currently developing a pilot program for a prediction based flood warning system for the Fairy Creek catchment. The outcomes of this pilot should be monitored, and successful elements applied to the Hewitts Creek catchment. This would be coupled with the installation of additional rainfall and flow gauges to inform the estimates.

Upon completion of the FRMS, Council and the SES will be provided with high resolution GIS layers of design flood behaviour, including extents, depths, hazards, flood emergency response classifications, road inundation information and impacted property information. The provision of this information can assist in informing both preparedness and response actions during flood events, including relating forecast rainfalls to potential flood scenarios.

This option coupled with an education and awareness program improves community awareness and operations during a flood event, allowing preparedness. This can in turn reduce social disruption and anxiety resulting from experiencing a flood event.

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8.5. Flood Modification Measures

Flood modification measures aim to modify the behaviour of a flood itself by reducing flood levels or velocities or by excluding water from areas under threat. These measures usually involve structural works (often permanent, though temporary structures can also be assessed) which are generally installed to modify flood behaviour on a wider scale; and typically include works such as levee banks, retarding basins and drainage networks. Depending on the type of flood behaviour, spatial constraints and catchment conditions, different flood modification measures will be better suited to reducing flood risk than others. A key consideration when assessing flood modification options is ensuring that, in pursuit of reducing flood risk in one area, the option does not adversely affect other areas.

A number of different structural options were identified and assessed for flood impacts at each location, with preferred options selected for the Multi-Criteria Matrix Assessment. Each of the mitigation measures investigated are described in the following sections, which have been grouped by option type.

Flood impact maps have been produced to display the effect that the various mitigation works would have on flood behaviour. These maps display the difference in peak flood level between a design flood event and the same event with the mitigation works implemented. Impacts maps are presented in Appendix C. Intangible benefits and disadvantages of each option have been assessed via a Multi-Criteria Matrix Assessment, presented in Section 9.

8.5.1. Options Not Considered Further

A range of options were identified in the initial assessment and found, to not be viable in reducing flood risk or the option presented significant constraints across other assessed criteria; these options were discounted with no further assessment undertaken. The following table provides an overview of these options not considered further.

Table 17 Options Not Considered Further

ID	Description	Assessment
LV02 – Slacky Creek	Construct a 50m levee adjacent to the Bulli Showground, with the aim of reducing flood transfer between Tramway and Slacky Creeks	Exacerbates flooding by 0.1m in events up to the 1% AEP. Does not improve flood behaviour and therefore does not improve property damage
LV03 – Thomas Gibson Creek	Increase the existing eastern footpath embankment height by 1m at Thomas Gibson Park to increase the capacity of the informal detention basin. This option was identified in the 2002 Floodplain Risk Management Study.	Option results in no change to flood behaviour up to the 5% AEP. Minimal improvements to flood behaviour in the 1% AEP event that are limited to the creek and therefore does not improve property damage.
LV04 – Slacky Creek	Construct a 120m long embankment at the rear of properties along Hutton Avenue. This option was identified in the 2002 Floodplain Risk Management Study.	The levee worsens the impacts from overland flow and due to the nature of the flood mechanism is unlikely to be able to be improved through design.

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DB01 – Slacky Creek	Construct a 800m^3 (average excavation of 1.4m) capacity offline detention basin to the north of 8-10 Hobart Street. This option was identified as a sediment basin in the 2002 Floodplain Risk Management Study.	Option results in no material change to flood behaviour and therefore does not improve property damage.
DB03 – Woodlands Creek	Construct a 3,200m^3 capacity (average excavation of 2.9m) offline detention basin behind 30 – 42 George Avenue. This option was identified as a sediment basin in the 2002 Floodplain Risk Management Study.	Option results in no material change to flood behaviour and therefore does not improve property damage.
DB05 – Tramway Creek	Construct a 1,100m^3 capacity (average excavation of 1.0m) detention basin upstream of William Street.	Option results in no material change to flood behaviour and therefore does not improve property damage.
DB06 – Woodlands Creek	Formalise the existing floodplain storage upstream of existing vehicle ramp. Requires removal of existing structure]under ramp.	Without additional excavation the capacity of the proposed storage is insignificant to prevent overtopping of the vehicle ramp, increasing flows travelling towards Hewitts Creek, significantly worsening flood behaviour.
CM03 – Hewitts Creek	Regrade Lachlan Street to divert flows from low point towards Thomas Gibson Creek Creek.	While this option reduces flood levels in Hewitts Creek (up to 0.1m) it results in a significantly worsened flood behaviour in Thomas Gibson Creek. This includes inundation of Lachlan Street properties and overtopping of Lawrence Hargrave Drive.
CM04 – Slacky Creek	Regrade access road near Bulli Showground to facilitate the flow of water from the Princes Highway into Slacky Creek.	Option results in minimal benefit to flood behaviour. Works may increase damage to access road during events.
CM05 – Slacky Creek	Channelise the Slacky Creek overflows along Hobart Street towards Tramway Creek with the aim of reducing road inundation.	The option does not achieve a reduction in inundation on Hobart Street and results in an increase in inundation in Tramway Creek.
CM07 – Woodlands Creek	Install 30m wide spillway into Lawrence Hargrave Drive safety ramp with the aim to control the overtopping that currently occurs. This option was identified in the 2002 Floodplain Risk Management Study.	Option diverts overtopping away from some properties in Hewitts Avenue, however concentration of overtopping significantly increases velocity and scour potential is significant. Other options in this area were found to be more effective.
CM08 – Tramway Creek	Adjust road levels on William Street to reduce the extent of road overtopping.	The option reduces the extent of overtopping but also increases flood levels along Slacky and Tramway Creeks. Option also increases the flood hazard when overtopping of William Street occurs.
CM09 – Thomas Gibson Creek	Raise kerb level along Philip Street to direct flows away from the existing carpark towards the creek. This option was identified in the 2002 Floodplain Risk Management Study.	The option achieves a reduction in flood levels of up to 0.1m in the 5% AEP event but worsens flood levels in the 1% AEP event. The option also has significant feasibility challenges with tying in driveways.

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CM11 – Thomas Gibson Creek	Raise kerb level along the south side of Bath Street to reduce property inundation. This option was identified in the 2002 Floodplain Risk Management Study.	The option achieves a reduction in flood levels of up to 0.1m in the 5% AEP event but worsens flood levels in the 1% AEP event. The option also has significant feasibility challenges with tying in driveways.
CM12 – Thomas Gibson Creek	Raise kerb level along the southern side of Seafoam Avenue to reduce property and school inundation.	The option achieves a reduction in flood levels in both the 5% and 1% AEP event but worsens flood levels elsewhere, including developing a new flowpath. The option also has significant feasibility challenges with tying in driveways.
CM13 – Thomas Gibson Creek	Create overland flowpath along the northern side of Seafoam Avenue to redirect overland flow into public land. The option also includes an upgrade to the culverts at Phillip Street.	Option results in limited material change to flood behaviour and impacts properties adjacent to new overland flowpath. The option therefore does not improve property damage.
DM04 – Thomas Gibson Creek	Doubling of the structure under the Illawarra Railway Line south of Thirroul railway station.	Option results in no material change to flood behaviour and therefore does not improve property damage.
DM06 – Hewitts Creek	Improve effectiveness of Virginia Terrace culverts to minimise surcharging. Works include reducing length of culvert, sealing downstream pit and creating a new line. This option was identified in the 2002 Floodplain Risk Management Study.	Option results in no material change to flood behaviour and therefore does not improve property damage.
DM08 – Thomas Gibson Creek	Upgrade the stormwater line capacity by duplicating the line.	Option results in no material change to flood behaviour and therefore does not improve property damage.

8.5.2. Embankments and Levees

Embankments and levees are barriers between a watercourse and developed areas that prevent the ingress of floodwater up to a design height (usually a design event plus freeboard). Levees usually take the form of earth embankments but can also be constructed of concrete walls or steel sheet piles where there is limited space or other constraints. Flood gates, flap valves and pumps are often installed through larger levees to prevent floodwaters backing up through the drainage systems in the area protected by a levee and/or to remove ponding of local water behind the levee.

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8.5.2.1. Option LV01: Woodlands Creek North Bank Levee

☑	LV01 – Woodlands Creek North Bank Levee		
Description	• A 170m levee along the north bank of Woodlands Creek with the aim of preventing property inundation along Hewitts Avenue • Parts of the levee (110m) would be set at 18.5mAHD with the remainder at 16mAHD.		
Benefits	• Removes property inundation in frequent events • Improved flood levels for some properties in less frequent events • The land is vacant and likely without services • Low cost and positive BC ratio		
Concerns	• Worsens flood behaviour for some properties • Visual amenity impacts • Impede local drainage		
B/C Ratio	0.77	**Cost Estimate**	$216,000 (construction)
Outcome	Recommended to be considered for further investigation as part of the Floodplain Risk Management Plan		

Location and Flood Issue

Properties in Hewitts Avenue are first inundated in the 20% AEP flood event, in addition the former vehicle ramp to the south is overtopped, with floodwaters moving north along the railway line towards Hewitts Creek.

Option Description

The Floodplain Risk Management Study and Plan (2002) recommended the construction of a levee along the rear of properties on the north bank of Woodlands Creek (Option W3). This option involves the construction of a levee along the southern boundary of the properties on Hewitts Avenue, adjacent to Woodlands Creek. The 170m long levee would be set at 18.5 mAHD at the western end grading to 16m AHD at the eastern end. The lower eastern end assists in preventing overtopping of the railway embankment in less frequent flood events. Image 5 shows the option configuration as modelled.

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Image 5: Option LV01 - Proposed Levee Location (line).

Feasibility

The proposed works would require ongoing maintenance to maintain the integrity of the levee. Adjacent landholders may hold concerns around visual amenity and the works may cause a disruption during construction. There is likely to be minor environmental impacts as some trees and small bushes may require removal. Consideration will need to be given to ensure the works are tied into the existing landscape, the works have the potential to exacerbate ponding of local runoff and a dish drain or similar may be required as part of the design increasing the levee footprint. Land tenure and easement requirements will also require consideration.

Modelled Impacts

The levee prevents inundation of properties in Hewitts Avenue up to the 10% AEP event and flood levels are reduced by up to 0.1m in the 5% and 1% AEP events. Vast area along Hewitts Avenue is no longer flooded in a 10% AEP event. The relatively small reduction in flood levels is due to the shallow depth of water along Hewitts Avenue. There are however similar increases within property yards adjacent to the railway and to the south of the levee. Figure C1 and Figure C2 show peak flood level impacts for the 5% and 1% AEP event.

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Costs and Economic Analysis

This option is estimated to have a relatively low capital cost (~$216,000), owing to the relatively straightforward design and construction process for a low embankment. There is a minor reduction in over-floor property damages, however the Annual Average Damages for the catchment is almost unchanged with a reduction of less than 1%, refer to Table 18. The low cost of this option results in a Benefit Cost Ratio (B/C) ratio of 0.77.

Table 18: Change in damages due to the option LV01

Event	Change in No. of Properties Flood Affected	Change in No. of Properties Flooded Above Floor Level	Change in Total Tangible Flood Damages
20% AEP	0	0	-$ 36,900
10% AEP	-2	0	-$ 700
5% AEP	-8	0	-$ 25,000
2% AEP	-1	0	-$ 65,700
1% AEP	0	0	-$ 17,000
0.5% AEP	-1	-1	-$ 158,100
0.2% AEP	-1	0	-$ 49,700
PMF	-2	-7	-$ 674,000
Change Average Annual Damages (AAD)			-$ 11,300

Evaluation

The proposed option removes property impacts for some properties in Hewitts Avenue up to the 10% AEP event, reducing inconvenience to property owners. In addition, flood levels are reduced by up to 0.1m in both the 5% and 1% AEP events. Some properties are worse off in larger flood events, however, these impacts may be improved through the design process. The B/C of the option is 0.77. The works are recommended for further consideration as part of the Floodplain Risk Management Plan.

8.5.2.2. Option LV05: Hewitts Creek South Bank Levee

☒	**LV05 – Hewitts Creek South Bank Levee**
Description	• A 120m levee along the north bank of Hewitts Creek with the aim of preventing property inundation along Lachlan Street • The levee is set as 1.0 m above the ground
Benefits	• Protect properties north of Lachlan Street up to the 1% AEP event • Low cost
Concerns	• Worsens flood behavior for other properties • Visual amenity impacts • Divert floodwater to the east
Outcome	Option results in worsened flood behaviour for properties on the eastern side of the creek, reducing the benefit cost ratio, in addition to some technical challenges. This option should not be recommended as part of the Floodplain Management Plan.

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Location and Flood Issue

Properties in Lachlan Street are first inundated in the 20% AEP flood event. In frequent events floodwater escape the creek banks and run along a secondary flowpath parallel to the creek through properties.

Option Description

Following recent flood events in the area, residents have requested for the investigation of further flood mitigation in this area. One of these options is an embankment along the southern side of Hewitts Creek. This option includes a 1.0 m high embankment along the property boundaries.

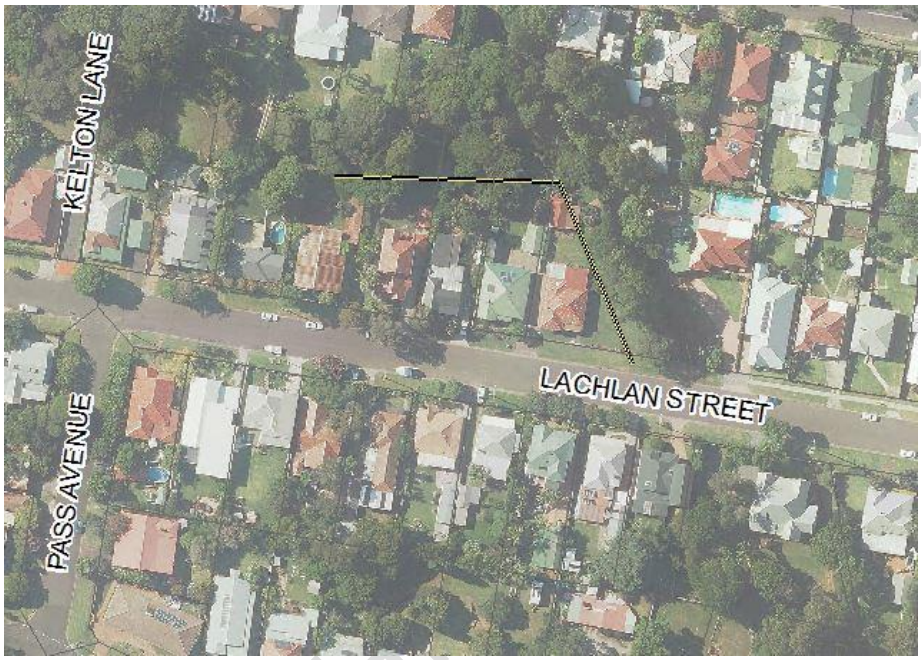


Image 6 Option LV05 - Proposed Levee Location (dashed line).

Feasibility

The proposed works would require ongoing maintenance to maintain the integrity of the levee. Adjacent landholders may hold concerns around visual amenity and the works may cause a disruption during construction. There is likely to be minor environmental impacts as some trees and small bushes may require removal. Land tenure and easement requirements will also require consideration.

Modelled Impacts

The levee prevents inundation of properties on the north side of Lachlan Street in the 1% AEP event and flood levels are reduced by up to 0.4m in the 1% event. There are however increases in flood levels up to 0.5m for properties to the east of Hewitts Creek in a 1% AEP event. Figure C3 and Figure C4 show peak flood level impacts for the 5% and 1% AEP event.

Evaluation

The proposed option reduces property impacts on the western side of Hewitts Creek, reducing inconvenience to property owners. Property impacts are however increased on the eastern side of the creek, these impacts may be improved through the design process. This option is likely to

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have a very low B/C ratio due to comparable benefits and impacts to properties. The option is not considered viable and should not be investigated further.

8.5.3. Detention Basins

Detention basins work by storing floodwaters during an event and then controlling the release of the water once the peak has passed. They can be built above or below ground and can be installed either as part of a new development to prevent increases in runoff rates or retrofitted into existing catchment drainage systems to assist in alleviating existing flood problems. Like the rest of the drainage system, detention basins have maintenance requirements.

The effectiveness of detention basins depends on their capacity, which for retrofitting options, can be significantly constrained by existing assets and development. However, they can also substantially reduce peak flows and are typically cost effective and easy to implement, provided there is a suitable location available. Hydraulic structures, such as low flow culverts at the bottom of a basin, can be used to restrict the discharge rates from site to a variable rate, dependent on rainfall volumes and the water level in the detention basin. In total six locations were reviewed for potential detention basins or improvements to the effectiveness of existing basins, four were found to be ineffective and are discussed in Table 17, with the remaining two discussed below.

8.5.3.1. Option DB02 - Former Bulli Mine Basin

☑	DB02 – Former Bulli Mine Basin		
Description	• Undertake embankment stability works to formalise the existing floodplain storage near the Old Bulli Mine (south of 16-22 Hobart Street) with the aim to reduce the peak flow and transfer of flows between Tramway and Slacky Creeks. • The bank stability works will allow the construction of an embankment to increase the floodplain storage.		
Benefits	• Reduces flood levels in frequent events (0.4m in the 5% AEP) • Reduced flood volume along Hobart Street • Utilises existing culvert structure as outlet • Straight forward design • Low cost and significant economic benefit		
Concerns	• Worsens flood behaviour for some properties along Slacky Creek • Visual amenity impacts • Land ownership • Minimal benefit in larger events		
B/C Ratio	2.67 (Could be up to ≈$700,000 to remain >1.0)	**Cost Estimate**	$246,000
Outcome	Recommended to be considered for further investigation as part of the Floodplain Risk Management Plan		

Location and Flood Issue

West of the Princes Highway, Slacky Creek diverts towards Tramway Creek and flows down Hobart Street, resulting in significant flooding to properties and inconvenience to motorists. This flow inundates roads as well as property floor levels in events as frequent as the 20% AEP. The former Bulli mine site is currently vacant and located upstream of multiple creeks which flood properties along Hobart Street and Tramway Creek.

Option Description

This option involves the construction of a 200m long, 2m high embankment in the upper reaches of Slacky Creek to create additional flood storage. The option utilises the existing twin box culverts (3.5m wide and 1.2m high) as the outlet of the basin. Storing additional flood water at this location is aimed at reducing peak flows and subsequent diversion (from Tramway Creek) and flood affectation along Hobart Street. Image 7 shows the option configuration as modelled.



Image 7: Option DB02 – Former Bulli Mine Basin (dashed Line).

Feasibility

The proposed works involve a relatively simple design and low height, in addition to utilising the existing culvert structure as the basin outlet. Potential constraints on the site are land ownership (private), existing services and environmental with removal of existing trees required. These constraints may increase the cost of the proposed works. During operation public safety (signage and fencing) and ongoing maintenance (including the structure) require consideration. The works are unlikely to cause a significant disruption during construction. Consideration will need to be given to ensure the works are tied into the existing landscape and to drainage infrastructure for local runoff.

Modelled Impacts

The proposed works are shown to reduce flood levels by up to 0.4m along Hobart Street in the 5% AEP event, extending to the Illawarra Railway Line, however consequently there are increases in flood levels, by up to 0.1 m, downstream through Slacky Creek as a result of the additional flow remaining in Slacky Creek. A similar pattern of improvement and impacts, with less change in flood levels is observed in the 1% AEP event. There is limited change to the overall flood extent, in both the areas with increased and decreased flood levels, except for a small area downstream of the railway where there is a slight increase in flood extent in the 5% AEP event. Figure C5 and Figure C6 show the impacts on peak flood levels for the 5% and 1% AEP event. The peak flow is reduced from 4.5 m^3/s to 0.4 m^3/s in a 5% AEP event, with a floodwater volume discharging from the mine site reduced by 93%. The peak flow upstream of Hobart Street is reduced from 13.8 m^3/s to 10.2 m^3/s in the 1% AEP event, with a floodwater volume reduced by 43%.

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Cost and Economic Analysis

This option is estimated to have a relatively low capital cost, in the order of $250,000, owing to the relatively straightforward design. Potential constraints may increase costs. There is a minor reduction in over-floor property damages which reduces Annual Average Damages for the catchment by 4%. The low cost of this option results in a B/C of 2.67, indicating the option is economically viable.

Table 19: Change in damages due to the option DB02

Event	Change in No. of Properties Flood Affected	Change in No. of Properties Flooded Above Floor Level	Change in Total Tangible Flood Damages
20% AEP	0	-1	-$ 144,300
10% AEP	0	0	-$ 199,400
5% AEP	-4	0	-$ 19,900
2% AEP	1	0	-$ 13,000
1% AEP	-1	1	$ 32,000
0.5% AEP	1	0	-$ 53,100
0.2%PMF	4	1	$ 73,000
PMF	0	0	$ 92,700
Average Annual Damages (AAD)			-$ 44,500

Evaluation

The proposed option results in a minor reduction to property impacts in addition to reduced inundation of Hobart Street, reducing hazard and inconvenience. The option has limited constraints, including minor flood increases downstream in Slacky Creek, which may be resolved through the design process. The works are therefore recommended for further consideration as part of the Floodplain Risk Management Plan.

8.5.3.2. Option DB04 – Basin Upstream Railway on Woodlands Creek

DB04 – Basin Upstream Railway on Woodlands Creek			
Description	• Construct a 2,400 m³ basin behind the properties at 12 Hewitts Avenue and 455 Lawrence Hargrave Drive with the aim to reduce downstream peak flows and levels.		
Benefits	• Some reduced flood levels and flows • Land unoccupied		
Concerns	• Worsens flood behavior in frequent events by redirecting floodwater northward towards Hewitts Creek • Land ownership • Public safety during operation • No material change to property affectation		
B/C Ratio	<0	**Cost Estimate**	$790,000
Outcome	Option results in worsened flood behaviour in frequent events reducing the benefit cost ratio, in addition to a number of constraints and technical challenges. This option should not be recommended as part of the Floodplain Management Plan.		

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Location and Flood Issue

Floodwater from Woodlands Creek builds up upstream of the Princes Highway, upstream of the existing vehicle ramp as well as upstream of the railway line. Once the water builds up, the floodwater overtops the creek bank and flows northward along the railway line through properties on Hewitts Avenue towards Hewitts Creek. Properties on Hewitts Avenue are first inundated in the 20% AEP flood event.

Option Description

This option investigates an increase in water storage upstream of the railway line to mitigate the transfer of water toward Hewitts creek. The option involves the excavation of a 2,400m^3 capacity detention basin between the railway line and vehicle safety ramp. Storing additional flood water at this location is aimed at reducing downstream peak flows and subsequent diversion and flood affectation along Hewitts Avenue. Image 8 shows the extent of the basin as modelled.



Image 8: Option DB04 – Basin upstream of the railway line, on Woodlands Creek, (yellow dashed polygon)

Feasibility

The proposed works are significant and would require a comprehensive design process including consideration of aesthetics and visual amenity. Potential constraints on the site are land ownership, existing services, minor environmental with existing trees. These constraints may increase the cost of the proposed works. During operation public safety (signage and fencing) is a concern, particularly with the proximity to existing properties. Additionally, ongoing maintenance requires consideration. The works are unlikely to cause a significant disruption during construction.

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Modelled Impacts

The proposed works are shown to reduce flood levels by up to 0.4m and 0.5m upstream of the railway line, during the 5% and 1% AEP event respectively (Figure C7 and Figure C8). However, the works do not improve flood affectation in Hewitts Avenue. The basin is located in an important flowpath and exacerbates the transfer of flow from Woodlands Creek to Hewitts Creek in frequent events. Additional works to upgrade the size of the railway pipe were also considered to improve the performance of the basin. The pipe upgrade was assessed as a separate option (Option DM04, 8.5.5.4)

Cost and Economic Analysis

This option is estimated to have a relatively high capital cost, in the order of $790,000. Potential constraints may increase costs. There is negligible change to over-floor property damages resulting in a small increase to Annual Average Damages for the catchment and results in a Benefit Cost Ratio of less than 0. The option is therefore not considered to be economically viable.

Table 20: Change in damages due to the option DB04

Event	Change in No. of Properties Flood Affected	Change in No. of Properties Flooded Above Floor Level	Change in Total Tangible Flood Damages
20% AEP	2	0	$ 1,800
10% AEP	0	0	$ 800
5% AEP	0	0	-$ 4,100
2% AEP	0	0	-$ 5,500
1% AEP	-2	0	-$ 2,400
0.5% AEP	-1	0	-$ 14,800
0.2%PMF	1	0	$ 28,000
PMF	0	0	$ 29,700
Average Annual Damages (AAD)			$ 200

Evaluation

The proposed option results in limited change to property impacts and has a number of design constraints which are likely to increase costs and therefore, is not recommended for further consideration as a floodplain risk management option.

Alternative options have been considered at this location, including LV01 (Section 8.5.2.1) and DM04 (Section 8.5.1) , with LV01 being determined to be the preferred option at this location.

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8.5.4. Channel Modification

Channel modification can include a range of works including increasing the size, shape, or materials of a channel, to altering the natural surrounds or creek shape via dredging, lining (or naturalising lined channels), or other vegetation management practices. Channel modifications can help to reduce peak upstream flood levels by improving conveyance, although such measures may also increase flood levels in adjacent or downstream locations. Changes to velocity are also likely to occur due to modifying the channel shape or size. In general, for channel modifications to be effective in reducing flood levels, significant excavation is required which can have a range of environmental impacts, including removal of riparian vegetation, and as a result, loss of native habitat and in some cases, bank stability.

8.5.4.1. Option CM01 – Cliff Parade Swale

☒	CM01 – Cliff Parade Swale		
Description	• Excavate 1,400m^3 to create a swale through Tingara Park with the aim of providing an alternative discharge point for floodwater.		
Benefits	• Improve flood behaviour and reduced flood levels and property impacts across all events • Straight forward design • Low cost and significant economic benefit		
Concerns	• Increased hazard through public space • Existing services may be present		
B/C Ratio	2.8 (Could be up to ≈$1,500,000 to remain >1.0)	**Cost Estimate**	$546,000
Outcome	Option has a number of feasibility and technical challenges. This option should not be recommended as part of the Floodplain Management Plan.		

Location and Flood Issue

A flowpath moves north from Raymond Road. Limited capacity results in significant ponding in events as frequent as the 20% AEP event at Tingara Park at the corner of Cliff Parade and Bath Street. Property inundation also occurs in frequent events.

Option Description

This option involves the creation of a flowpath through Tingara Park via excavation of a swale to provide an alternative exit point for floodwaters. This is achieved by excavating approximately 1,400m^3 of earth to create a swale between 0.5m and 2.0m deep. The proposed alignment is shown in Image 8.

Two alternative scenarios were considered at this location, including an alignment which commences further to the south near the intersection with Ocean Street and an alignment which follows the northern boundary of the park. The above option, which is discussed below, was found to be the most beneficial of the three.

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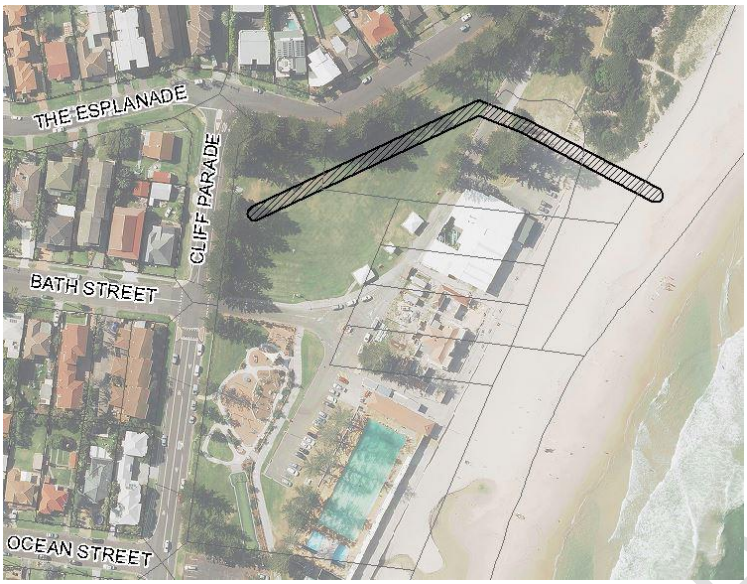


Image 9 : Option CM01 Proposed Swale

Feasibility

While the construction of a swale is relatively straight forward, there are a number of constraints for this option. The existing grade through the park may not facilitate easy drainage and result in water ponding, this would be compounding in times of high tide and may worsen tidal impacts. The works may cause a moderate disruption during construction and on going impacts on the recreational and social use of the park following construction. There is likely to be minor environmental impacts as some trees and small bushes may require removal. Consideration will need to be given to ensure the works are tied into the existing landscape and to drainage infrastructure for local runoff. Consideration should be given to flood hazard and safety during flood events, which could potentially be considered through the design process by providing a broad flat channel. This would, however, increase the footprint of the proposed works. This would also improve usability across the park post construction. There is a significant concern that the outlet of the swale may impact on coastal processes.

Modelled Impacts

In both the 5% and 1% AEP events this option improves flood behaviour by reducing flood levels by up to 0.2m (Figure C9 and Figure C10). The improved flood behaviour extends from Ocean Street to the north end of The Esplanade. The top of the swale is set at 2.5 mAHD which is below the 20 Year ARI tide level of 2.35mAHD.

Costs and Economic Analysis

This option is estimated to have a relatively low capital cost, in the order of $550,000. However, depending on the final design, costs could vary in the market. There are reasonable property benefits across all events. As a result, the AAD is reduced by 9%. With the estimated capital costs and reduction in AAD for the catchment, the option results in a BC ratio of 2.8. This option is therefore considered to be economically viable.

PUBLIC EXHIBITION DRAFT

Table 21: Change in damages due to the option CM01

Event	Change in No. of Properties Flood Affected	Change in No. of Properties Flooded Above Floor Level	Change in Total Tangible Flood Damages
20% AEP	-8	-5	-$ 258,800
10% AEP	-6	-4	-$ 264,600
5% AEP	-4	-5	-$ 294,100
2% AEP	-9	-9	-$ 596,800
1% AEP	-8	-8	-$ 577,400
0.5% AEP	-4	-9	-$ 711,900
0.2%PMF	-6	-7	-$ 487,700
PMF	0	0	-$ 131,500
Average Annual Damages (AAD)			-$ 103,800

Evaluation

The proposed option improves flood behaviour through reducing flood levels and improving property impacts across all events in addition to being considered to be economically viable. The works have a number of significant constraints which would be challenging to resolve through the design process. The works are not recommended for further consideration as a floodplain risk management option.

8.5.4.2. Option CM02 – Lachlan Street Bridge

☒	**Option CM02 – Lachlan Street Bridge**		
Description	• Replace the existing Lachlan Street culvert with a single span structure.		
Benefits	• Reduction in flood levels upstream and overtopping of Lachlan Street • Reduced flood extent on the eastern side of Lachlan Street • Sensitivity to structure blockage reduced		
Concerns	• Works recently undertaken • Disruption during construction • Increased flood levels, velocity and flow downstream • Existing services		
B/C Ratio	0.14	**Cost Estimate**	$2,160,000
Outcome	Option results in only localised improvement to flood behaviour, constraints due to existing services, offsetting mitigation works likely required and significant costs. This option should not be recommended as part of the Floodplain Management Plan.		

DRAFT

Location and Flood Issue

The capacity of the Lachlan Street structure was investigated as part of the Floodplain Risk Management Study and Plan (2002). As part of that report works were recommended and subsequently implemented which included improvements to the efficiency of the structure's inlet and outlet and the installation of handrails. With the upgrade in place, flow overtops the road and results in localised property impacts.

Option Description

This option aims to improve the conveyance of Hewitts Creek at Lachlan Street and reduce the constriction caused by the crossing. It involves the replacement of the existing culverts by a clear span bridge of a similar width. Image 9 shows the extent of the bridge.

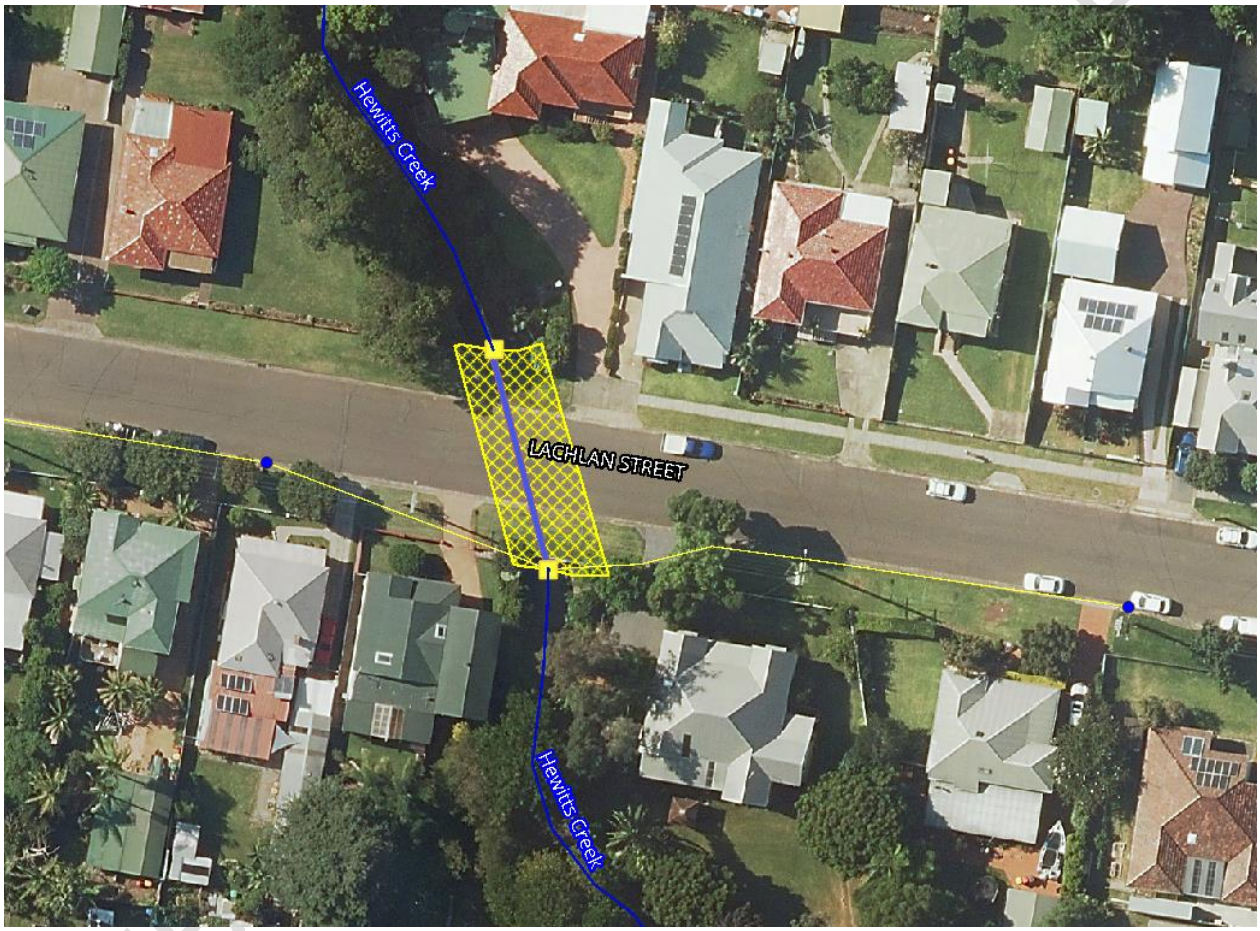


Image 10 : Option CM02 Proposed Bridge Extent (yellow polygon)

Feasibility

The proposed works are relatively straight forward as the works follow the existing culvert location. Construction of the bridge may impact on existing services. The works will cause disruption during construction as the road will require temporary closure. Consideration should be given to the treatment of the creek downstream of the upgraded culvert as the creek will likely experience additional flow and increased velocity.

Modelled Impacts

The proposed option results in a localised improvement to flood behaviour upstream and across Lachlan Street (Figure C11 and Figure C12). In a 5% AEP portions of the road are no longer overtopped creating a large area that is no longer flooded and flood levels are reduced upstream by up to 0.7m. On Lachlan Street, the depth of inundation is reduced by up to 0.15m in some locations. Reduced improvements are observed in the 1% AEP event. With the option in place there is a slight increase in flood levels downstream (less than 0.1m) in both the 5% and 1% events.

Costs and Economic Analysis

This option is estimated to have a high capital cost, in the order of $2,160,000. The option results in some improvement in property affectation across a range of flood events and the Annual Average Damages for the catchment is reduced by 2%. However, the high cost of this option results in a B/C ratio of 0.14. This option would therefore not be considered to be economically viable.

Table 22: Change in damages due to the option CM02

Event	Change in No. of Properties Flood Affected	Change in No. of Properties Flooded Above Floor Level	Change in Total Tangible Flood Damages
20% AEP	-5	0	-$ 28,400
10% AEP	-5	0	-$ 29,300
5% AEP	-6	-1	-$ 100,500
2% AEP	-8	-2	-$ 171,500
1% AEP	-8	-5	-$ 338,300
0.5% AEP	-8	-4	-$ 397,500
0.2%PMF	-5	-4	-$ 246,400
PMF	-4	-10	-$ 698,500
Average Annual Damages (AAD)			-$ 20,800

Evaluation

The proposed option reduces depth and hazard on Lachlan Street, reducing inconvenience but otherwise only provides a local improvement to flood behaviour and property impacts. Constraints related to existing services and disruption during construction have the potential to be significant. An extensive array of services and a sewer line is expected under the road. In addition, higher flows will pass through the crossing and other mitigation work may be required to alleviate the increase in flood levels downstream. These coupled with the significant costs reduces the viability of the option (B/C 0.14) and therefore the works should not be investigated further as a floodplain risk management option.

PUBLIC EXHIBITION DRAFT

8.5.4.3. Option CM06 – Channel Widening on Hewitts Creek

CM06 – Channel Widening on Hewitts Creek	
Description	• Widen the Hewitts Creek upstream of Lachlan Street by 5m by excavating 900m^3 with the aim of increasing conveyance capacity.
Benefits	• Reduction in flood levels upstream of Lachlan Street
Concerns	• Improvements to flood behaviour do not extend to property benefits • Disruption during construction • Increased hazard • Land ownership • Existing services • Bank stabilization required • Environmental impacts
B/C Ratio	<0
Outcome	Option results in limited improvement to flood behaviour, some constraints and technical challenges which would likely increase costs and further reduce the cost benefit ratio through the design process. This option should not be recommended as part of the Floodplain Management Plan.

Location and Flood Issue

Overtopping of Lachlan Street was investigated as part of the Floodplain Risk Management Study and Plan (2002). During events floodwaters overflow the creek and divert through property towards Lachlan Street. As part of that report, works were recommended which included excavation and enlargement of the creek in addition to construction of a low levee.

Option Description

This option revisits the recommendation from the Floodplain Risk Management Study and Plan (2002) to consider increasing the width of Hewitts Creek upstream of Lachlan Street. The option was assessed in the form of a 5m widening for 120m (Image 11). The aim is to increase conveyance capacity for the reach of Hewitts Creek upstream of Lachlan Street.

In a deviation from the option assessed as part of the Floodplain Risk Management Study and Plan (2002), the levee was not investigated as part of the current option. It was considered to have significant viability concerns including, space constraints and potential flood impacts.

PUBLIC EXHIBITION



Image 11: Option CM06 Existing creek extent (green lines) and proposed widening (hatched region)

Feasibility

The proposed works are likely to be complex and cause a significant disruption during construction due to the proximity to existing properties. There is likely to be environmental impacts with the removal of creek and bank vegetation. Space and private land ownership constraints are also of concern. Consideration will need to be given to ensure the works are tied into the existing landscape and how bank stability is maintained. Consideration should be given to flood hazard and safety during flood events due to the proximity to existing properties.

Modelled Impacts

The works significantly reduce flood levels through Hewitts Creek (by up to 0.5m) in both the 5% and 1% AEP events (Figure C13 and Figure C14). The benefits of the works do not however extend beyond the creek and therefore do not improve property affectation during these events. A slight increase in flood levels occurs downstream up to 0.1 m.

Costs and Economic Analysis

This option is likely to be very expensive to design and construct and with only minor improvements in flood behaviour, there is a minimal increase in AAD for the catchment. The resulting BC ratio is therefore less than 0.

PUBLIC EXHIBITION DRAFT

Table 23: Change in damages due to the option CM06

Event	Change in No. of Properties Flood Affected	Change in No. of Properties Flooded Above Floor Level	Change in Total Tangible Flood Damages
20% AEP	-1	0	-$ 400
10% AEP	-3	0	-$ 1,800
5% AEP	-2	0	-$ 6,100
2% AEP	-4	2	$ 55,000
1% AEP	-2	0	-$ 20,100
0.5% AEP	-2	0	-$ 78,600
0.2%PMF	-3	-2	-$ 15,800
PMF	-1	0	-$ 87,700
Average Annual Damages (AAD)			$ 100

Two properties downstream of the works have greater overfloor flooding impacts in the 2% AEP event.

Evaluation

The proposed option provides limited improvements to property affectation, has a number of constraints which are likely to increase an already significant cost (and extremely low BC ratio) or limit the design and functionality of the option; and therefore, is not recommended for further consideration as a floodplain risk management option.

8.5.4.4. Option CM10 – South Arm Diversion

☑	CM10 – South Arm Diversion		
Description	• Create a lowered section between Cliff Parade and the ocean for Thomas Gibson Creek floodwater that overtop Cliff Parade		
Benefits	• Improved flood behaviour • Reduced property impacts		
Concerns	• Excavation up to 2m required • Existing cycle path likely to be impacted • Existing services		
B/C Ratio	0.83	**Cost Estimate**	$560,000
Outcome	Recommended to be considered for further investigation as part of the Floodplain Risk Management Plan		

Location and Flood Issue

Thomas Gibson creek overtops Cliff Parade in frequent events due to the low capacity of the stormwater pipes under the road.

Option Description

This option lowers a section to the east of Cliff Parade, by up to 2 m, to capture floodwaters overtopping the road and reduce diversion to the north. Image 12 shows the option configuration as modelled.

EXHIBITION DRAFT



Image 12 Option CM10, Proposed regrading extent (yellow dashed polygon)

Feasibility

The proposed works could be incorporated as part of ongoing road or carpark maintenance works. The works have the potential to cause a disruption during construction and on going impacts on the recreational and social use of the park following construction. There is unlikely to be environmental impacts, however standard erosion and sediment control measures would be required during construction. The design process would also need to consider the impacts on the sand dune environment and coastal processes, tidal inundation may also encroach further into the park. Consideration will need to be given to tying into existing driveways and existing services. Retrofitting the existing cycleway and pedestrian connectivity will require design consideration.

Modelled Impacts

Flood levels north of the proposed works are generally reduced by up to 0.1m in some areas for both the 5% and 1% AEP events (Figure C15 and Figure C16). During the 5% AEP event properties on the corner of Cliff Parade and Harbord Street are no longer flooded. The benefits are achieved as the works increase the flow volume in the existing outlet through Thomas Gibson Creek. The crest of the Road prevents any backwatering from the high tide or the creek.

Economic Analysis

This option is estimated to have a capital cost in the order of $560,000, and the Annual Average Damages for the catchment is reduced by 3%. These result in a B/C ratio of 0.83.

PUBLIC EXHIBITION DRAFT

Table 24: Change in damages due to the option CM10

Event	Change in No. of Properties Flood Affected	Change in No. of Properties Flooded Above Floor Level	Change in Total Tangible Flood Damages
20% AEP	-3	-1	-$ 89,700
10% AEP	-2	0	-$ 50,000
5% AEP	-4	-2	-$ 92,000
2% AEP	0	-3	-$ 166,600
1% AEP	-2	-2	-$ 148,200
0.5% AEP	-1	-2	-$ 169,800
0.2%PMF	-4	-3	-$ 286,500
PMF	0	-2	-$ 282,300
Average Annual Damages (AAD)			-$ 31,500

Evaluation

The proposed option improves flood behaviour through reducing flood levels across all events and improving property impacts. The works are relatively straightforward with limited constraints that can be addressed as part of the design process. The works have a number of significant constraints which would be challenging to resolve through the design process. The works are not recommended for further consideration as a floodplain risk management option.

8.5.5. Drainage Modification

Local drainage systems typically reach capacity in an event equivalent to a 20% AEP, and excess runoff flows overland, potentially posing a threat to pedestrians, motorists, and if inundation is of sufficient depth, and properties. The options assessed in the following section are intended to decrease the flood risk associated with overland flow. It is noted that these options are unlikely to have significant benefits in terms of reducing property damages, however the reduction in severity or frequency of nuisance inundation, particularly along roads, could be beneficial to the community.

PUBLIC EXHIBITION DRAFT

8.5.5.1. Option DM01 – Upgrade Hobart Street Culvert

DM01 – Upgrade Hobart Street Culvert			
Description	• Amplification of the existing structure under the discarded railway and Hobart Street to 4 x 2m high by 2m wide box culvert		
Benefits	• Improved flood behaviour • Reduced property impacts • Reduced road inundation		
Concerns	• Increase flood levels downstream • Deep excavation required • No alternative access road for properties during construction • Existing services • Land ownership		
B/C Ratio	0.52	**Cost Estimate**	$1,690,000
Outcome	Option has high costs, some constraints and technical challenges and therefore should not be recommended as part of the Floodplain Management Plan.		

Location and Flood Issue

The two upper reaches of Slacky Creek join together upstream of the discarded railway line. A series of culverts pass this flow through the discarded railway line. When the culverts reach capacity, floodwaters overtop the creek banks and move down Hobart Street flowing towards Tramway Creek. Multiple properties are impacted as a result of this diverted flow in events as frequent as the 20% AEP.

Option Description

This option considers the upgrade of the existing culverts under the discarded railway and Hobart Street. The aim is to increase capacity of the system and reduce the frequency of surcharge along Hobart Street. Works at this location were identified as part of the Floodplain Risk Management Study and Plan (2002), and included removal of the discarded railway and regrading of Hobart Street. A review of those proposed works as part of this study identified that they would significantly increase flooding within Slacky Creek. An alternative configuration has been assessed as part of the current study, including upgrading the three existing 1.8m diameter circular pipes under Hobart Street to four culverts 2m wide by 2 m high. The existing twin 1.8m diameter circular pipes south of Hobart Street under the discarded railway are upgraded to four culverts 2m wide by 2m high, and an additional box culvert 2.75m by 1.7m is added further to the south. Image 13 shows the three structures upgraded. Those three individual structures work together to carry floodwater from the upper reaches of Slacky Creek across the discarded railway.

PUBLIC EXHIBITION

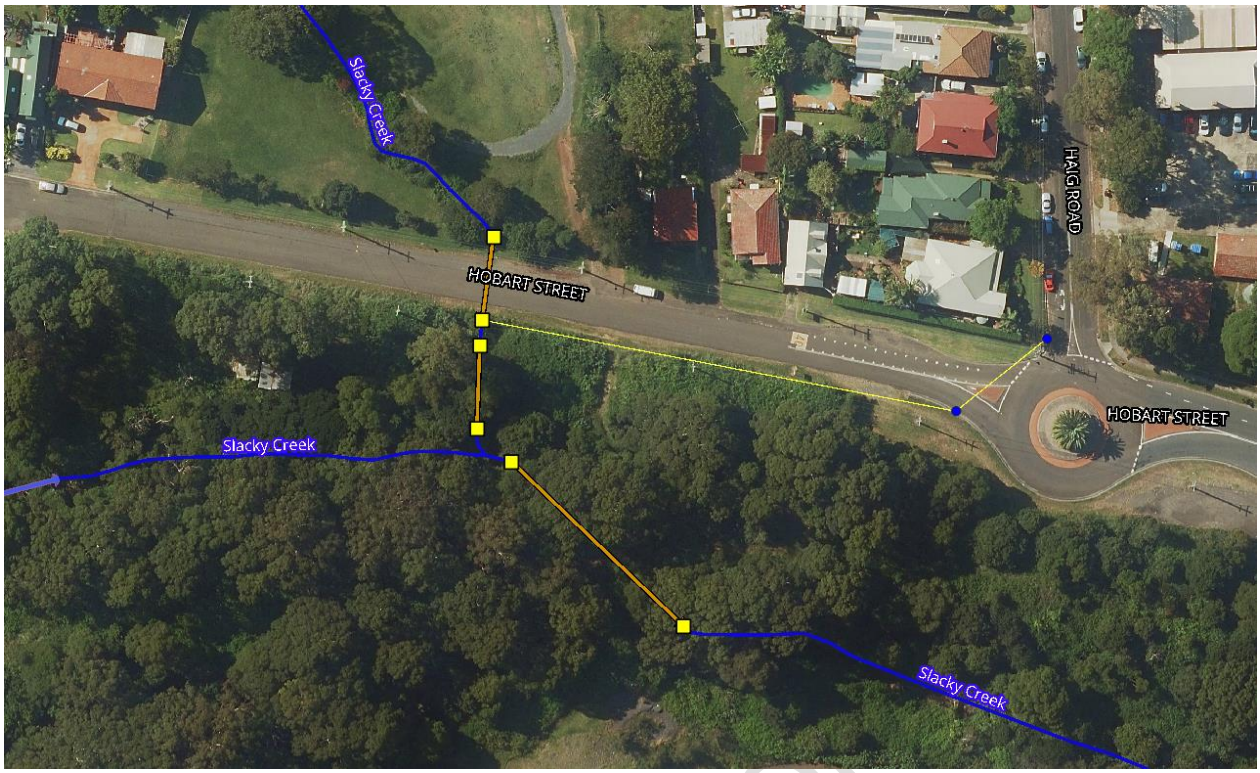


Image 13 Option DM01, Proposed Structure Upgraded (orange lines)

Feasibility

The proposed works are relatively straight forward as the structures are proposed along the same alignment as the existing culverts. However, given the size of the proposed culvert structures, a significant depth of excavation would be required. A wider and longer footprint will be required, which may impact on existing services and privately owned land. The works will cause disruption during construction as the road will require temporary closure. Consideration should be given to the treatment of the creek to minimise environmental impacts, at the upgraded culvert outlets and further downstream as the creek will likely experience additional flow and increased velocity.

Modelled Impacts

The option improves flood behaviour across a range of events with reductions of up to 0.3m upstream of Hobart Street and reduces the extent of inundation, particularly in the 1% AEP event (Figure C17 and Figure C18). The reduced inundation also improves property affectation for properties on Haig Street and Princes Highway in the 1% AEP. The reduction in overtopping flows on Hobart Street has caused an increase in flow and volume is diverted into Slacky Creek and increasing flood levels downstream as a result.

Costs and Economic Analysis

This option is estimated to have a high capital cost, in the order of $1,690,000. The improved property affection reduces direct and tangible damages, resulting in the Annual Average Damages for the catchment being reduced by 5%. The resulting B/C ratio is 0.52. This option is not considered to be economically viable.

PUBLIC EXHIBITION

Table 25: Change in damages due to the option DM01

Event	Change in No. of Properties Flood Affected	Change in No. of Properties Flooded Above Floor Level	Change in Total Tangible Flood Damages
20% AEP	-1	-3	-$ 198,300
10% AEP	0	-2	-$ 204,400
5% AEP	-4	0	-$ 28,600
2% AEP	4	0	-$ 116,200
1% AEP	1	0	-$ 30,600
0.5% AEP	-3	0	-$ 82,600
0.2%PMF	0	-1	-$ 18,100
PMF	1	-1	$ 128,500
Average Annual Damages (AAD)			-$ 58,900

Evaluation

The proposed option reduces depth and hazard of flooding on Hobart Street, Haig Road and the Princes Highway, reducing inconvenience and improving property impacts. The works have a high cost, some constraints and technical challenges and should not be investigated further as a floodplain risk management option.

8.5.5.2. Option DM02 – Upgrade Railway Culvert at Tramway Creek

	DM02 – Upgrade Railway Culvert at Tramway Creek		
Description	• Amplification of the existing structure under railway and addition of a new 2.4m diameter culvert to reduce the impacts when the capacity of the culvert is exceeded. This aligns with the recommendations of a 2014 design report at this location.		
Benefits	• Improved flood behaviour • Reduced impact to railway embankment		
Concerns	• Pipe jacking required • High capital cost and limited financial viability • Existing services • Land ownership • Multi Stakeholder Project		
B/C Ratio	0.06	**Cost Estimate**	$1,280,000 (lower limit)
Outcome	Option has only localised benefits, results in worsened flood behaviour in frequent events, has technical challenges, has high costs and is not considered to be economically viable and therefore should not be recommended as part of the Floodplain Management Plan.		

CONSULTATION DRAFT

Location and Flood Issue

Tramway Creek passes behind the properties on Allenby Parade. In events as frequent as the 20% AEP, the capacity of the culvert under the railway line is exceeded and floodwaters back up. In events less frequent than the 2% AEP, property impacts occur and the railway line is overtopped.

Option Description

This option aims to reduce the impacts when the capacity of the culvert is exceeded and floodwaters back up behind the railway line. The Floodplain Risk Management Study and Plan (2002) recommended construction of a new high level culvert (6m wide by 4m high) through the railway embankment to the south of the existing low level culvert. Following the 2002 study, a detailed design report was completed in 2014 which concluded that amplifying the existing pipe with the addition of two 3.0m diameter culverts was the preferred option. The 2014 design report determined that the costs of the proposed works would be in the order of $4.6 million.

This option reviews the recommendation from the 2014 study by assessing the benefits of a twin 2.4m diameter pipe. Image 14 shows the option configuration as modelled. The proposed pipe size has been modified based on the new ARR2019 hydrology and the existing size of the pipe under the railway (2.4m), in addition to the standard pipe sizes available.

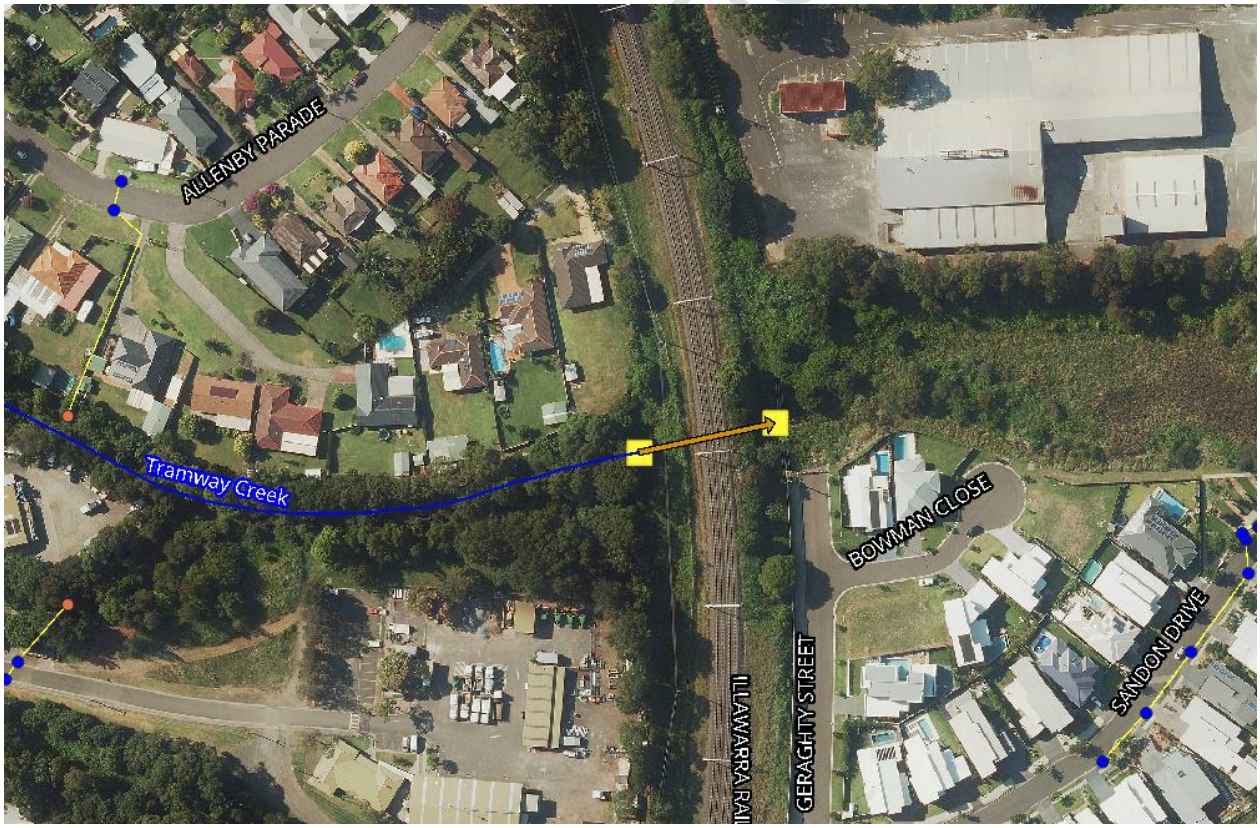


Image 14 Option DM02, Upgraded structure (orange).

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Feasibility

The proposed works have a number of technical and feasibility challenges related to the railway line operation, including disruption. Collaboration with Transport for NSW, the infrastructure owner, would be required through all stages from concept development to construction. Methods such as pipe jacking may be suitable to minimise disruption to the line. Existing services are likely to be present and may add to costs. Design consideration will need to be given to minimising environmental impacts on the creek, including management of increased flow downstream of the railway line.

Modelled Impacts

The works increase the volume of water passing through the culvert structures for both the 5% and 1% AEP event. Peak flood levels immediately upstream of the railway line are also significantly reduced in events up to the 5% AEP, with a 2.2m reduction in that event. During the 1% AEP event peak flood levels are reduced by 0.16m (Figure C19 and Figure C20). Flood levels are increased downstream of the railway by up to 0.3m in the 5% AEP event and 0.05m in the 1% AEP event.

Costs and Economic Analysis

This option is estimated to have a high capital cost, with a lower level estimate in the order of $1,280,000. The 2014 design report estimated costs to be up to $4.6 million. While there are significant reductions in flood levels and extent of inundation, improvements to property impacts are limited to the rarer events. Due to the reduced probability of rarer events, they contribute less to the calculation of Annual Average Damages representing direct and tangible benefits. In this case the option results in a minimal change to the AAD for the catchment. Considering this and the high capital cost the option has a B/C ratio of 0.06 and is not considered to be economically viable.

Table 26: Change in damages due to the option DM02.

Event	Change in No. of Properties Flood Affected	Change in No. of Properties Flooded Above Floor Level	Change in Total Tangible Flood Damages
20% AEP	0	0	$ -
10% AEP	0	0	$ 200
5% AEP	-3	0	-$ 19,000
2% AEP	0	0	-$ 183,300
1% AEP	-2	0	-$ 30,500
0.5% AEP	-1	0	-$ 107,500
0.2%PMF	-5	-2	-$ 50,200
PMF	-1	-3	-$ 227,000
Average Annual Damages (AAD)			-$ 5,400

Evaluation

This option significantly reduces the extent of inundation and flood levels immediately upstream of the railway line. Benefits are localised to the creek and some upstream properties in rarer events. There are therefore limited improvements to direct and tangible benefits, reducing the economic viability of the option and suitability as a floodplain management measure.

PUBLIC EXHIBITION DRAFT

In addition, in more frequent events flood levels are increased downstream of the railway. The option has technical challenges including responsibility being with Transport for NSW. This option should not be investigated further as a floodplain risk management option.

8.5.5.3. Option DM03 – Additional Culvert to the Ocean at Cliff Parade

☑	DM03 – Additional Culvert to the Ocean at Cliff Parade		
Description	• New drainage structure (3 x 1.5m by 0.8m) under Tingara Park and outlet to ocean		
Benefits	• Improved flood behaviour		
Concerns	• Existing services • Additional outlet on the beach • A number of considerations required through the design process • Traffic disruption during construction • Reduced hydraulic efficiency		
B/C Ratio	0.85	**Cost Estimate**	$1,011,000
Outcome	Recommended to be considered for further investigation as part of this Floodplain Risk Management Plan		

Location and Flood Issue

A flowpath moves north from Raymond Road. Limited capacity results in significant ponding in events as frequent as the 20% AEP event at Tingara Park between Ocean and Bath Street. Property inundation also occurs in frequent events.

Option Description

This option connects the existing three box culverts under Cliff Parade to the ocean using a new outlet. Three box culvert 1.5m wide and 0.8m high would connect the existing stormwater outlet at the beach. Image 15 shows the option configuration as modelled. The new stormwater outlet would supplement the existing stormwater network. The invert of the new outlet is set at 1.4mAHD which is a similar invert to the existing outlet further south.

PUBLIC EXHIBITION

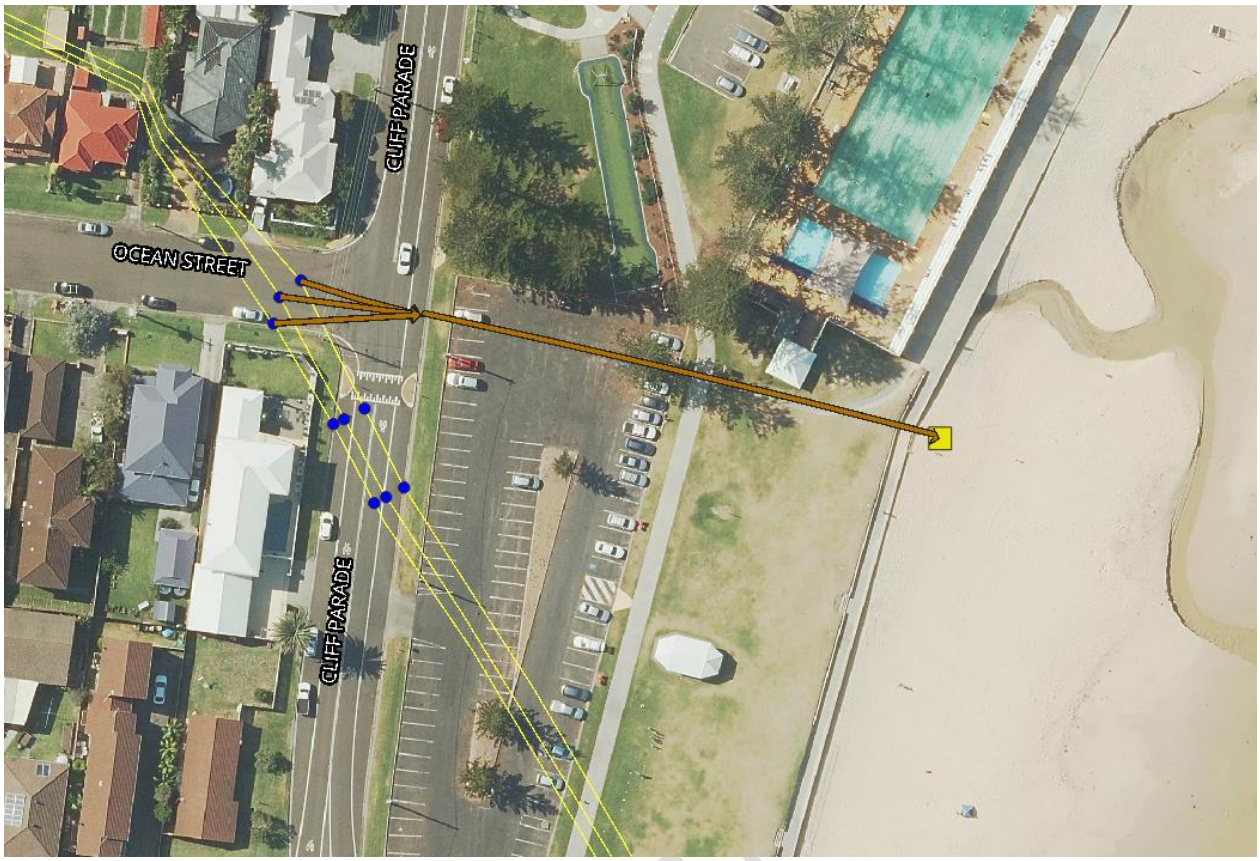


Image 15 Option DM03, Existing structure in yellow and proposed culverts in orange.

PUBLIC EXHIBITION

Feasibility

The proposed works are relatively straightforward, however would result in disruption to both the road and carpark during construction. The works have the potential to cause a disruption to recreational and social amenity and access during construction. The box culverts will require maintenance considerations as it will have a fairly flat grade and may be susceptible to debris blockage and tidal impacts. This, in addition to the fork in the drainage system which will limit the hydraulic efficiency of the design. The hydraulic efficiency of the design may be able to be improved in the design phase. The removal of isolated trees would be required, however the design process would also need to consider the impacts of the works on coastal processes, which may be significant, and additionally standard erosion and sediment control would be required during construction. Treatment of the outlet would require design consideration from a visual amenity, erosion and safety perspective. Consideration will need to be given to potential conflict with existing services. Retrofitting the existing cycleway and pedestrian connectivity will also require design consideration.

Modelled Impacts

The option results in a broad flood level reduction of less thane 0.1m for both the 5% and 1% AEP events (Figure C21 and Figure C22). The relatively minor reduction improves over floor property affectation for a number of properties.

Costs and Economic Analysis

This option is estimated to have a relatively high capital cost, in the order of $1,011,000. The improvements in property affection reduces direct and tangible damages and a reduction in Annual Average Damages for the catchment of 5%. Considering this, with the estimated costs results in a B/C ratio of 0.85.

Table 27: Change in damages due to the option DM03

Event	Change in No. of Properties Flood Affected	Change in No. of Properties Flooded Above Floor Level	Change in Total Tangible Flood Damages
20% AEP	-6	-3	-$ 161,400
10% AEP	-3	-1	-$ 127,800
5% AEP	-3	-2	-$ 86,900
2% AEP	-7	-6	-$ 493,100
1% AEP	-3	-4	-$ 225,600
0.5% AEP	-2	-5	-$ 279,300
0.2%PMF	-2	0	-$ 34,100
PMF	0	0	-$ 8,100
Average Annual Damages (AAD)			-$ 58,100

Evaluation

The design of this option is fairly straightforward however there are a number of constraints which may limit the viability of the option, including significant impacts on coastal processes. The works are therefore recommended for further consideration as part of the Floodplain Risk Management Plan.

PUBLIC EXHIBITION DRAFT

8.5.5.4. Option DM05 – Upgrade Railway Culvert at Woodlands Creek

	Option DM05 – Upgrade Railway Culvert at Woodlands Creek		
Description	• Amplification of the existing structure under railway and addition of a new 2.4m diameter culvert to reduce the impacts when the capacity of the culvert is exceeded.		
Benefits	• Improved flood behaviour • Improved property benefits • Reduced impact to railway embankment		
Concerns	• Pipe jacking required • High capital cost and limited financial viability • Existing services • Land ownership • Multi Stakeholder Project		
B/C Ratio	0.3	**Cost Estimate**	$1,251,000
Outcome	Option results in limited improvement to over floor inundation and direct and tangible flood damages, which reduces the economic viability, increases flood levels downstream and has a number of technical challenges. This option should not be recommended as part of the Floodplain Management Plan.		

Location and Flood Issue

Floodwater from Woodlands Creek builds up upstream of the Princes Highway, upstream of the existing vehicle ramp as well as upstream of the railway line. Once the water builds up, the floodwater overtops the creek bank and flows northward along the railway line through properties on Hewitts Avenue towards Hewitts Creek. Properties on Hewitts Avenue are first inundated in the 20% AEP flood event.

Option Description

This option aims to reduce the impacts when the capacity of the culvert is exceeded by mitigating the transfer of water towards the Hewitts Avenue properties. The Floodplain Risk Management Study and Plan (2002) recommended the construction of a new culvert (6m wide by 4m high) through the railway embankment to the north of the existing low level culvert. This FRMS&P reviews the recommendation from the 2002 study by assessing the benefits of a twin 2.4m diameter pipe. The 2002 proposed structure was deemed oversized for Woodlands Creek. Image 16 shows the option configuration as modelled.

PUBLIC EXHIBITION



Image 16 Option DM05, new structure under the railway (orange)

Feasibility

The proposed works have a number of technical and feasibility challenges related to the railway line operation, including disruption. Collaboration with Transport for NSW, the infrastructure owner, would be required through all stages from concept development to construction. Methods such as pipe jacking may be suitable to minimise disruption to the line. Existing services are likely to be present and may add to costs. Design consideration will need to be given to minimising environmental impacts on the creek, including management of increased flow downstream of the railway line.

Modelled Impacts

The works increase the volume of water passing through the culvert structures for both the 5% and 1% AEP event. Peak flood levels immediately upstream of the railway line are also significantly reduced in events up to the 5% AEP, with a 1.5m reduction upstream of the railway line in that event. During the 1% AEP event peak flood levels are reduced by up to 1.0m upstream of the railway line (Figure C23 and Figure C24). The overland flow path connecting Woodlands Creek and Hewitts Creek is almost dry in events below the 5% AEP event with a peak flow reduced to 10% in the 5% AEP event. Flood levels along Hewitts Avenue are also significantly reduced by 0.5m and 0.2m, in the 5% and 1% AEP events, respectively. Flood levels are increased downstream of the railway by up to 0.1m in the 5% AEP event and 0.05m in the 1% AEP event.

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Costs and Economic Analysis

This option is estimated to have relatively high capital cost, in the order of $1,251,000. The direct and tangible benefits of this option are limited, and the Annual Average Damages for the catchment is reduced by 2%. Considering both these aspects, the B/C ratio equates to 0.3. This option is not considered to be economically viable.

Table 28: Change in damages due to the option DM05

Event	Change in No. of Properties Flood Affected	Change in No. of Properties Flooded Above Floor Level	Change in Total Tangible Flood Damages
20% AEP	-4	-1	-$ 69,300
10% AEP	-4	-1	-$ 68,100
5% AEP	-16	-1	-$ 113,800
2% AEP	-2	0	-$ 102,900
1% AEP	-2	1	-$ 53,700
0.5% AEP	-1	-2	-$ 199,100
0.2%PMF	-1	0	-$ 78,200
PMF	-3	-2	-$ 220,800
Average Annual Damages (AAD)			-$ 27,200

Evaluation

This option significantly reduces the extent of inundation and flood levels immediately upstream of the railway line. Benefits extend to properties and in a reduction of water banking up against the railway line. Benefits occur mainly across yard inundation and therefore limited improvements to direct and tangible benefits are observed, reducing the economic viability of the option and suitability as a floodplain management measure. In addition, in more frequent events flood levels are increased downstream of the railway. The option has technical challenges including responsibility being with Transport for NSW. This option should not be investigated further as a floodplain risk management option.

A number of alternative options have been assessed in this area, including DB06 (Section 8.5.1), CM07 (Section 8.5.1), LV01 (Section 8.5.2.1), and DB04 (Section 8.5.3.2), with LV01 being found to be the preferred option.

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8.5.5.5. Option DM07 – Cliff Parade Culvert Upgrade

☑	DM07 – Cliff Parade Culvert Upgrade		
Description	• New drainage structure (3 x 1.5m by 0.8m) under Cliff Parade creating an outlet to the ocean through Tingara Park		
Benefits	• Improved flood behaviour • Improved property impacts • Cliff Parade no longer overtopped in events up to the 5% AEP		
Concerns	• Existing services • Land ownership • Creek may need widening		
B/C Ratio	0.87	**Cost Estimate**	$831,000
Outcome	Recommended to be considered for further investigation as part of this Floodplain Risk Management Plan		

Location and Flood Issue

Thomas Gibson Creek passes through the catchment through a drainage system which in dome sections is located in the backyards of properties. Both McCauley Street and Cliff Parade are overtopped in frequent events due to the low capacity of the stormwater pipes under the road. Property inundation also occurs in frequent events.

Option Description

The Floodplain Risk Management Study and Plan (2002) recommended as a medium priority, that an additional cell be added under Cliff Parade to the existing 0.95m pipe to improve its capacity to carry floodwaters. This option has been reconsidered as part of the current investigation and involves the replacement of the pipes below Cliff Parade with a box culvert that is 4m wide and 1.5m high. Image 17 shows the option configuration as modelled. The size of the upgrade has been revised based on the revised hydraulic and hydrological modelling.

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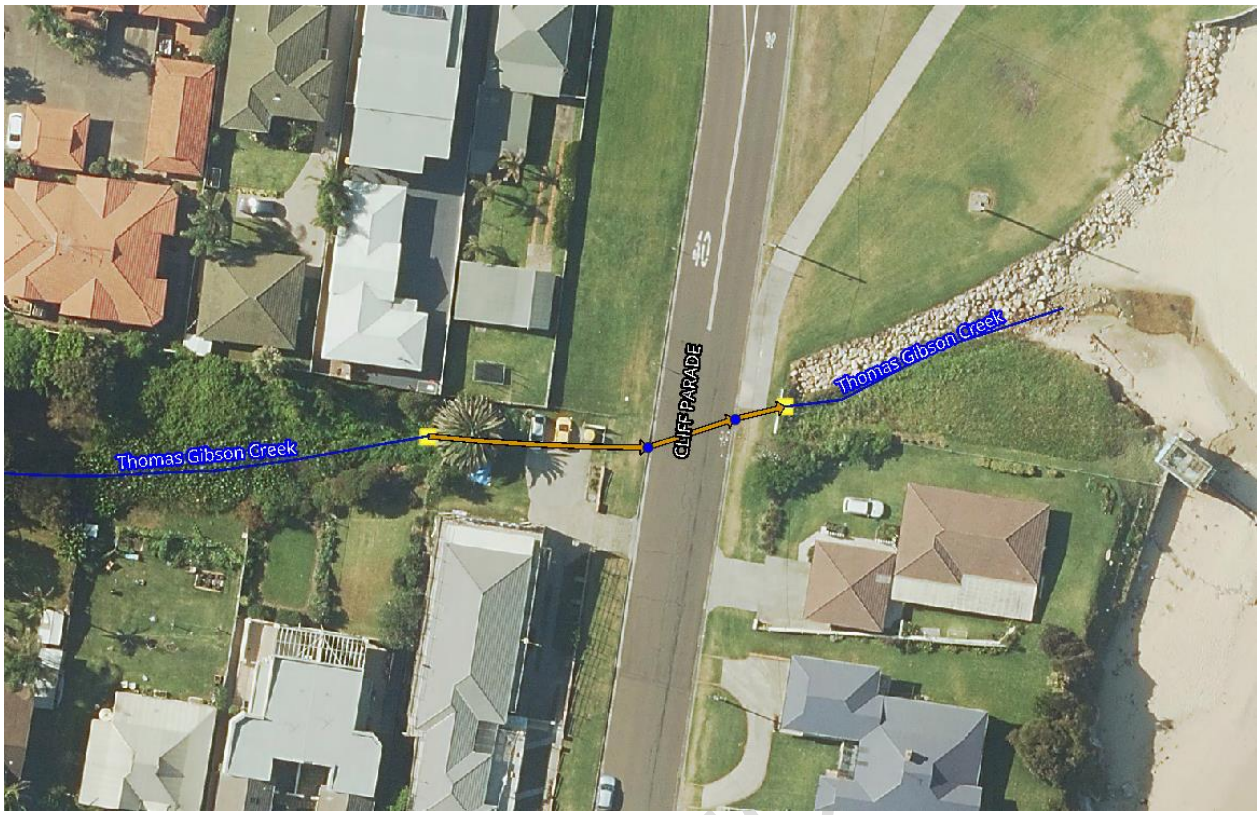


Image 17 Option DM07, Proposed structure upgrade in orange

Feasibility

The proposed works are relatively straightforward. There would be disruption to the road during construction. The works have the potential to cause a disruption during construction. There is likely to be minor environmental impacts associated with the removal of isolated trees, however the impacts on coastal processes have the potential to be more significant. Standard erosion and sediment control would be required during construction. Treatment of the outlet would require design consideration, from a visual amenity, erosion and safety perspective. The creek downstream will likely require widening. Consideration will need to be given to existing services and land ownership as parts of the works are located on private land. Retrofitting the existing cycleway and pedestrian connectivity will also require design consideration as the new culvert will pass under the existing cycleway.

Modelled Impacts

Cliff Parade at the proposed structure is no longer overtopped in a 5% AEP event with all existing overland flow able to be conveyed by the culvert. In a 1% AEP event the overtopping has significantly reduced in inundation depths. Flood levels are also broadly reduced by up to 0.3m in both the 5% and 1% AEP event (Figure C25 and Figure C26). The invert levels of the new structure are similar to the existing structure. The risk of backwatering due to high tide is unchanged with the proposed option in place.

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Costs and Economic Analysis

This option is estimated to have a relatively high capital cost, in the order of $831,000. However, a number of properties are no longer experiencing over floor flooding across a range of events. This reduces direct and tangible damages as well as Annual Average Damages for the catchment by 4%. Considering these factors, the resulting B/C ratio is 0.87.

Table 29: Change in damages due to the option DM07

Event	Change in No. of Properties Flood Affected	Change in No. of Properties Flooded Above Floor Level	Change in Total Tangible Flood Damages
20% AEP	-8	-2	-$ 119,800
10% AEP	-5	-1	-$ 109,500
5% AEP	-8	-2	-$ 113,000
2% AEP	-12	-8	-$ 526,200
1% AEP	-2	-3	-$ 46,400
0.5% AEP	0	-2	-$ 263,600
0.2%PMF	-3	-1	-$ 72,400
PMF	0	0	-$ 19,100
Average Annual Damages (AAD)			-$ 48,800

Evaluation

The design of this option is fairly straightforward however there are a number of constraints which may limit the viability of the option, including significant impacts on coastal processes. The works are therefore recommended for further consideration as part of the Floodplain Risk Management Plan.

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8.5.6. Maintenance of Drainage

8.5.6.1. Option VM01 – Vegetation Management

Vegetation management refers to the planning and implementation of the activities involved in managing native and exotic plant species within a particular area. Activities typically include removal of weeds or debris, thinning of shrub layers or targeting a particularly problematic noxious plant species. In a flooding context, vegetation management may aim to improve flood behaviour, however in a broader context it may bring about a range of ecological values, for example the improvement of habitats for native fauna or bushfire hazard reduction. Removal of vegetation requires careful planning, as vegetation plays an essential role in erosion protection and stream bank stability. If vegetation is removed or thinned excessively, creeks can become susceptible to erosion and scouring, which among other things, may lead to banks slumping and greatly reducing the channel capacity, and impacting on flood behaviour. Often feedback from the community indicates a widespread belief that 'clearing the creek' would result in the reduction of flood risk.

Since 2003, a vegetation management program has been implemented through Council's Stormwater Levy Program. Works include revegetation, removal of invasive species, removing vegetation in any catch points, rubbish removal and weed maintenance control. Programs including these works will naturally reduce the debris load within the catchment. Large parts of the creek system are located on privately owned land, limiting the areas where Council can implement the vegetation management program (Image 18).

As part of this study the consequences on flood levels of the existing vegetation management program was investigated as well as the implication of extending the program to all Council owned flood prone land.

Impact of the existing vegetation management program (VM01):
The TUFLOW hydraulic models which forms the basis of option assessment in this study, can be used to estimate how flood behaviour would change if Council did not continue its vegetation management practices. Without ongoing intervention, vegetation density would increase, resulting in an increase in the hydraulic roughness of the channel. Existing and potential future vegetation density can be represented in flood modelling using the hydraulic roughness parameter known as 'Manning's 'n'. The 'n' value is determined by a number of factors that affect the resistance of channels and floodplains, including but not limited to vegetation. To simulate the effect of ceasing vegetation management activities, the hydraulic roughness assigned to the in-bank area was increased by 20%. This scenario effectively simulates the impact to flood level should these areas be left unmanaged.

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Image 18: Existing vegetation program

The results of the assessment for the 5% and 1% AEP events are shown on Figure C27 and Figure C28. The assessment shows that Council's current vegetation management program is reducing flood levels by up to 0.1m.

Extension of the vegetation management program (VM02):
Under this scenario the TUFLOW hydraulic model was modified to simulate a possible extension of the program to all Council owned flood prone land. Additional areas are currently not part of Council's program and therefore there is potential that the vegetation density could be reduced, resulting in a decrease in the hydraulic roughness and flood levels within the channel. To simulate the effect of extending vegetation management activities, the hydraulic roughness assigned to the in-bank section of channels for the additional areas was reduced by 20%.

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Image 19: Extended vegetation program

The results of the assessment for the 5% and 1% AEP events are shown on Figure C29 and Figure C30. The assessment shows that should Council's current vegetation management program be extended additional reductions in flood level of up to 0.1m could be achieved.

It is recommended that Council continue its riparian vegetation management plan as it provides some benefit in floodplain risk management. This plan should be reviewed on a regular basis, for example via future Floodplain Risk Management Studies and Plans and following major flood events which may affect the vegetation characteristics and channel geometry the creek system.

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8.5.6.2. Option DCM - Debris Control Measures

Past community feedback has shown the community are concerned about vegetation and debris in creeks and waterways. Similarly, residents have noted structures become blocked with vegetation.

Structure blockage can be improved with the introduction of maintenance protocols or policies to ensure that drainage assets are effectively managed and regularly maintained, and the vegetation load is managed. These policies aim to ensure that assets will perform when they are needed.

Alternatively, the implementation of trash racks or bollards (to prevent large debris entering creeks) upstream of structures could be considered by Council to keep structures free of debris. The cost of trash racks or bollards varies greatly depending upon the nature of the structure. Consideration needs to be given to the type of debris these structures are designed to capture and for what size flood event. For example, the structure needs to be designed to ensure it will not silt up and become blocked in low flow flood events.

It is not possible to completely prevent the occurrence of blockages at structures and within the creek channel. It is a natural effect of flooding and even with regular large-scale clearing of the creek channel which can also result in bank instability, floodwaters will still collect debris and block drainage structures to some extent. It is considerably more efficient to manage pollutant loads prior to their entry into waterways. This means implementing good landscape management practices to retain soil on the ground. These landscape management practices include work such as riparian revegetation and bank stabilisation to reduce erosion potential, which have the added benefit of improving ecosystem health.

The TUFLOW hydraulic models which forms the basis of option assessment in this study, can be used to estimate how sensitive flood behaviour is at structures throughout the catchment to blockage. This scenario assists in understanding the consequences of increased blockage at structures throughout the catchment and identifies locations where intervention would be beneficial. The design flood behaviour, which includes Council's Blockage Policy for the 5% and 1% AEP events were compared to a simulation with no assumed blockage. The results are shown on Figure C31 and Figure C32. Table 30 identifies locations where Council should consider the installation of debris control measures. The installation of debris control structures at targeted locations locally improves flood behaviour and, in some circumstances, removes road inundation for some events. Due to the localised nature of the improvements to flood behaviour, there is not widespread improvements to property damage at some locations.

Table 31 identifies locations where Council should consider the installation of debris control measures and an associated implementation priority.

Table 30: Structures Sensitive to Blockage

Creek	Crossing	Consequences	Potential Increase in Flood Level (m)		Priority
			5% AEP	1% AEP	
Slacky Creek	Old Mine Site	Diversion of flow to Tramway Creek along Hobart Street	0.8	1.1	Optional
Slacky Creek*	William Street	Overflow on William Street and property inundation	1.1	0.7	Optional
Slacky Creek	Hobart Street	Newly inundated areas and property inundation	0.0	0.3	Optional
Tramway Creek	Railway	Newly inundated areas, property inundation and railway overtopping	4.5	3.4	Medium

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Woodlands Creek	Vehicle ramp and railway	Newly inundated properties in Hewitts Avenue	1.7	0.6	High
Turnbul Gully	Deborah Avenue	Newly inundated properties and new overland flow path	1.89	2.0	Optional

* This locations were also identified in the Floodplain Risk Management Study and Plan (2002)

Table 31 provides an overview of the economic assessment for the structures, assuming a structure cost of $300,000. Other costs such as ongoing maintenance, project management and possible easement acquisition have also been included.

Table 31: Economic Assessment

Location	Total Cost	Total Costs (NPV)	Reduction in AAD	Benefits (NPV)	Benefit Cost Ratio
Tramway Creek	$370,000 Capital $3000 Annual	$620,000	$23,900	$353,000	0.57
Woodlands Creek	$370,000 Capital $3000 Annual	$620,000	$35,100	$518,000	0.83
All locations	$2,220,000 Capital $18,000 Annual	$3,400,000	$2,800	$1,120,000	0.33

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9. MULTI CRITERIA ASSESSMENT MATRIX

9.1. Introduction

The Floodplain Development Manual (Floodplain Development Manual (2005)) recommends the use of multi-criteria assessment when assessing flood risk mitigation measures. A multi-criteria assessment (MCA) provides a method by which options can be assessed against a range of criteria and offers a greater breadth of assessment than is available by considering only the reduction in flood risk or economic damages, for example. Such additional criteria may include social, political and environmental considerations and intangible flood impacts that cannot be quantified or included in a Cost-Benefit Analysis. It should be noted that the assessment of the suitability of floodplain mitigation options is a complex matter, and an MCA will not give a definitive 'right' answer but will provide a tool to debate the relative merits of each option. A draft score has been allocated to "Community and Stakeholder Support" and will be confirmed following Public Exhibition.

9.2. Scoring System

A scoring system has been devised to allow stakeholders to assess the various options across a consistent basis to allow for direct comparison. The scoring system is divided into four key criterion: Economic, Social, Environmental and Other Aspects. Scores for each criteria are to be assigned to each option then summed to determine the overall score. Options with higher scores indicate benefits across a range of criteria and should be prioritised over those with lower positive scores, which may be more neutral or have a combination of pros and cons. Conversely, options with the lowest negative scores indicate the option would cause adverse outcomes in a number of criteria and should not be considered further. The scoring system is provided in Table 32.

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Table 32: Multicriteria Assessment Scoring System

	Criteria	Metric	Score -3	-2	-1	0	1	2	3
Economic	Economic Merits	*Comparison of the economic benefits against the capital and ongoing costs*	BC < 0.1	BC: 0.1- 0.5	BC: 0.5-0.9	BC = 1 (Or NA)	BC: 1.0 - 1.4	BC: 1.4 - 1.7	BC >1.7
	Implementation Complexity	*Potential design, implementation and operational challenges and constraints. Risk can increase with implementation timeframe*	Major constraints and uncertainties which may render the option unfeasible	Constraints or uncertainties which may significantly increase costs or timeframes	Constraints or uncertainties which may increase costs or timeframes moderately	NA	Constraints that can be overcome with moderate investment of time and resources	Constraints that can be overcome easily	No constraints or uncertainties
	Staging of Works	*Ability to stage proposed works*			Works cannot be staged	NA	Some minor components of the works may be staged	Some major components of the works may be staged	
Social	Impact on Emergency Services	*Change in demand on emergency services (SES, Police, Ambulance, Fire, RFS etc).*	Major disbenefit	Moderate Disbenefit	Minor Disbenefit	Neutral	Minor Benefit	Moderate Benefit	Major Benefit
	Emergency Access	*Flood depths and duration changes for critical transport routes*	Key access roads become flooded that were previously flood free	Significant increase in main road flooding	Moderate increase in local or main road flooding	No Change	Moderate decrease in local or main road flooding	Significant decrease in main road flooding	Local and main roads previously flooded now flood free
	Impact on critical and/or vulnerable facilities[1]	*Disruption to critical facilities*	Inoperational for several days	Inoperational for one day	Inoperational for several hours	No Change	Period of inoperation reduced by 0-4 hours	Period of inoperation reduced by > 4 hours	Prevents disruption of critical facility altogether
	Impact on Properties	*No. of properties flooded over floor. Across all events*	>5 adversely affected	2-5 adversely affected	<2 adversely affected	None	<2 benefitted	2 to 5 benefitted	>5 benefitted
	Impact on flood hazard	*Change in hazard classification*	Significantly increased in highly populated area (Increasing to H5/H6)	Moderately increased in populated area (Increasing by 2 or more categories)	Slightly increased (Increase by 1 category)	No Change	Slightly reduced (Decrease by 1 category)	Moderately reduced in populated area (Decrease by 2 or more categories)	Significantly reduced in highly populated area (Decrease from H5/H6)
	Community Flood Awareness	*Change in community flood awareness, preparedness and response*	Significantly reduced	Moderately reduced	Slightly reduced	No Change	Slightly improved	Moderately improved	Significantly improved
	Social disruption	*Closure of or restricted access to community facilities (including recreation)*	Normal access significantly reduced or facilities disrupted for > 5 days	Normal access routes moderately reduced or facilities disrupted for 2-4 days	No Change to acess but facilities disrupted for up to 12 hours	No Change	Reduces duration of access disruption or facility disruption by up to 12 hours	Reduces duration of access disruptioin or facility disruption by 2-4 days	Prevents disruption of access or facility altogether
	Community and stakeholder support[2]	*Level of agreement (expressed via formal submissions and informal discussions)*	Strong opposition by numerous submissions	Moderate opposition in several submissions	Individual submissions with opposition	Neutral	Individual submissions with support	Moderate support in several submissions	Strong support by numerous submissions
Environmental	Impacts on Flora & Fauna (inc. street trees)	*Impacts or benefits to flora/fauna*	Likely broad-scale vegetation/habitat impacts	Likely isolated vegetation/habitat impacts	Removal of isolated trees, minor landscapng.	Neutral	Planting of isolated trees, minor landscapng.	Likely isolated vegetation/habitat benefits	Likely broad-scale vegetation/habitat benefits
	Heritage Conservation Areas and Heritage Items	*Impacts to heritage items*	Likely impact on State, National or Aboriginal Heritage Item	Likely impact on local heritage item	Likely impact on contributory item within a heritage conservation area	No impact	Reduced impact on contributory item within a heritage conservation area	Reduced impact on local heritage item	Reduced impact on State, National or Aboriginal Heritage item
Other Aspects	Financial Feasibility and Funding Availability	*Capital and ongoing costs and funding sources available*	Significant capital and ongoing costs, or no external funding or assistance available	Moderate capital and ongoing costs, no funding available	High capital and ongoing costs, partial funding available	NA	Moderate capital and ongoing costs, partial funding available; or low capital and ongoing costs, no funding available	Low to moderate capital and ongoing costs, partial funding available	Full external funding and management available
	Compatibility with existing Council plans, policies or projects	*Level of compatibility*	Conflicts directly with objectives of several plans, policies or projects	Conflicts with several objectives or direct conflict with one or few objectives	Minor conflicts with some objectives, with scope to overcome conflict	Not relevant	Minor support for one or few objectives	Some support for several objectives, or achieving one objective	Achieving objectives of several plans, policies or projects

[1] Critical facilities are those properties that, if flooded, would result in severe consequences to public health and safety. These may include fire, ambulance and police stations, hospitals, water and electricity supply, buses/train stations and chemical plants. Vulnerable facilities refer to those properties with vulnerable occupants, such as nursing homes or schools.
[2] Community and stakeholder support scores will be completed following Public Exhibition

Table 33: Multi Criteria Assessment Results

			Economic			Social								Environmental		Other Aspects			
Category	ID	Option	Economic Merits	Implementation Complexity	Staging of Works	Impact on Emergency Services	Road Access	Impact on critical and/or vulnerable facilities[1]	Impact on Properties	Impact on flood hazard	Community Flood Awareness	Social disruption	Community and Stakeholder Support[2]	Impacts on Flora & Fauna (inc. street trees)	Heritage Conservation Areas and Heritage Items	Financial Feasibility and Funding Availability	Compatibility with existing Council plans, policies or projects	Total Score	Overall Rank
Property Modification	PM01	Flood Planning Level	1	1	0	1	0	1	3	1	1	0		0	0	2	3	14	2
	PM02	Flood Planning Area	1	3	0	1	0	0	3	0	1	0		0	0	2	3	14	2
	PM03	Provision of Flood Information to Residents via s10.7 Planning Certificates	1	2	0	1	0	0	1	0	2	0		0	0	2	3	12	5
	PM04	Managing Development in the Flood Prone Areas	1	1	2	2	0	2	3	1	1	0		0	0	1	3	17	1
	PM05	Voluntary House Raising	2	-1	0	1	0	0	3	0	1	0		0	0	1	1	8	9
	PM06	Voluntary Purchase	0	-1	0	2	0	0	3	0	1	0		0	0	1	1	7	11
	PM07	Flood Proofing/Flood Resilient Buildings	2	1	0	0	0	2	2	0	1	1		0	0	0	1	10	6
Response Modification	RM01	Amend Local Flood Plans with Flood Information Derived from this Study	0	1	2	3	0	0	0	0	1	0		0	0	1	1	9	7
	RM02	Facilitation of Communication with Emergency Services and Response Agencies	0	1	2	2	0	0	0	0	0	0		0	0	2	1	8	9
	RM03	Improve Community Flood Education and Awareness	0	2	2	3	0	0	0	0	3	0		0	0	1	3	14	2
	RM04	Flood Warning Improvements	0	2	1	1	0	0	0	0	2	0		0	0	1	2	9	7
Flood Modification	LV01	Woodlands Creek North Bank Levee	1	-1	-1	1	1	0	1	1	0	0		-1	0	1	1	4	12
	DB02	Former Bulli Mine Basin	3	-1	-1	1	1	0	0	1	0	0		-2	0	1	1	4	12
	VM01/VM02	Vegetation Management	0	1	2	0	0	0	0	0	0	0		-2	0	-2	1	0	15
	DCM	Debris Control Measures	0	1	2	1	1	0	0	0	0	0		-1	0	-2	1	3	14

(1) Critical facilities are those properties that, if flooded, would result in severe consequences to public health and safety. These may include fire, ambulance and police stations, hospitals, water and electricity supply, buses/train stations and chemical plants. Vulnerable facilities refer to those properties with vulnerable occupants, such as nursing homes or schools.
(2) Community and stakeholder support scores will be completed following Public Exhibition

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9.3. Discussion of Results

The multi-criteria matrix assessment results, presented in Table 33, can be used to both understand the benefits and disadvantages of individual options, but to also see trends across the full suite of options assessed in the FRMS&P. The following results and trends are noted:

- Improve Managing Development in the Flood Prone Areas (PM04) received the highest score, as it delivers strong widescale benefits across a range of criteria including economics, reduction in flood risk, property affectation, as well as playing a role in community flood awareness;
- Property Modification Measures, Adopt Flood Planning Level (PM01), Flood Planning Area (PM02), and Provision of Flood Information (upon application from residents) on Section 10.7 Certificates (PM03) are cost effective and have additional benefits relating to improvements to community flood awareness. These options are the next highest scoring options.
- Response Modification Measures and Property Modification Measures tend to score more highly than Flood Modification measures, as they can be implemented for a relatively low cost, lead to the reduction of property damage and improvement in community resilience in the long term, and do not incur negative environmental impacts;
- Majority of flood modification measures, that is, structural options, do not score well in terms of economic merits. Reasons for this include:
    - “Tangible Benefits” included in the Cost Benefit Analysis are determined from the reduction in property damages (Annual Average Damages (AAD)). The benefits from the majority of these options come from improved road access which is not included in the AAD calculation.
- The lowest scoring options include VM01/VM02 and DCM are focused on minor improvements to flood behaviour and do not have significant reductions in direct and tangible damages.

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10. DRAFT FLOODPLAIN RISK MANAGEMENT PLAN

The draft Hewitts Creek Catchment Flood Risk Management Plan has been prepared in accordance with the NSW Floodplain Development Manual (Floodplain Development Manual (2005)). The Plan:

- *Is based on a comprehensive and detailed evaluation of factors that affect and are affected by the use of flood prone land;*
- *Represents the considered opinion of the local community on how to best manage its flood risk and its flood prone land; and*
- *Provides a long-term path for the future development of the community.*

An investigation of possible management measures was undertaken to assess the effectiveness of each option against a range of criteria. The assessment criteria included how the option affected property damages, community flood awareness, impact on the SES, and economic merits, and a range of other factors described in Section 9.

The following options were found to be effective in reducing flood risk across a range of criteria and have been recommended for implementation. Each measure has been prioritised based on its ability to reduce flood risk in the study area, and how readily it can be implemented (and funded, if necessary), what constraints exist, and how effective the measures are. Measures with little cost that can readily be implemented, and which are effective in reducing damage or personal danger should have high priority. Others that are more complex and expensive to implement or are less effective in reducing flood risk, generally have a lower priority.

The Draft Floodplain Risk Management Plan is provided in Table 34. The tables describe the purpose of the measure, as well as its priority, cost, timeframe and the party responsible for its implementation. Detailed description of each recommendation is provided in Section 8 of the Study, which also contains measures that were assessed but were not viable for recommendation.

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Table 34 Draft Floodplain Risk Management Plan

	Option ID (Ref)	Option	Description	Benefits	Concerns	Responsibility	Funding	Cost	B/C Ratio	Time Frame	Priority
Property Modification Options	**PM01 (8.3.1)**	Adoption of Flood Planning Levels (FPL)	Council to adopt the following Flood Planning Levels: • Defined Flood Event + freeboard where the Defined Flood Event has been determined to be the 1% AEP (including envelope of blocked and unblocked scenarios) plus climate change rainfall increases (RCP8.5 2090) and 0.90 m SLR. Freeboard is 0.5m Adopt the Flood Planning Level, for sensitive, vulnerable or critical uses: • Probable Maximum Flood where Freeboard is 0.5m Amend LEP Dictionary definition for FPL	FPLs are effective tools to limit property damage to new development and redevelopment.	Developer may consider a FPL onerous. Education can help to mitigate this.	Council	N/A	In house, nominally $10,000	Typically shown to be economically viable	Short	High
	PM02 (8.3.2)	Adoption of Flood Planning Area (FPA)	The FPL, and other flood related development controls, are applied to properties within the Flood Planning Area (FPA). Adopt associated Flood Planning Area map developed in this FRMS&P, which delineates the FPA. Adopt the Flood Planning Area for residential development as the area defined by the extent of: • Defined Flood Event + Freeboard where the Defined Flood Event has been determined to be the 1% AEP (including envelope of blocked and unblocked scenarios) plus climate change rainfall increases (RCP8.5 2090) and 0.90 m SLR. Freeboard is 0.5 m. Adopt the extent of the Probable Maximum Flood for planning purposes on land with a significant risk to life, sensitive, vulnerable or critical uses, or land with hazardous materials or industry.	The FPA will provide clear guidance on the properties subject to flood related development controls.	A planning proposal may be required to amend the LEP and implement the new FPA definition. Consultation would be required.	Council	N/A	In house, nominally $10,000	N/A	Short	High
	PM03 (8.3.3)	Provision of Flood Information to Residents via Section 10.7 Planning Certificates.	Increase resolution of flood information to be provided on s10.7(2) and (5) certificates to identify the property's flood hazard, hydraulic category and whether or not flood related development controls apply using high resolution outputs from this study.	The more informed a home owner is, the greater the understanding of their flood risk. During a flood event this information can help prepare residents to evacuate and reduces the number of residents that elect to take shelter in high hazard areas.	Limited - s10.7(2) certificates already contain basic information, Council to provide further detail from current FRMS results. May increase demand on Council staff, however GIS systems can be established to provide this information efficiently.	Council	NA	In house, nominally $15,000	Typically shown to be economically viable	Short	High
Property Modification Options	**PM04 (8.3.4)**	Managing Development in Flood Prone Areas	Adopt the DFE as the 1% AEP (including envelope of blocked and unblocked scenarios) plus climate change rainfall increases (RCP8.5 2090) and 0.90 m SLR for planning related matters. Adopt the Flood Risk Precinct Definition and Mapping as defined by Figure 13 from this study for the purposes of flood related planning controls. Adopt a consistent set of flood related planning controls across the LGA with guidance from the example matrix and controls from this study. Adopt Major/Minor Overland Flow definition and mapping as defined by Figure 5 from this study. Adopt a revised clause within Council's DCP to better achieve Chapter E13 Objective 3(1)(i): Ensure new development (with the exception of waterway crossings) does not encroach within areas susceptible to channel erosion, migration, bank failure and slumping. Consider Flood Risk Precincts and Flood Emergency Response Classifications in land use planning decisions.	Ensure developments are designed, constructed and managed in such a way as to minimise flood risk to the structure and (if relevant) its occupants, in addition to minimising the impacts of flooding.	There may be resistance from developers who consider new controls to be onerous or likely to reduce the development yield.	Council	Council	In house, nominally $15,000	N/A	Short	High

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	Option ID (Ref)	Option	Description	Benefits	Concerns	Responsibility	Funding	Cost	B/C Ratio	Time Frame	Priority
	PM05 (8.3.5)	Voluntary House Raising	Undertake a feasibility investigation for the 10 identified properties (including to confirm structural compatibility of the identified buildings, owner interest and a more accurate cost estimate of raising to at least the DFE + 0.5 m flood level), and if found viable, prepare the documentation for funding applications.	Seeks to reduce the frequency of exposure to flood damage of the house and its contents by raising the house above the Flood Planning Level (FPL), resulting in a reduction in the frequency of household disruption and associated trauma and anxiety.	External flood risk remains, and evacuation is required before inundation in cases where the property becomes isolated. Community appetite may be a challenge. VHR schemes are long term options and may take approximately a decade to implement.	Council/ Landholder	Landholder/ May be eligible for NSW Government funding assistance	Approximately $100,000 (Dependent on quotes) Feasibility Investigation $50,000	0.39 – 1.71	Mid (Further Investigation) Long (Implementation)	High (Feasibility Study)
	PM06 (8.3.6)	Voluntary Purchase	Undertake further investigation to determine inclusion of the additional 15 properties in the ongoing VP scheme, including consultation with the identified properties, prioritisation and if appropriate, prepare the documentation for funding applications.	Voluntary Purchase (VP) schemes are a long-term option to remove residential properties from areas of high flood hazard.	Community appetite for or acceptance of VP may be a challenge. VP schemes are long term options and may take approximately a decade to implement.	Council	Council/May be eligible for NSW Government funding assistance	Dependent on property purchase price Further Investigation $50,000	N/A	Mid (Further Investigation) Long (Implementation)	High (Further Investigation)
	PM07 (8.3.7)	Flood Proofing/Flood Resilient Buildings	Allow flood proofing within Council's DCP enabling new and existing buildings to be developed with due consideration given to their flood risk and minimisation of internal flood damages and recovery time.	Flood proofing reduces damage and recovery costs and time following flood events.	Retrofitting to existing buildings can have challenges.	Council/ Landholder	Council/ Landholder	Varies for Implentation Guideline development $20,000	N/A	Short	High
Response Modification Options	**RM01 (8.4.1)**	Amend Local Flood Plans with Flood Information Derived from this Study	Develop local flood plans and operational plans to include information on flood risk due to overland flow, drawing on modelling and information provided in this FRMS&P	Detailed information will allow for better management and recovery of overland flow flood risk and will increase understanding of the different levels and types of risk present in the study area.	Modelled results should be used as a guide only, as real flood behaviour may vary from modelled design results.	SES	SES	In house, nominally, $15,000	N/A	Mid	High
	RM02 (8.4.2)	Facilitation of Communication with Emergency Services and Response Agencies	Ongoing facilitation of communication between Council and emergency service agencies. Improvements to volunteer coordination. Identify vulnerable occupants.	Improved understanding of roles and responsibilities for more effective, efficient, and safe actions during and following flood events.	Challenges include change of personnel, difficulty in organising meetings and exercises between flood events.	All response agencies, including but not limited to the SES, Council, RFS, Fire and Rescue, and community organisations.	May be eligible for NSW Government funding assistance	Minimal - In house	N/A	Short	High
	RM03 (8.4.3)	Improve Community Flood Education and Awareness	Council to implement a flood education program to improve ongoing flood awareness in study area using a range of approaches and engagement strategies.	Flood awareness significantly improves preparedness for and recovery from flood events, building a more flood resilient community.	Ongoing efforts to ensure information is not forgotten. Potential for residents to become bored or complacent with messaging.	Council in collaboration with other response agencies and community organisations.	May be eligible for NSW Government funding assistance	Annual Budget to be determined and allocated.	Typically shown to be economically viable	Mid	High
	RM04 (8.4.4)	Flood Warning Improvements	Utilise Severe Weather Warnings from the BOM to prepare for potential flash flooding events, look at utilising innovative gauge technologies following review of the Fairy Creek pilot program, couple with community awareness campaigns and utilise information from the FRMS&P to understand the consequences of the warning (SES and Council).	Improve current system understanding by using outputs from the FRMS&P to inform interpretation. Potentially to increase warning time of possible event for the community.	May not be possible to significantly increase warning time in overland catchments due to short catchment response time. Communication needs to be at the correct level to avoid false alarms and complacency.	Council, SES	May be eligible for NSW Government funding assistance	$250,000 Upfront $40,000 ongoing	N/A	Mid	Medium

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	Option ID (Ref)	Option	Description	Benefits	Concerns	Responsibility	Funding	Cost	B/C Ratio	Time Frame	Priority
Flood Modification Options	**LV01 (8.5.2.1)**	Woodlands Creek North Bank Levee	A 170m levee along the north bank of Woodlands Creek with the aim of preventing property inundation along Hewitts Avenue. Parts of the levee (110m) would be set at 18.5mAHD with the remainder at 16mAHD.	Removes property inundation in frequent events, improved flood levels for some properties in less frequent events, the land is vacant and likely without services, low cost and positive BC ratio	Worsens flood behaviour for some properties, visual amenity impacts, impede local drainage	Council	May be eligible for NSW Government funding assistance	$216,000	0.77	Mid	Medium
	DB02 (8.5.3.1)	Former Bulli Mine Basin	Undertake embankment stability works to formalise existing basin near the Old Bulli Mine (south of 16-22 Hobart Street) with the aim to reduce the peak flow and transfer of flows between Tramway and Slacky Creeks. The bank stability works will allow the construction of an embankment to increase the floodplain storage.	Reduces flood levels in frequent events (0.4m in the 5% AEP), reduced flood volume along Hobart Street, utilises existing culvert structure as outlet, straight forward design, low cost and significant economic benefit.	Worsens flood behaviour for some properties and along Slacky Creek, visual amenity impacts, land ownership, minimal benefit in larger events.	Council	May be eligible for NSW Government funding assistance	$246,000	2.67	Mid	High
	CM10 (8.5.4.4)	South Arm Diversion	Create a lowered section between Cliff Parade and the ocean for Thomas Gibson Creek floodwater that overtop Cliff Parade	Improved flood behaviour, reduced property impacts.	Excavation up to 2m required, Existing cycle path likely to be impacted, existing services.	Council	May be eligible for NSW Government funding assistance	$560,000	0.83	Mid	Medium
	DM03 (8.5.5.3)	Additional Culvert to the Ocean at Cliff Parade	New drainage structure (3 x 1.5m by 0.8m) under Tingara Park and outlet to ocean.	Improved flood behaviour.	Existing services, additional outlet on the beach, a number of considerations required through the design process, traffic disruption during construction, reduced hydraulic efficiency	Council	May be eligible for NSW Government funding assistance	$1,011,000	0.85	Mid	Medium
	DM07 (8.5.5.5)	Cliff Parade Culvert Upgrade	New drainage structure (3 x 1.5m by 0.8m) under Cliff Parade creating an outlet to the ocean through Tingara Park.	Improved flood behaviour, improved property impacts Cliff Parade no longer overtopped in events up to the 5% AEP.	Existing services, land ownership, creek may need widening	Council	May be eligible for NSW Government funding assistance	$831,000	0.87	Mid	Medium
	VM01/VM02 (8.5.6.1)	Vegetation Management	Continuation of existing and extension of Council's vegetation management program to maintain vegetation density.	The current vegetation management practices have been shown to be reducing flood levels by between 0.1 – 0.3m at various locations throughout the catchment.	Community may perceive that current works are insufficient. Education required to communicate the importance of vegetation to bank stability, and that further removal of riparian vegetation would not achieve significant reductions in flood levels, may cause erosion and sedimentation and require artificial bank stabilisation or reducing the bank slope.	Council	May be eligible for NSW Government funding assistance	$40,000 - $60,000	N/A	Mid	High

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	Option ID (Ref)	Option	Description	Benefits	Concerns	Responsibility	Funding	Cost	B/C Ratio	Time Frame	Priority
	DCM (8.5.6.2)	Debris Control Measures	Consider the installation of debris control measures at locations identified to be sensitive to blockage.	Flood levels at the identified locations can potentially increase by up to 2.5m if blockage is not appropriately managed.	Management of blockage requires catchment wide approach to reduce potential debris load. Structures may still become blocked.	Council	May be eligible for NSW Government funding assistance	From $370,000	0.33 – 0.83	Mid	High

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Appendix A

Appendix A. GLOSSARY

Taken from the Floodplain Development Manual (April 2005 edition)

acid sulfate soils	Are sediments which contain sulfidic mineral pyrite which may become extremely acid following disturbance or drainage as sulfur compounds react when exposed to oxygen to form sulfuric acid. More detailed explanation and definition can be found in the NSW Government Acid Sulfate Soil Manual published by Acid Sulfate Soil Management Advisory Committee.
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, if a peak flood discharge of 500 m^3/s has an AEP of 5%, it means that there is a 5% chance (that is one-in-20 chance) of a 500 m^3/s or larger event occurring in any one year (see ARI).
Australian Height Datum (AHD)	A common national surface level datum approximately corresponding to mean sea level.
Average Annual Damage (AAD)	Depending on its size (or severity), each flood will cause a different amount of flood damage to a flood prone area. AAD is the average damage per year that would occur in a nominated development situation from flooding over a very long period of time.
Average Recurrence Interval (ARI)	The long term average number of years between the occurrence of a flood as big as, or larger than, the selected event. For example, floods with a discharge as great as, or greater than, the 20 year ARI flood event will occur on average once every 20 years. ARI is another way of expressing the likelihood of occurrence of a flood event.
caravan and moveable home parks	Caravans and moveable dwellings are being increasingly used for long-term and permanent accommodation purposes. Standards relating to their siting, design, construction and management can be found in the Regulations under the LG Act.
catchment	The land area draining through the main stream, as well as tributary streams, to a particular site. It always relates to an area above a specific location.
consent authority	The Council, government agency or person having the function to determine a development application for land use under the EP&A Act. The consent authority is most often the Council, however legislation or an EPI may specify a Minister or public authority (other than a Council), or the Director General of DIPNR, as having the function to determine an application.
development	Is defined in Part 4 of the Environmental Planning and Assessment Act (EP&A Act). **infill development:** refers to the development of vacant blocks of land that are generally surrounded by developed properties and is permissible under the current zoning of the land. Conditions such as minimum floor levels may be imposed on infill development. **new development:** refers to development of a completely different nature to that associated with the former land use. For example, the urban subdivision of an area previously used for rural purposes. New developments involve rezoning and typically require major extensions of existing urban services, such as roads, water supply, sewerage and electric power.

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	redevelopment: refers to rebuilding in an area. For example, as urban areas age, it may become necessary to demolish and reconstruct buildings on a relatively large scale. Redevelopment generally does not require either rezoning or major extensions to urban services.
disaster plan (DISPLAN)	A step by step sequence of previously agreed roles, responsibilities, functions, actions and management arrangements for the conduct of a single or series of connected emergency operations, with the object of ensuring the coordinated response by all agencies having responsibilities and functions in emergencies.
discharge	The rate of flow of water measured in terms of volume per unit time, for example, cubic metres per second (m^3/s). Discharge is different from the speed or velocity of flow, which is a measure of how fast the water is moving for example, metres per second (m/s).
ecologically sustainable development (ESD)	Using, conserving and enhancing natural resources so that ecological processes, on which life depends, are maintained, and the total quality of life, now and in the future, can be maintained or increased. A more detailed definition is included in the Local Government Act 1993. The use of sustainability and sustainable in this manual relate to ESD.
effective warning time	The time available after receiving advice of an impending flood and before the floodwaters prevent appropriate flood response actions being undertaken. The effective warning time is typically used to move farm equipment, move stock, raise furniture, evacuate people and transport their possessions.
emergency management	A range of measures to manage risks to communities and the environment. In the flood context it may include measures to prevent, prepare for, respond to and recover from flooding.
flash flooding	Flooding which is sudden and unexpected. It is often caused by sudden local or nearby heavy rainfall. Often defined as flooding which peaks within six hours of the causative rain.
flood	Relatively high stream flow which overtops the natural or artificial banks in any part of a stream, river, estuary, lake or dam, and/or local overland flooding associated with major drainage before entering a watercourse, and/or coastal inundation resulting from super-elevated sea levels and/or waves overtopping coastline defences excluding tsunami.
flood awareness	Flood awareness is an appreciation of the likely effects of flooding and a knowledge of the relevant flood warning, response and evacuation procedures.
flood education	Flood education seeks to provide information to raise awareness of the flood problem so as to enable individuals to understand how to manage themselves an their property in response to flood warnings and in a flood event. It invokes a state of flood readiness.
flood fringe areas	The remaining area of flood prone land after floodway and flood storage areas have been defined.
flood liable land	Is synonymous with flood prone land (i.e. land susceptible to flooding by the probable maximum flood (PMF) event). Note that the term flood liable land covers

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	the whole of the floodplain, not just that part below the flood planning level (see flood planning area).
flood mitigation standard	The average recurrence interval of the flood, selected as part of the floodplain risk management process that forms the basis for physical works to modify the impacts of flooding.
floodplain	Area of land which is subject to inundation by floods up to and including the probable maximum flood event, that is, flood prone land.
floodplain risk management options	The measures that might be feasible for the management of a particular area of the floodplain. Preparation of a floodplain risk management plan requires a detailed evaluation of floodplain risk management options.
floodplain risk management plan	A management plan developed in accordance with the principles and guidelines in this manual. Usually includes both written and diagrammetic information describing how particular areas of flood prone land are to be used and managed to achieve defined objectives.
flood plan (local)	A sub-plan of a disaster plan that deals specifically with flooding. They can exist at State, Division and local levels. Local flood plans are prepared under the leadership of the State Emergency Service.
flood planning area	The area of land below the flood planning level and thus subject to flood related development controls. The concept of flood planning area generally supersedes the Aflood liable land@ concept in the 1986 Manual.
Flood Planning Levels (FPLs)	FPL=s are the combinations of flood levels (derived from significant historical flood events or floods of specific AEPs) and freeboards selected for floodplain risk management purposes, as determined in management studies and incorporated in management plans. FPLs supersede the Astandard flood event@ in the 1986 manual.
flood proofing	A combination of measures incorporated in the design, construction and alteration of individual buildings or structures subject to flooding, to reduce or eliminate flood damages.
flood prone land	Is land susceptible to flooding by the Probable Maximum Flood (PMF) event. Flood prone land is synonymous with flood liable land.
flood readiness	Flood readiness is an ability to react within the effective warning time.
flood risk	Potential danger to personal safety and potential damage to property resulting from flooding. The degree of risk varies with circumstances across the full range of floods. Flood risk in this manual is divided into 3 types, existing, future and continuing risks. They are described below. **existing flood risk:** the risk a community is exposed to as a result of its location on the floodplain. **future flood risk:** the risk a community may be exposed to as a result of new development on the floodplain. **continuing flood risk:** the risk a community is exposed to after floodplain risk management measures have been implemented. For a town protected by levees, the continuing flood risk is the consequences of the levees being overtopped. For

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	an area without any floodplain risk management measures, the continuing flood risk is simply the existence of its flood exposure.
flood storage areas	Those parts of the floodplain that are important for the temporary storage of floodwaters during the passage of a flood. The extent and behaviour of flood storage areas may change with flood severity, and loss of flood storage can increase the severity of flood impacts by reducing natural flood attenuation. Hence, it is necessary to investigate a range of flood sizes before defining flood storage areas.
floodway areas	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 flows, or a significant increase in flood levels.
freeboard	Freeboard provides reasonable certainty that the risk exposure selected in deciding on a particular flood chosen as the basis for the FPL 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, rumpus 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.
hazard	A source of potential harm or a situation with a potential to cause loss. In relation to this manual the hazard is flooding which has the potential to cause damage to the community. Definitions of high and low hazard categories are provided in the Manual.
hydraulics	Term given to the study of water flow in waterways; in particular, the evaluation of flow parameters such as water level and velocity.
hydrograph	A graph which shows how the discharge or stage/flood level at any particular location varies with time during a flood.
hydrology	Term given to the study of the rainfall and runoff process; in particular, the evaluation of peak flows, flow volumes and the derivation of hydrographs for a range of floods.
local overland flooding	Inundation by local runoff rather than overbank discharge from a stream, river, estuary, lake or dam.
local drainage	Are smaller scale problems in urban areas. They are outside the definition of major drainage in this glossary.
mainstream flooding	Inundation of normally dry land occurring when water overflows the natural or artificial banks of a stream, river, estuary, lake or dam.
major drainage	Councils have discretion in determining whether urban drainage problems are associated with major or local drainage. For the purpose of this manual major drainage involves:

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- the floodplains of original watercourses (which may now be piped, channelised or diverted), or sloping areas where overland flows develop along alternative paths once system capacity is exceeded; and/or

- water depths generally in excess of 0.3 m (in the major system design storm as defined in the current version of Australian Rainfall and Runoff). These conditions may result in danger to personal safety and property damage to both premises and vehicles; and/or

- major overland flow paths through developed areas outside of defined drainage reserves; and/or

- the potential to affect a number of buildings along the major flow path.

mathematical/computer models — The mathematical representation of the physical processes involved in runoff generation and stream flow. These models are often run on computers due to the complexity of the mathematical relationships between runoff, stream flow and the distribution of flows across the floodplain.

merit approach — The merit approach weighs social, economic, ecological and cultural impacts of land use options for different flood prone areas together with flood damage, hazard and behaviour implications, and environmental protection and well being of the State=s rivers and floodplains.

The merit approach operates at two levels. At the strategic level it allows for the consideration of social, economic, ecological, cultural and flooding issues to determine strategies for the management of future flood risk which are formulated into Council plans, policy and EPIs. At a site specific level, it involves consideration of the best way of conditioning development allowable under the floodplain risk management plan, local floodplain risk management policy and EPIs.

minor, moderate and major flooding — Both the State Emergency Service and the Bureau of Meteorology use the following definitions in flood warnings to give a general indication of the types of problems expected with a flood:

minor flooding: causes inconvenience such as closing of minor roads and the submergence of low level bridges. The lower limit of this class of flooding on the reference gauge is the initial flood level at which landholders and townspeople begin to be flooded.

moderate flooding: low-lying areas are inundated requiring removal of stock and/or evacuation of some houses. Main traffic routes may be covered.

major flooding: appreciable urban areas are flooded and/or extensive rural areas are flooded. Properties, villages and towns can be isolated.

modification measures — Measures that modify either the flood, the property or the response to flooding. Examples are indicated in Table 2.1 with further discussion in the Manual.

peak discharge — The maximum discharge occurring during a flood event.

Probable Maximum Flood (PMF) — The PMF is the largest flood that could conceivably occur at a particular location, usually estimated from probable maximum precipitation, and where applicable, snow melt, coupled with the worst flood producing catchment conditions. Generally, it is not physically or economically possible to provide complete

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	protection against this event. The PMF defines the extent of flood prone land, that is, the floodplain. The extent, nature and potential consequences of flooding associated with a range of events rarer than the flood used for designing mitigation works and controlling development, up to and including the PMF event should be addressed in a floodplain risk management study.
Probable Maximum Precipitation (PMP)	The PMP is the greatest depth of precipitation for a given duration meteorologically possible over a given size storm area at a particular location at a particular time of the year, with no allowance made for long-term climatic trends (World Meteorological Organisation, 1986). It is the primary input to PMF estimation.
probability	A statistical measure of the expected chance of flooding (see AEP).
risk	Chance of something happening that will have an impact. It is measured in terms of consequences and likelihood. In the context of the manual it is the likelihood of consequences arising from the interaction of floods, communities and the environment.
runoff	The amount of rainfall which actually ends up as streamflow, also known as rainfall excess.
stage	Equivalent to Awater level@. Both are measured with reference to a specified datum.
stage hydrograph	A graph that shows how the water level at a particular location changes with time during a flood. It must be referenced to a particular datum.
survey plan	A plan prepared by a registered surveyor.
water surface profile	A graph showing the flood stage at any given location along a watercourse at a particular time.
wind fetch	The horizontal distance in the direction of wind over which wind waves are generated.

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Appendix B

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Appendix B. AUSTRALIAN RAINFALL AND RUNOFF 2019 ASESSMENT

B.1.1. Overview

The Hewitts Creek Flood Study (2019) presented revised design flood behaviour considering Council's blockage policy, in addition to catchment changes since the 2015 Flood Study and recommendations coming out of the review of the models as part of the Flood Study including the inclusion of the pit and pipe network. The design flood behaviour produced as part of the Flood Study Update was developed using the methodologies described in Australian Rainfall and Runoff 1987 (ARR 1987).

In 2019, the 4th Edition of Australian Rainfall and Runoff (ARR 2019) was released. This edition of the guideline was a significant update from previous editions, outlining an updated design methodology with revised design flood inputs including intensity frequency duration (IFD) depths, losses, areal reduction factors and temporal patterns. Technological developments and a significantly larger dataset (such as continuously recorded rainfall and a generally longer record of recorded storms) since the previous edition (in 1987) have contributed to the revised design inputs.

On initial release of the current edition of ARR in 2016, it was highlighted that some of the revised design flood inputs did not appropriately represent the unique storm behaviour in the Illawarra region. Further refinement of some of these design flood inputs has been undertaken to develop Illawarra specific inputs, including IFD depths and temporal patterns. These refined datasets have been adopted for this assessment.

Three major changes have been made to the approach adopted in ARR 1987 (ARR (1987)) for the revised ARR 2019 approach (ARR (2016)):

1. The recommended Intensity, Frequency and Duration (IFD) rainfall data values across Australia have been updated based on analysis of available records, Illawarra specific data has also been developed;
2. The recommended preburst, and initial and continuing loss values across Australia have been updated based on analysis of available records and the rainfall loss method incorporates an urban pervious differentiation which was not present in the previous approach. Advice is available from the Department of Planning and Environment for use of the recommended values from the ARR Datahub;
3. ARR 2019 recommends an ensemble assessment of 10 temporal patterns for each storm duration, in order to determine the median catchment response for each design event. In this case, the temporal pattern that produces flood levels closest to and above the mean within each duration was selected to be representative of the median catchment response. The *critical duration* is the duration for which the selected temporal pattern produces the maximum flood level. Illawarra specific temporal patterns have also been developed and adopted for this study.

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B.1.2. IFD Data

Revised IFD curves for the Illawarra region are available on the Bureau of Meteorology (BoM) website. The following are noted in comparison to the ARR 1987 IFD:

- There is generally a decrease in design rainfall intensities across the catchment in the ARR2019 IFD.
- The portions of the catchment closer to the escarpment show a slight increase across the 2 – 9 hour durations.
- The portions of the catchment closer to the coast show a greater general reduction in rainfall for longer duration events.
- More frequent events show greater decreases across both coastal and escarpment proximate parts of the catchment.

B.1.3. Rainfall Losses

The previous flood assessments have utilised the “Initial-Continuing” loss model (as recommended by ARR1987 for eastern NSW) which assumes that an initial amount of rainfall is lost during the initial wetting of the catchment and the filling of localised depressions prior to runoff starting to occur, and the continuing loss represents the ongoing infiltration of water into the saturated soils while rainfall continues.

Methods for modelling the proportion of rainfall that is “lost” to infiltration are outlined in ARR 1987 (ARR (1987)) and ARR 2019 (ARR (2016)). Both guidelines describe a method that applies an initial loss (in millimetres) and continuing loss (in millimetres per hour) to the design rainfall.

The adopted losses in the previous investigations were based on a combination of recommended values provided in ‘Australian Rainfall and Runoff – A Guide to Flood Estimation’ (Engineers Australia, 1987) and those applied in previous studies. An initial loss value of 0mm and a continuing loss of 2.5mm/hr were applied.

The recommended process for calculating losses is described in ARR 2019, with relevant data being accessible from the ARR Data Hub. In addition, in January 2019, the Department of Planning and Environment released guidance regarding the implementation of ARR 2019 methodologies in NSW specifically: “Incorporating 2016 Australian Rainfall and Runoff in Studies Section 3.7.1 initial and continuing losses, pre burst and burst losses in NSW”.

Due to some uncertainty in the available design loss inputs, a review of an alternative loss approach was undertaken. The second loss approached attempted to assign different loss values based on proximity to the escarpment. It was determined that when comparing resulting flood levels the two methods compared well, with both methods resulting in flood levels sitting at appropriate magnitudes in the context of historical events. It was determined to therefore apply the loss approach as outlined in ARR 2019 in combination with the advice from the then Office of Environment and Heritage (now DPE) in relation to an adjustment to the applied continuing loss.

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The ARR 2019 chapter on losses (Book 5, Chapter 3) recognises that there are significantly different infiltration regimes present across the varying urban surface types and therefore recommends applying varied losses to these different urban surface types in the catchment. These surface types are:

- Effective Impervious Areas – including areas directly connected to the drainage system, such as roads, pavements and some building roofs, and other portions of a catchment area which have a similar response to impervious areas,
- Indirectly Connected Areas – areas that runoff over a pervious area before entering the drainage system such as roofs that discharge onto a lawn, both the roof and lawn are within this category,
- Pervious areas – such as parks.

Previously a catchment would be split into pervious and impervious areas, with more developed areas containing a higher proportion of impervious surfaces. This also assumed that the entire impervious area contributes fully to generating runoff, neglecting consideration of depression storages and areas not connected to the drainage system. ARR 2019 identifies that an estimate of Effective Impervious Area (EIA) is more appropriate. For this catchment, the EIA represents 38% of the urban portions of the catchment. The remaining urban area has been defined as 41% Indirectly Connected Area and 21% Pervious Areas. These areas have been estimated based on GIS based analysis of the urban portions of the catchment. While the urban potion of the catchment is developed large portions of the lots include green space, reducing the impervious areas. The non urban portions of the catchment are classified as Rural Pervious Areas.

The ARR Data Hub defines loss values for Rural Pervious Areas while ARR 2019 provides guidance for losses for the other surface types.

For all pervious areas, rural probability neutral burst initial losses obtained from the ARR Data Hub (recommended in DPE guidance) were applied and are shown in Table B 1. Typical pervious areas within the catchment includes parks and open space such as sports ovals. Probability neutral burst initial losses accounts for the combination of storm initial loss and pre-burst.

Table B 1: Probability Neutral Burst Initial Losses (mm)

Duration (min)	AEP (%)					
	50	20	10	5	2	1
60	31.8	16.1	15.8	17	18.3	18.1
90	26.7	16.5	16.7	17.8	17.2	14.3
120	25.2	17.2	18	18.4	17.8	15.7
180	27.6	19.6	19.1	18.5	16.2	13
360	29.2	21.2	19.3	17.2	15.1	7.5
1440	29.4	20.6	19.6	17	17.3	4.9

Given the urbanised density of the catchment, burst initial loss for Indirectly Connected Areas was assumed to be 70% of rural probability neutral burst initial losses for the catchment as defined on the ARR Data Hub (Reference 18). ARR 2019 recommends adopting between 60% - 80% of rural initial loss for Indirectly Connected Areas and the appropriate value is selected based on the relative density of development in the catchment.

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Burst initial loss for impervious and Effective Impervious Areas was taken as 1.5mm and a continuing loss of 0 mm/hr was applied. This is consistent with the ARR 2019 recommended range of 1 – 2 mm initial loss and 0 mm/hr continuing loss.

In January 2019, the then NSW OEH (now DPE) released new guidance regarding the implementation of ARR 2016 (now ARR2019) methodologies in NSW specifically: *"Incorporating 2016 Australian Rainfall and Runoff in Studies Section 3.7.1 initial and continuing losses, pre burst and burst losses in NSW"*.

The new guidance was developed in response to a study that indicated that there is significant bias in the standard ARR 2019 design event method with default ARR 2019 losses and pre-burst, available from the ARR Datahub.

It identified that default rural continuing losses from ARR 2019 over-estimated losses and therefore were not fit for purpose and should only be used where better information was not available. If default continuing losses from the ARR Datahub are to be used these should only be used with a multiplier of 0.4 applied.

In the absence of calibrated losses (i.e. calibrated flow to a stream gauge), the factored ARR Data Hub rural continuing loss rate has been applied for all pervious areas and varied from 1.04 to 1.56 mm/hr. As recommended in ARR 2019 2.5 mm/hr continuing loss has been adopted for Indirectly Connected Areas.

A summary of the values considered as part of the ARR 2019 losses scenario are shown below in Table B 2.

Table B 2: Adopted Losses (ARR 2019)

Surface Type	Burst Initial Loss (mm)	Continuous Loss (mm/hr)
Effective Impervious Area	1.5	0
Indirectly Connected Area	70% Probability Neutral Burst Initial Loss (Table 5)	2.5
Pervious Area (Urban and Rural)	Probability Neutral Burst Initial Loss (Table 5)	1.04 – 1.56

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B.1.4. Storm Temporal Patterns

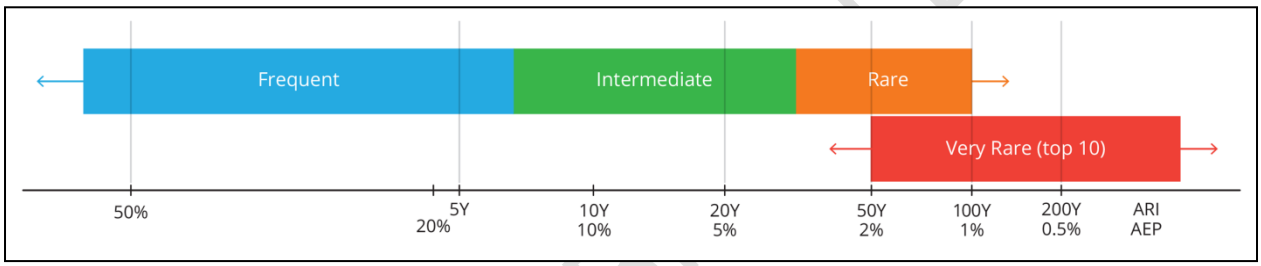
Temporal patterns describe how rain falls over time and forms a component of storm hydrograph estimation. Previously, with the ARR 1987 guidelines, a single temporal pattern (one set for events less than a 30 year ARI and one set for greater) was adopted for each rainfall event duration. However, the ARR 2019 update discusses the potential deficiencies of adopting a single temporal pattern. It is widely accepted that there are a large variety of temporal patterns possible for rainfall events of similar magnitude. This variation in temporal pattern can result in significant effects on the estimated peak flow. As such, the revised temporal patterns have adopted an ensemble of ten different temporal patterns for a particular design event and location. Given the rainfall-runoff response can be quite catchment specific, using an ensemble of temporal patterns attempts to

produce the median or representative catchment response.
The ten temporal patterns have the same total rainfall depth, but there are differences in rainfall distribution across the storm duration: some patterns may represent storms with intense bursts at the start, middle or end of the storm duration, some may represent storms with multiple bursts, and some may represent storms with constant rainfall. Different patterns can produce different peak flood levels for the same catchment depending on catchment topography and response.

ARR 2019 provides patterns for each duration which are sub-divided into three temporal pattern bins based on the frequency of the events for different climatic regions across Australia. Diagram 3 illustrates the three categories of bins (frequent, intermediate, and rare) and the corresponding AEP groups.

The Wollongong LGA sits near the boundary of two temporal pattern zones. Given the unique storm behaviour within the LGA, an analysis was undertaken to identify Wollongong LGA specific temporal patterns. These have been adopted in this assessment.

Diagram B 1: Temporal Pattern Bins



ARR 2019 (Book 2 Section 5.9.4) notes that in some cases there is not a smooth transition in results across AEP, for example a significant jump may occur from one AEP to the next, which cannot be explained by changes in rainfall depth. This behaviour is typically more common in drier regions where losses dominate over rainfall and can be influenced by the temporal patterns in either the frequent or intermediate bin. In these cases, ARR recommends either utilising temporal patterns from both the frequent and intermediate bin across the relevant event range, essentially considering 20 temporal patterns or adopting only those from the intermediate bin. A review of plots of flow versus frequency for the nearby Hewitts Creek catchment showed a smooth transition between events at all extracted locations and no further consideration of the application of the temporal patterns bins is required.

Additionally, this section of ARR discusses the possible need to filter embedded bursts from available temporal patterns. While embedded bursts were a significant concern with the ARR 1987 temporal patterns, a key aim in the development of the temporal pattern database was to reduce the occurrence of embedded bursts. Considering that the results appear reasonable and appropriate particularly in a historical context, and filtering tends to lower peaks flows, it was considered unnecessary to consider this further for this catchment.

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B.1.5. Areal Reduction Factors

Areal Reduction Factor (ARF) account for the fact that larger catchments are less likely to experience high intensity storms across the whole catchment simultaneously. The ARF simply influences the average rainfall depth across the catchment, it does not account for variability in the spatial pattern over the catchment. This aspect is represented in the application of a variable IFD across the catchment. The following equation was applied to obtain the ARF factors for each duration per AEP. Input parameters were obtained from the Data Hub and are outlined in Table B 3 below.

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

Table B 3: ARF Input Parameters for SE Coast Zone

Zone	a	b	c	d	e	f	g	h	i
SE Coast	0.06	0.361	0	0.317	8.11e-05	0.651	0	0	0

Table B 4: Calculated ARF

Duration (mins)	50% AEP	20% AEP	10% AEP	5% AEP	2% AEP	1% AEP
15	0.86	0.86	0.85	0.85	0.84	0.84
30	0.90	0.90	0.89	0.89	0.88	0.88
45	0.92	0.92	0.91	0.91	0.90	0.89
60	0.93	0.93	0.92	0.92	0.91	0.90
90	0.95	0.94	0.94	0.93	0.92	0.91
120	0.96	0.95	0.94	0.93	0.93	0.91
180	0.97	0.96	0.95	0.94	0.93	0.92
270	0.97	0.97	0.96	0.95	0.95	0.94
360	0.98	0.98	0.97	0.96	0.96	0.95
540	0.98	0.98	0.98	0.98	0.97	0.97
720	0.99	0.98	0.98	0.98	0.98	0.97

B.1.6. Representative Event Selection

The critical storm is the temporal pattern and duration that best represents the flood behaviour (e.g. flow, level) for a specific design magnitude. It is generally related to the catchment size, as flow takes longer to concentrate at the outlet from a larger catchment, as well as other considerations like land use, shape, stream characteristics, etc. Typically, mainstream flooding in catchments of this size is generated by longer storm durations, whereas local overland catchments are generally more responsive to shorter, more intense storms. Peak flow is often used as an indicator to determine the representative temporal pattern, however in urbanised catchments peak flow can be less representative and peak flood level is a more suitable indicator.

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With ARR 2019 methodology, the critical duration is the storm duration that produces the highest mean flow or level at a point of interest (where the mean is calculated from the ensemble of ten temporal patterns for that duration. Where there are multiple locations of interest with different contributing catchment sizes, there can be multiple critical durations that need to be considered. Figure APPB2 highlights the variability in critical duration across the catchment for the 1% AEP event.

Once the critical duration is established, it is usually desirable to select a representative design storm temporal pattern that reproduces this behaviour for all points of interest. This representative storm can then be used for determining design flood behaviour and for future modelling to inform floodplain management decisions.

No single temporal pattern produced results just above the average of the 10 patterns across the entirety of the catchment. The temporal pattern producing the flood level just above the average across most of the catchment (within 0.1m) was selected. Figure APPB3 shows the different in level between the selected duration/temporal pattern and the envelope of average peak flood level grids. The applied duration/temporal pattern combinations for each event are included in Table B 5 below.

Table B 5: Representative Storm Selection

Event	Duration (minutes)	Temporal Pattern Number
20% AEP	180	118547
10% AEP	90	118046
5% AEP	90	118046
2% AEP	90	120443
1% AEP	180	120443
0.5% AEP	180	120443
0.2% AEP	180	120443

B.1.7. Comparison to Flood Study (2019) (ARR 1987)

The peak flood levels produced using ARR 2019 were compared to those produced using ARR 1987 as part of the Flood Study Review (2015) and are shown on Figure APPB4 and in Table B 6. Differences between peak flood levels produced using ARR 1987 and ARR 2019 are generally within +/- 0.1m, although more significant variations do occur in localised locations of the catchment. Such as upstream of the Kelton Lane, Hamilton Road and the Princes Highway.

A comparison of peak flow is also provided in Table B 6.

In addition, it is noted that the flood extents remain largely unchanged between the ARR 1987 and ARR 2019 results. The exceptions are upstream of Haig Road and in the upper reaches of Hewitts Creek.

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Table B 6: Peak Flood Level and Flow Comparison – ARR 1987 and ARR 2019

Location (Figure APPB1)	Watercourse	1% AEP Event Peak Flood level (mAHD)		Change in Peak Flood Level (m)	1% AEP Event Peak Flow (m^3/s)		Change in Peak Flow (%)
		ARR1987	ARR2019		ARR1987	ARR2019	
32:US Deborah Avenue	Hewitts Creek	63.3	63.2	-0.1	13.7	10.4	-24%
33:US Virginia Terrace	Hewitts Creek	50.6	50.5	-0.1	11.4	9.9	-13%
34:US George Street	Hewitts Creek	32.2	32.1	-0.1	12.7	11.3	-11%
21:US Kelton Lane	Hewitts Creek	24.7	24.4	-0.3	62.1	48.9	-21%
29:US Palm Grove	Hewitts Creek	75.0	74.9	-0.1	0.7	0.5	-27%
30:US Virginia Terrace	Hewitts Creek	41.1	41.0	-0.1	4.5	3.0	-32%
31:US George Street	Hewitts Creek	25.4	25.4	0.0	9.8	7.0	-29%
22:US Lachlan Street	Hewitts Creek	18.9	18.8	-0.2	68.8	54.2	-21%
23:US Lawrence Hargrave Drive	Hewitts Creek	13.7	13.5	-0.2	54.6	40.1	-27%
26:US Illawarra Railway	Hewitts Creek	12.3	12.3	-0.0	100.9	100.5	0%
27:US Brickworks Avenue	Hewitts Creek	10.1	10.1	-0.0	101.4	100.9	0%
28:US Hamilton Road	Hewitts Creek	2.0	2.6	0.6	112.3	111.5	-1%
36:US Illawarra Railway	Thomas Gibson Creek	12.0	11.9	-0.1	1.4	0.9	-32%
38:US McCauley Street	Thomas Gibson Creek	7.1	7.1	-0.1	4.2	3.0	-28%
39:US Cliff Parade	Thomas Gibson Creek	4.7	4.6	-0.0	9.8	9.5	-3%
15:US Princes Highway	Woodlands Creek	18.9	18.9	-0.0	49.4	44.6	-10%
17:US Illawarra Railway	Woodlands Creek	16.5	16.5	-0.0	39.5	38.2	-3%
18:US Air Avenue	Woodlands Creek	11.2	11.2	0.0	27.6	27.4	-1%
14:US Illawarra Railway	Tramway Creek	17.0	17.0	0.0	31.2	29.6	-5%
1:US William Street	Slacky Creek	27.2	27.1	-0.1	38.4	33.8	-12%
2:US Hobart Street	Slacky Creek	22.6	22.5	-0.1	38.6	34.3	-11%
5:US disused railway line	Slacky Creek	21.5	21.3	-0.2	25.2	24.0	-5%
7:US Access bridge at Bulli showground	Slacky Creek	18.2	18.2	-0.1	29.8	29.2	-2%
8:US Princes Highway	Slacky Creek	14.6	18.2	3.5	39.7	39.3	-1%
9:Park at Black Diamond Place	Slacky Creek	12.7	12.7	0.0	36.5	36.6	0%
9:US Illawarra Railway	Slacky Creek	12.6	12.6	-0.0	39.0	39.0	0%
10:US Illawarra Railway (Beacon Avenue)	Slacky Creek	11.8	11.8	-0.0	4.3	4.2	-2%
11:US of timber footbridge (Beach Street)	Slacky Creek	4.5	4.5	0.0	51.7	52.3	1%
12:US Blackhall Street	Slacky Creek	2.8	2.8	0.0	48.0	48.1	0%

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B.1.8. ARR 2019 Design Flood Behaviour

The hydrologic and hydraulic modelling suite updated as part of the Hewitts Creek Flood Study (2019) were revised to incorporate the changes in design flood methodology described above. Updated design flood mapping is provided for the 0.2EY, 10%, 5%, 2%, 1%, 0.5% and 0.2% AEP and PMF events (Volume 2 Map Set B Figure B1 to Figure B17). Other mapping relevant to the Floodplain Risk Management Study is discussed in Section 5 and mapping provided in Volume 2 Map Set B.

Design envelope flood results have been filtered for mapping purposes to exclude areas of very shallow inundation or runoff, that would typically not be considered flooding. The following criteria have been applied to the mapping:

- Peak flood depths less than 0.15 m were excluded, removing very shallow inundation and catchment runoff,
- Velocity x Depth greater than 0.025m^2/s were reinstated, including shallow areas where greater velocity and therefore hazard exists. These areas are typically part of overland flowpaths or located in the steep sections of the upper catchment. This criteria ensures continuity of mapping along these paths,
- Areas of inundation less than 100m^2 were excluded, removing isolated puddles formed as a result of shallow depressions in the ground terrain representation within the hydraulic model.

During events as frequent as the 20% AEP flow is not contained to the main creek lines and shallow overland flow travels through developed areas, particularly roadways. Road inundation begins in relatively frequent events (20% AEP) at the following locations:

- Princes Highway, at Woodlands Creek and Slacky Creek,
- Beacon Avenue,
- Hobart Street,
- Cliff Parade,
- Bath Street,
- Station Street,
- Lawrence Hargrave Drive at the Thirroul Community Centre,
- Lachlan Street,
- Phillip Street,
- Deborah Avenue,
- Kanangra Drive and
- George Street.

Property inundation also occurs in relatively frequent events (20% AEP). The most significantly affected location is the Bath Street and Cliff Parade area. At this location depths increase to up to 0.5m in the 1% AEP event. Similarly, properties are impacted on the eastern side of Hewitts Avenue, where depths are up to 0.5m in the 1% AEP event. Property inundation is also shown to occurs with shallow depths of up to 0.3m in the 1% AEP event, on Corbett Avenue and the western side of Pass Avenue.

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As larger events occur inundation tends to spread from these areas becoming deeper, with large developed areas being inundated to substantial depths in the 1% AEP event. Overflow occurs between Hewitts and Woodlands Creeks in the larger events.

Peak flood level, and flow are tabulated at reporting locations across the catchment in Table B 7. Reporting locations are shown on Figure APPB1.

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Table B 7: Design Flood Results (ARR 2019)

Location (refer to Figure APPB1)	Design Peak Flood Level and Flow															
	20% AEP		10% AEP		5% AEP		2% AEP		1% AEP		0.5% AEP		0.2% AEP		PMF	
	Level (mAHD)	Flow (m^3/s)	Level (mAHD)	Flow (m^3/s)	Level (mAHD)	Flow (m^3/s)	Level (mAHD)	Flow (m^3/s)	Level (mAHD)	Flow (m^3/s)	Level (mAHD)	Flow (m^3/s)	Level (mAHD)	Flow (m^3/s)	Level (mAHD)	Flow (m^3/s)
32:US Deborah Avenue	62.85	4.48	62.92	5.44	62.99	6.80	63.10	8.70	63.16	10.39	63.19	10.32	63.24	12.90	63.64	32.79
33:US Virginia Terrace	50.17	4.61	50.21	5.57	50.26	7.02	50.48	9.00	50.54	9.94	50.56	11.82	50.60	10.94	50.97	21.88
34:US George Street	31.82	5.14	31.85	6.24	31.93	7.60	32.05	10.07	32.12	11.34	32.15	53.34	32.22	12.57	32.57	24.77
21:US Kelton Lane	23.56	21.59	23.73	25.46	23.96	31.51	24.23	41.72	24.41	48.94	24.55	0.52	24.67	60.05	25.98	136.72
29:US Palm Grove	74.78	0.24	74.82	0.30	74.84	0.36	74.91	0.43	74.94	0.49	74.95	3.45	74.97	0.56	75.14	1.23
30:US Virginia Terrace	40.77	1.21	40.83	1.56	40.90	2.04	40.98	2.59	41.02	3.03	41.03	7.61	41.06	3.61	41.26	7.51
31:US George Street	-	2.39	25.33	3.14	25.35	4.55	25.38	5.32	25.40	6.96	25.41	58.86	25.42	8.51	25.51	17.06
22:US Lachlan Street	18.25	24.33	18.35	28.61	18.48	35.38	18.67	46.17	18.77	54.23	18.82	44.77	18.90	66.37	19.55	151.37
23:US Lawrence Hargrave Drive	12.91	4.27	13.01	7.49	13.14	14.11	13.41	30.51	13.52	40.05	13.57	110.13	13.65	52.62	15.48	153.32
26:US Illawarra Railway	10.47	34.21	10.59	37.83	10.82	45.74	11.86	79.32	12.30	100.50	12.55	110.70	12.95	124.66	15.41	240.13
27:US Brickworks Avenue	8.63	34.04	8.75	38.01	8.99	46.08	9.77	79.66	10.11	100.92	10.25	122.22	10.47	125.13	11.79	249.91
28:US Hamilton Road	1.44	50.05	1.48	53.34	2.35	61.61	2.35	87.60	2.55	111.54	2.55	1.02	2.58	137.87	3.17	255.82
36:US Illawarra Railway	11.64	0.44	11.66	0.60	11.69	0.72	11.83	0.81	11.93	0.94	11.97	3.34	12.02	1.13	14.68	3.18
38:US McCauley Street	6.95	1.43	6.98	1.74	7.01	2.15	7.05	2.61	7.07	3.01	7.09	9.90	7.13	3.96	7.32	9.70
39:US Cliff Parade	4.37	3.42	4.41	4.09	4.46	4.91	4.55	6.74	4.63	9.51	4.66	49.06	4.71	11.27	5.04	25.70
15:US Princes Highway	17.92	18.74	17.98	21.73	18.33	26.26	18.83	36.96	18.91	44.57	18.95	39.98	19.00	55.82	19.40	130.71
17:US Illawarra Railway	16.15	19.11	16.16	21.18	16.25	24.20	16.40	34.60	16.51	38.23	16.56	27.69	16.64	41.68	17.10	60.21
18:US Air Avenue	11.08	19.29	11.12	21.32	11.16	23.82	11.22	26.91	11.23	27.43	11.24	37.08	11.24	27.90	11.56	43.70
14:US Illawarra Railway	12.54	9.26	12.96	10.39	14.49	13.22	16.85	22.28	17.04	29.55	17.09	37.02	17.16	46.55	17.50	134.69
1:US William Street	26.48	13.29	26.62	15.80	26.77	20.11	27.03	28.30	27.12	33.77	27.17	37.67	27.23	41.94	27.72	96.35
2:US Hobart Street	21.57	13.72	21.67	15.75	21.86	20.06	22.28	29.06	22.47	34.33	22.55	23.97	22.64	42.43	23.28	56.36
5:US disused railway line	20.09	13.64	20.22	14.98	20.52	17.41	20.70	21.56	21.33	24.01	21.43	28.98	21.60	25.92	22.71	38.67
7:US Access bridge at Bulli showground	17.76	18.48	17.82	20.28	17.93	23.17	18.09	27.23	18.15	29.23	18.20	39.89	18.27	30.46	18.46	38.46
8:US Princes Highway	17.76	22.75	17.82	24.32	17.93	28.36	18.09	36.30	18.15	39.33	18.20	37.87	18.27	45.52	18.46	79.03

PUBLIC EXHIBITION DRAFT

9:Park at Black Diamond Place	11.70	21.86	11.76	22.82	12.05	26.87	12.57	34.52	12.73	36.56	12.78	40.24	12.89	40.44	13.99	53.80
9:US Illawarra Railway	11.62	24.00	11.67	24.89	11.95	28.97	12.45	36.73	12.58	38.97	12.65	5.45	12.78	42.69	13.90	63.28
10:US Illawarra Railway (Beacon Avenue)	11.30	0.26	11.32	0.37	11.36	0.48	11.55	1.94	11.76	4.19	11.90	55.86	12.17	8.18	13.84	32.57
11:US of timber footbridge (Beach Street)	3.76	28.82	3.77	29.05	3.94	34.68	4.35	47.47	4.47	52.30	4.58	51.25	4.68	61.42	5.43	114.70
12:US Blackhall Street	2.44	26.82	2.45	27.23	2.57	31.92	2.70	43.58	2.81	48.11	2.84	11.28	2.88	56.26	4.08	110.05

PUBLIC EXHIBITION DRAFT

FIGURE APPB1
HEWITTS CREEK CATCHMENT
IFD GAUGE AND REPORTING LOCATIONS

HEWITTS#1
HEWITTS#2
HEWITTS#3
HEWITTS#4
HEWITTS#5
HEWITTS#6
FREEWAY F6
PRINCES HIGHWAY
MOUNT OUSLEY ROAD
SYLVAN WAY
FORDS ROAD
TREETOP GLEN
PHILLIP STREET
COAST STREET
THE WAVES
THE LOOKOUT
29 : US Palm Grove
PALM GROVE
SEAVIEW TERRACE
32 : US Deborah Avenue
DEBORAH AVENUE
33 : US Virginia Terrace
30 : US Virginia Terrace
PALMYRA AVENUE
THIRROUL
ROXBURGH AVENUE
31 : US George Street
21 : US Kelton Lane
LACHLAN STREET
KELTON LANE
HEWITTS CREEK
RAILWAY PARADE
RAILWAY LANE
RAYMOND ROAD
STATION STREET
OCEAN STREET
BATH STREET
THE ESPLANADE
Flanagan's Creek
REDMAN AVENUE
HENLEY ROAD
JONES LANE
MOUNTAIN ROAD
HILLCREST ROAD
KENNEDY ROAD
OCEANA PARADE
DUNNE ST
39 : US Cliff Parade
38 : US McCauley Street
ANN STREET
NEWBOLD CLOSE
SURFERS PARADE
THOMAS GIBSON CREEK
HIGH STREET
23 : US Lawrence Hargrave Drive
26 : US Illawarra Railway
27 : US Brickworks Avenue
MARION STREET
GUM TREE LANE
WOODLANDS CREEK
CORBETT AVENUE
15 : US Princes Highway
17 : US Illawarra Railway
18 : US Air Avenue
28 : US Hamilton Road
PANMILLS DRIVE
GEORGE AVENUE
NATIONAL AVENUE
LANE 54
BEATTIE AVENUE
LANE 55
1 : US William Street
WILLIAM STREET
ALLENBY PARADE
14 : US Illawarra Railway
TRAMWAY CREEK
SANDON DRIVE
5 : US disused railway line
7 : US Access bridge at Bulli showground
SANDON POINT
O'BRIEN STREET
POINT STREET
LANE 56
ILLAWARRA RAILWAY
HILL STREET
BLACKALL STREET
8 : US Princes Highway
SLACKY CREEK
BULLI
9 : US Illawarra Railway
9 : Park at Black Diamond Place
11 : US of timber footbride (Beach Street)
HUTTON AVENUE
12 : US Blackhall S
PARK ROAD
COLEMANS LANE
TRINITY
COPE PLACE
STURT PLACE
STOKES LANE
RAILWAY STREET
ALANSON AVENUE
HOSPITAL ROAD
ORGANS ROAD
STEPHEN DRIVE
SPINNERS WAY
URSULA ROAD

N

Result Location
IFD Location for Comparison
Subcatchment
Study Area Catchment
Surrounding Catchment
Cadastre

0 0.5 1 km

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FIGURE APPB2A

HEWITTS CREEK CATCHMENT
CRITICAL DURATION
1% AEP EVENT, ARR2019



GEORGE STREET
LACHLAN STREET
HIGH STREET
HEWITTS CREEK
RAILWAY PARADE
WREXHAM ROAD
LANE 52
MARION STREET
PASS AVENUE
HEWITTS AVENUE
WOODLANDS CREEK
NATIONAL AVENUE
UNNAMED
GEORGE AVENUE
STURDEE AVENUE
WILLIAM STREET
HAIG ROAD
ALLENBY PARADE
HOBART STREET
TRAMWAY CREEK
PRINCES HIGHWAY
LANE 55
STATION STREET
McCAULEY STREET
OCEAN STREET
CLIFF PARADE
THOMAS GIBSON CREEK
ANN STREET
NEWBOLD CLOSE
SURFERS PARADE
TASMAN PARADE
CLYDE CLOSE
SAMUEL CLOSE
HAMILTON ROAD
PANMILLS DRIVE
ARAGAN CIRCUIT
SANDON DRIVE
SANDON POINT
POINT STREET
LANE 56
RANGE PLACE
WESTMACOTT PARADE
HILL STREET
BEACON AVENUE
BEACH STREET
BLACKALL STREET
HUTTON AVENUE
PARK ROAD
COLEMANS LANE
FRANKLIN AVENUE
URSULA ROAD
ORGANS ROAD
HOSPITAL ROAD
ALANSON AVENUE
STURT PLACE
COPE PLACE
BULLI
SLACKY CREEK
QUILKEY PLACE
BANK STREET

N

Cadastre
Model Extent

Critical Duration
15 min
30 min
45 min
60 min
90 min
120 min
180 min
270 min
360 min
540 min
720 min

0 62.5 125 250 375 500 (m)

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FIGURE APPB2B

HEWITTS CREEK CATCHMENT
CRITICAL DURATION
1% AEP EVENT, ARR2019



JARAGA CIRCUIT
TREETOP GLEN
PHILLIP STREET
SEA FOAM AVENUE
REDMAN AVENUE
HENLEY ROAD
JONES LANE
ARUNTA DRIVE
HICKS ROAD
PALM GROVE
THE WAVES
ARMAGH PARADE
KANANGRA DRIVE
DEBORAH AVENUE
SEAVIEW TERRACE
THE LOOKOUT
RAILWAY LANE
Flanagan's Creek
KING STREET
VIRGINIA TERRACE
SOUDAN STREET
MASON STREET
CHURCH STREET
THE ESPLANADE
BATH STREET
GEORGE STREET
RAYMOND ROAD
McCAULEY STREET
OCEAN STREET
CLIFF PARADE
HEWITTS CREEK
LACHLAN STREET
STATION STREET
HARBORD STREET
HIGH STREET
RAILWAY PARADE
THOMAS GIBSON CREEK
ANN STREET
WREXHAM ROAD
NEWBOLD CLOSE
SURFERS PARADE
LANE 52
CLYDE CLOSE
TASMAN PARADE
PASS AVENUE
MARION STREET
HEWITTS AVENUE
SAMUEL CLOSE
HAMILTON ROAD
WOODLANDS CREEK
PANMILLS DRIVE
NATIONAL AVENUE
STURDEE AVENUE
GEORGE AVENUE
UNNAMED
LANE 55
WILLIAM STREET
ALLENBY PARADE
HAIG ROAD
HOBART STREET
TRAMWAY CREEK
SANDON DRIVE
ARAGAN CIRCUIT
PRINCES HIGHWAY
O'BRIEN STREET
SOMERVILLE STREET

N

Cadastre
Model Extent

Critical Duration
- 15 min
- 30 min
- 45 min
- 60 min
- 90 min
- 120 min
- 180 min
- 270 min
- 360 min
- 540 min
- 720 min

0 62.5 125 250 375 500 (m)

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FIGURE APPB3A

HEWITTS CREEK CATCHMENT
IMPACT OF STORM 90MINUTES 119535 V ENVELOPE OF MEAN GRIDS
1% AEP EVENT, ARR2019



GEORGE STREET
LACHLAN STREET
HIGH STREET
HEWITTS CREEK
RAILWAY PARADE
STATION STREET
THOMAS GIBSON CREEK
ANN STREET
NEWBOLD CLOSE
SURFERS PARADE
WREXHAM ROAD
LANE 52
TASMAN PARADE
CLYDE CLOSE
SAMUEL CLOSE
HAMILTON ROAD
PASS AVENUE
MARION STREET
HEWITTS AVENUE
PANMILLS DRIVE
WOODLANDS CREEK
STURDEE AVENUE
NATIONAL AVENUE
UNNAMED
GEORGE AVENUE
LANE 55
WILLIAM STREET
ALLENBY PARADE
HAIG ROAD
HOBART STREET
TRAMWAY CREEK
ARAGAN CIRCUIT
PRINCES HIGHWAY
SANDON DRIVE
SANDON POINT
POINT STREET
LANE 56
HILL STREET
RANGE PLACE
WESTMACOTT PARADE
BEACON AVENUE
BEACH STREET
SLACKY CREEK
BULLI
COPE PLACE
STURT PLACE
QUILKEY PLACE
BANK STREET
HUTTON AVENUE
BLACKALL STREET
PARK ROAD
COLEMANS LANE
FRANKLIN AVENUE
ORGANS ROAD
URSULA ROAD

N

Cadastre
Model Extent

Impact (m)

- < -1.0
- -1.0 to -0.5
- -0.5 to -0.3
- -0.3 to -0.1
- -0.1 to -0.05
- -0.05 to -0.02
- -0.02 to 0.02
- 0.02 to 0.05
- 0.05 to 0.1
- 0.1 to 0.3
- 0.3 to 0.5
- 0.5 to 1.0
- > 1.0

0 62.5 125 250 375 500 (m)

NOTES:
Difference mapping created by subtracting flood levels
For Scenario ID4 : ARR2019, ENVELOPE OF AVERAGE GRIDS
From Scenario ID4 : ARR2019, 90 MINUTES, STORM 119535

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FIGURE APPB3B

HEWITTS CREEK CATCHMENT
IMPACT OF STORM 90MINUTES 119535 V ENVELOPE OF MEAN GRIDS
1% AEP EVENT, ARR2019



JARAGA CIRCUIT
TREETOP GLEN
PHILLIP STREET
FOAM AVENUE
ARUNTA DRIVE
HICKS ROAD
PALM GROVE
THE WAVES
REDMAN AVENUE
HENLEY ROAD
JONES LANE
ARMAGH PARADE
KANANGRA DRIVE
DEBORAH AVENUE
SEAVIEW TERRACE
THE LOOKOUT
RAILWAY LANE
Flanagan's Creek
VIRGINIA TERRACE
SOUDAN STREET
MASON STREET
CHURCH STREET
KING STREET
THE ESPLANADE
BATH STREET
GEORGE STREET
RAYMOND ROAD
McCAULEY STREET
OCEAN STREET
CLIFF PARADE
HEWITTS CREEK
LACHLAN STREET
STATION STREET
HARBORD STREET
HIGH STREET
RAILWAY PARADE
THOMAS GIBSON CREEK
ANN STREET
WREXHAM ROAD
NEWBOLD CLOSE
SURFERS PARADE
LANE 52
CLYDE CLOSE
TASMAN PARADE
PASS AVENUE
MARION STREET
SAMUEL CLOSE
HAMILTON ROAD
HEWITTS AVENUE
WOODLANDS CREEK
PANMILLS DRIVE
STURDEE AVENUE
NATIONAL AVENUE
UNNAMED
GEORGE AVENUE
LANE 55
WILLIAM STREET
ALLENBY PARADE
HAIG ROAD
HOBART STREET
TRAMWAY CREEK
SANDON DRIVE
ARAGAN CIRCUIT
PRINCES HIGHWAY
O'BRIEN STREET
SOMERVILLE STREET

N

Cadastre
Model Extent

Impact (m)

- < -1.0
- -1.0 to -0.5
- -0.5 to -0.3
- -0.3 to -0.1
- -0.1 to -0.05
- -0.05 to -0.02
- -0.02 to 0.02
- 0.02 to 0.05
- 0.05 to 0.1
- 0.1 to 0.3
- 0.3 to 0.5
- 0.5 to 1.0
- > 1.0

0 62.5 125 250 375 500 (m)

NOTES:
Difference mapping created by subtracting flood levels
For Scenario ID4 : ARR2019, ENVELOPE OF AVERAGE GRIDS
From Scenario ID4 : ARR2019, 90 MINUTES, STORM 119535

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FIGURE APPB4A

HEWITTS CREEK CATCHMENT
COMPARISON OF MAPPED DESIGN FLOOD EXTENTS/DEPTHS ARR2019 VS ARR 1987
1% AEP EVENT



GEORGE STREET
LACHLAN STREET
HIGH STREET
HEWITTS CREEK
WREXHAM ROAD
RAILWAY PARADE
STATION STREET
THOMAS GIBSON CREEK
ANN STREET
NEWBOLD CLOSE
SURFERS PARADE
TASMAN PARADE
LANE 52
CLYDE CLOSE
SAMUEL CLOSE
HAMILTON ROAD
PASS AVENUE
MARION STREET
HEWITTS AVENUE
WOODLANDS CREEK
PANMILLS DRIVE
STURDEE AVENUE
NATIONAL AVENUE
UNNAMED
GEORGE AVENUE
LANE 53
WILLIAM STREET
HAIG ROAD
ALLENBY PARADE
HOBART STREET
TRAMWAY CREEK
ARAGAN CIRCUIT
PRINCES HIGHWAY
SANDON DRIVE
SANDON POINT
POINT STREET
LANE 56
HILL STREET
RANGE PLACE
WESTMACOTT PARADE
BEACON AVENUE
BEACH STREET
BLACKALL STREET
SLACKY CREEK
COPE PLACE
BULLI
STURT PLACE
QUILKEY PLACE
BANK STREET
HUTTON AVENUE
PARK ROAD
COLEMANS LANE
ORGANS ROAD
FRANKLIN AVENUE
URSULA ROAD

N

Cadastre
Model Extent

Impact (m)

- < -1.0
- -1.0 to -0.5
- -0.5 to -0.3
- -0.3 to -0.1
- -0.1 to -0.05
- -0.05 to -0.02
- -0.02 to 0.02
- 0.02 to 0.05
- 0.05 to 0.1
- 0.1 to 0.3
- 0.3 to 0.5
- 0.5 to 1.0
- > 1.0
- Newly Flooded
- No Longer Flooded

0 62.5 125 250 375 500 (m)

NOTES:
Difference mapping created by subtracting flood levels
For Scenario ID2 : ARR1987, DESIGN BLOCKAGE
From Scenario ID4 : ARR2019, DESIGN BLOCKAGE, OEH LOSS

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FIGURE APPB4B

HEWITTS CREEK CATCHMENT
COMPARISON OF MAPPED DESIGN FLOOD EXTENTS/DEPTHS ARR2019 VS ARR 1987
1% AEP EVENT



NOTES:
Difference mapping created by subtracting flood levels
For Scenario ID2 : ARR1987, DESIGN BLOCKAGE
From Scenario ID4 : ARR2019, DESIGN BLOCKAGE, OEH LOSS

Cadastre
Model Extent

Impact (m)
- < -1.0
- -1.0 to -0.5
- -0.5 to -0.3
- -0.3 to -0.1
- -0.1 to -0.05
- -0.05 to -0.02
- -0.02 to 0.02
- 0.02 to 0.05
- 0.05 to 0.1
- 0.1 to 0.3
- 0.3 to 0.5
- 0.5 to 1.0
- > 1.0
- Newly Flooded
- No Longer Flooded

0 62.5 125 250 375 500 (m)

N

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PUBLIC EXHIBITION DRAFT

Appendix C

Appendix C. OPTION PRELIMINARY COSTING

	Rates/Period	Source
Discount Rate (annual)	7%	Based on NSW Treasury Guidelines
Period (years)	50	20-30 years is recommended in NSW Treasury Guidelines
Existing Conditions AAD	$1,137,300	

Option ID	Costs			Benefits			
	Capital Cost	Annual Cost	Total Costs (NPV)	Reduction in AAD	% Reduction in AAD	Benefit NPV	Benefit Cost Ratio
DM01	$ 1,080,000	$ 3,000	$ 1,686,451	$ 58,900	5%	$869,764	0.52
DM02	$ 810,000	$ 3,000	$ 1,281,451	$ 5,387	0%	$79,547	0.06
DM03	$ 630,000	$ 3,000	$ 1,011,451	$ 58,100	5%	$857,951	0.85
CM01	$ 320,000	$ 3,000	$ 546,451	$ 103,800	9%	$1,532,794	2.80
DB02	$ 120,000	$ 3,000	$ 246,451	$ 44,500	4%	$657,123	2.67
CM02	$ 1,400,000	$ 3,000	$ 2,166,451	$ 20,800	2%	$307,149	0.14
DM07	$ 510,000	$ 3,000	$ 831,451	$ 48,800	4%	$720,620	0.87
CM10	$ 330,000	$ 3,000	$ 561,451	$ 31,500	3%	$465,154	0.83
DB04	$ 480,000	$ 3,000	$ 786,451	-$ 200	0%	-$2,953	0.00
LV01	$ 100,000	$ 3,000	$ 216,451	$ 11,300	1%	$166,865	0.77
DM05	$ 790,000	$ 3,000	$ 1,251,451	$ 27,200	2%	$401,657	0.32
All DCM	$ 2,220,000	$ 3,000	$ 3,396,451	$ 75,900	7%	$1,120,800	0.33
DCM on 3 and 6 (Slacky Creek)	$ 370,000	$ 3,000	$ 621,451	$ 1,800	0%	$26,580	0.04
DCM on 2, 5 and 6 (Slacky Creek)	$ 370,000	$ 3,000	$ 621,451	$ 8,500	1%	$125,518	0.20
DCM on 1 (Slacky Creek)	$ 370,000	$ 3,000	$ 621,451	$ 7,000	1%	$103,368	0.17
DCM on 14 (Tramway Creek)	$ 370,000	$ 3,000	$ 621,451	$ 23,900	2%	$352,926	0.57
DCM on 16 and 17 (Woodlands Creek)	$ 370,000	$ 3,000	$ 621,451	$ 35,100	3%	$518,315	0.83
DCM on 32 (Hewitts Creek)	$ 370,000	$ 3,000	$ 621,451	-$ 2,300	0%	-$33,964	-0.05

DRAFT

Option ID: **CM01**

Excavate 1,400m 3 to create a swale through Tingarra Park

NOTE: Edit Quantities and Sizes in the Options Summary table, not in the below box

3	4	5	6	7	8	9	10	12	13	14	15
Length (m)	Height (m)	Crest Width (m)	Batter Slope (1v: xh)	Embankment Footprint Width (m)	Fill Volume (m^3)	Cut Volume (m^3)	Surface Area (m^2)	Pipe Upgrade Length (m)	Culvert Diameter (m)	Trench Width (m)	Total Trench Volume
0	0	0	0	0	0	1465	1200	0	0	0	0

Removal of existing pipe
0

	Fixed Costs	UNIT	QUANTITY	Rate (ex GST)	COST
General	Design, Consultations, Approvals and Construction Management	item	1	$ 20,000.00	$ 20,000.00
	Project Management & General Construction Cost (15% of subtotal)	item	1	15%	$ 41,455.50
Roadworks	Site Preparation, removal of existing road surface	m²	300	$ 40.00	$ 12,000.00
	Control of traffic during works (nominal allowance) (assumed $500 per lin.m)	lin.m	10	$ 500.00	$ 5,000.00
	Reinstate Road Surface	m²	300	$ 40.00	$ 12,000.00
	Adjustment of existing services (nominal allowance) (assumed 10% of drainage installation cost)	item	1	10%	$ 3,700.00
Earthworks	Removal of top soil and vegetation (100 mm)	m³	120	$ 16.00	$ 1,920.00
	Excavation	m³	1,465	$ 50.00	$ 73,250.00
	Improvement of Excavated material	m³	1,200	$ 18.00	$ 21,600.00
	Haulage of imported Fill	km	20	$ 18.00	$ 360.00
	Disposal of Contaminated Spoil (80% of total soil)	m³	1,172	$ 80.00	$ 93,760.00
	~~Fill in embankment~~	~~m³~~	~~0~~	~~$ 55.00~~	~~$ -~~
	Fuel	l/m³	240	$ 0.75	$ 180.00
	Compaction	m³	1,200	$ 8.00	$ 9,600.00
	Top soil placement/seeding	m²	1,200	$ 15.00	$ 18,000.00
	Erosion Protection/ RipRap/ Site Remediation	item	1	$ 5,000.00	$ 5,000.00
	~~Remove Rail and Bridge Infrastucture~~	~~m²~~	~~0~~	~~$ 100.00~~	~~$ -~~
Culvert Upgrade	~~Box Culvert: 2.0m x 2.0m~~	~~m~~	~~0~~	~~$ 3,600.00~~	~~$ -~~
	~~Box Culvert: 2.75m x 1.7m~~	~~m~~	~~0~~	~~$ 5,000.00~~	~~$ -~~
	~~Box Culvert: 1.5m x 0.8m~~	~~m~~	~~0~~	~~$ 2,700.00~~	~~$ -~~
	~~Box Culvert: 2.0m x 1.5m~~	~~m~~	~~0~~	~~$ 3,600.00~~	~~$ -~~
	~~Pipe 600 x 2.44 RJ Class 4~~	~~m~~	~~0~~	~~$ 335.34~~	~~$ -~~
	~~Pipe 750 x 2.44 RJ Class 4~~	~~m~~	~~0~~	~~$ 479.74~~	~~$ -~~
	~~Pipe 900 x 2.44 RJ Class 4~~	~~m~~	~~0~~	~~$ 256.00~~	~~$ -~~
	~~Pipe 1800 x 2.44 RJ Class 4~~	~~m~~	~~0~~	~~$ 3,000.00~~	~~$ -~~
	~~Pipe 2400 x 2.44 RJ Class 4~~	~~m~~	~~0~~	~~$ 7,500.00~~	~~$ -~~
	~~Single Cell Headwall to suit 375DN pipe~~	~~item~~	~~0~~	~~$ 315.00~~	~~$ -~~
	~~Single Cell Headwall to suit 600DN pipe~~	~~item~~	~~0~~	~~$ 410.00~~	~~$ -~~
	~~Single Cell Headwall to suit 750DN pipe~~	~~item~~	~~0~~	~~$ 720.00~~	~~$ -~~
	~~Single Cell Headwall to suit 900DN pipe~~	~~item~~	~~0~~	~~$ 945.00~~	~~$ -~~
	~~Single Cell Headwall to suit 1200DN pipe~~	~~item~~	~~0~~	~~$ 1,190.00~~	~~$ -~~
	~~Single Cell Headwall to suit 1800DN pipe~~	~~item~~	~~0~~	~~$ 1,500.00~~	~~$ -~~
	~~Drainage Pit~~	~~item~~	~~0~~	~~$ 5,000.00~~	~~$ -~~
	~~Junction Pit~~	~~item~~	~~0~~	~~$ 5,000.00~~	~~$ -~~
	~~Excavate Trench~~	~~m³~~	~~0~~	~~$ 80.00~~	~~$ -~~
	~~Install Bridge~~	~~m~~	~~0~~	~~$ 50,000.00~~	~~$ -~~
	~~Backfill and Site Remediation~~	~~m~~	~~0~~	~~$ 50,000.00~~	~~$ -~~
	~~Install new outlet structure, including erosion protection as required~~	~~m~~	~~0~~	~~$ 5,000.00~~	~~$ -~~
	~~Land Value - Commerical~~	~~item~~	~~0~~	~~$ 600,500.00~~	~~$ -~~
Property Items	~~Land Value - Commerical~~	item	~~0~~	~~$ 600,500.00~~	~~$ -~~
	~~Land Value - Residential~~	item	~~0~~	~~$ 352,000.00~~	~~$ -~~
	~~Land Value - Combined~~	item	~~0~~	~~$ 476,000.00~~	~~$ -~~
	~~Building/ Business Value (Allowance)~~	item	~~0~~	~~$ 1,500,000.00~~	~~$ -~~
	~~Demolition and Debris Removal~~	Item	~~0~~	~~$ 600,000.00~~	~~$ -~~
	Total				**$0.32 M**

Option ID: **CM10**

Provide controlled overland flowpath for Thomas Gibson Creek flow

NOTE: Edit Quantities and Sizes in the Options Summary table, not in the below box

3	4	5	6	7	8	9	10	12	13	14	15
Length (m)	Height (m)	Crest Width (m)	Batter Slope (1v: xh)	Embankment Footprint Width (m)	Fill Volume (m^3)	Cut Volume (m^3)	Surface Area (m^2)	Pipe Upgrade Length (m)	Culvert Diameter (m)	Trench Width (m)	Total Trench Volume
0	0	0	0	0	0	1600	1800	0	0	0	0

Removal of existing pipe
0

	Fixed Costs	UNIT	QUANTITY	Rate (ex GST)	COST
General	Design, Consultations, Approvals and Construction Management	item	1	$ 20,000.00	$ 20,000.00
General	Project Management & General Construction Cost (15% of subtotal)	item	1	15%	$ 42,706.50
Roadworks	~~Site Preparation, removal of existing road surface~~	~~m^2~~	~~0~~	~~$ 40.00~~	~~$ -~~
Roadworks	~~Control of traffic during works (nominal allowance) (assumed $500 per lin.m)~~	~~lin.m~~	~~0~~	~~$ 500.00~~	~~$ -~~
Roadworks	~~Reinstate Road Surface~~	~~m^2~~	~~0~~	~~$ 40.00~~	~~$ -~~
Roadworks	~~Adjustment of existing services (nominal allowance) (assumed 10% of drainage installation cost)~~	~~item~~	~~0~~	~~10%~~	~~$ -~~
Earthworks	Removal of top soil and vegetation (100 mm)	m^3	180	$ 16.00	$ 2,880.00
Earthworks	Excavation	m^3	1,600	$ 50.00	$ 80,000.00
Earthworks	Improvement of Excavated material	m^3	1,800	$ 18.00	$ 32,400.00
Earthworks	Haulage of imported Fill	km	20	$ 18.00	$ 360.00
Earthworks	Disposal of Contaminated Spoil (80% of total soil)	m^3	1,280	$ 80.00	$ 102,400.00
Earthworks	~~Fill in embankment~~	~~m^3~~	~~0~~	~~$ 55.00~~	~~$ -~~
Earthworks	Fuel	l/m^3	360	$ 0.75	$ 270.00
Earthworks	Compaction	m^3	1,800	$ 8.00	$ 14,400.00
Earthworks	Top soil placement/seeding	m^2	1,800	$ 15.00	$ 27,000.00
Earthworks	Erosion Protection/ RipRap/ Site Remediation	item	1	$ 5,000.00	$ 5,000.00
Earthworks	~~Remove Rail and Bridge Infrastucture~~	~~m^2~~	~~0~~	~~$ 100.00~~	~~$ -~~
Culvert Upgrade	~~Box Culvert: 2.0m x 2.0m~~	~~m~~	~~0~~	~~$ 3,600.00~~	~~$ -~~
Culvert Upgrade	~~Box Culvert: 2.75m x 1.7m~~	~~m~~	~~0~~	~~$ 5,000.00~~	~~$ -~~
Culvert Upgrade	~~Box Culvert: 1.5m x 0.8m~~	~~m~~	~~0~~	~~$ 2,700.00~~	~~$ -~~
Culvert Upgrade	~~Box Culvert: 2.0m x 1.5m~~	~~m~~	~~0~~	~~$ 3,600.00~~	~~$ -~~
Culvert Upgrade	~~Pipe 600 x 2.44 RJ Class 4~~	~~m~~	~~0~~	~~$ 335.34~~	~~$ -~~
Culvert Upgrade	~~Pipe 750 x 2.44 RJ Class 4~~	~~m~~	~~0~~	~~$ 479.74~~	~~$ -~~
Culvert Upgrade	~~Pipe 900 x 2.44 RJ Class 4~~	~~m~~	~~0~~	~~$ 256.00~~	~~$ -~~
Culvert Upgrade	~~Pipe 1800 x 2.44 RJ Class 4~~	~~m~~	~~0~~	~~$ 3,000.00~~	~~$ -~~
Culvert Upgrade	~~Pipe 2400 x 2.44 RJ Class 4~~	~~m~~	~~0~~	~~$ 7,500.00~~	~~$ -~~
Culvert Upgrade	~~Single Cell Headwall to suit 375DN pipe~~	~~item~~	~~0~~	~~$ 315.00~~	~~$ -~~
Culvert Upgrade	~~Single Cell Headwall to suit 600DN pipe~~	~~item~~	~~0~~	~~$ 410.00~~	~~$ -~~
Culvert Upgrade	~~Single Cell Headwall to suit 750DN pipe~~	~~item~~	~~0~~	~~$ 720.00~~	~~$ -~~
Culvert Upgrade	~~Single Cell Headwall to suit 900DN pipe~~	~~item~~	~~0~~	~~$ 945.00~~	~~$ -~~
Culvert Upgrade	~~Single Cell Headwall to suit 1200DN pipe~~	~~item~~	~~0~~	~~$ 1,190.00~~	~~$ -~~
Culvert Upgrade	~~Single Cell Headwall to suit 1800DN pipe~~	~~item~~	~~0~~	~~$ 1,500.00~~	~~$ -~~
Culvert Upgrade	~~Drainage Pit~~	~~item~~	~~0~~	~~$ 5,000.00~~	~~$ -~~
Culvert Upgrade	~~Junction Pit~~	~~item~~	~~0~~	~~$ 5,000.00~~	~~$ -~~
Culvert Upgrade	~~Excavate Trench~~	~~m^3~~	~~0~~	~~$ 80.00~~	~~$ -~~
Culvert Upgrade	~~Install Bridge~~	~~m~~	~~0~~	~~$ 50,000.00~~	~~$ -~~
Culvert Upgrade	~~Backfill and Site Remediation~~	~~m~~	~~0~~	~~$ 50,000.00~~	~~$ -~~
Culvert Upgrade	~~Install new outlet structure, including erosion protection as required~~	~~m~~	~~0~~	~~$ 5,000.00~~	~~$ -~~
Culvert Upgrade	~~Land Value - Commerical~~	~~item~~	~~0~~	~~$ 600,500.00~~	~~$ -~~
Property Items	~~Land Value - Commerical~~	item	~~0~~	~~$ 600,500.00~~	~~$ -~~
Property Items	~~Land Value - Residential~~	item	~~0~~	~~$ 352,000.00~~	~~$ -~~
Property Items	~~Land Value - Combined~~	item	~~0~~	~~$ 476,000.00~~	~~$ -~~
Property Items	~~Building/ Business Value (Allowance)~~	item	~~0~~	~~$ 1,500,000.00~~	~~$ -~~
Property Items	~~Demolition and Debris Removal~~	Item	~~0~~	~~$ 600,000.00~~	~~$ -~~
	Total				**$0.33 M**

Option ID: **DB02**

Undertake embankment stability works to formalise existing basin near the Old Bulli Mine

NOTE: Edit Quantities and Sizes in the Options Summary table, not in the below box

3	4	5	6	7	8	9	10	12	13	14	15
Length (m)	Height (m)	Crest Width (m)	Batter Slope (1v: xh)	Embankment Footprint Width (m)	Fill Volume (m^3)	Cut Volume (m^3)	Surface Area (m^2)	Pipe Upgrade Length (m)	Culvert Diameter (m)	Trench Width (m)	Total Trench Volume
196	1	1	2	5	588	0	980	0	0	0	0

Removal of existing pipe
0

	Fixed Costs	UNIT	QUANTITY	Rate (ex GST)	COST
Design	Design, Consultations, Approvals and Construction Management	item	1	$ 20,000.00	$ 20,000.00
General	Project Management & General Construction Cost (15% of subtotal)	item	1	15%	$ 15,561.45
Roadworks	~~Site Preparation, removal of existing road surface~~	~~m^2~~	~~0~~	~~$ 40.00~~	~~$ -~~
	~~Control of traffic during works (nominal allowance) (assumed $500 per lin.m)~~	~~lin.m~~	~~0~~	~~$ 500.00~~	~~$ -~~
	~~Reinstate Road Surface~~	~~m^2~~	~~0~~	~~$ 40.00~~	~~$ -~~
	~~Adjustment of existing services (nominal allowance) (assumed 10% of drainage installation cost)~~	~~item~~	~~0~~	~~10%~~	~~$ -~~
Earthworks	Removal of top soil and vegetation (100 mm)	m^3	98	$ 16.00	$ 1,568.00
	~~Excavation~~	~~m^3~~	~~0~~	~~$ 50.00~~	~~$ -~~
	~~Improvement of Excavated material~~	~~m^3~~	~~0~~	~~$ 18.00~~	~~$ -~~
	~~Haulage of imported Fill~~	~~km~~	~~0~~	~~$ 18.00~~	~~$ -~~
	~~Disposal of Contaminated Spoil (80% of total soil)~~	~~m^3~~	~~0~~	~~$ 80.00~~	~~$ -~~
	Fill in embankment	m^3	980	$ 55.00	$ 53,900.00
	Fuel	l/m^3	980	$ 0.75	$ 735.00
	Compaction	m^3	980	$ 8.00	$ 7,840.00
	Top soil placement/seeding	m^2	980	$ 15.00	$ 14,700.00
	Erosion Protection/ RipRap/ Site Remediation	item	1	$ 5,000.00	$ 5,000.00
	~~Remove Rail and Bridge Infrastucture~~	~~m^2~~	~~0~~	~~$ 100.00~~	~~$ -~~
Culvert Upgrade	~~Box Culvert: 2.0m x 2.0m~~	~~m~~	~~0~~	~~$ 3,600.00~~	~~$ -~~
	~~Box Culvert: 2.75m x 1.7m~~	~~m~~	~~0~~	~~$ 5,000.00~~	~~$ -~~
	~~Box Culvert: 1.5m x 0.8m~~	~~m~~	~~0~~	~~$ 2,700.00~~	~~$ -~~
	~~Box Culvert: 2.0m x 1.5m~~	~~m~~	~~0~~	~~$ 3,600.00~~	~~$ -~~
	~~Pipe 600 x 2.44 RJ Class 4~~	~~m~~	~~0~~	~~$ 335.34~~	~~$ -~~
	~~Pipe 750 x 2.44 RJ Class 4~~	~~m~~	~~0~~	~~$ 479.74~~	~~$ -~~
	~~Pipe 900 x 2.44 RJ Class 4~~	~~m~~	~~0~~	~~$ 256.00~~	~~$ -~~
	~~Pipe 1800 x 2.44 RJ Class 4~~	~~m~~	~~0~~	~~$ 3,000.00~~	~~$ -~~
	~~Pipe 2400 x 2.44 RJ Class 4~~	~~m~~	~~0~~	~~$ 7,500.00~~	~~$ -~~
	~~Single Cell Headwall to suit 375DN pipe~~	~~item~~	~~0~~	~~$ 315.00~~	~~$ -~~
	~~Single Cell Headwall to suit 600DN pipe~~	~~item~~	~~0~~	~~$ 410.00~~	~~$ -~~
	~~Single Cell Headwall to suit 750DN pipe~~	~~item~~	~~0~~	~~$ 720.00~~	~~$ -~~
	~~Single Cell Headwall to suit 900DN pipe~~	~~item~~	~~0~~	~~$ 945.00~~	~~$ -~~
	~~Single Cell Headwall to suit 1200DN pipe~~	~~item~~	~~0~~	~~$ 1,190.00~~	~~$ -~~
	~~Single Cell Headwall to suit 1800DN pipe~~	~~item~~	~~0~~	~~$ 1,500.00~~	~~$ -~~
	~~Drainage Pit~~	~~item~~	~~0~~	~~$ 5,000.00~~	~~$ -~~
	~~Junction Pit~~	~~item~~	~~0~~	~~$ 5,000.00~~	~~$ -~~
	~~Excavate Trench~~	~~m^3~~	~~0~~	~~$ 80.00~~	~~$ -~~
	~~Install Bridge~~	~~m~~	~~0~~	~~$ 50,000.00~~	~~$ -~~
	~~Backfill and Site Remediation~~	~~m~~	~~0~~	~~$ 50,000.00~~	~~$ -~~
	~~Install new outlet structure, including erosion protection as required~~	~~m~~	~~0~~	~~$ 5,000.00~~	~~$ -~~
	~~Land Value - Commerical~~	~~item~~	~~0~~	~~$ 600,500.00~~	~~$ -~~
Property Items	~~Land Value - Commerical~~	item	~~0~~	~~$ 600,500.00~~	~~$ -~~
	~~Land Value - Residential~~	item	~~0~~	~~$ 352,000.00~~	~~$ -~~
	~~Land Value - Combined~~	item	~~0~~	~~$ 476,000.00~~	~~$ -~~
	~~Building/ Business Value (Allowance)~~	item	~~0~~	~~$ 1,500,000.00~~	~~$ -~~
	~~Demolition and Debris Removal~~	Item	~~0~~	~~$ 600,000.00~~	~~$ -~~
	Total				**$0.12 M**

Option ID: DB04

New basin upstream railway

NOTE: Edit Quantities and Sizes in the Options Summary table, not in the below box

3	4	5	6	7	8	9	10	12	13	14	15
Length (m)	Height (m)	Crest Width (m)	Batter Slope (1v: xh)	Embankment Footprint Width (m)	Fill Volume (m^3)	Cut Volume (m^3)	Surface Area (m^2)	Pipe Upgrade Length (m)	Culvert Diameter (m)	Trench Width (m)	Total Trench Volume
0	0	0	0	0	0	2400	2000	0	0	0	0

Removal of existing pipe
0

	Fixed Costs	UNIT	QUANTITY	Rate (ex GST)	COST
General	Design, Consultations, Approvals and Construction Management	item	1	$ 20,000.00	$ 20,000.00
	Project Management & General Construction Cost (15% of subtotal)	item	1	15%	$ 62,574.00
Roadworks	Site Preparation, removal of existing road surface	m²	300	$ 40.00	$ 12,000.00
	Control of traffic during works (nominal allowance) (assumed $500 per lin.m)	lin.m	10	$ 500.00	$ 5,000.00
	Reinstate Road Surface	m²	300	$ 40.00	$ 12,000.00
	Adjustment of existing services (nominal allowance) (assumed 10% of drainage installation cost)	item	1	10%	$ 3,700.00
Earthworks	Removal of top soil and vegetation (100 mm)	m³	200	$ 16.00	$ 3,200.00
	Excavation	m³	2,400	$ 50.00	$ 120,000.00
	Improvement of Excavated material	m³	2,000	$ 18.00	$ 36,000.00
	Haulage of imported Fill	km	20	$ 18.00	$ 360.00
	Disposal of Contaminated Spoil (80% of total soil)	m³	1,920	$ 80.00	$ 153,600.00
	~~Fill in embankment~~	~~m³~~	~~0~~	~~$ 55.00~~	~~$ -~~
	Fuel	l/m³	400	$ 0.75	$ 300.00
	Compaction	m³	2,000	$ 8.00	$ 16,000.00
	Top soil placement/seeding	m²	2,000	$ 15.00	$ 30,000.00
	Erosion Protection/ RipRap/ Site Remediation	item	1	$ 5,000.00	$ 5,000.00
	~~Remove Rail and Bridge Infrastucture~~	~~m²~~	~~0~~	~~$ 100.00~~	~~$ -~~
Culvert Upgrade	~~Box Culvert: 2.0m x 2.0m~~	~~m~~	~~0~~	~~$ 3,600.00~~	~~$ -~~
	~~Box Culvert: 2.75m x 1.7m~~	~~m~~	~~0~~	~~$ 5,000.00~~	~~$ -~~
	~~Box Culvert: 1.5m x 0.8m~~	~~m~~	~~0~~	~~$ 2,700.00~~	~~$ -~~
	~~Box Culvert: 2.0m x 1.5m~~	~~m~~	~~0~~	~~$ 3,600.00~~	~~$ -~~
	~~Pipe 600 x 2.44 RJ Class 4~~	~~m~~	~~0~~	~~$ 335.34~~	~~$ -~~
	~~Pipe 750 x 2.44 RJ Class 4~~	~~m~~	~~0~~	~~$ 479.74~~	~~$ -~~
	~~Pipe 900 x 2.44 RJ Class 4~~	~~m~~	~~0~~	~~$ 256.00~~	~~$ -~~
	~~Pipe 1800 x 2.44 RJ Class 4~~	~~m~~	~~0~~	~~$ 3,000.00~~	~~$ -~~
	~~Pipe 2400 x 2.44 RJ Class 4~~	~~m~~	~~0~~	~~$ 7,500.00~~	~~$ -~~
	~~Single Cell Headwall to suit 375DN pipe~~	~~item~~	~~0~~	~~$ 315.00~~	~~$ -~~
	~~Single Cell Headwall to suit 600DN pipe~~	~~item~~	~~0~~	~~$ 410.00~~	~~$ -~~
	~~Single Cell Headwall to suit 750DN pipe~~	~~item~~	~~0~~	~~$ 720.00~~	~~$ -~~
	~~Single Cell Headwall to suit 900DN pipe~~	~~item~~	~~0~~	~~$ 945.00~~	~~$ -~~
	~~Single Cell Headwall to suit 1200DN pipe~~	~~item~~	~~0~~	~~$ 1,190.00~~	~~$ -~~
	~~Single Cell Headwall to suit 1800DN pipe~~	~~item~~	~~0~~	~~$ 1,500.00~~	~~$ -~~
	~~Drainage Pit~~	~~item~~	~~0~~	~~$ 5,000.00~~	~~$ -~~
	~~Junction Pit~~	~~item~~	~~0~~	~~$ 5,000.00~~	~~$ -~~
	~~Excavate Trench~~	~~m³~~	~~0~~	~~$ 80.00~~	~~$ -~~
	~~Install Bridge~~	~~m~~	~~0~~	~~$ 50,000.00~~	~~$ -~~
	~~Backfill and Site Remediation~~	~~m~~	~~0~~	~~$ 50,000.00~~	~~$ -~~
	~~Install new outlet structure, including erosion protection as required~~	~~m~~	~~0~~	~~$ 5,000.00~~	~~$ -~~
	~~Land Value - Commerical~~	~~item~~	~~0~~	~~$ 600,500.00~~	~~$ -~~
Property Items	~~Land Value - Commerical~~	item	~~0~~	~~$ 600,500.00~~	~~$ -~~
	~~Land Value - Residential~~	item	~~0~~	~~$ 352,000.00~~	~~$ -~~
	~~Land Value - Combined~~	item	~~0~~	~~$ 476,000.00~~	~~$ -~~
	~~Building/ Business Value (Allowance)~~	item	~~0~~	~~$ 1,500,000.00~~	~~$ -~~
	~~Demolition and Debris Removal~~	Item	~~0~~	~~$ 600,000.00~~	~~$ -~~
	Total				**$0.48 M**

Option ID: **DCM**

Debris Control Measure

NOTE: Edit Quantities and Sizes in the Options Summary table, not in the below box

3	4	5	6	7	8
Length (m)	Height (m)	Crest Width (m)	Batter Slope (1v: xh)	Embankment Footprint Width (m)	Fill Volume (m^3)
0	0	0	0	0	0

Removal of existing pipe
0

9	10	12	13	14	15
Cut Volume (m^3)	Surface Area (m^2)	Pipe Upgrade Length (m)	Culvert Diameter (m)	Trench Width (m)	Total Trench Volume
0	0	0	0	0	0

	Fixed Costs	UNIT	QUANTITY	Rate (ex GST)	COST
General	Design, Consultations, Approvals and Construction Management	item	1	$ 20,000.00	$ 20,000.00
General	Project Management & General Construction Cost (15% of subtotal)	item	1	15%	$ 48,000.00
Roadworks	~~Site Preparation, removal of existing road surface~~	~~m^2~~	~~0~~	~~$ 40.00~~	~~$ -~~
Roadworks	~~Control of traffic during works (nominal allowance) (assumed $500 per lin.m)~~	~~lin.m~~	~~0~~	~~$ 500.00~~	~~$ -~~
Roadworks	~~Reinstate Road Surface~~	~~m^2~~	~~0~~	~~$ 40.00~~	~~$ -~~
Roadworks	~~Adjustment of existing services (nominal allowance) (assumed 10% of drainage installation cost)~~	~~item~~	~~0~~	~~10%~~	~~$ -~~
Earthworks	~~Removal of top soil and vegetation (100 mm)~~	~~m^3~~	~~0~~	~~$ 16.00~~	~~$ -~~
Earthworks	~~Excavation~~	~~m^3~~	~~0~~	~~$ 50.00~~	~~$ -~~
Earthworks	~~Improvement of Excavated material~~	~~m^3~~	~~0~~	~~$ 18.00~~	~~$ -~~
Earthworks	~~Haulage of imported Fill~~	~~km~~	~~0~~	~~$ 18.00~~	~~$ -~~
Earthworks	~~Disposal of Contaminated Spoil (80% of total soil)~~	~~m^3~~	~~0~~	~~$ 80.00~~	~~$ -~~
Earthworks	~~Fill in embankment~~	~~m^3~~	~~0~~	~~$ 55.00~~	~~$ -~~
Earthworks	~~Fuel~~	~~l/m^3~~	~~0~~	~~$ 0.75~~	~~$ -~~
Earthworks	~~Compaction~~	~~m^3~~	~~0~~	~~$ 8.00~~	~~$ -~~
Earthworks	~~Top soil placement/seeding~~	~~m^2~~	~~0~~	~~$ 15.00~~	~~$ -~~
Earthworks	~~Erosion Protection/ RipRap/ Site Remediation~~	~~item~~	~~0~~	~~$ 5,000.00~~	~~$ -~~
Earthworks	~~Remove Rail and Bridge Infrastucture~~	~~m^2~~	~~0~~	~~$ 100.00~~	~~$ -~~
Culvert Upgrade	~~Box Culvert: 2.7m x 2.4m~~	~~m~~	~~0~~	~~$ 5,000.00~~	~~$ -~~
Culvert Upgrade	~~Box Culvert: 2.0m x 0.5m~~	~~m~~	~~0~~	~~$ 1,281.00~~	~~$ -~~
Culvert Upgrade	~~Box Culvert: 2.4 x 1.2m~~	~~m~~	~~0~~	~~$ 2,000.00~~	~~$ -~~
Culvert Upgrade	~~Pipe 375 x 2.44 RJ Class 4~~	~~m~~	~~0~~	~~$ 204.27~~	~~$ -~~
Culvert Upgrade	~~Pipe 600 x 2.44 RJ Class 4~~	~~m~~	~~0~~	~~$ 335.34~~	~~$ -~~
Culvert Upgrade	~~Pipe 750 x 2.44 RJ Class 4~~	~~m~~	~~0~~	~~$ 479.74~~	~~$ -~~
Culvert Upgrade	~~Pipe 900 x 2.44 RJ Class 4~~	~~m~~	~~0~~	~~$ 256.00~~	~~$ -~~
Culvert Upgrade	~~Pipe 1200 x 2.44 RJ Class 4~~	~~m~~	~~0~~	~~$ 2,400.00~~	~~$ -~~
Culvert Upgrade	~~Pipe 1800 x 2.44 RJ Class 4~~	~~m~~	~~0~~	~~$ 3,600.00~~	~~$ -~~
Culvert Upgrade	~~Single Cell Headwall to suit 375DN pipe~~	~~item~~	~~0~~	~~$ 315.00~~	~~$ -~~
Culvert Upgrade	~~Single Cell Headwall to suit 600DN pipe~~	~~item~~	~~0~~	~~$ 410.00~~	~~$ -~~
Culvert Upgrade	~~Single Cell Headwall to suit 750DN pipe~~	~~item~~	~~0~~	~~$ 720.00~~	~~$ -~~
Culvert Upgrade	~~Single Cell Headwall to suit 900DN pipe~~	~~item~~	~~0~~	~~$ 945.00~~	~~$ -~~
Culvert Upgrade	~~Single Cell Headwall to suit 1200DN pipe~~	~~item~~	~~0~~	~~$ 1,190.00~~	~~$ -~~
Culvert Upgrade	~~Single Cell Headwall to suit 1800DN pipe~~	~~item~~	~~0~~	~~$ 14,175.14~~	~~$ -~~
Culvert Upgrade	~~Drainage Pit~~	~~item~~	~~0~~	~~$ 5,000.00~~	~~$ -~~
Culvert Upgrade	~~Junction Pit~~	~~item~~	~~0~~	~~$ 5,000.00~~	~~$ -~~
Culvert Upgrade	~~Excavate Trench~~	~~m^3~~	~~0~~	~~$ 80.00~~	~~$ -~~
Culvert Upgrade	~~Excavate Trench~~	~~m~~	~~0~~	~~$ 80.00~~	~~$ -~~
Culvert Upgrade	~~new bridge~~	~~m~~	~~0~~	~~$ 80.00~~	~~$ -~~
Culvert Upgrade	~~Remove Culvert~~	~~m~~	~~0~~	~~$ -~~	~~$ -~~
Culvert Upgrade	Debris Conrol	item	1	$ 300,000.00	$ 300,000.00
Culvert Upgrade	~~Install new outlet structure, including erosion protection as required~~	~~item~~	~~0~~	~~$ 5,000.00~~	~~$ -~~
Property Items	~~Land Value - Commerical~~	item	~~0~~	~~$ 600,500.00~~	~~$ -~~
Property Items	~~Land Value - Residential~~	item	~~0~~	~~$ 352,000.00~~	~~$ -~~
Property Items	~~Land Value - Combined~~	item	~~0~~	~~$ 476,000.00~~	~~$ -~~
Property Items	~~Building/ Business Value (Allowance)~~	item	~~0~~	~~$ 1,500,000.00~~	~~$ -~~
Property Items	~~Demolition and Debris Removal~~	Item	~~0~~	~~$ 600,000.00~~	~~$ -~~
	Total				**$0.37 M**

Option ID: **DM01**

Amplification of the existing structure under the discarded railway and Hobart Street to 4 x 2m high by 2m wide

NOTE: Edit Quantities and Sizes in the Options Summary table, not in the below box

3	4	5	6	7	8
Length (m)	Height (m)	Crest Width (m)	Batter Slope (1v: xh)	Embankment Footprint Width (m)	Fill Volume (m^3)
78	0	0	0	12	0

Removal of existing pipe
77

9	10	12	13	14	15
Cut Volume (m^3)	Surface Area (m^2)	Pipe Upgrade Length (m)	Culvert Diameter (m)	Trench Width (m)	Total Trench Volume
0	936	78	8	12	936

	Fixed Costs	UNIT	QUANTITY	Rate (ex GST)	COST
General	Design, Consultations, Approvals and Construction Management	item	1	$ 20,000.00	$ 20,000.00
	Project Management & General Construction Cost (15% of subtotal)	item	1	15%	$ 140,747.94
Roadworks	~~Site Preparation, removal of existing road surface~~	~~m^2~~	~~0~~	~~$ 40.00~~	~~$ -~~
	~~Control of traffic during works (nominal allowance) (assumed $500 per lin.m)~~	~~lin.m~~	~~0~~	~~$ 500.00~~	~~$ -~~
	~~Reinstate Road Surface~~	~~m^2~~	~~0~~	~~$ 40.00~~	~~$ -~~
	~~Adjustment of existing services (nominal allowance) (assumed 10% of drainage installation cost)~~	~~item~~	~~0~~	~~10%~~	~~$ -~~
Earthworks	Removal of top soil and vegetation (100 mm)	m^3	94	$ 16.00	$ 1,497.60
	Excavation	m^3	936	$ 50.00	$ 46,800.00
	Improvement of Excavated material	m^3	936	$ 18.00	$ 16,848.00
	Haulage of imported Fill	km	20	$ 18.00	$ 360.00
	Disposal of Contaminated Spoil (80% of total soil)	m^3	749	$ 80.00	$ 59,904.00
	~~Fill in embankment~~	~~m^3~~	~~0~~	~~$ 55.00~~	~~$ -~~
	Fuel	l/m^3	936	$ 0.75	$ 702.00
	Compaction	m^3	936	$ 8.00	$ 7,488.00
	Top soil placement/seeding	m^2	936	$ 15.00	$ 14,040.00
	Erosion Protection/ RipRap/ Site Remediation	item	1	$ 5,000.00	$ 5,000.00
	~~Remove Rail and Bridge Infrastucture~~	~~m^2~~	~~0~~	~~$ 100.00~~	~~$ -~~
Culvert Upgrade	Box Culvert: 2.0m x 2.0m	m	128	$ 3,600.00	$ 460,800.00
	Box Culvert: 2.75m x 1.7m	m	46	$ 5,000.00	$ 230,000.00
	~~Box Culvert: 1.5m x 0.8m~~	~~m~~	~~0~~	~~$ 2,700.00~~	~~$ -~~
	~~Box Culvert: 2.0m x 1.5m~~	~~m~~	~~0~~	~~$ 3,600.00~~	~~$ -~~
	~~Pipe 600 x 2.44 RJ Class 4~~	~~m~~	~~0~~	~~$ 335.34~~	~~$ -~~
	~~Pipe 750 x 2.44 RJ Class 4~~	~~m~~	~~0~~	~~$ 479.74~~	~~$ -~~
	~~Pipe 900 x 2.44 RJ Class 4~~	~~m~~	~~0~~	~~$ 256.00~~	~~$ -~~
	~~Pipe 1800 x 2.44 RJ Class 4~~	~~m~~	~~0~~	~~$ 3,000.00~~	~~$ -~~
	~~Pipe 2400 x 2.44 RJ Class 4~~	~~m~~	~~0~~	~~$ 7,500.00~~	~~$ -~~
	~~Single Cell Headwall to suit 375DN pipe~~	~~item~~	~~0~~	~~$ 315.00~~	~~$ -~~
	~~Single Cell Headwall to suit 600DN pipe~~	~~item~~	~~0~~	~~$ 410.00~~	~~$ -~~
	~~Single Cell Headwall to suit 750DN pipe~~	~~item~~	~~0~~	~~$ 720.00~~	~~$ -~~
	~~Single Cell Headwall to suit 900DN pipe~~	~~item~~	~~0~~	~~$ 945.00~~	~~$ -~~
	~~Single Cell Headwall to suit 1200DN pipe~~	~~item~~	~~0~~	~~$ 1,190.00~~	~~$ -~~
	~~Single Cell Headwall to suit 1800DN pipe~~	~~item~~	~~0~~	~~$ 1,500.00~~	~~$ -~~
	~~Drainage Pit~~	~~item~~	~~0~~	~~$ 5,000.00~~	~~$ -~~
	~~Junction Pit~~	~~item~~	~~0~~	~~$ 5,000.00~~	~~$ -~~
	Excavate Trench	m^3	936	$ 80.00	$ 74,880.00
	~~Install Bridge~~	~~m~~	~~0~~	~~$ 50,000.00~~	~~$ -~~
	~~Backfill and Site Remediation~~	~~m~~	~~0~~	~~$ 50,000.00~~	~~$ -~~
	~~Install new outlet structure, including erosion protection as required~~	~~m~~	~~0~~	~~$ 5,000.00~~	~~$ -~~
	~~Land Value - Commerical~~	~~item~~	~~0~~	~~$ 600,500.00~~	~~$ -~~
Property Items	~~Land Value - Commerical~~	item	~~0~~	~~$ 600,500.00~~	~~$ -~~
	~~Land Value - Residential~~	item	~~0~~	~~$ 352,000.00~~	~~$ -~~
	~~Land Value - Combined~~	item	~~0~~	~~$ 476,000.00~~	~~$ -~~
	~~Building/ Business Value (Allowance)~~	item	~~0~~	~~$ 1,500,000.00~~	~~$ -~~
	~~Demolition and Debris Removal~~	Item	~~0~~	~~$ 600,000.00~~	~~$ -~~
	Total				**$1.08 M**

Option ID: **DM02**

Addition of one new 2.4m dia. Pipe

NOTE: Edit Quantities and Sizes in the Options Summary table, not in the below box

3	4	5	6	7	8	9	10	12	13	14	15
Length (m)	Height (m)	Crest Width (m)	Batter Slope (1v: xh)	Embankment Footprint Width (m)	Fill Volume (m^3)	Cut Volume (m^3)	Surface Area (m^2)	Pipe Upgrade Length (m)	Culvert Diameter (m)	Trench Width (m)	Total Trench Volume
43	**0**	**0**	**0**	**3.15**	**0**	**0**	**135.45**	**43**	**2.1**	**3.15**	**135.45**

Removal of existing pipe
0

	Fixed Costs	UNIT	QUANTITY	Rate (ex GST)	COST
General	Design, Consultations, Approvals and Construction Management	item	1	$ 20,000.00	$ 20,000.00
	Project Management & General Construction Cost (15% of subtotal)	item	1	15%	$ 105,376.36
Roadworks	~~Site Preparation, removal of existing road surface~~	~~m^2~~	~~0~~	~~$ 40.00~~	~~$ -~~
	~~Control of traffic during works (nominal allowance) (assumed $500 per lin.m)~~	~~lin.m~~	~~0~~	~~$ 500.00~~	~~$ -~~
	~~Reinstate Road Surface~~	~~m^2~~	~~0~~	~~$ 40.00~~	~~$ -~~
	~~Adjustment of existing services (nominal allowance) (assumed 10% of drainage installation cost)~~	~~item~~	~~0~~	~~10%~~	~~$ -~~
Earthworks	Removal of top soil and vegetation (100 mm)	m^3	14	$ 16.00	$ 216.72
	Excavation	m^3	135	$ 50.00	$ 6,772.50
	Improvement of Excavated material	m^3	135	$ 18.00	$ 2,438.10
	Haulage of imported Fill	km	20	$ 18.00	$ 360.00
	Disposal of Contaminated Spoil (80% of total soil)	m^3	108	$ 80.00	$ 8,668.80
	~~Fill in embankment~~	~~m^3~~	~~0~~	~~$ 55.00~~	~~$ -~~
	Fuel	l/m^3	135	$ 0.75	$ 101.59
	Compaction	m^3	135	$ 8.00	$ 1,083.60
	Top soil placement/seeding	m^2	135	$ 15.00	$ 2,031.75
	Erosion Protection/ RipRap/ Site Remediation	item	1	$ 5,000.00	$ 5,000.00
	~~Remove Rail and Bridge Infrastucture~~	~~m^2~~	~~0~~	~~$ 100.00~~	~~$ -~~
Culvert Upgrade	~~Box Culvert: 2.0m x 2.0m~~	~~m~~	~~0~~	~~$ 3,600.00~~	~~$ -~~
	~~Box Culvert: 2.75m x 1.7m~~	~~m~~	~~0~~	~~$ 5,000.00~~	~~$ -~~
	~~Box Culvert: 1.5m x 0.8m~~	~~m~~	~~0~~	~~$ 2,700.00~~	~~$ -~~
	~~Box Culvert: 2.0m x 1.5m~~	~~m~~	~~0~~	~~$ 3,600.00~~	~~$ -~~
	~~Pipe 600 x 2.44 RJ Class 4~~	~~m~~	~~0~~	~~$ 335.34~~	~~$ -~~
	~~Pipe 750 x 2.44 RJ Class 4~~	~~m~~	~~0~~	~~$ 479.74~~	~~$ -~~
	~~Pipe 900 x 2.44 RJ Class 4~~	~~m~~	~~0~~	~~$ 256.00~~	~~$ -~~
	~~Pipe 1800 x 2.44 RJ Class 4~~	~~m~~	~~0~~	~~$ 3,000.00~~	~~$ -~~
	Pipe 2400 x 2.44 RJ Class 4	m	86	$ 7,500.00	$ 645,000.00
	~~Single Cell Headwall to suit 375DN pipe~~	~~item~~	~~0~~	~~$ 315.00~~	~~$ -~~
	~~Single Cell Headwall to suit 600DN pipe~~	~~item~~	~~0~~	~~$ 410.00~~	~~$ -~~
	~~Single Cell Headwall to suit 750DN pipe~~	~~item~~	~~0~~	~~$ 720.00~~	~~$ -~~
	~~Single Cell Headwall to suit 900DN pipe~~	~~item~~	~~0~~	~~$ 945.00~~	~~$ -~~
	~~Single Cell Headwall to suit 1200DN pipe~~	~~item~~	~~0~~	~~$ 1,190.00~~	~~$ -~~
	~~Single Cell Headwall to suit 1800DN pipe~~	~~item~~	~~0~~	~~$ 1,500.00~~	~~$ -~~
	~~Drainage Pit~~	~~item~~	~~0~~	~~$ 5,000.00~~	~~$ -~~
	~~Junction Pit~~	~~item~~	~~0~~	~~$ 5,000.00~~	~~$ -~~
	Excavate Trench	m^3	135	$ 80.00	$ 10,836.00
	~~Install Bridge~~	~~m~~	~~0~~	~~$ 50,000.00~~	~~$ -~~
	~~Backfill and Site Remediation~~	~~m~~	~~0~~	~~$ 50,000.00~~	~~$ -~~
	~~Install new outlet structure, including erosion protection as required~~	~~m~~	~~0~~	~~$ 5,000.00~~	~~$ -~~
	~~Land Value - Commerical~~	~~item~~	~~0~~	~~$ 600,500.00~~	~~$ -~~
Property Items	~~Land Value - Commerical~~	item	~~0~~	~~$ 600,500.00~~	~~$ -~~
	~~Land Value - Residential~~	item	~~0~~	~~$ 352,000.00~~	~~$ -~~
	~~Land Value - Combined~~	item	~~0~~	~~$ 476,000.00~~	~~$ -~~
	~~Building/ Business Value (Allowance)~~	item	~~0~~	~~$ 1,500,000.00~~	~~$ -~~
	~~Demolition and Debris Removal~~	Item	~~0~~	~~$ 600,000.00~~	~~$ -~~
	Total				**$0.81 M**

Option ID: **DM03**

New Drainage structure (3X 1.5m by 0.8m) under Tingarra Park and outlet to ocean

NOTE: Edit Quantities and Sizes in the Options Summary table, not in the below box

3	4	5	6	7	8	9	10	12	13	14	15
Length (m)	Height (m)	Crest Width (m)	Batter Slope (1v: xh)	Embankment Footprint Width (m)	Fill Volume (m^3)	Cut Volume (m^3)	Surface Area (m^2)	Pipe Upgrade Length (m)	Culvert Diameter (m)	Trench Width (m)	Total Trench Volume
110	0	0	0	9	0	0	990	110	6	9	990

Removal of existing pipe
0

	Fixed Costs	UNIT	QUANTITY	Rate (ex GST)	COST
General	Design, Consultations, Approvals and Construction Management	item	1	$ 20,000.00	$ 20,000.00
	Project Management & General Construction Cost (15% of subtotal)	item	1	15%	$ 81,595.73
Roadworks	~~Site Preparation, removal of existing road surface~~	~~m^2~~	~~0~~	~~$ 40.00~~	~~$ -~~
	~~Control of traffic during works (nominal allowance) (assumed $500 per lin.m)~~	~~lin.m~~	~~0~~	~~$ 500.00~~	~~$ -~~
	~~Reinstate Road Surface~~	~~m^2~~	~~0~~	~~$ 40.00~~	~~$ -~~
	~~Adjustment of existing services (nominal allowance) (assumed 10% of drainage installation cost)~~	~~item~~	~~0~~	~~10%~~	~~$ -~~
Earthworks	Removal of top soil and vegetation (100 mm)	m^3	99	$ 16.00	$ 1,584.00
	Excavation	m^3	990	$ 50.00	$ 49,500.00
	Improvement of Excavated material	m^3	990	$ 18.00	$ 17,820.00
	Haulage of imported Fill	km	20	$ 18.00	$ 360.00
	Disposal of Contaminated Spoil (80% of total soil)	m^3	792	$ 80.00	$ 63,360.00
	~~Fill in embankment~~	~~m^3~~	~~0~~	~~$ 55.00~~	~~$ -~~
	Fuel	l/m^3	990	$ 0.75	$ 742.50
	Compaction	m^3	990	$ 8.00	$ 7,920.00
	Top soil placement/seeding	m^2	99	$ 15.00	$ 1,485.00
	Erosion Protection/ RipRap/ Site Remediation	item	1	$ 5,000.00	$ 5,000.00
	~~Remove Rail and Bridge Infrastucture~~	~~m^2~~	~~0~~	~~$ 100.00~~	~~$ -~~
Culvert Upgrade	~~Box Culvert: 2.0m x 2.0m~~	~~m~~	~~0~~	~~$ 3,600.00~~	~~$ -~~
	~~Box Culvert: 2.75m x 1.7m~~	~~m~~	~~0~~	~~$ 5,000.00~~	~~$ -~~
	Box Culvert: 1.5m x 0.8m	m	110	$ 2,700.00	$ 297,000.00
	~~Box Culvert: 2.0m x 1.5m~~	~~m~~	~~0~~	~~$ 3,600.00~~	~~$ -~~
	~~Pipe 600 x 2.44 RJ Class 4~~	~~m~~	~~0~~	~~$ 335.34~~	~~$ -~~
	~~Pipe 750 x 2.44 RJ Class 4~~	~~m~~	~~0~~	~~$ 479.74~~	~~$ -~~
	~~Pipe 900 x 2.44 RJ Class 4~~	~~m~~	~~0~~	~~$ 256.00~~	~~$ -~~
	~~Pipe 1800 x 2.44 RJ Class 4~~	~~m~~	~~0~~	~~$ 3,000.00~~	~~$ -~~
	~~Pipe 2400 x 2.44 RJ Class 4~~	~~m~~	~~0~~	~~$ 7,500.00~~	~~$ -~~
	~~Single Cell Headwall to suit 375DN pipe~~	~~item~~	~~0~~	~~$ 315.00~~	~~$ -~~
	~~Single Cell Headwall to suit 600DN pipe~~	~~item~~	~~0~~	~~$ 410.00~~	~~$ -~~
	~~Single Cell Headwall to suit 750DN pipe~~	~~item~~	~~0~~	~~$ 720.00~~	~~$ -~~
	~~Single Cell Headwall to suit 900DN pipe~~	~~item~~	~~0~~	~~$ 945.00~~	~~$ -~~
	~~Single Cell Headwall to suit 1200DN pipe~~	~~item~~	~~0~~	~~$ 1,190.00~~	~~$ -~~
	~~Single Cell Headwall to suit 1800DN pipe~~	~~item~~	~~0~~	~~$ 1,500.00~~	~~$ -~~
	~~Drainage Pit~~	~~item~~	~~0~~	~~$ 5,000.00~~	~~$ -~~
	~~Junction Pit~~	~~item~~	~~0~~	~~$ 5,000.00~~	~~$ -~~
	Excavate Trench	m^3	990	$ 80.00	$ 79,200.00
	~~Install Bridge~~	~~m~~	~~0~~	~~$ 50,000.00~~	~~$ -~~
	~~Backfill and Site Remediation~~	~~m~~	~~0~~	~~$ 50,000.00~~	~~$ -~~
	~~Install new outlet structure, including erosion protection as required~~	~~m~~	~~0~~	~~$ 5,000.00~~	~~$ -~~
	~~Land Value - Commerical~~	~~item~~	~~0~~	~~$ 600,500.00~~	~~$ -~~
Property Items	~~Land Value - Commerical~~	item	~~0~~	~~$ 600,500.00~~	~~$ -~~
	~~Land Value - Residential~~	item	~~0~~	~~$ 352,000.00~~	~~$ -~~
	~~Land Value - Combined~~	item	~~0~~	~~$ 476,000.00~~	~~$ -~~
	~~Building/ Business Value (Allowance)~~	item	~~0~~	~~$ 1,500,000.00~~	~~$ -~~
	~~Demolition and Debris Removal~~	Item	~~0~~	~~$ 600,000.00~~	~~$ -~~
	Total				**$0.63 M**

Option ID: DM05

Two Additional 2.4m pipe below railway

NOTE: Edit Quantities and Sizes in the Options_Summary table, not in the below box

3	4	5	6	7	8	9	10	12	13	14	15
Length (m)	Height (m)	Crest Width (m)	Batter Slope (1v: xh)	Embankment Footprint Width (m)	Fill Volume (m^3)	Cut Volume (m^3)	Surface Area (m^2)	Pipe Upgrade Length (m)	Culvert Diameter (m)	Trench Width (m)	Total Trench Volume
54	0	0	0	7	0	0	189	54	2.4	7	378

Removal of existing pipe
0

	Fixed Costs	UNIT	QUANTITY	Rate (ex GST)	COST
Design	Design, Consultations, Approvals and Construction Management	item	1	$ 20,000.00	$ 20,000.00
General	Project Management & General Construction Cost (15% of subtotal)	item	1	15%	$ 103,319.95
Roadworks	Site Preparation, removal of existing road surface	m²	680	$ 40.00	$ 27,200.00
	Control of traffic during works (nominal allowance) (assumed $500 per lin.m)	lin.m	170	$ 500.00	$ 85,000.00
	Reinstate Road Surface	m²	680	$ 40.00	$ 27,200.00
	Adjustment of existing services (nominal allowance) (assumed 10% of drainage installation cost)	item	1	10%	$ 6,732.00
Earthworks	Removal of top soil and vegetation (100 mm)	m³	19	$ 16.00	$ 302.40
	Excavation	m³	189	$ 50.00	$ 9,450.00
	Improvement of Excavated material	m³	189	$ 18.00	$ 3,402.00
	Haulage of imported Fill	km	20	$ 18.00	$ 360.00
	Disposal of Contaminated Spoil (80% of total soil)	m³	151	$ 80.00	$ 12,096.00
	~~Fill in embankment~~	~~m³~~	~~0~~	~~$ 55.00~~	~~$ -~~
	Fuel	l/m³	189	$ 0.75	$ 141.75
	Compaction	m³	189	$ 8.00	$ 1,512.00
	Top soil placement/seeding	m²	19	$ 15.00	$ 283.50
	Erosion Protection/ RipRap/ Site Remediation	item	1	$ 5,000.00	$ 5,000.00
	~~Remove Rail and Bridge Infrastucture~~	~~m²~~	~~0~~	~~$ 100.00~~	~~$ -~~
Culvert Upgrade	~~Box Culvert: 2.0m x 2.0m~~	~~m~~	~~0~~	~~$ 3,600.00~~	~~$ -~~
	~~Box Culvert: 2.75m x 1.7m~~	~~m~~	~~0~~	~~$ 5,000.00~~	~~$ -~~
	~~Box Culvert: 1.5m x 0.8m~~	~~m~~	~~0~~	~~$ 2,700.00~~	~~$ -~~
	~~Box Culvert: 2.0m x 1.5m~~	~~m~~	~~0~~	~~$ 3,600.00~~	~~$ -~~
	~~Pipe 600 x 2.44 RJ Class 4~~	~~m~~	~~0~~	~~$ 335.34~~	~~$ -~~
	~~Pipe 750 x 2.44 RJ Class 4~~	~~m~~	~~0~~	~~$ 479.74~~	~~$ -~~
	~~Pipe 900 x 2.44 RJ Class 4~~	~~m~~	~~0~~	~~$ 256.00~~	~~$ -~~
	~~Pipe 1800 x 2.44 RJ Class 4~~	~~m~~	~~0~~	~~$ 3,000.00~~	~~$ -~~
	Pipe 2400 x 2.44 RJ Class 4	m	54	$ 7,500.00	$ 405,000.00
	~~Single Cell Headwall to suit 375DN pipe~~	~~item~~	~~0~~	~~$ 315.00~~	~~$ -~~
	~~Single Cell Headwall to suit 600DN pipe~~	~~item~~	~~0~~	~~$ 410.00~~	~~$ -~~
	~~Single Cell Headwall to suit 750DN pipe~~	~~item~~	~~0~~	~~$ 720.00~~	~~$ -~~
	~~Single Cell Headwall to suit 900DN pipe~~	~~item~~	~~0~~	~~$ 945.00~~	~~$ -~~
	~~Single Cell Headwall to suit 1200DN pipe~~	~~item~~	~~0~~	~~$ 1,190.00~~	~~$ -~~
	~~Single Cell Headwall to suit 1800DN pipe~~	~~item~~	~~0~~	~~$ 1,500.00~~	~~$ -~~
	~~Drainage Pit~~	~~item~~	~~0~~	~~$ 5,000.00~~	~~$ -~~
	~~Junction Pit~~	~~item~~	~~0~~	~~$ 5,000.00~~	~~$ -~~
	Excavate Trench	m³	189	$ 80.00	$ 15,120.00
	~~Install Bridge~~	~~m~~	~~0~~	~~$ 50,000.00~~	~~$ -~~
	Backfill and Site Remediation	m	1	$ 50,000.00	$ 50,000.00
	Install new outlet structure, including erosion protection as required	m	4	$ 5,000.00	$ 20,000.00
	~~Land Value - Commerical~~	~~item~~	~~0~~	~~$ 600,500.00~~	~~$ -~~
Property Items	~~Land Value - Commerical~~	item	~~0~~	~~$ 600,500.00~~	~~$ -~~
	~~Land Value - Residential~~	item	~~0~~	~~$ 352,000.00~~	~~$ -~~
	~~Land Value - Combined~~	item	~~0~~	~~$ 476,000.00~~	~~$ -~~
	~~Building/ Business Value (Allowance)~~	item	~~0~~	~~$ 1,500,000.00~~	~~$ -~~
	~~Demolition and Debris Removal~~	Item	~~0~~	~~$ 600,000.00~~	~~$ -~~
	Total				**$0.79 M**

Option ID: **DM07**

New Drainage structure (4m by 1m) under Cliff Parade

NOTE: Edit Quantities and Sizes in the Options Summary table, not in the below box

3	4	5	6	7	8	9	10	12	13	14	15
Length (m)	Height (m)	Crest Width (m)	Batter Slope (1v: xh)	Embankment Footprint Width (m)	Fill Volume (m^3)	Cut Volume (m^3)	Surface Area (m^2)	Pipe Upgrade Length (m)	Culvert Diameter (m)	Trench Width (m)	Total Trench Volume
45	**0**	**0**	**0**	**6**	**0**	**0**	**270**	**43**	**4**	**6**	**258**

Removal of existing pipe
0

	Fixed Costs	UNIT	QUANTITY	Rate (ex GST)	COST
General	Design, Consultations, Approvals and Construction Management	item	1	$ 20,000.00	$ 20,000.00
	Project Management & General Construction Cost (15% of subtotal)	item	1	15%	$ 66,785.93
Roadworks	Site Preparation, removal of existing road surface	m^2	270	$ 40.00	$ 10,800.00
	Control of traffic during works (nominal allowance) (assumed $500 per lin.m)	lin.m	45	$ 500.00	$ 22,500.00
	Reinstate Road Surface	m^2	270	$ 40.00	$ 10,800.00
	Adjustment of existing services (nominal allowance) (assumed 10% of drainage installation cost)	item	1	10%	$ 5,740.00
Earthworks	Removal of top soil and vegetation (100 mm)	m^3	27	$ 16.00	$ 432.00
	Excavation	m^3	270	$ 50.00	$ 13,500.00
	Improvement of Excavated material	m^3	270	$ 18.00	$ 4,860.00
	Haulage of imported Fill	km	20	$ 18.00	$ 360.00
	Disposal of Contaminated Spoil (80% of total soil)	m^3	216	$ 80.00	$ 17,280.00
	~~Fill in embankment~~	~~m^3~~	~~0~~	~~$ 55.00~~	~~$ -~~
	Fuel	l/m^3	270	$ 0.75	$ 202.50
	Compaction	m^3	270	$ 8.00	$ 2,160.00
	Top soil placement/seeding	m^2	27	$ 15.00	$ 405.00
	Erosion Protection/ RipRap/ Site Remediation	item	1	$ 5,000.00	$ 5,000.00
	~~Remove Rail and Bridge Infrastucture~~	~~m^2~~	~~0~~	~~$ 100.00~~	~~$ -~~
Culvert Upgrade	~~Box Culvert: 2.0m x 2.0m~~	~~m~~	~~0~~	~~$ 3,600.00~~	~~$ -~~
	~~Box Culvert: 2.75m x 1.7m~~	~~m~~	~~0~~	~~$ 5,000.00~~	~~$ -~~
	~~Box Culvert: 1.5m x 0.8m~~	~~m~~	~~0~~	~~$ 2,700.00~~	~~$ -~~
	Box Culvert: 2.0m x 1.5m	m	86	$ 3,600.00	$ 309,600.00
	~~Pipe 600 x 2.44 RJ Class 4~~	~~m~~	~~0~~	~~$ 335.34~~	~~$ -~~
	~~Pipe 750 x 2.44 RJ Class 4~~	~~m~~	~~0~~	~~$ 479.74~~	~~$ -~~
	~~Pipe 900 x 2.44 RJ Class 4~~	~~m~~	~~0~~	~~$ 256.00~~	~~$ -~~
	~~Pipe 1800 x 2.44 RJ Class 4~~	~~m~~	~~0~~	~~$ 3,000.00~~	~~$ -~~
	~~Pipe 2400 x 2.44 RJ Class 4~~	~~m~~	~~0~~	~~$ 7,500.00~~	~~$ -~~
	~~Single Cell Headwall to suit 375DN pipe~~	~~item~~	~~0~~	~~$ 315.00~~	~~$ -~~
	~~Single Cell Headwall to suit 600DN pipe~~	~~item~~	~~0~~	~~$ 410.00~~	~~$ -~~
	~~Single Cell Headwall to suit 750DN pipe~~	~~item~~	~~0~~	~~$ 720.00~~	~~$ -~~
	~~Single Cell Headwall to suit 900DN pipe~~	~~item~~	~~0~~	~~$ 945.00~~	~~$ -~~
	~~Single Cell Headwall to suit 1200DN pipe~~	~~item~~	~~0~~	~~$ 1,190.00~~	~~$ -~~
	~~Single Cell Headwall to suit 1800DN pipe~~	~~item~~	~~0~~	~~$ 1,500.00~~	~~$ -~~
	~~Drainage Pit~~	~~item~~	~~0~~	~~$ 5,000.00~~	~~$ -~~
	~~Junction Pit~~	~~item~~	~~0~~	~~$ 5,000.00~~	~~$ -~~
	Excavate Trench	m^3	270	$ 80.00	$ 21,600.00
	~~Install Bridge~~	~~m~~	~~0~~	~~$ 50,000.00~~	~~$ -~~
	~~Backfill and Site Remediation~~	~~m~~	~~0~~	~~$ 50,000.00~~	~~$ -~~
	~~Install new outlet structure, including erosion protection as required~~	~~m~~	~~0~~	~~$ 5,000.00~~	~~$ -~~
	~~Land Value - Commerical~~	~~item~~	~~0~~	~~$ 600,500.00~~	~~$ -~~
Property Items	~~Land Value - Commerical~~	item	~~0~~	~~$ 600,500.00~~	~~$ -~~
	~~Land Value - Residential~~	item	~~0~~	~~$ 352,000.00~~	~~$ -~~
	~~Land Value - Combined~~	item	~~0~~	~~$ 476,000.00~~	~~$ -~~
	~~Building/ Business Value (Allowance)~~	item	~~0~~	~~$ 1,500,000.00~~	~~$ -~~
	~~Demolition and Debris Removal~~	Item	~~0~~	~~$ 600,000.00~~	~~$ -~~
	Total				**$0.51 M**

Option ID: **LV01**

A 170m levee along the north bank of Woodlands Creek

NOTE: Edit Quantities and Sizes in the Options Summary table, not in the below box

3	4	5	6	7	8	9	10	12	13	14	15
Length (m)	Height (m)	Crest Width (m)	Batter Slope (1v: xh)	Embankment Footprint Width (m)	Fill Volume (m^3)	Cut Volume (m^3)	Surface Area (m^2)	Pipe Upgrade Length (m)	Culvert Diameter (m)	Trench Width (m)	Total Trench Volume
160	**1**	**1**	**2**	**5**	**480**	**0**	**800**	**0**	**0**	**0**	**0**

Removal of existing pipe
0

	Fixed Costs	UNIT	QUANTITY	Rate (ex GST)	COST
General	Design, Consultations, Approvals and Construction Management	item	1	$ 20,000.00	$ 20,000.00
General	Project Management & General Construction Cost (15% of subtotal)	item	1	15%	$ 13,392.00
Roadworks	~~Site Preparation, removal of existing road surface~~	~~m^2~~	~~0~~	~~$ 40.00~~	~~$ -~~
Roadworks	~~Control of traffic during works (nominal allowance) (assumed $500 per lin.m)~~	~~lin.m~~	~~0~~	~~$ 500.00~~	~~$ -~~
Roadworks	~~Reinstate Road Surface~~	~~m^2~~	~~0~~	~~$ 40.00~~	~~$ -~~
Roadworks	~~Adjustment of existing services (nominal allowance) (assumed 10% of drainage installation cost)~~	~~item~~	~~0~~	~~10%~~	~~$ -~~
Earthworks	Removal of top soil and vegetation (100 mm)	m^3	80	$ 16.00	$ 1,280.00
Earthworks	~~Excavation~~	~~m^3~~	~~0~~	~~$ 50.00~~	~~$ -~~
Earthworks	~~Improvement of Excavated material~~	~~m^3~~	~~0~~	~~$ 18.00~~	~~$ -~~
Earthworks	~~Haulage of imported Fill~~	~~km~~	~~0~~	~~$ 18.00~~	~~$ -~~
Earthworks	~~Disposal of Contaminated Spoil (80% of total soil)~~	~~m^3~~	~~0~~	~~$ 80.00~~	~~$ -~~
Earthworks	Fill in embankment	m^3	800	$ 55.00	$ 44,000.00
Earthworks	Fuel	l/m^3	800	$ 0.75	$ 600.00
Earthworks	Compaction	m^3	800	$ 8.00	$ 6,400.00
Earthworks	Top soil placement/seeding	m^2	800	$ 15.00	$ 12,000.00
Earthworks	Erosion Protection/ RipRap/ Site Remediation	item	1	$ 5,000.00	$ 5,000.00
Earthworks	~~Remove Rail and Bridge Infrastucture~~	~~m^2~~	~~0~~	~~$ 100.00~~	~~$ -~~
Culvert Upgrade	~~Box Culvert: 2.0m x 2.0m~~	~~m~~	~~0~~	~~$ 3,600.00~~	~~$ -~~
Culvert Upgrade	~~Box Culvert: 2.75m x 1.7m~~	~~m~~	~~0~~	~~$ 5,000.00~~	~~$ -~~
Culvert Upgrade	~~Box Culvert: 1.5m x 0.8m~~	~~m~~	~~0~~	~~$ 2,700.00~~	~~$ -~~
Culvert Upgrade	~~Box Culvert: 2.0m x 1.5m~~	~~m~~	~~0~~	~~$ 3,600.00~~	~~$ -~~
Culvert Upgrade	~~Pipe 600 x 2.44 RJ Class 4~~	~~m~~	~~0~~	~~$ 335.34~~	~~$ -~~
Culvert Upgrade	~~Pipe 750 x 2.44 RJ Class 4~~	~~m~~	~~0~~	~~$ 479.74~~	~~$ -~~
Culvert Upgrade	~~Pipe 900 x 2.44 RJ Class 4~~	~~m~~	~~0~~	~~$ 256.00~~	~~$ -~~
Culvert Upgrade	~~Pipe 1800 x 2.44 RJ Class 4~~	~~m~~	~~0~~	~~$ 3,000.00~~	~~$ -~~
Culvert Upgrade	~~Pipe 2400 x 2.44 RJ Class 4~~	~~m~~	~~0~~	~~$ 7,500.00~~	~~$ -~~
Culvert Upgrade	~~Single Cell Headwall to suit 375DN pipe~~	~~item~~	~~0~~	~~$ 315.00~~	~~$ -~~
Culvert Upgrade	~~Single Cell Headwall to suit 600DN pipe~~	~~item~~	~~0~~	~~$ 410.00~~	~~$ -~~
Culvert Upgrade	~~Single Cell Headwall to suit 750DN pipe~~	~~item~~	~~0~~	~~$ 720.00~~	~~$ -~~
Culvert Upgrade	~~Single Cell Headwall to suit 900DN pipe~~	~~item~~	~~0~~	~~$ 945.00~~	~~$ -~~
Culvert Upgrade	~~Single Cell Headwall to suit 1200DN pipe~~	~~item~~	~~0~~	~~$ 1,190.00~~	~~$ -~~
Culvert Upgrade	~~Single Cell Headwall to suit 1800DN pipe~~	~~item~~	~~0~~	~~$ 1,500.00~~	~~$ -~~
Culvert Upgrade	~~Drainage Pit~~	~~item~~	~~0~~	~~$ 5,000.00~~	~~$ -~~
Culvert Upgrade	~~Junction Pit~~	~~item~~	~~0~~	~~$ 5,000.00~~	~~$ -~~
Culvert Upgrade	~~Excavate Trench~~	~~m^3~~	~~0~~	~~$ 80.00~~	~~$ -~~
Culvert Upgrade	~~Install Bridge~~	~~m~~	~~0~~	~~$ 50,000.00~~	~~$ -~~
Culvert Upgrade	~~Backfill and Site Remediation~~	~~m~~	~~0~~	~~$ 50,000.00~~	~~$ -~~
Culvert Upgrade	~~Install new outlet structure, including erosion protection as required~~	~~m~~	~~0~~	~~$ 5,000.00~~	~~$ -~~
Culvert Upgrade	~~Land Value - Commerical~~	~~item~~	~~0~~	~~$ 600,500.00~~	~~$ -~~
Property Items	~~Land Value - Commerical~~	item	~~0~~	~~$ 600,500.00~~	~~$ -~~
Property Items	~~Land Value - Residential~~	item	~~0~~	~~$ 352,000.00~~	~~$ -~~
Property Items	~~Land Value - Combined~~	item	~~0~~	~~$ 476,000.00~~	~~$ -~~
Property Items	~~Building/ Business Value (Allowance)~~	item	~~0~~	~~$ 1,500,000.00~~	~~$ -~~
Property Items	~~Demolition and Debris Removal~~	Item	~~0~~	~~$ 600,000.00~~	~~$ -~~
	Total				**$0.10 M**

PUBLIC EXHIBITION DRAFT

Appendix D

Appendix D. ROAD INUNDATION

Table D 1: Duration of Road Inundation (Hours)

	20% AEP Event			10% AEP Event			5% AEP Event			2% AEP Event			1% AEP Event			0.5% AEP Event			0.2% AEP Event			PMF Event		
Depth Above Road (m)	**0.3**	**0.5**	**1**	**0.3**	**0.5**	**1**	**0.3**	**0.5**	**1**	**0.3**	**0.5**	**1**	**0.3**	**0.5**	**1**	**0.3**	**0.5**	**1**	**0.3**	**0.5**	**1**	**0.3**	**0.5**	**1**
Location (Map Set A Figure 16)																								
1:Deborah Avenue	0	0	0	0	0	0	0	0	0	0.8	0	0	0.8	0	0	0.9	0	0	1	0	0	1.3	0.6	0
2:Palm Grove	0	0	0	0	0	0	0.2	0	0	1.5	0	0	2	0	0	2.1	0	0	2.2	0	0	1.3	0.8	0
3:Virginia Terrace near Soudan Street	0.4	0	0	0.5	0	0	0.5	0	0	2.3	0.9	0	2.6	1	0	2.7	1	0	2.9	1.1	0	1.7	1.2	0
4:Virginia Terrace	1	0	0	0.9	0	0	1.1	0	0	2.1	0.8	0	2.5	0.9	0	2.6	1	0	2.8	1	0	1.8	1.3	0
5:Jennifer Crescent	0.9	0	0	0.8	0	0	1	0	0	1.8	0	0	2.1	0	0	2.3	0.3	0	2.4	0.6	0	1.9	1.1	0
6:George Street West	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.3	0	0	1	0.7	0
7:George Street East	1	0	0	0.9	0	0	1.1	0	0	2.3	0	0	2.5	0	0	2.8	0	0	2.9	0.2	0	1.7	0.9	0
8:Lachlan Street @ Hewitts Creek	0	0	0	0.1	0	0	0.4	0	0	1	0	0	1.2	0.7	0	1.2	0.7	0	1.4	0.8	0	1.4	1.2	0.4
9:Corner of LHD and High Street	0	0	0	0.2	0	0	0.5	0	0	1.1	0.6	0	1.3	0.8	0	1.5	0.9	0	1.7	1	0	1.6	1.5	1.2
10:LHD near train station	1.2	0.8	0	1.3	0.7	0	1.4	1	0	2.4	1.5	0	2.8	2	0	2.9	2.4	0	3.3	2.6	0.3	1.8	1.7	1
11:The Esplanade	2.3	0	0	2.1	0.3	0	2.9	1.1	0	5.5	2.8	0.3	5.1	2.2	0.4	5.3	2.2	0.6	5.5	2.4	0.9	4.3	2.6	1.6
12:Cliff Parade	4.9	4.4	0.8	4.8	4.4	0.7	6.7	5.7	1.3	9.4	9.1	3.4	8.2	7.7	2.4	8.4	7.9	2.6	8.5	8	3.6	7.2	6.9	3
13:Cliff Parade @ Thomas Gibson Creek	0	0	0	0	0	0	0	0	0	0	0	0	0.4	0	0	0.6	0	0	0.8	0	0	1.5	0.4	0
14:Pass Avenue	0	0	0	0	0	0	0	0	0	0.3	0	0	0.7	0	0	0.7	0	0	0.9	0	0	1.2	0.1	0
15:High Street West	0	0	0	0	0	0	0	0	0	0	0	0	0.5	0	0	0.6	0	0	0.8	0	0	1.1	0	0
16:Hewitts Avenue	0	0	0	0	0	0	0	0	0	1	0.4	0	1.1	0.7	0	1.3	0.8	0	1.3	1	0	1.6	1.2	0.6
17:McCauley Street @ Thomas Gibson Creek	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.2	0	0	0.8	0	0	1.9	0.3	0
18:Station Street	0	0	0	0	0	0	0	0	0	0.2	0	0	0.7	0	0	0.8	0	0	0.8	0	0	1.2	0.8	0
19:Corner of LHD	0	0	0	0	0	0	0	0	0	0.7	0	0	0.9	0	0	0.9	0	0	1	0.5	0	1.3	1.1	0
20:McCauley Street	0	0	0	0	0	0	0.2	0	0	0.9	0	0	1	0	0	1.1	0	0	1.1	0	0	1.4	0.9	0

	20% AEP Event			10% AEP Event			5% AEP Event			2% AEP Event			1% AEP Event			0.5% AEP Event			0.2% AEP Event			PMF Event		
Depth Above Road (m)	0.3	0.5	1	0.3	0.5	1	0.3	0.5	1	0.3	0.5	1	0.3	0.5	1	0.3	0.5	1	0.3	0.5	1	0.3	0.5	1
Location (Map Set A Figure 16)																								
21:Raymond Road	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.1	0	0
22:LHD @ Woodlands Creek	2	1.9	1.4	1.8	1.6	1.2	2.1	1.9	1.5	4.5	4.3	2.5	4.7	4.6	3.8	4.9	4.7	4.2	4.9	4.8	4.3	3.1	3	2.6
23:National Avenue	2.6	0	0	2.3	0	0	2.3	0	0	4.4	0.4	0	4.4	0.8	0	4.4	0.8	0	4.5	0.8	0	1.7	1.2	0
24:William Street	0.4	0	0	0.4	0.1	0	0.6	0.5	0	1.5	1.3	0	1.8	1.4	0	2.1	1.5	0.3	2.5	2	0.6	1.9	1.7	1.1
25:Hobart Street	1.5	0.9	0	1.2	0.8	0	1.4	1	0	3.2	1.5	0.9	3.9	1.9	1	3.9	2.2	1.1	4	2.5	1.2	2.4	2	1.5
26:Corner of Princes Highway and Hobart Street	1.4	0	0	1.2	0.1	0	1.4	0.5	0	2.5	1.2	0	3.3	1.3	0	3.5	1.4	0	3.8	1.4	0	2.4	1.7	0
27:Princess Highway 1	2.1	0	0	1.7	0	0	2.2	0	0	3.9	1	0	4.2	1.2	0	4.3	1.3	0	4.5	1.4	0	2.8	1.8	0.7
28:Corner of Princes Highway and Black Diamond Place	1.2	0	0	1	0.3	0	1.4	0.6	0	2.5	1.4	0	3.1	1.5	0	3.4	1.6	0	3.6	2	0	2.4	1.8	0.4
29:Crevillia Park Road	1.8	1.4	0	1.7	1.3	0	1.9	1.6	0	4.4	3	0.8	4.5	3.7	1	4.6	3.8	1	4.7	4.3	1.2	2.6	2.4	1.5
30:Beacon Avenue East End	1.1	0.3	0	1	0.3	0	1.1	0.7	0	2	1.1	0	2.8	1.5	0	2.9	1.7	0	3.1	2	0	2.3	2.1	0.9
31:Blackall Street	10.9	10.8	4.1	8.6	8.5	3.8	8.9	8.9	6.7	9.9	9.9	6.9	10.3	10.3	6.9	11	11	7.3	10.1	10.1	7.3	8.6	8.6	7.2
32:Beacon Avenue	0	0	0	0	0	0	0	0	0	0	0	0	0.5	0	0	0.7	0	0	0.9	0.2	0	1.6	1.2	0

PUBLIC E

Table D 2: Depth and Velocity of Road Inundation

Location (Map Set A Figure 16)	First Event Flooded	20% AEP Event		10% AEP Event		5% AEP Event		2% AEP Event		1% AEP Event		0.5% AEP Event		0.2% AEP Event		PMF Event	
		Depth (m)	Velocity (m/s)	Depth (m)	Velocity (m/s)	Depth (m)	Velocity (m/s)	Depth (m)	Velocity (m/s)	Depth (m)	Velocity (m/s)	Depth (m)	Velocity (m/s)	Depth (m)	Velocity (m/s)	Depth (m)	Velocity (m/s)
1:Deborah Avenue	20% AEP	0.17	0.75	0.20	0.97	0.24	1.13	0.29	1.41	0.32	1.53	0.33	1.57	0.35	1.67	0.53	2.49
2:Palm Grove	20% AEP	0.26	0.10	0.31	0.16	0.34	0.21	0.43	0.37	0.45	0.42	0.47	0.43	0.48	0.45	0.62	0.80
3:Virginia Terrace near Soudan Street	20% AEP	0.20	0.77	0.26	0.87	0.34	0.92	0.42	1.01	0.47	1.06	0.48	1.08	0.50	1.11	0.66	1.33
4:Virginia Terrace	20% AEP	0.39	0.42	0.41	0.45	0.46	0.49	0.53	0.64	0.57	0.68	0.60	0.69	0.64	0.74	0.89	1.08
5:Jennifer Crescent	20% AEP	0.37	0.24	0.39	0.30	0.43	0.39	0.48	0.52	0.51	0.64	0.53	0.71	0.55	0.80	0.74	1.43
6:George Street West	20% AEP	0.12	2.20	0.14	2.35	0.18	2.72	0.22	3.07	0.25	3.26	0.27	3.35	0.30	3.48	0.57	3.93
7:George Street East	20% AEP	0.35	0.47	0.39	0.35	0.42	0.44	0.44	0.45	0.46	0.51	0.48	0.53	0.49	0.65	0.61	1.03
8:Lachlan Street @ Hewitts Creek	20% AEP	0.23	0.79	0.29	0.93	0.36	1.10	0.46	1.44	0.52	1.55	0.56	1.61	0.63	1.84	1.02	2.65
9:Corner of LHD and High Street	20% AEP	0.26	0.33	0.33	0.45	0.41	0.50	0.56	0.65	0.62	0.64	0.65	0.70	0.76	0.78	3.14	1.47
10:LHD near train station	20% AEP	0.59	0.45	0.67	0.47	0.78	0.49	0.91	0.68	1.02	0.62	1.02	0.62	1.08	0.65	1.32	0.71
11:The Esplanade	20% AEP	0.51	0.10	0.55	0.13	0.70	0.19	1.07	0.36	1.15	0.38	1.20	0.35	1.26	0.35	1.85	0.50
12:Cliff Parade	20% AEP	0.91	0.51	0.94	0.69	1.10	0.53	1.49	0.70	1.56	0.54	1.61	0.53	1.66	0.54	2.23	0.61
13:Cliff Parade @ Thomas Gibson Creek	20% AEP	0.22	0.79	0.24	0.88	0.26	0.97	0.31	1.13	0.34	1.29	0.36	1.36	0.38	1.46	0.59	2.18
14:Pass Avenue	20% AEP	0.22	0.28	0.25	0.31	0.28	0.31	0.31	0.28	0.33	0.31	0.34	0.29	0.36	0.32	0.50	0.73
15:High Street West	20% AEP	0.21	0.66	0.23	0.70	0.25	0.73	0.27	0.73	0.29	0.75	0.30	0.75	0.32	0.78	0.45	0.95
16:Hewitts Avenue	20% AEP	0.04	0.15	0.06	0.37	0.15	0.70	0.51	1.02	0.60	1.22	0.64	1.32	0.70	1.45	1.06	2.15
17:McCauley Street @ Thomas Gibson Creek	20% AEP	0.22	1.36	0.23	1.58	0.27	1.58	0.29	1.61	0.32	1.61	0.33	1.64	0.35	1.74	0.52	2.13
18:Station Street	20% AEP	0.06	0.59	0.08	0.69	0.19	0.99	0.27	1.21	0.32	1.26	0.35	1.27	0.40	1.28	0.59	1.39
19:Corner of LHD	20% AEP	0.21	0.41	0.22	0.56	0.28	0.52	0.36	0.49	0.43	0.52	0.47	0.50	0.53	0.52	0.95	0.60
20:McCauley Street	20% AEP	0.29	0.31	0.35	0.56	0.39	0.60	0.43	0.59	0.47	0.70	0.49	0.77	0.52	0.85	0.75	1.45
21:Raymond Road	2% AEP	0.00	0.00	0.00	0.00	0.00	0.00	0.09	0.09	0.18	0.33	0.19	0.35	0.20	0.40	0.31	0.75
22:LHD @ Woodlands Creek	20% AEP	1.50	0.14	1.57	0.19	1.91	0.22	2.41	0.26	2.49	0.34	2.53	0.46	2.57	0.60	2.94	1.14
23:National Avenue	20% AEP	0.43	0.16	0.45	0.18	0.47	0.20	0.49	0.23	0.51	0.26	0.52	0.27	0.54	0.29	0.66	0.43
24:William Street	20% AEP	0.28	0.77	0.43	0.85	0.57	0.87	0.80	0.98	0.87	1.07	0.91	1.12	0.96	1.19	1.36	1.94
25:Hobart Street	20% AEP	0.64	0.75	0.74	0.81	0.93	0.78	1.36	0.75	1.55	0.86	1.63	0.94	1.72	1.01	2.36	1.66

Location (Map Set A Figure 16)	First Event Flooded	20% AEP Event		10% AEP Event		5% AEP Event		2% AEP Event		1% AEP Event		0.5% AEP Event		0.2% AEP Event		PMF Event	
		Depth (m)	Velocity (m/s)	Depth (m)	Velocity (m/s)	Depth (m)	Velocity (m/s)	Depth (m)	Velocity (m/s)	Depth (m)	Velocity (m/s)	Depth (m)	Velocity (m/s)	Depth (m)	Velocity (m/s)	Depth (m)	Velocity (m/s)
26:Corner of Princes Highway and Hobart Street	20% AEP	0.48	0.52	0.52	0.58	0.57	0.65	0.72	1.12	0.78	1.35	0.80	1.47	0.82	1.54	1.02	2.51
27:Princess Highway 1	20% AEP	0.45	0.13	0.46	0.13	0.49	0.13	0.57	0.13	0.62	0.14	0.65	0.14	0.70	0.14	1.21	0.32
28:Corner of Princes Highway and Black Diamond Place	20% AEP	0.47	0.44	0.49	0.45	0.56	0.41	0.64	0.49	0.67	0.57	0.69	0.59	0.71	0.63	1.33	1.42
29:Crevillia Park Road	20% AEP	0.89	0.63	0.93	0.86	1.00	0.84	1.09	0.96	1.12	0.95	1.14	1.01	1.16	1.11	1.40	2.55
30:Beacon Avenue East End	20% AEP	0.52	0.27	0.57	0.34	0.60	0.41	0.64	0.52	0.73	0.74	0.77	0.84	0.82	0.96	1.15	1.66
31:Blackall Street	20% AEP	1.95	1.49	1.96	1.49	2.08	1.67	2.26	2.08	2.30	2.39	2.33	2.57	2.38	2.63	3.28	3.97
32:Beacon Avenue	20% AEP	0.08	0.38	0.10	0.43	0.12	0.46	0.26	0.64	0.37	0.75	0.43	0.82	0.51	0.91	0.86	1.58

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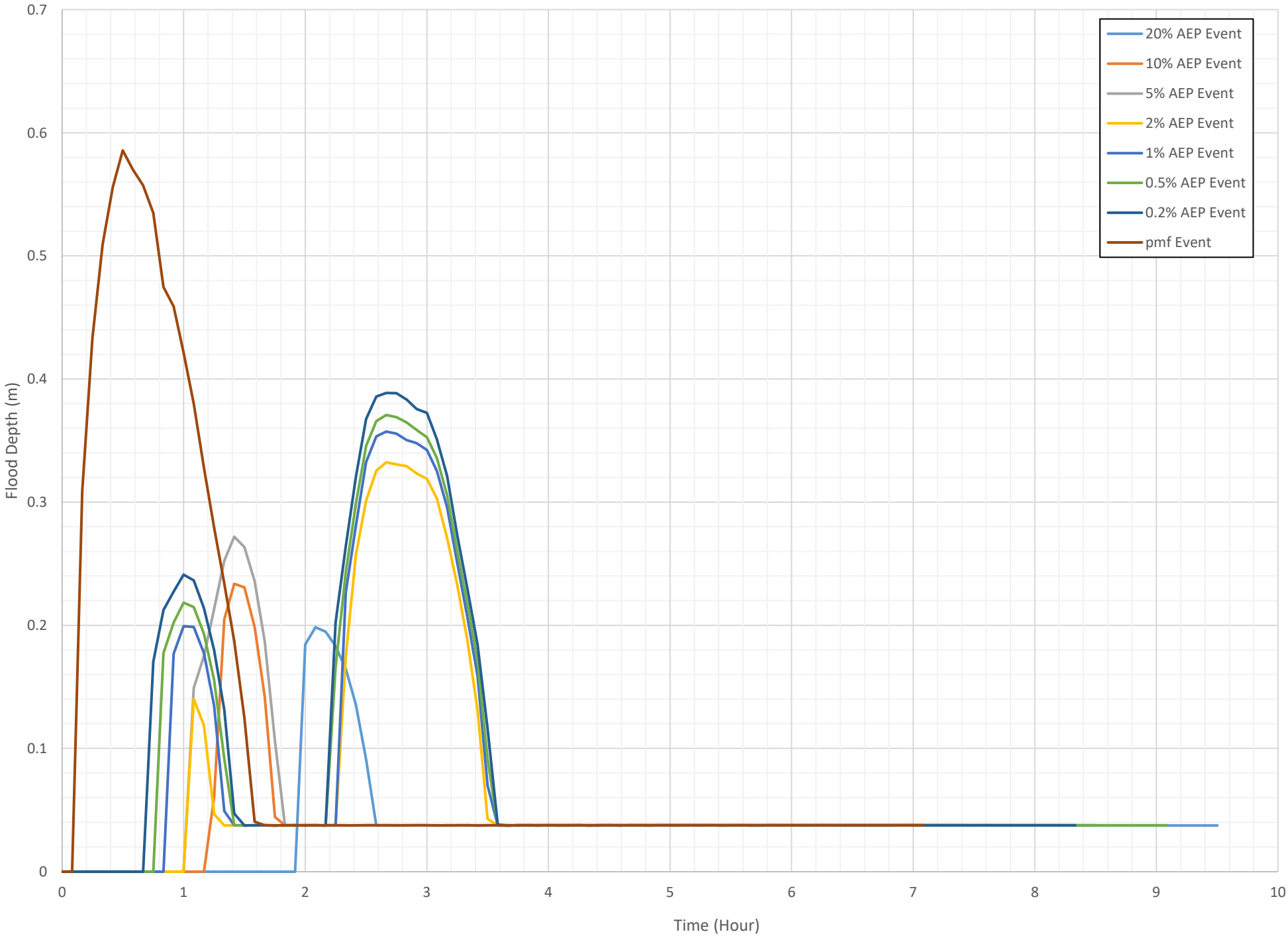


FIGURE D1
HEWITTS CREEK CATCHMENT
LOCATION 1: DEBORAH AVENUE

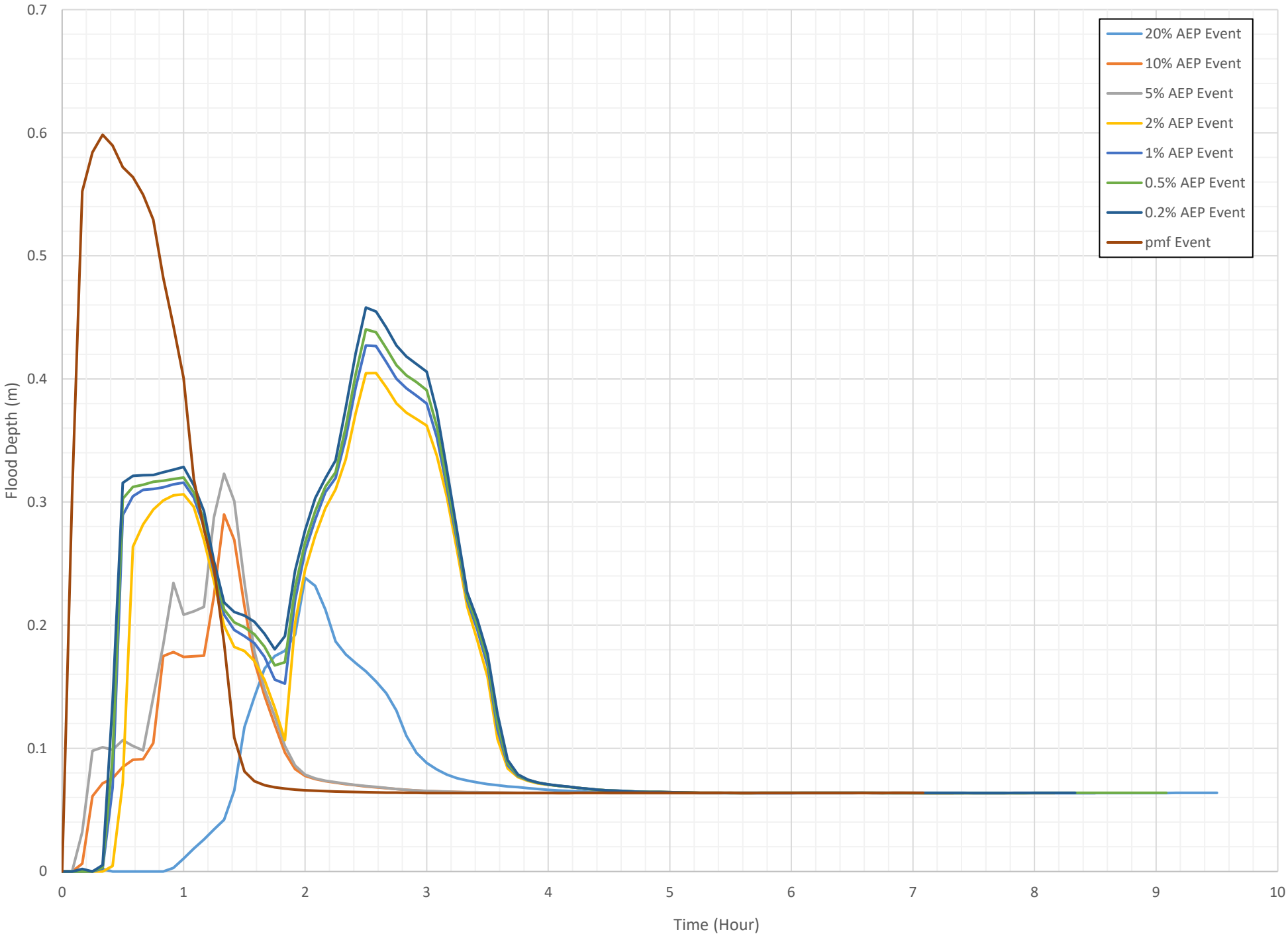


FIGURE D2
HEWITTS CREEK CATCHMENT
LOCATION 2: PALM GROVE

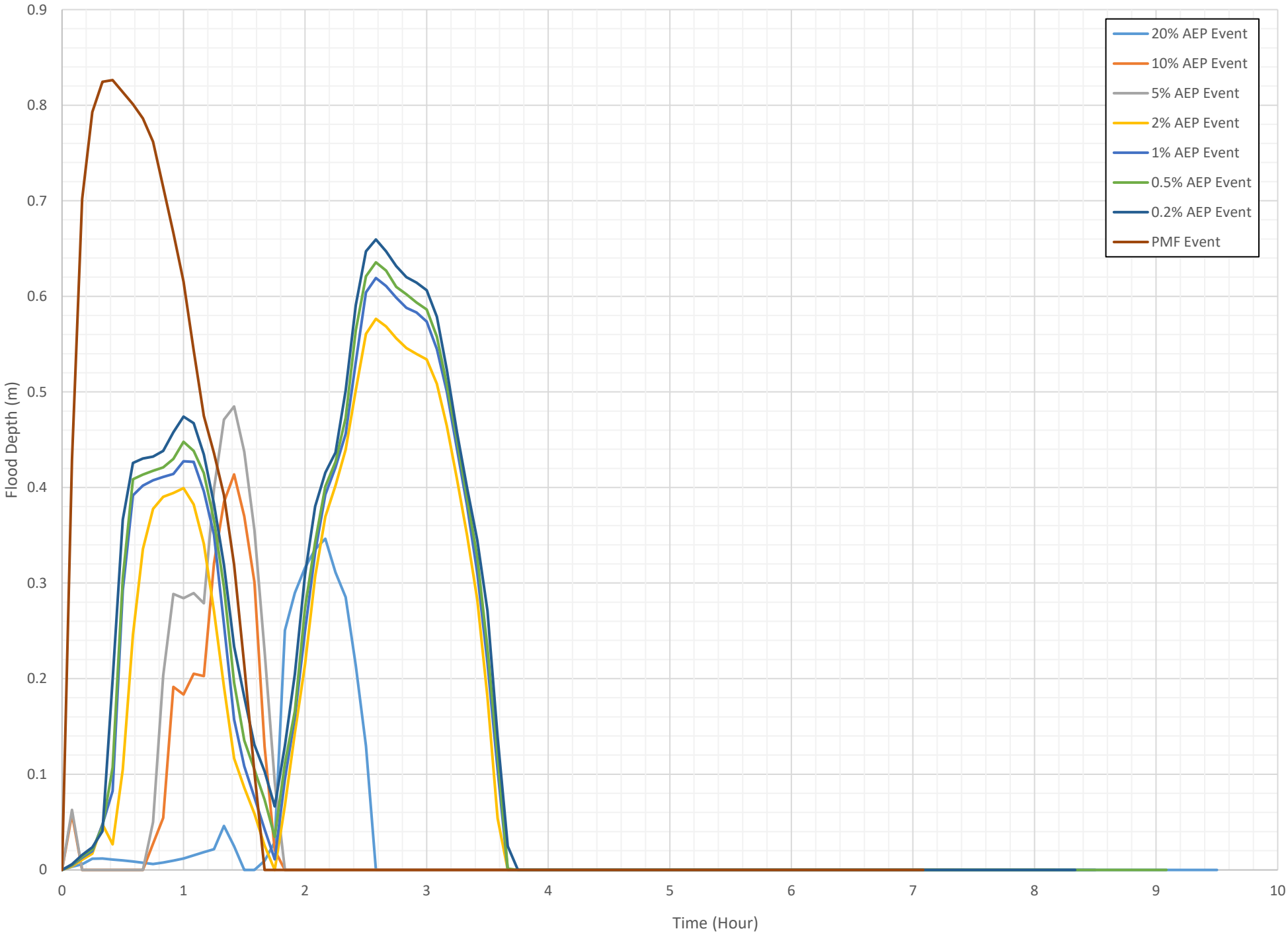


FIGURE D3
HEWITTS CREEK CATCHMENT
LOCATION 3: VIRGINIA TERRACE NEAR SOUDAN STREET

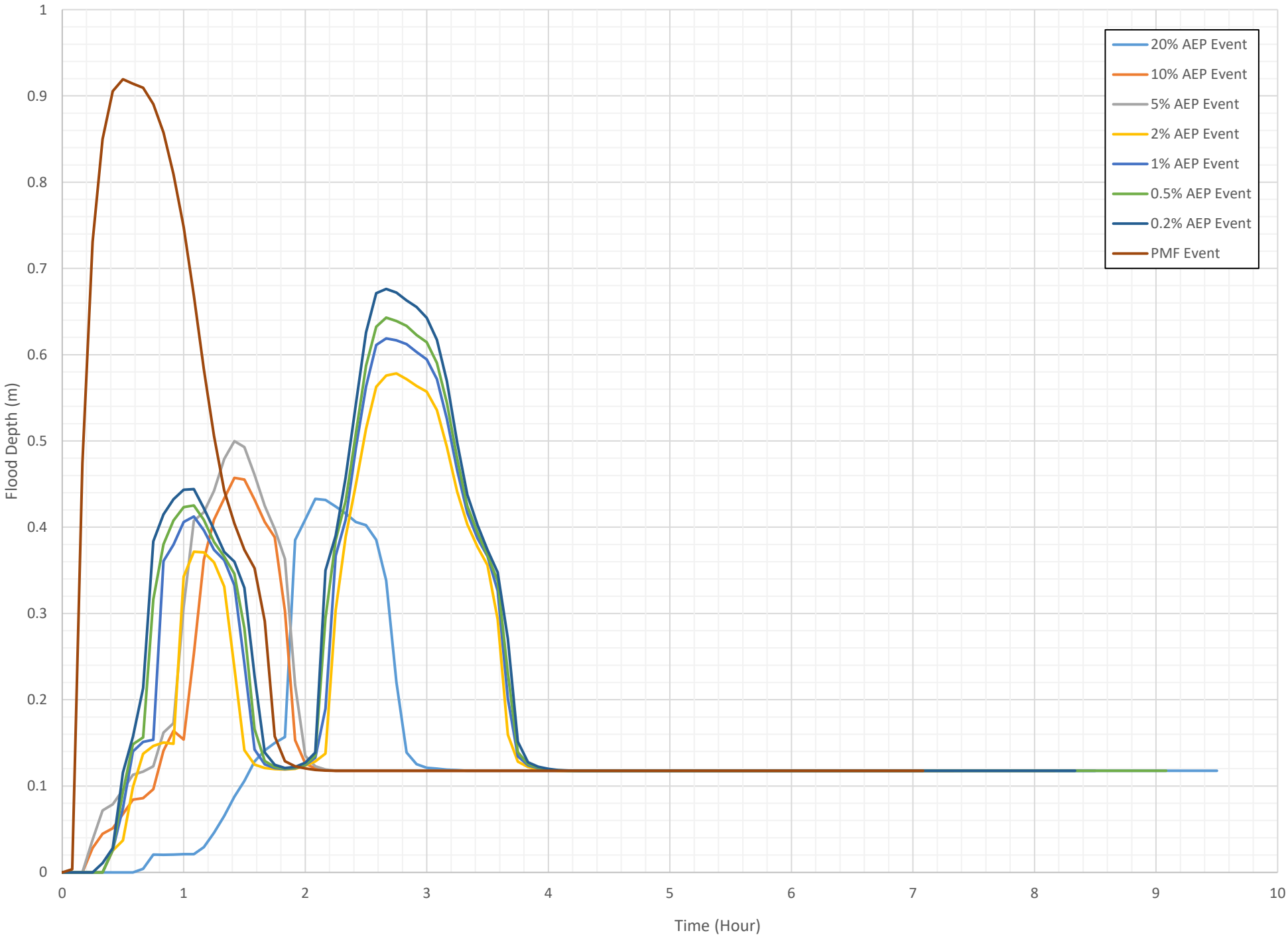
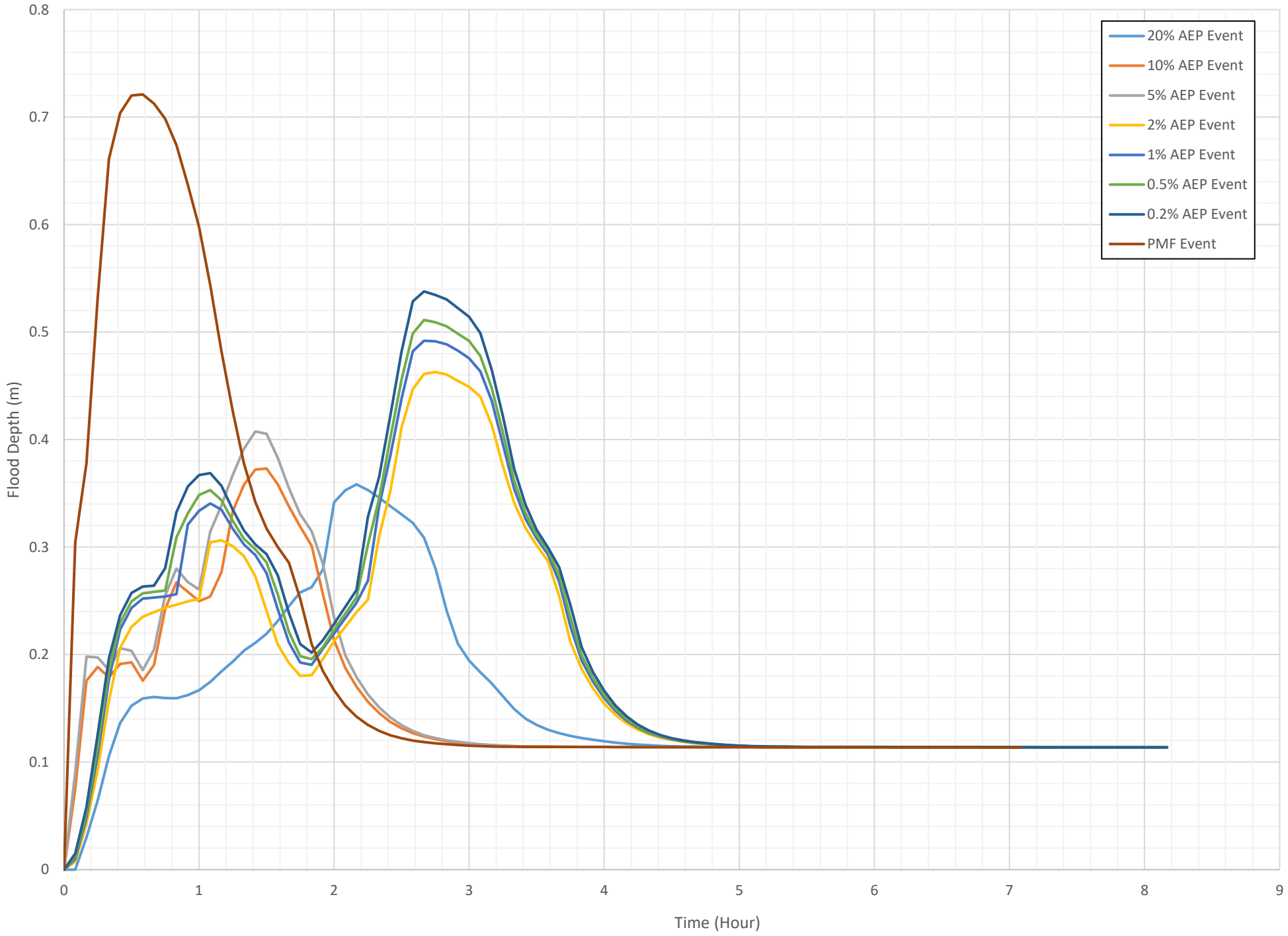


FIGURE D4
HEWITTS CREEK CATCHMENT
LOCATION 4: VIRGINIA TERRACE



HEWITTS CREEK CATCHMENT
LOCATION 5: JENNIFER CRESCENT

FIGURE D5

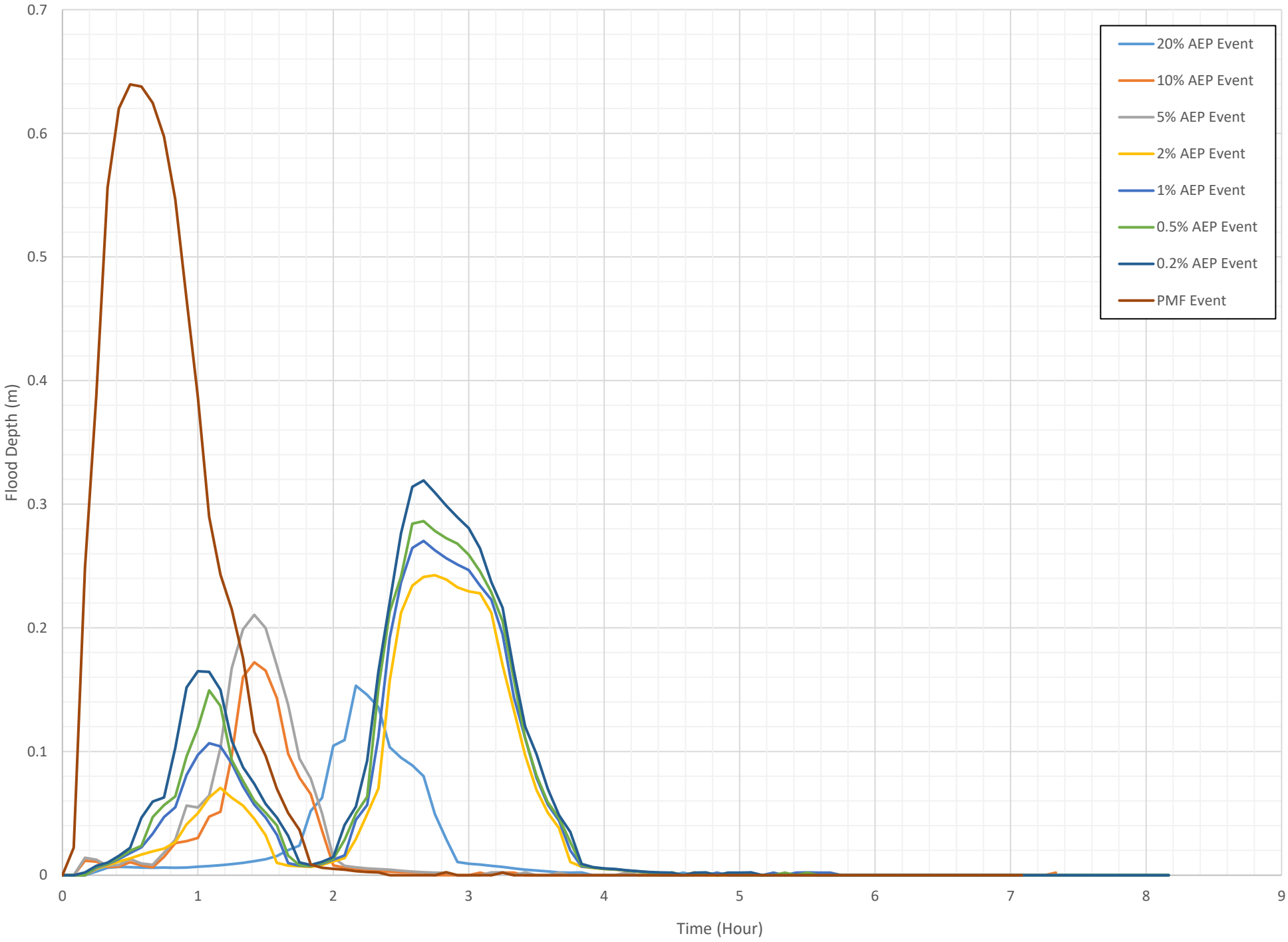


FIGURE D6
HEWITTS CREEK CATCHMENT
LOCATION 6: GEORGE STREET WEST

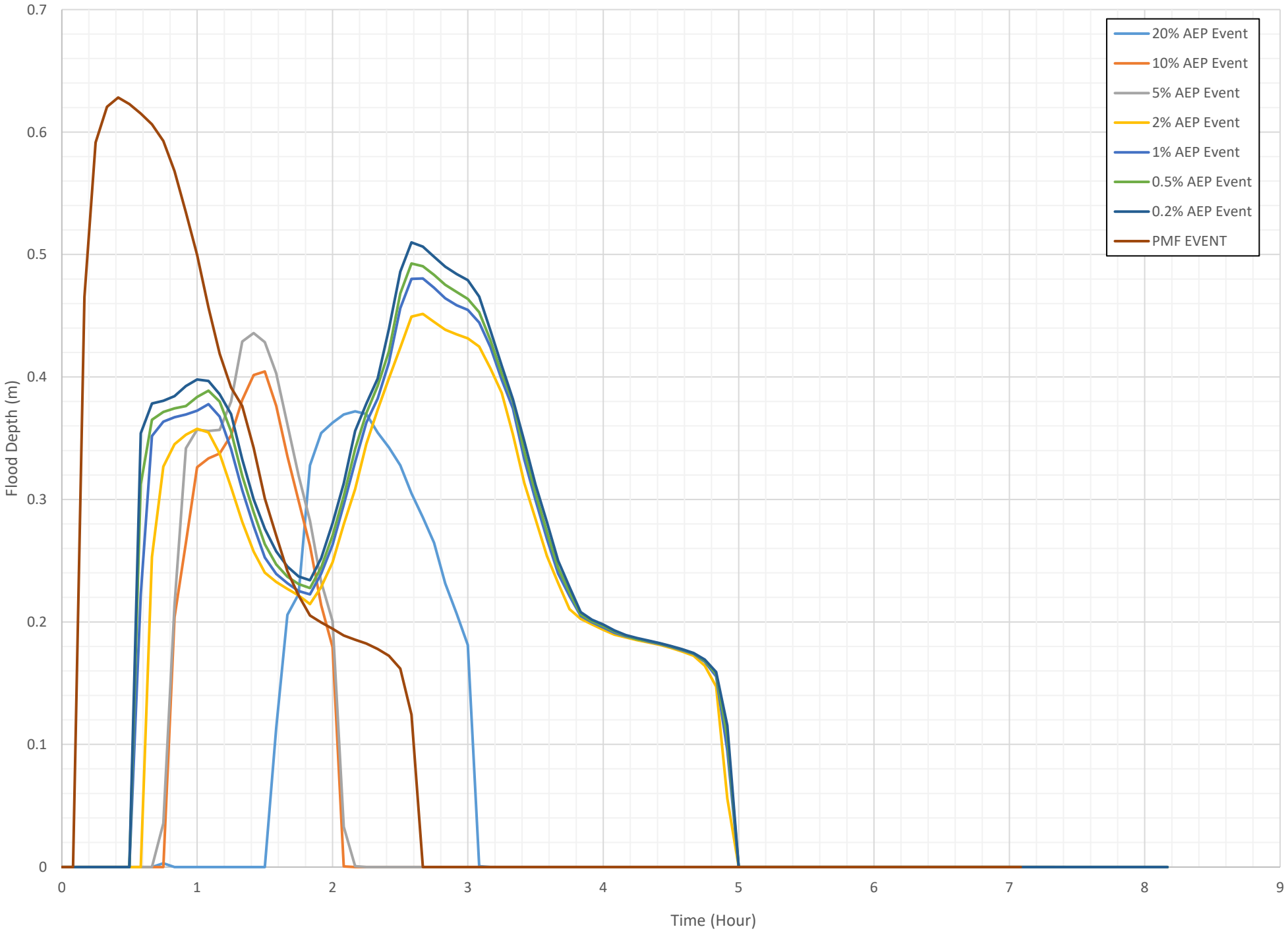


FIGURE D7
HEWITTS CREEK CATCHMENT
LOCATION 7: GEORGE STREET EAST

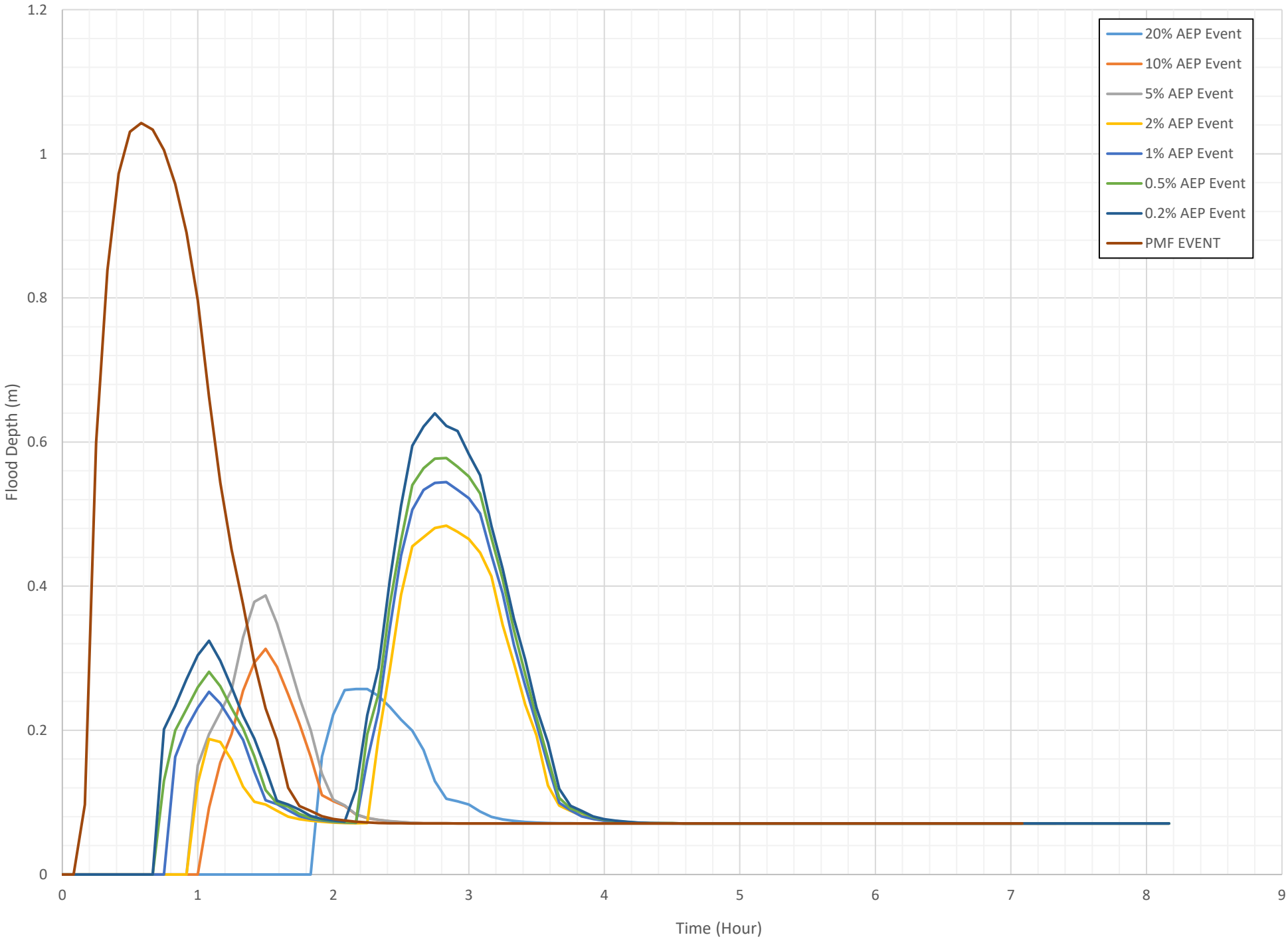


FIGURE D8
HEWITTS CREEK CATCHMENT
LOCATION 8: LACHLAN STREET @ HEWITTS CREEK

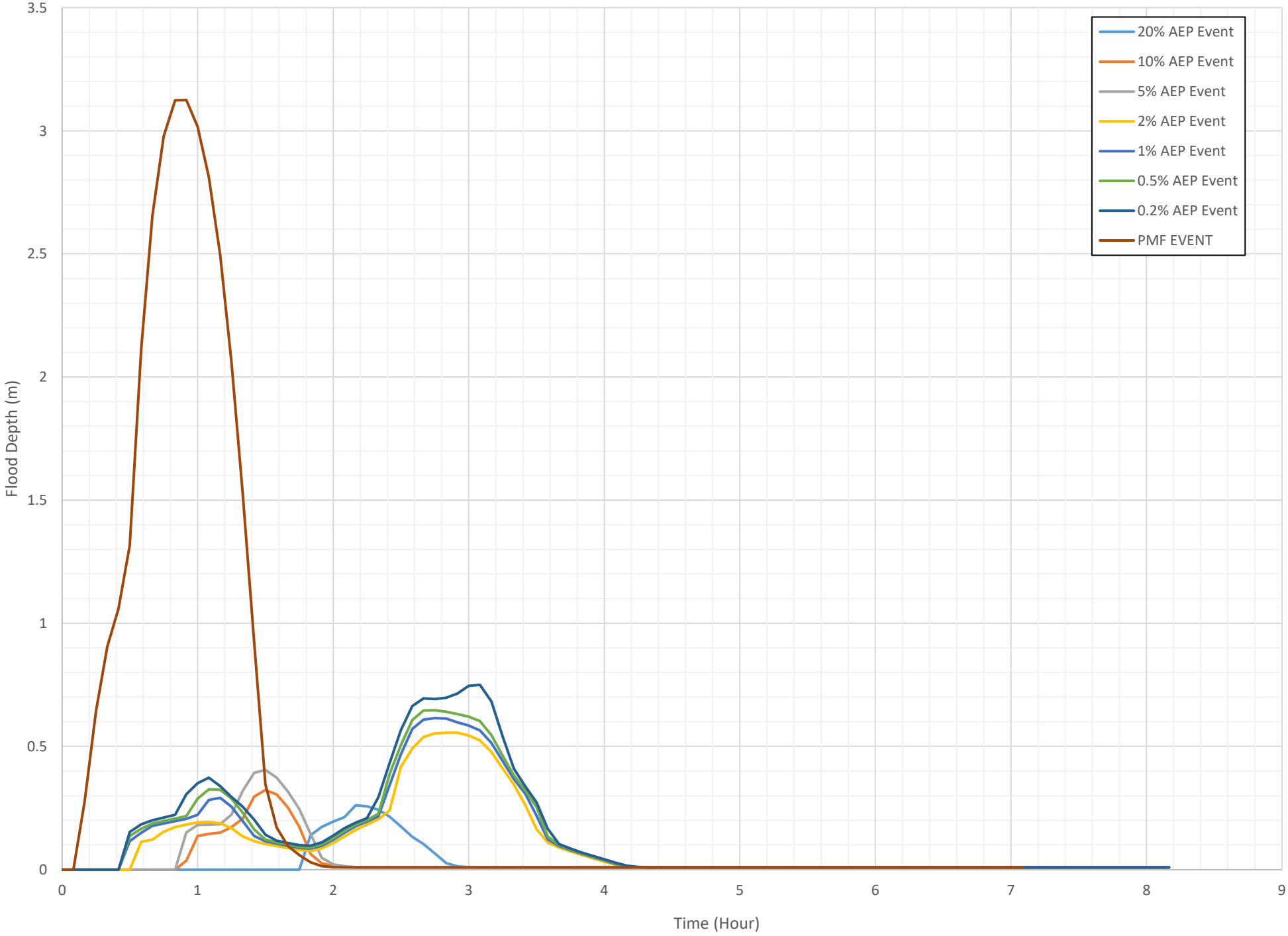


FIGURE D9
HEWITTS CREEK CATCHMENT
LOCATION 9: CORNER OF LHD AND HIGH STREET

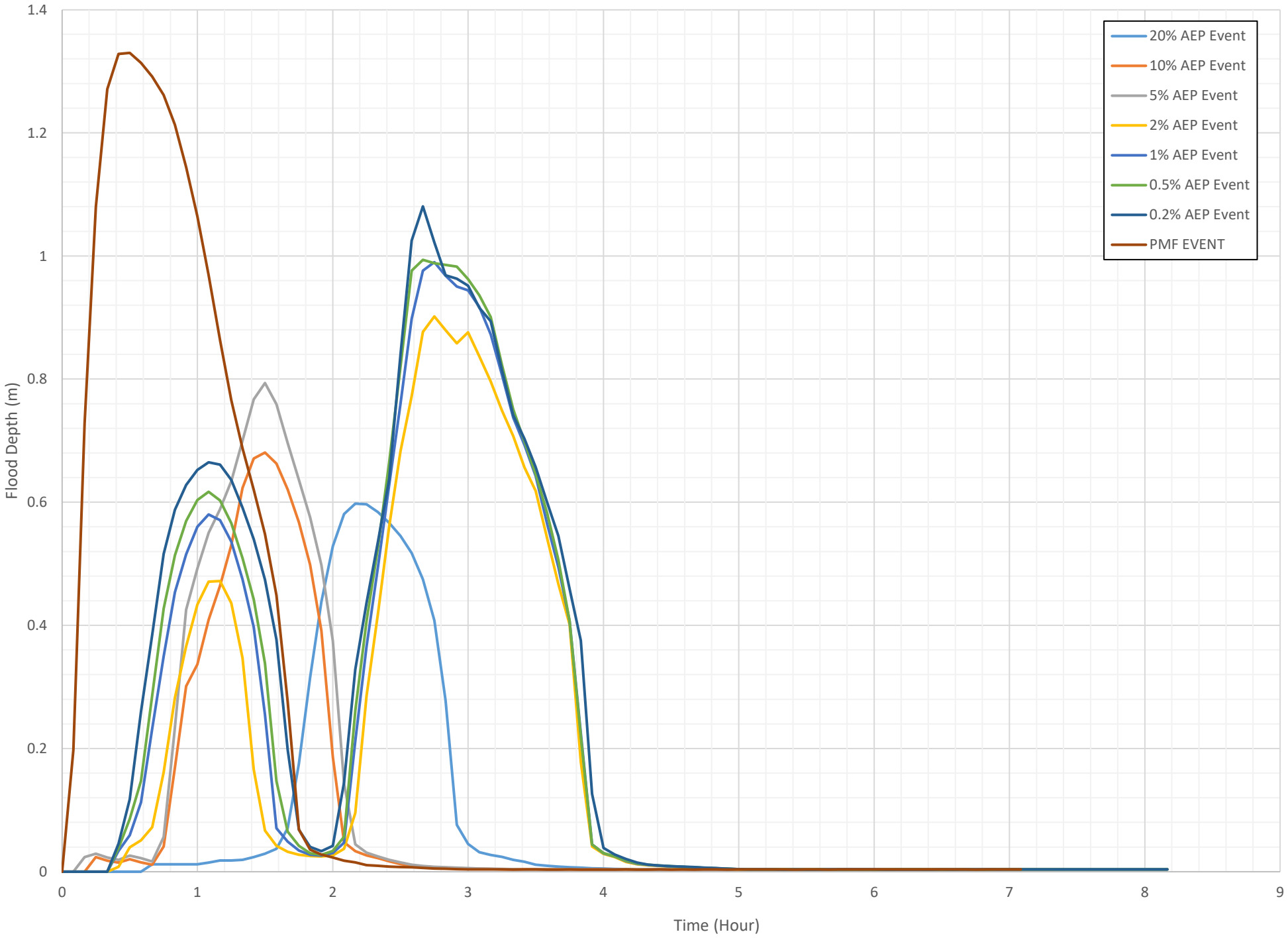


FIGURE D10
HEWITTS CREEK CATCHMENT
LOCATION 10: LHD NEAR TRAIN STATION

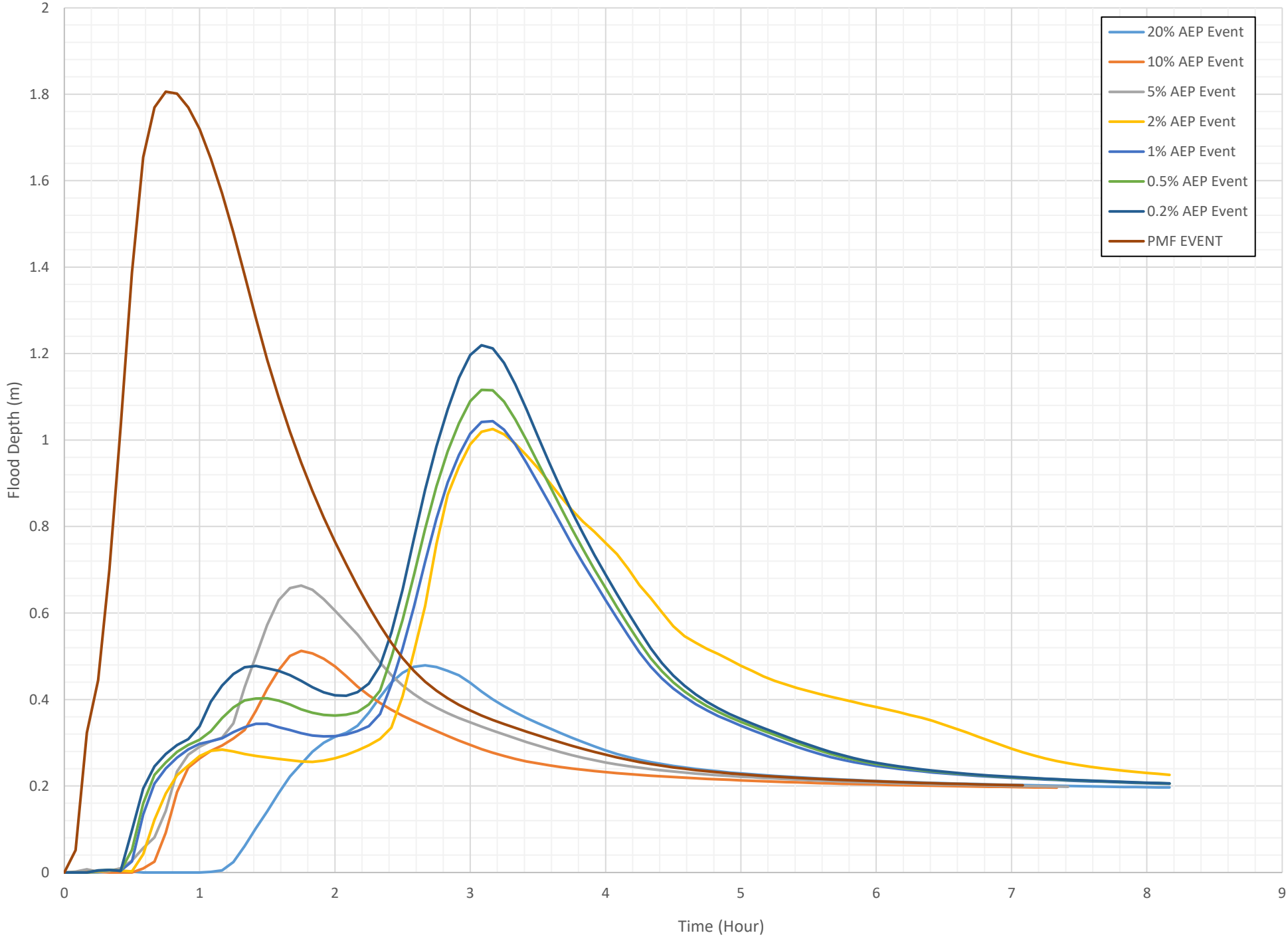


FIGURE D11
HEWITTS CREEK CATCHMENT
LOCATION 11: THE ESPLANADE

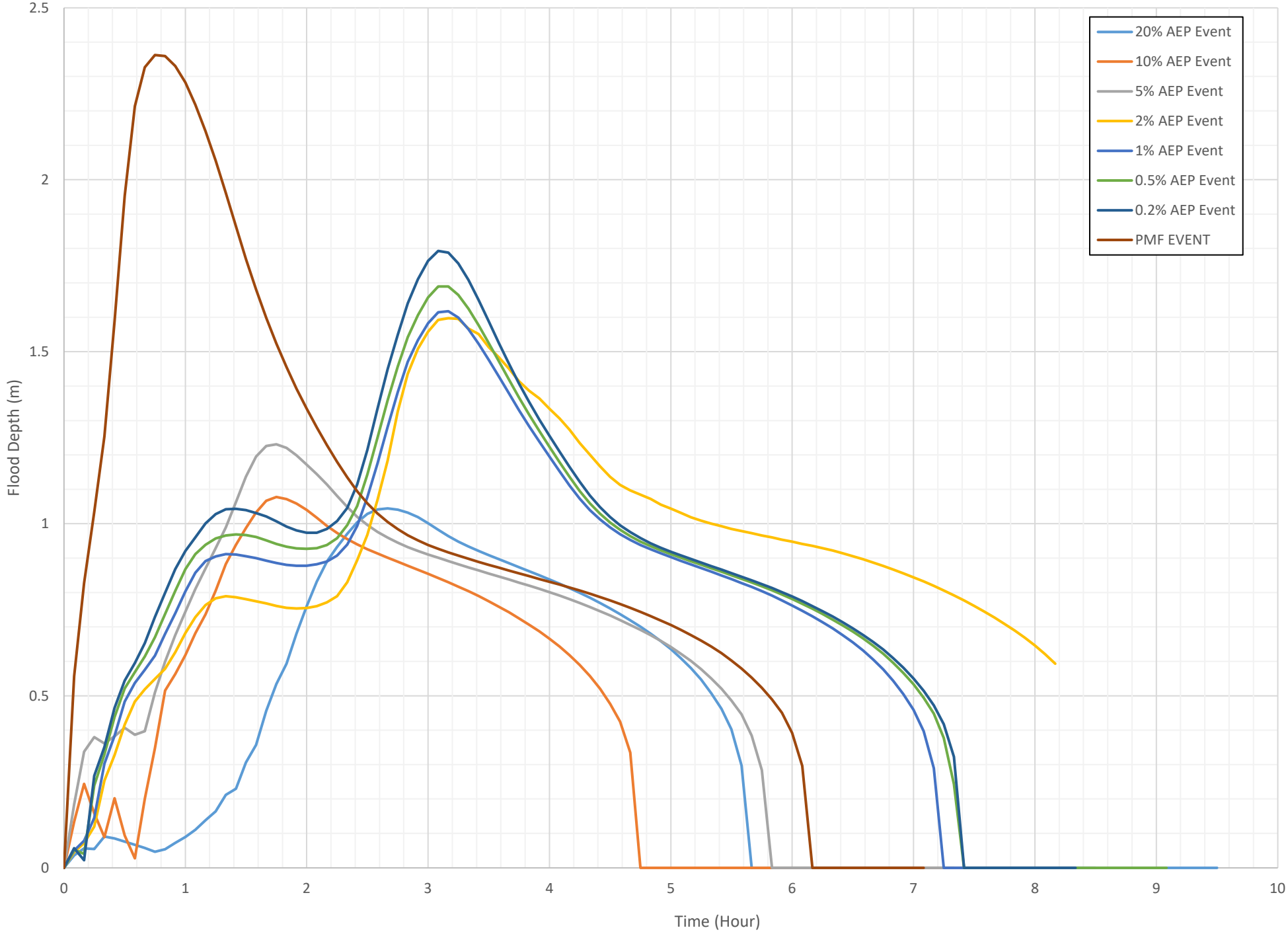


FIGURE D12
HEWITTS CREEK CATCHMENT
LOCATION 12: CLIFF PARADE

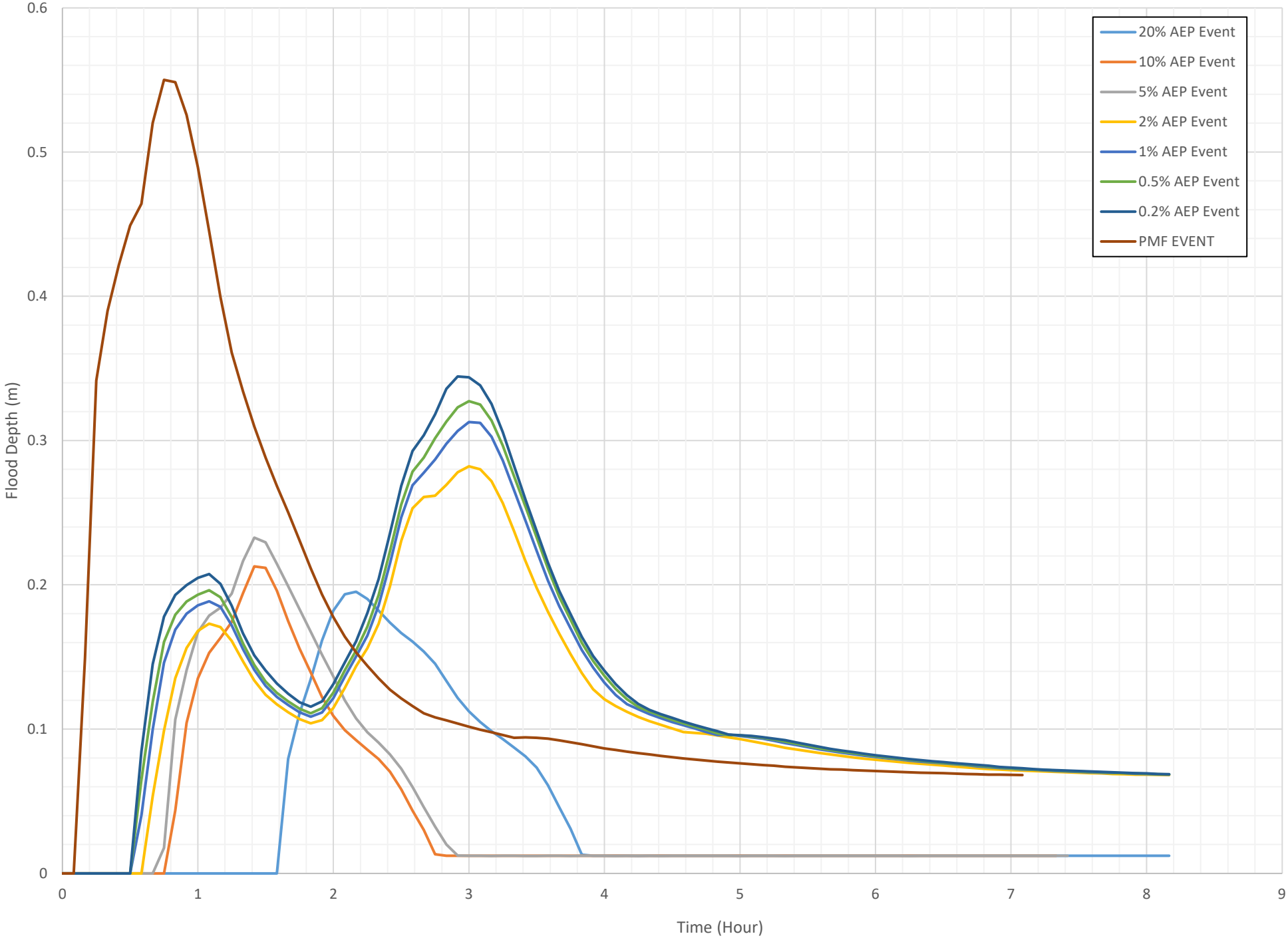


FIGURE D13
HEWITTS CREEK CATCHMENT
LOCATION 13: CLIFF PARADE @ THOMAS GIBSON CREEK

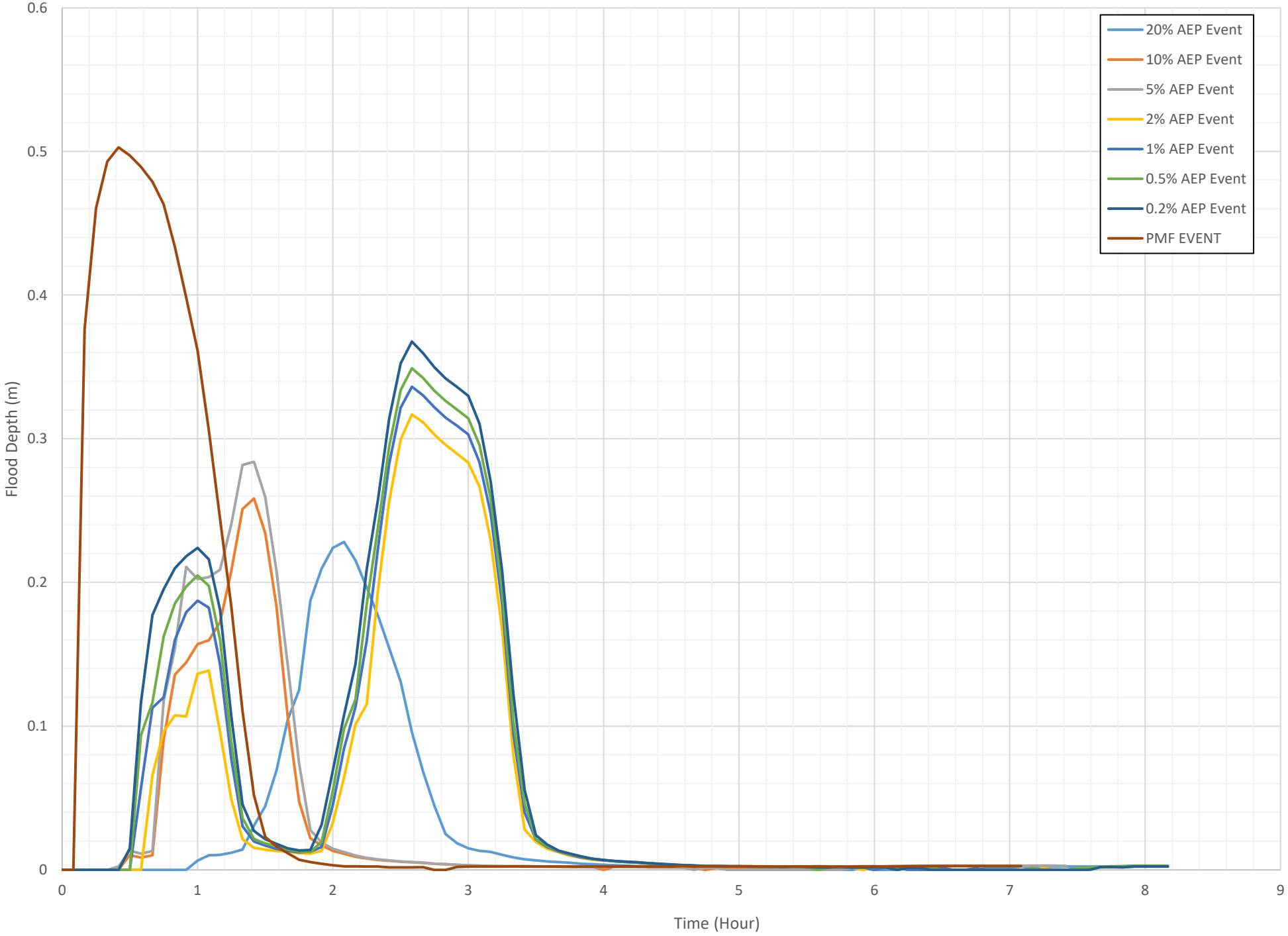


FIGURE D14
HEWITTS CREEK CATCHMENT
LOCATION 14: PASS AVENUE

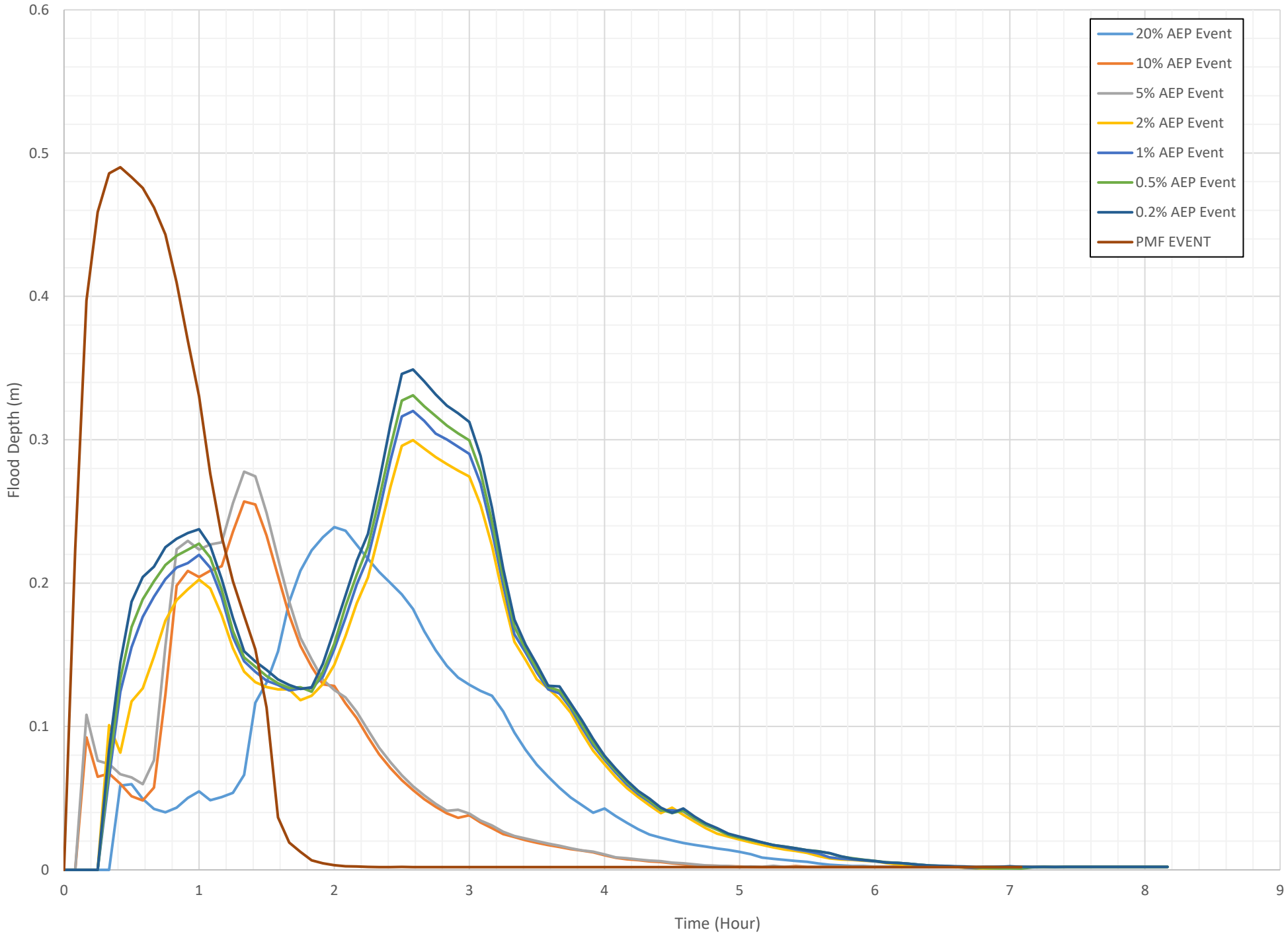


FIGURE D15
HEWITTS CREEK CATCHMENT
LOCATION 15: HIGH STREET WEST

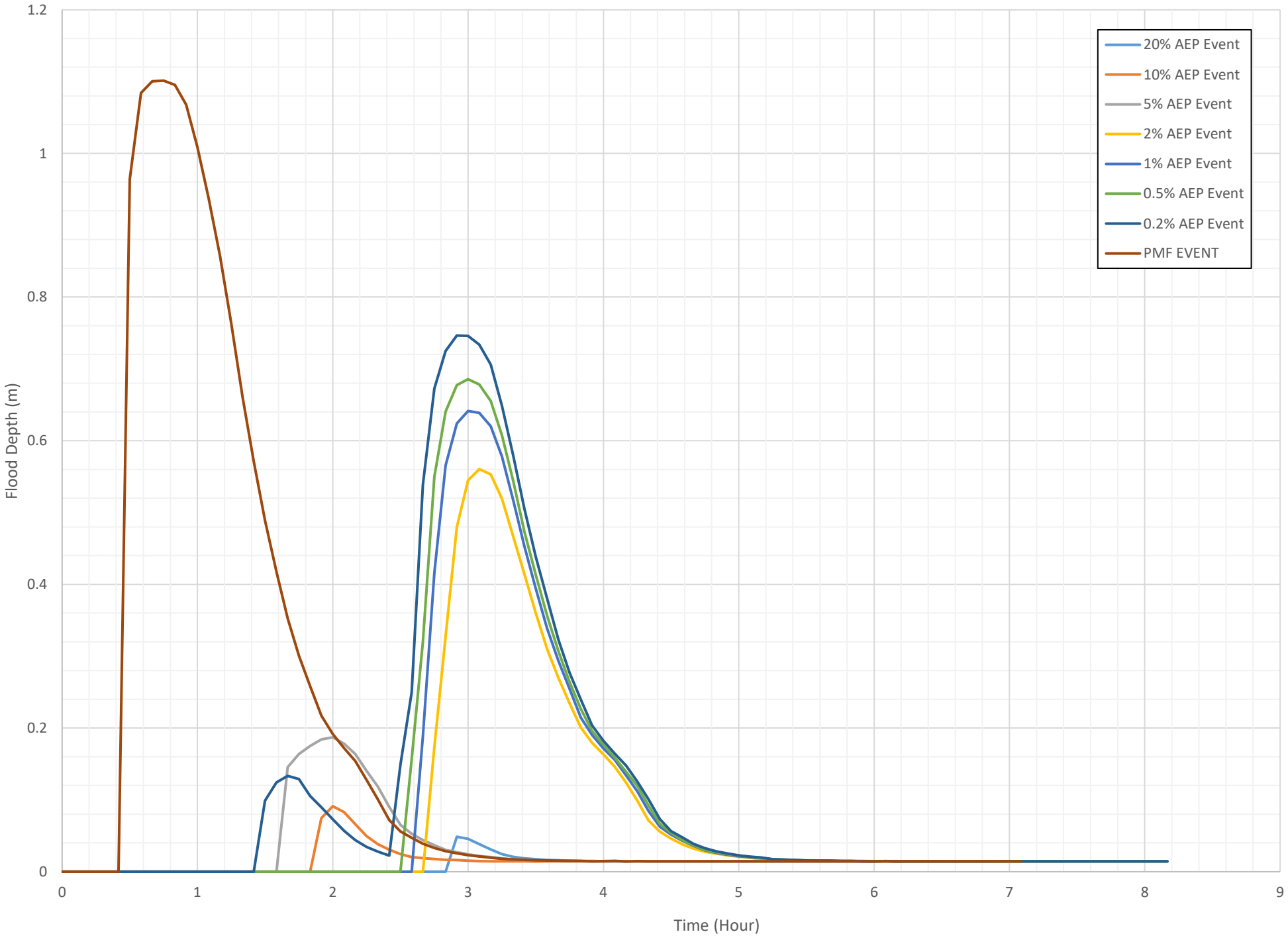


FIGURE D16
HEWITTS CREEK CATCHMENT
LOCATION 16: HEWITTS AVENUE

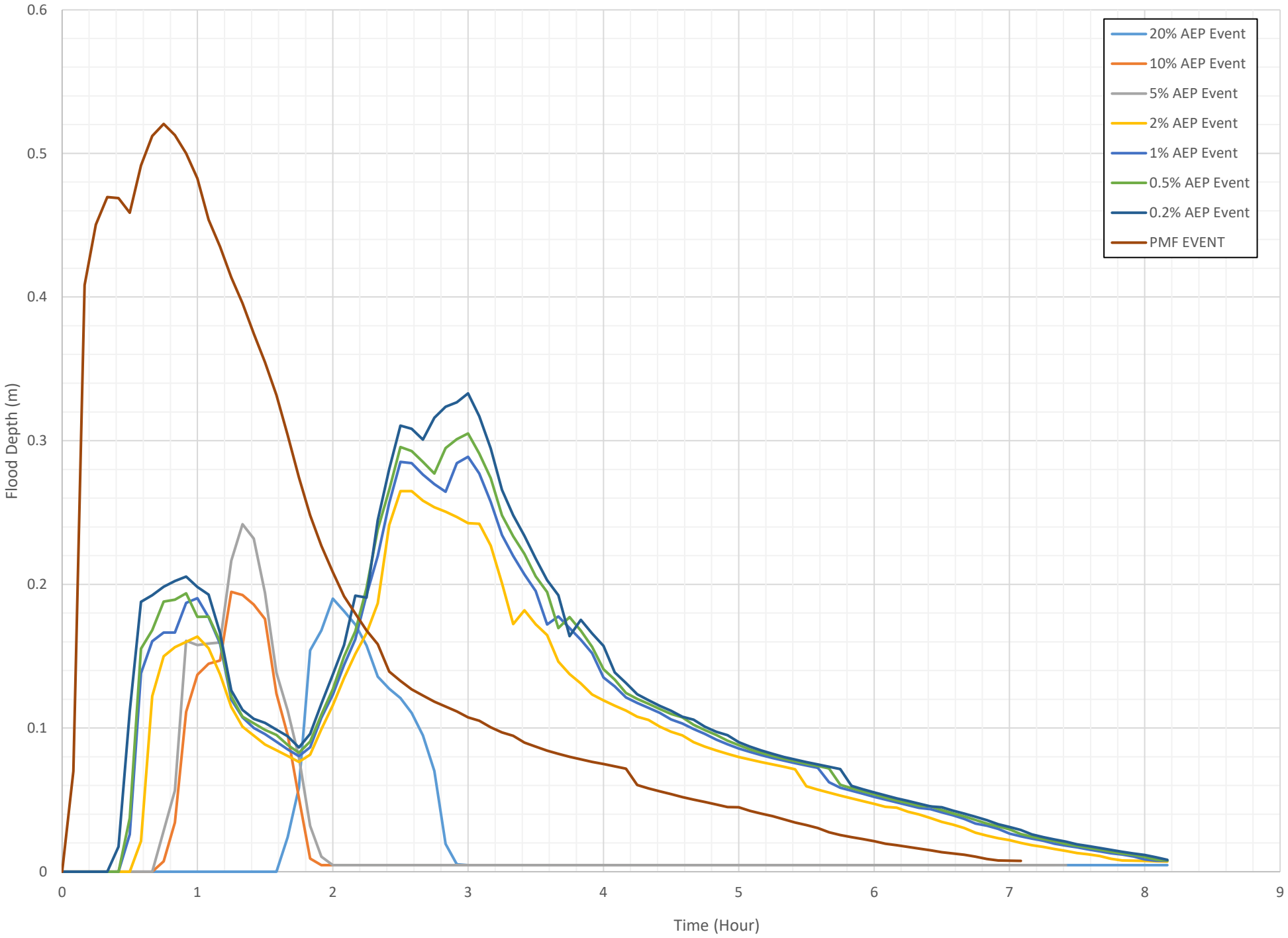


FIGURE D17
HEWITTS CREEK CATCHMENT
LOCATION 17: MCCAULEY STREET @ THOMAS GIBSON CREEK

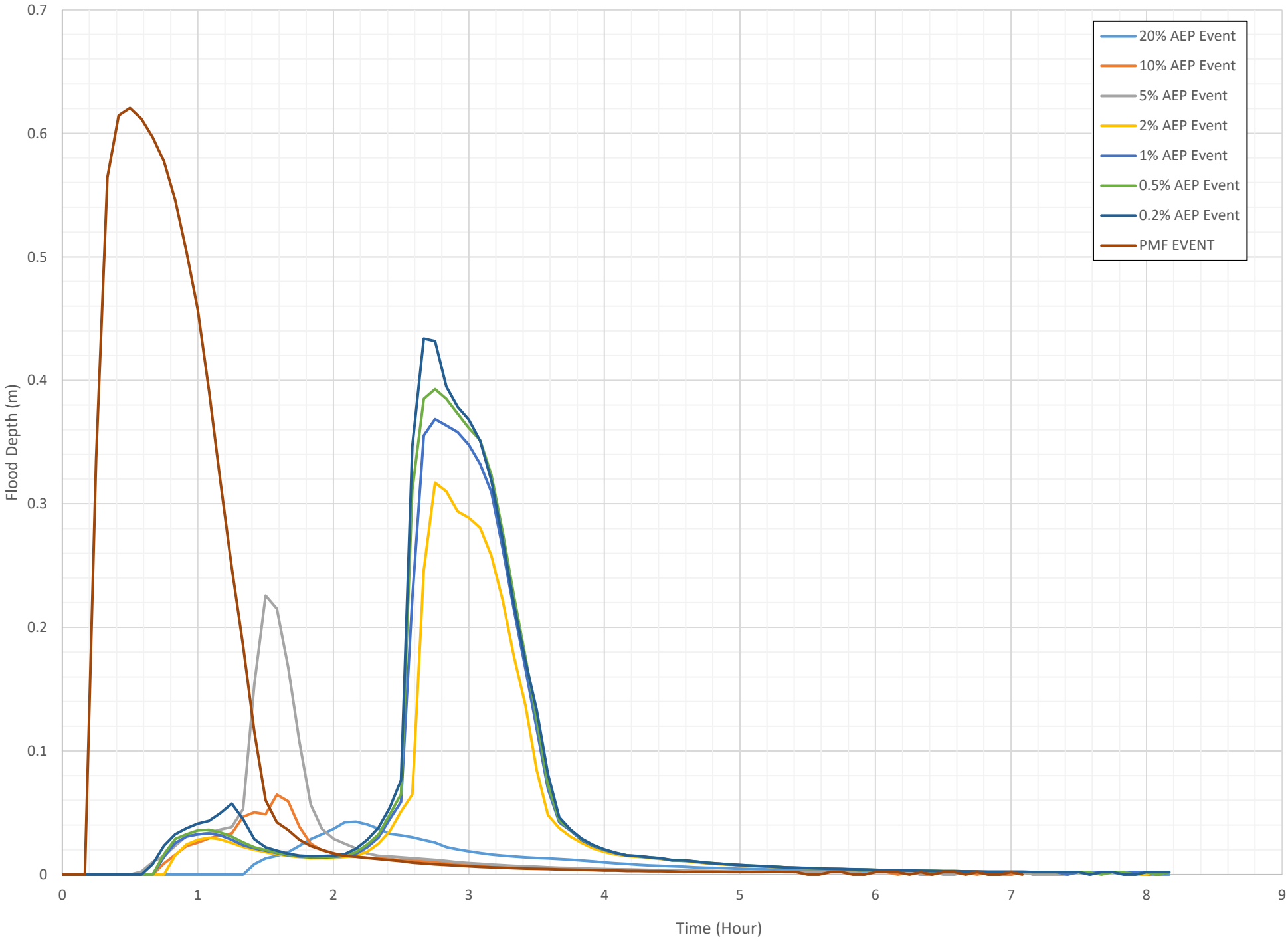


FIGURE D18
HEWITTS CREEK CATCHMENT
LOCATION 18: STATION STREET

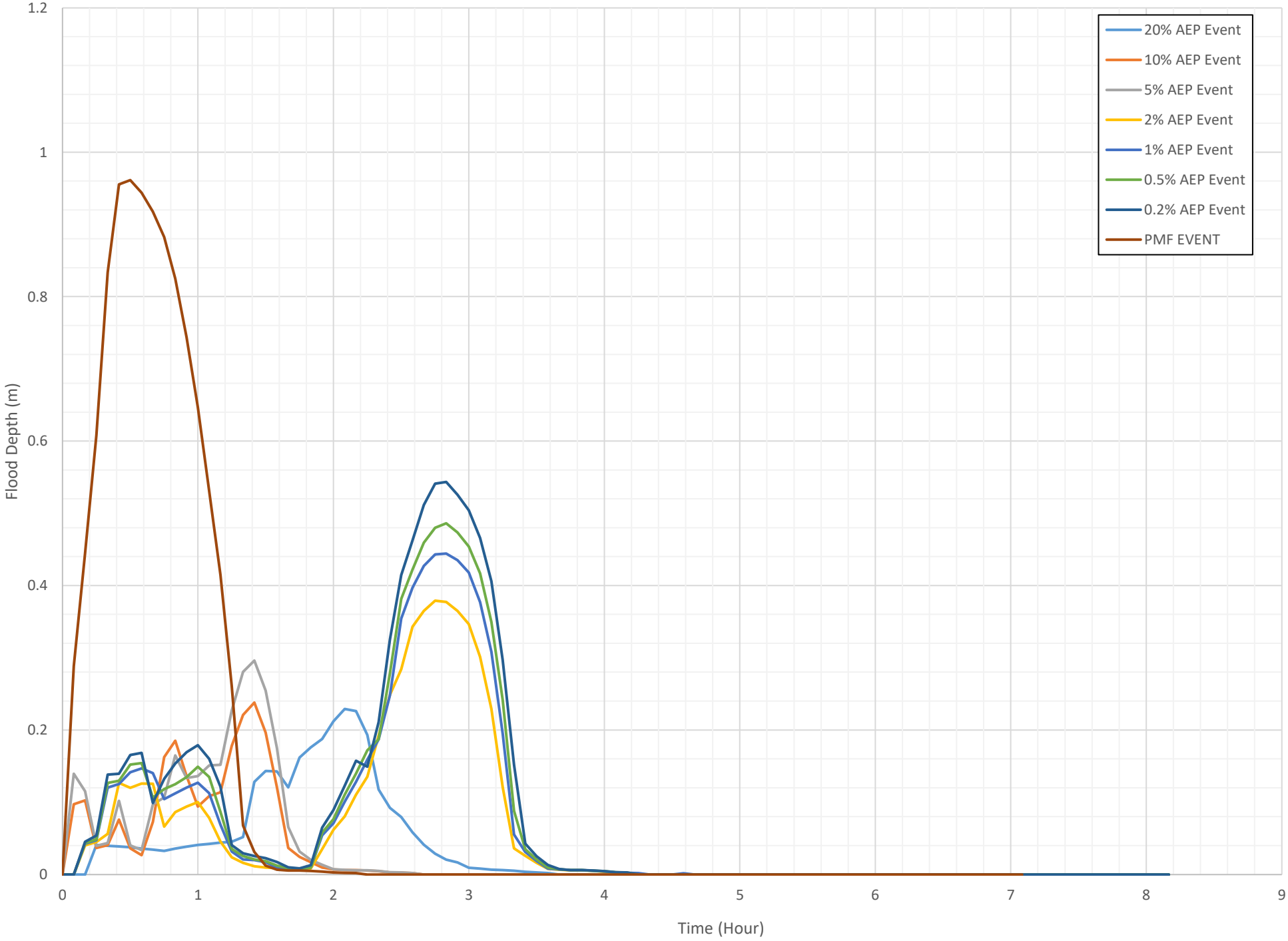


FIGURE D19
HEWITTS CREEK CATCHMENT
LOCATION 19: CORNER OF LHD

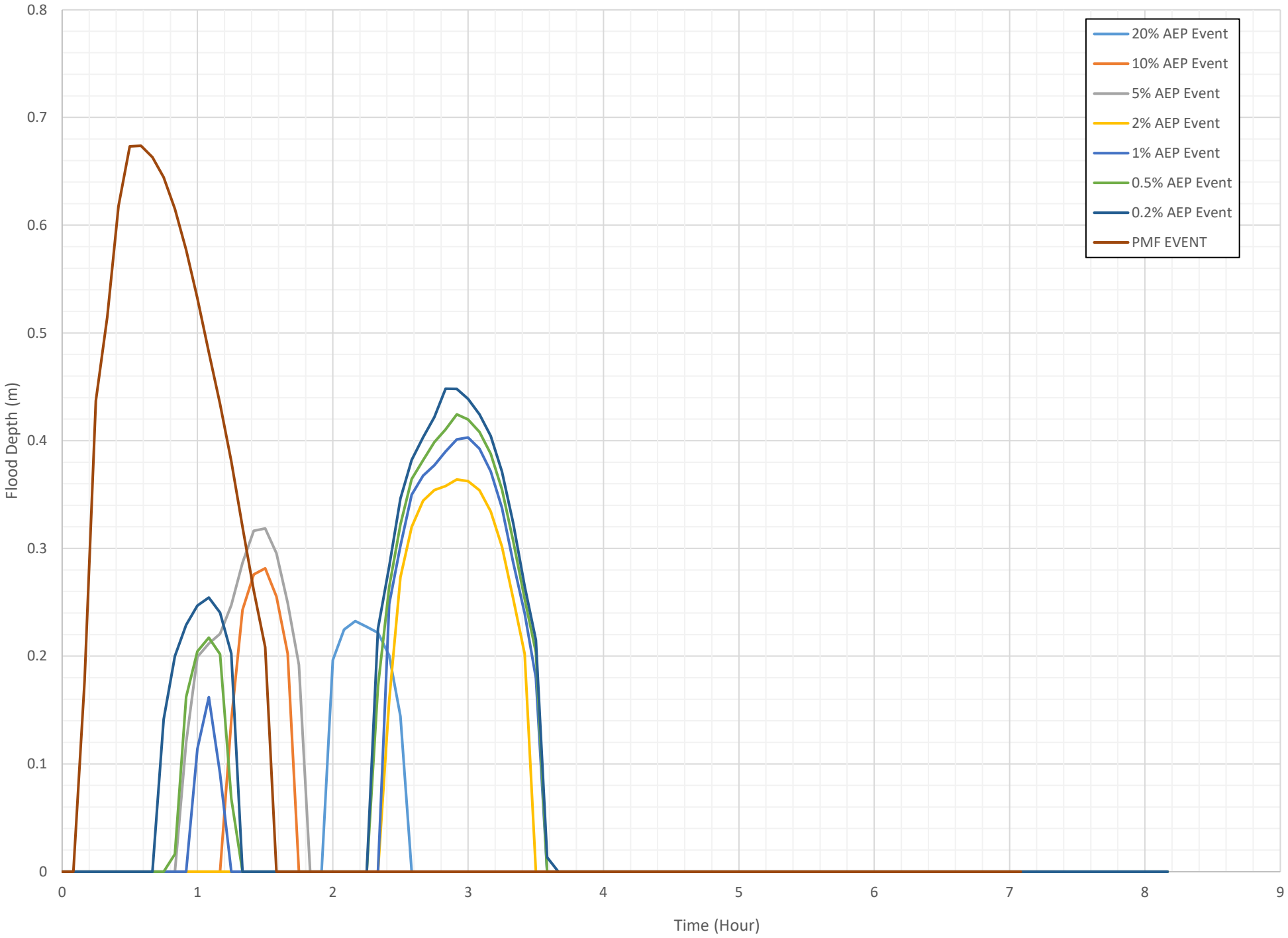


FIGURE D20
HEWITTS CREEK CATCHMENT
LOCATION 20: MCCAULEY STREET

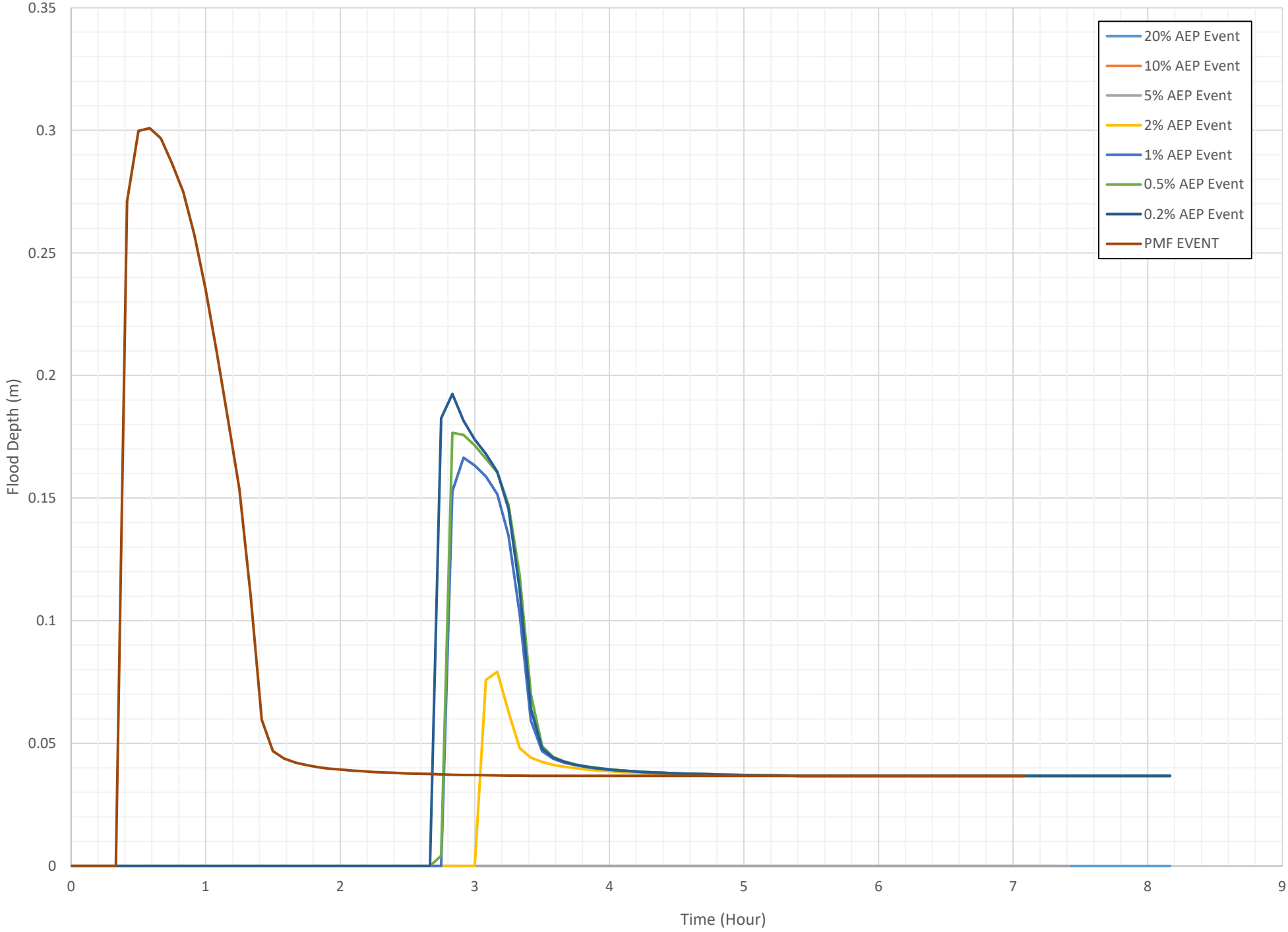


FIGURE D21
HEWITTS CREEK CATCHMENT
LOCATION 21: RAYMOND ROAD

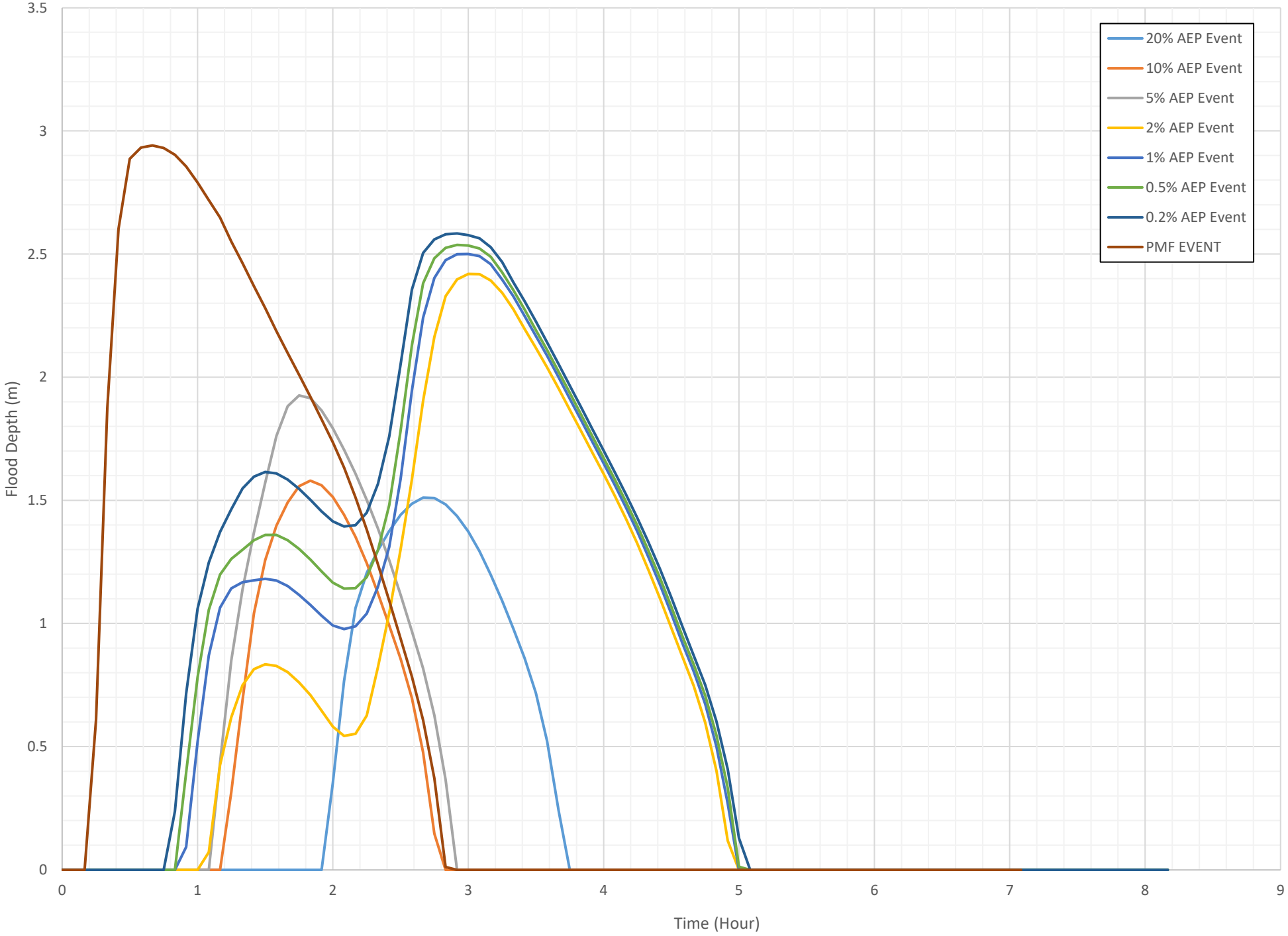


FIGURE D22
HEWITTS CREEK CATCHMENT
LOCATION 22: LHD @ WOODLAND CREEK

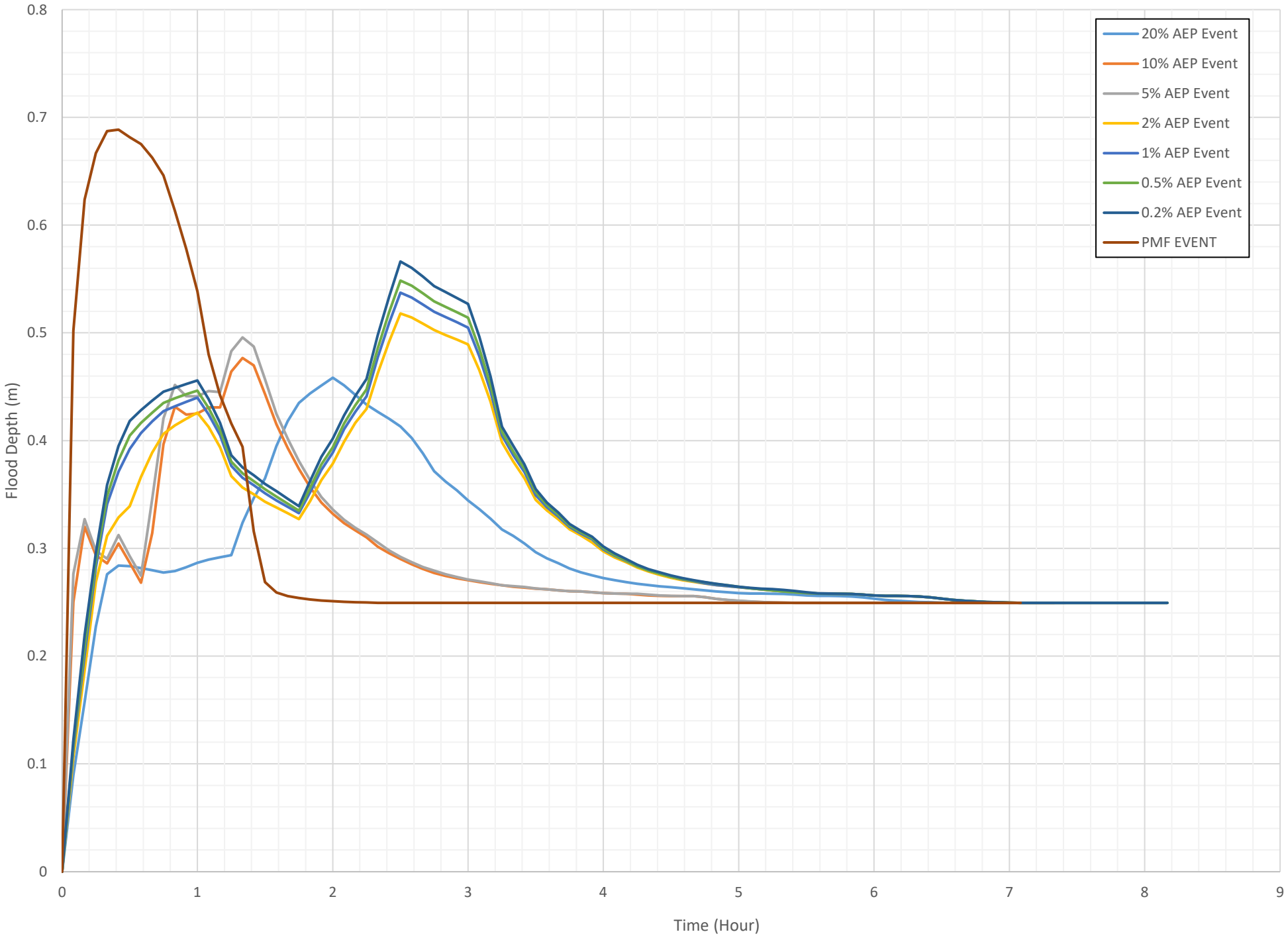
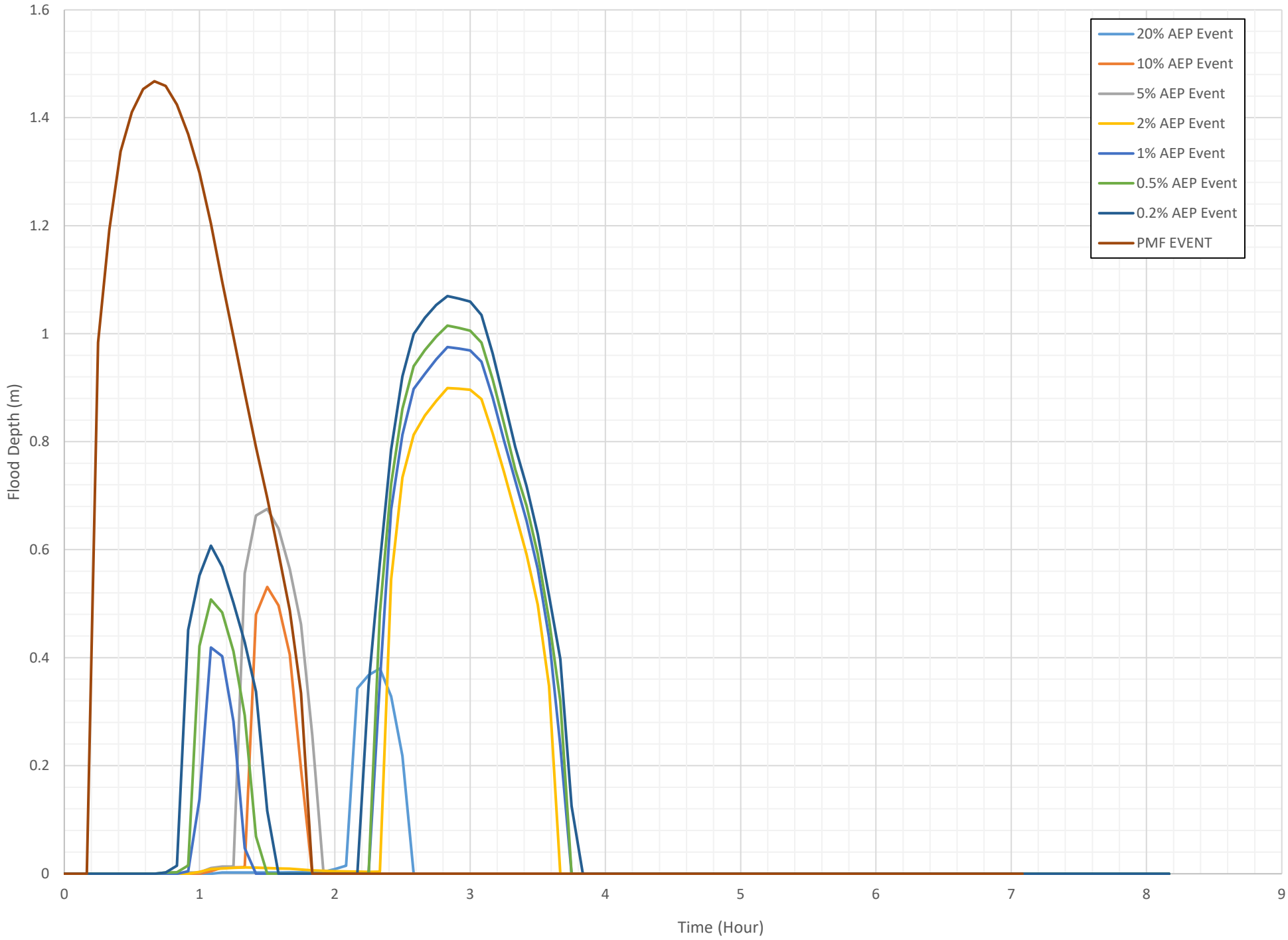


FIGURE D23
HEWITTS CREEK CATCHMENT
LOCATION 23: NATIONAL AVENUE



HEWITTS CREEK CATCHMENT
LOCATION 24: WILLIAM STREET

FIGURE D24

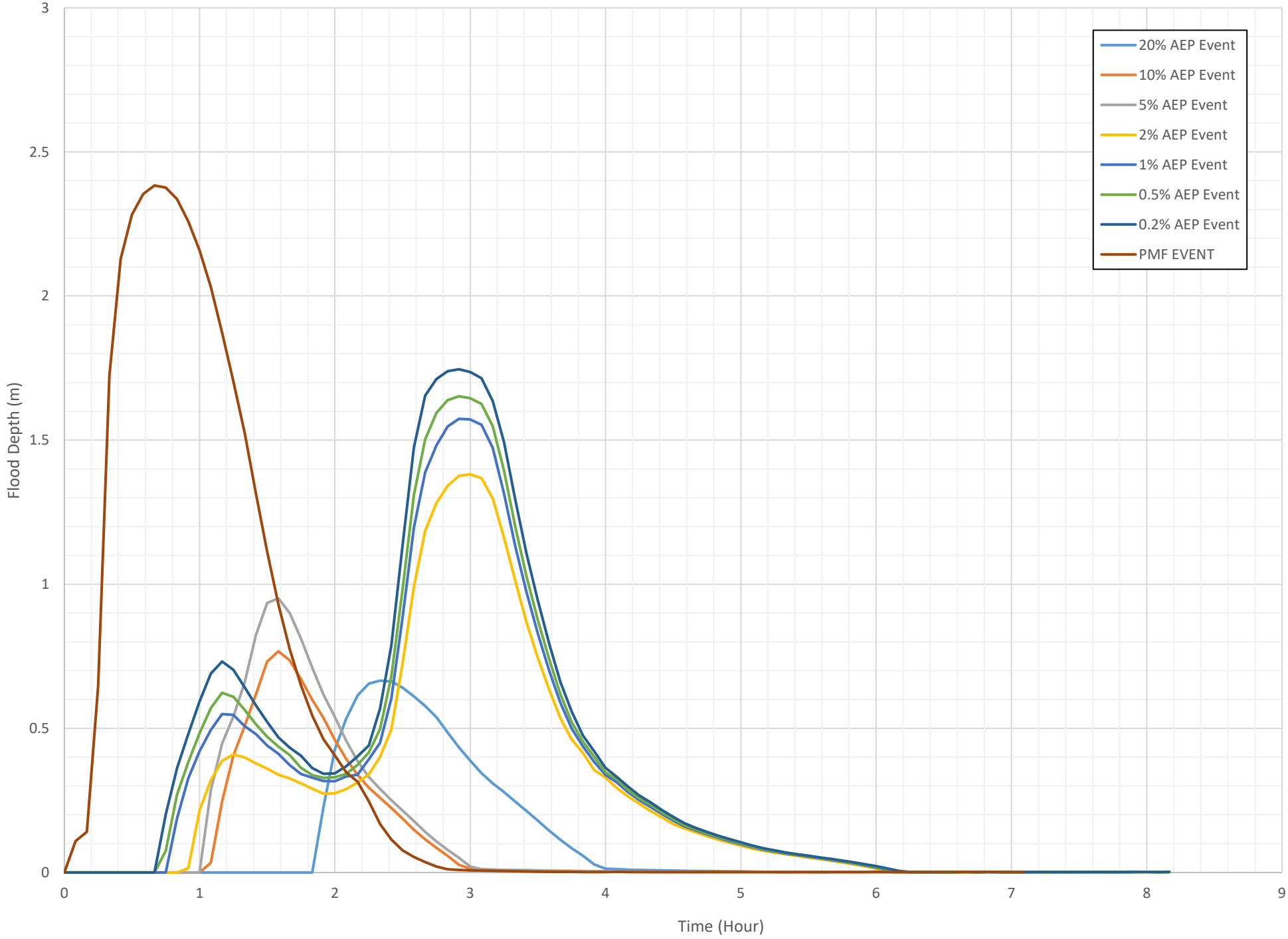
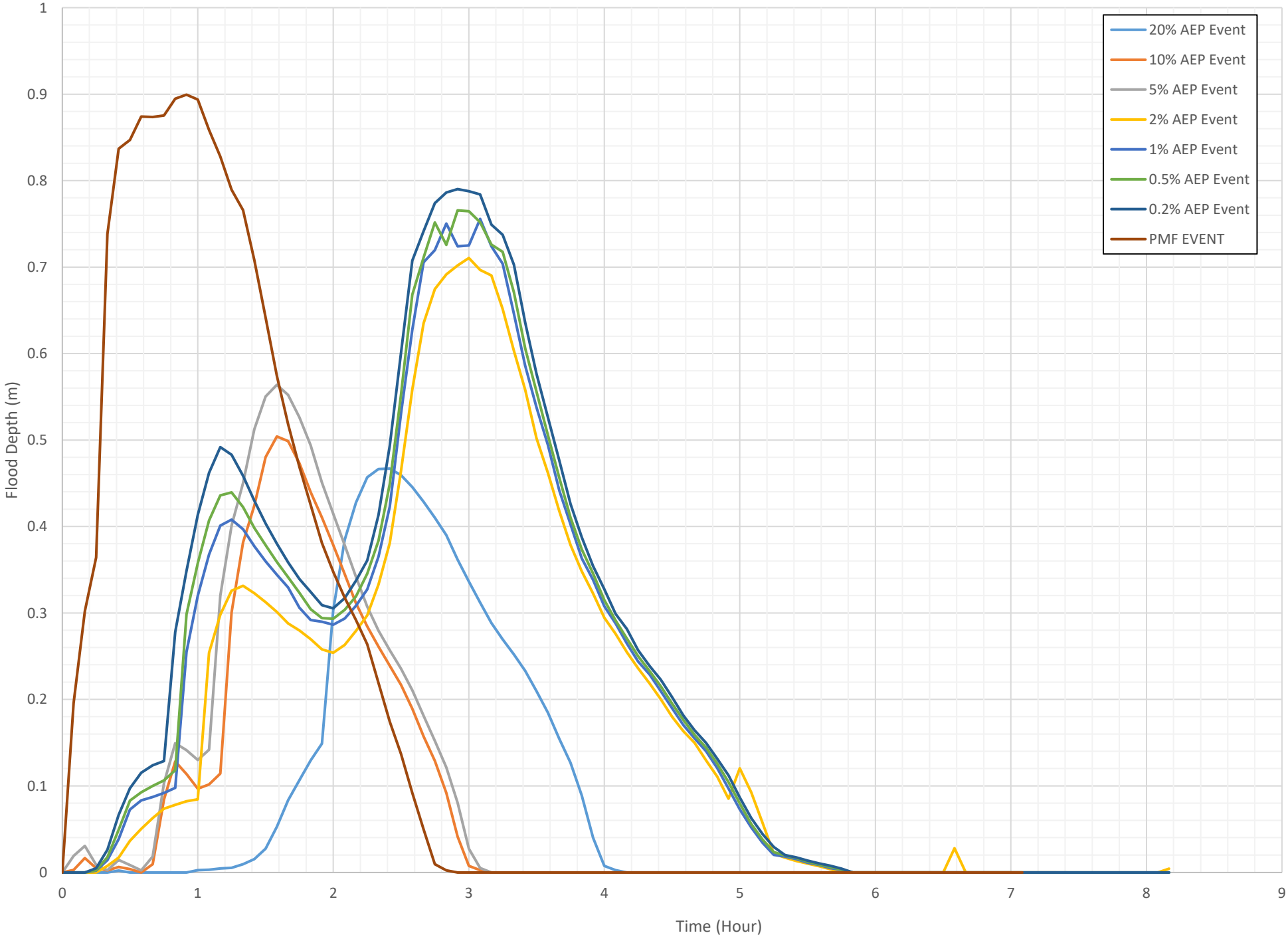


FIGURE D25
HEWITTS CREEK CATCHMENT
LOCATION 25: HOBART STREET



LOCATION 26: CORNER OF PRICESS HIGHWAY AND HOBART STREET

HEWITTS CREEK CATCHMENT

FIGURE D26

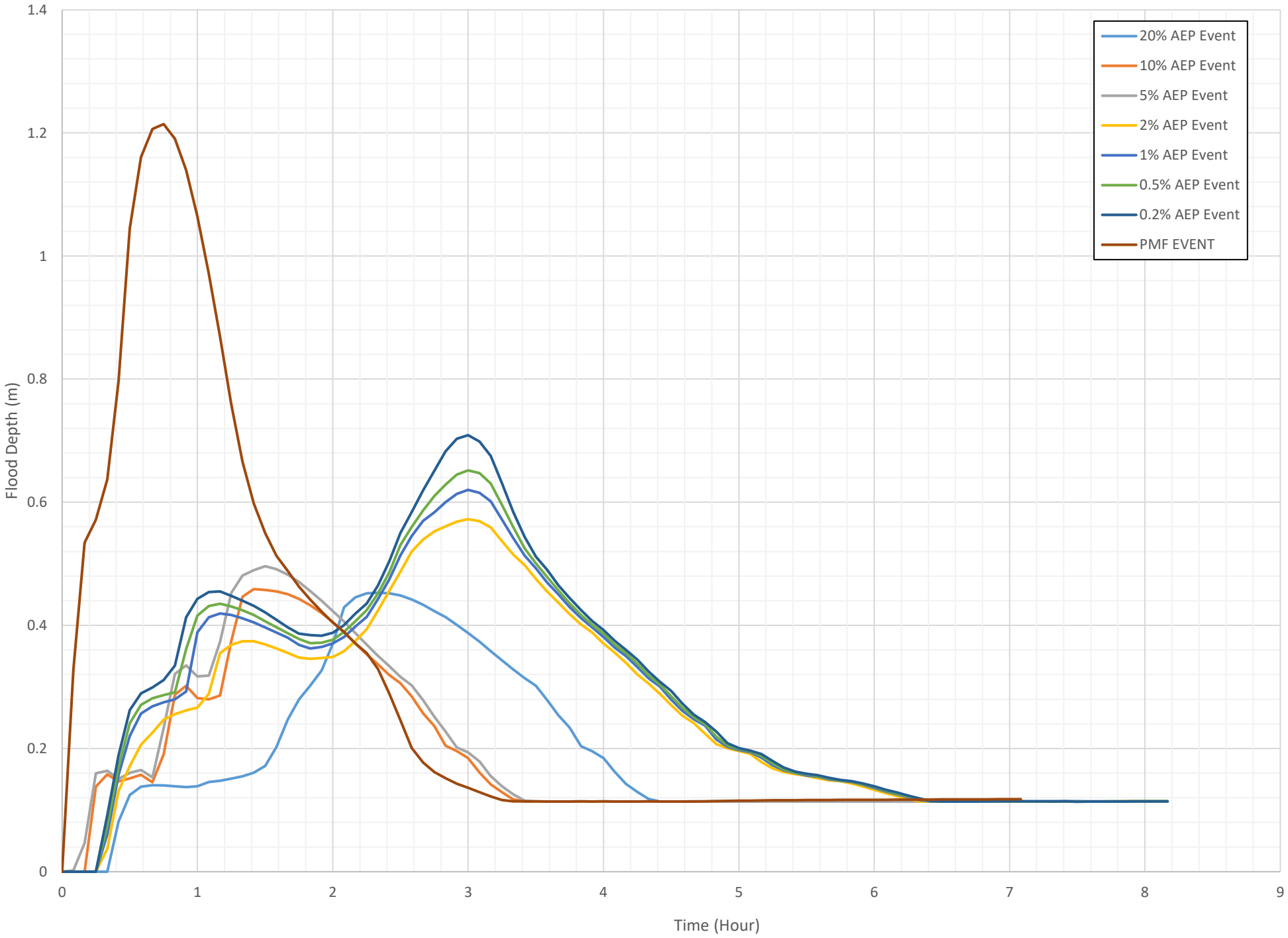


FIGURE D27
HEWITTS CREEK CATCHMENT
LOCATION 27: PRINCESS HIGHWAY 1

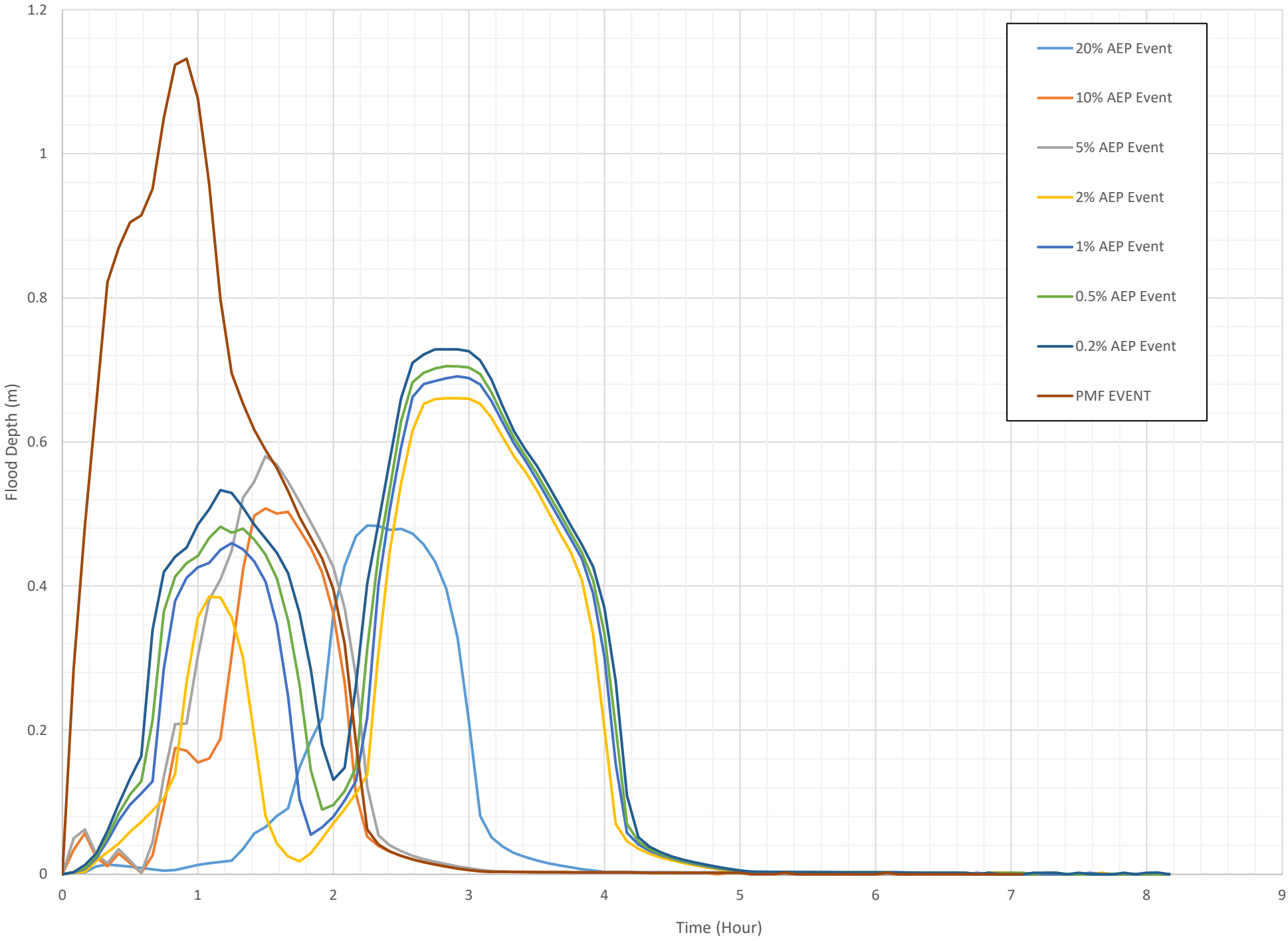


FIGURE D28
HEWITTS CREEK CATCHMENT
LOCATION 28: CORNER OF PRINCESS HIGHWAY AND BLACK DIAMOND PLACE

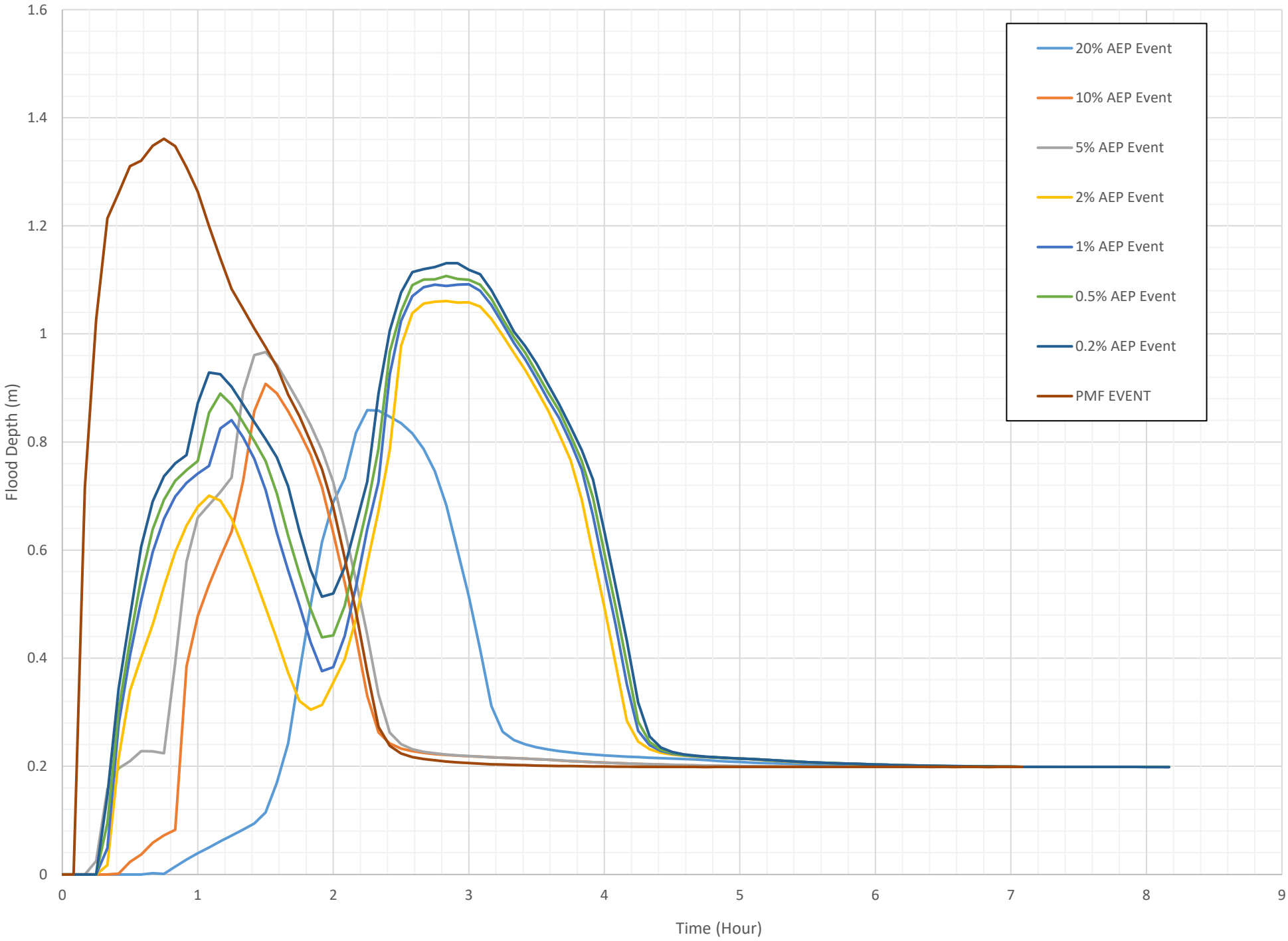


FIGURE D29
HEWITTS CREEK CATCHMENT
LOCATION 29: CREVILLIA PARK ROAD

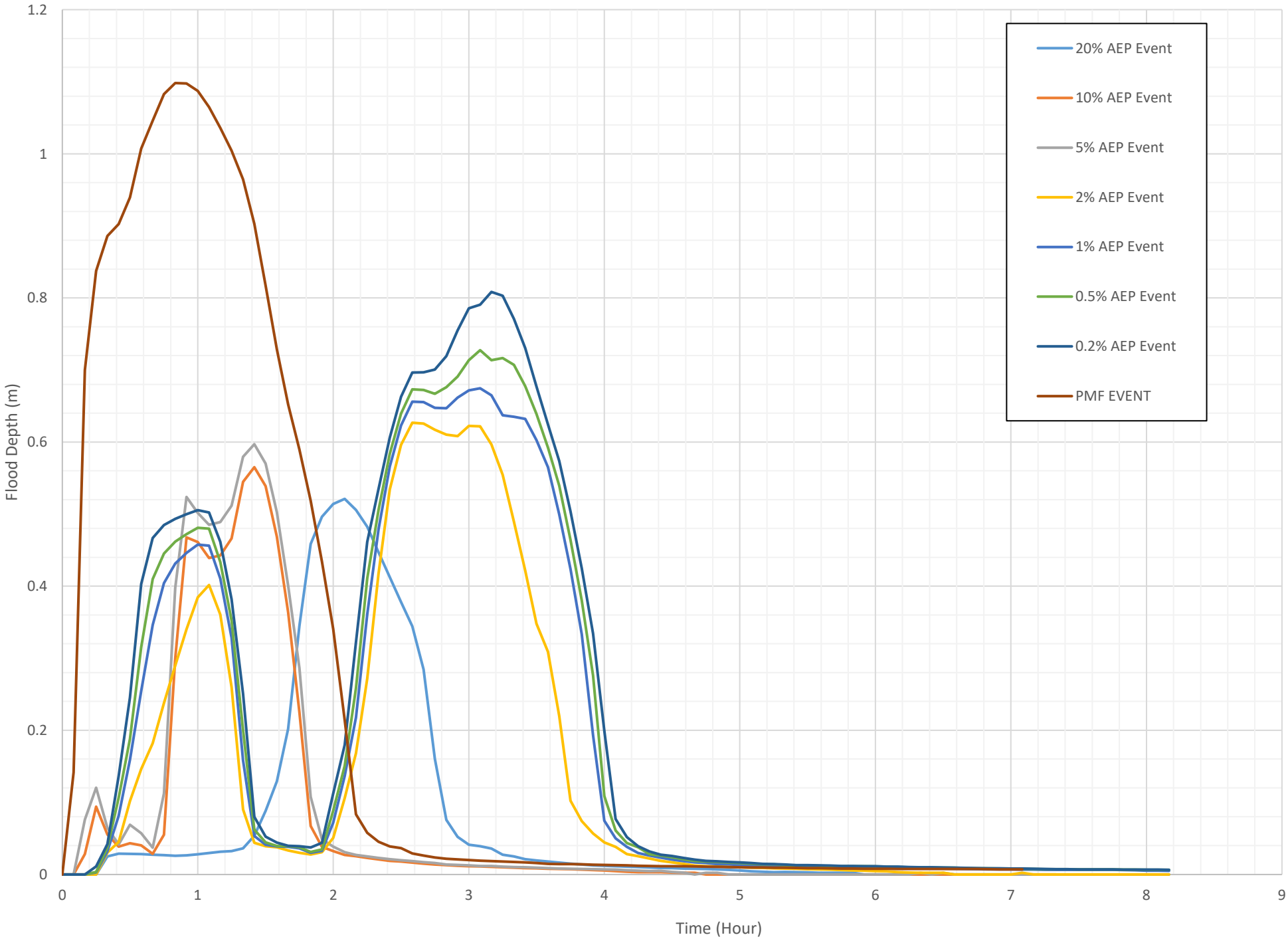


FIGURE D30
HEWITTS CREEK CATCHMENT
LOCATION 30: BEACON AVENUE EAST END

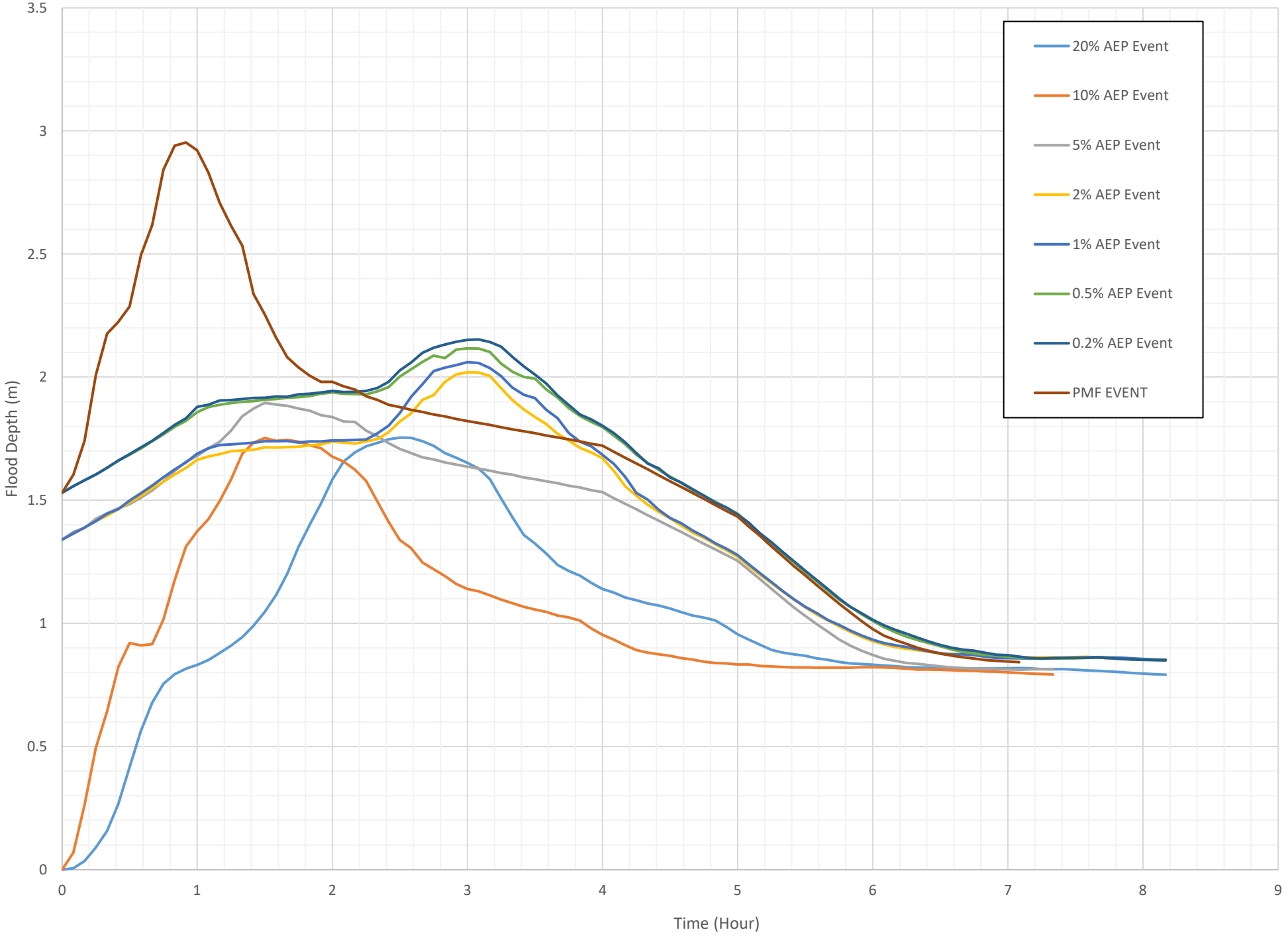


FIGURE D31
HEWITTS CREEK CATCHMENT
LOCATION 31: BLACKALL STREET

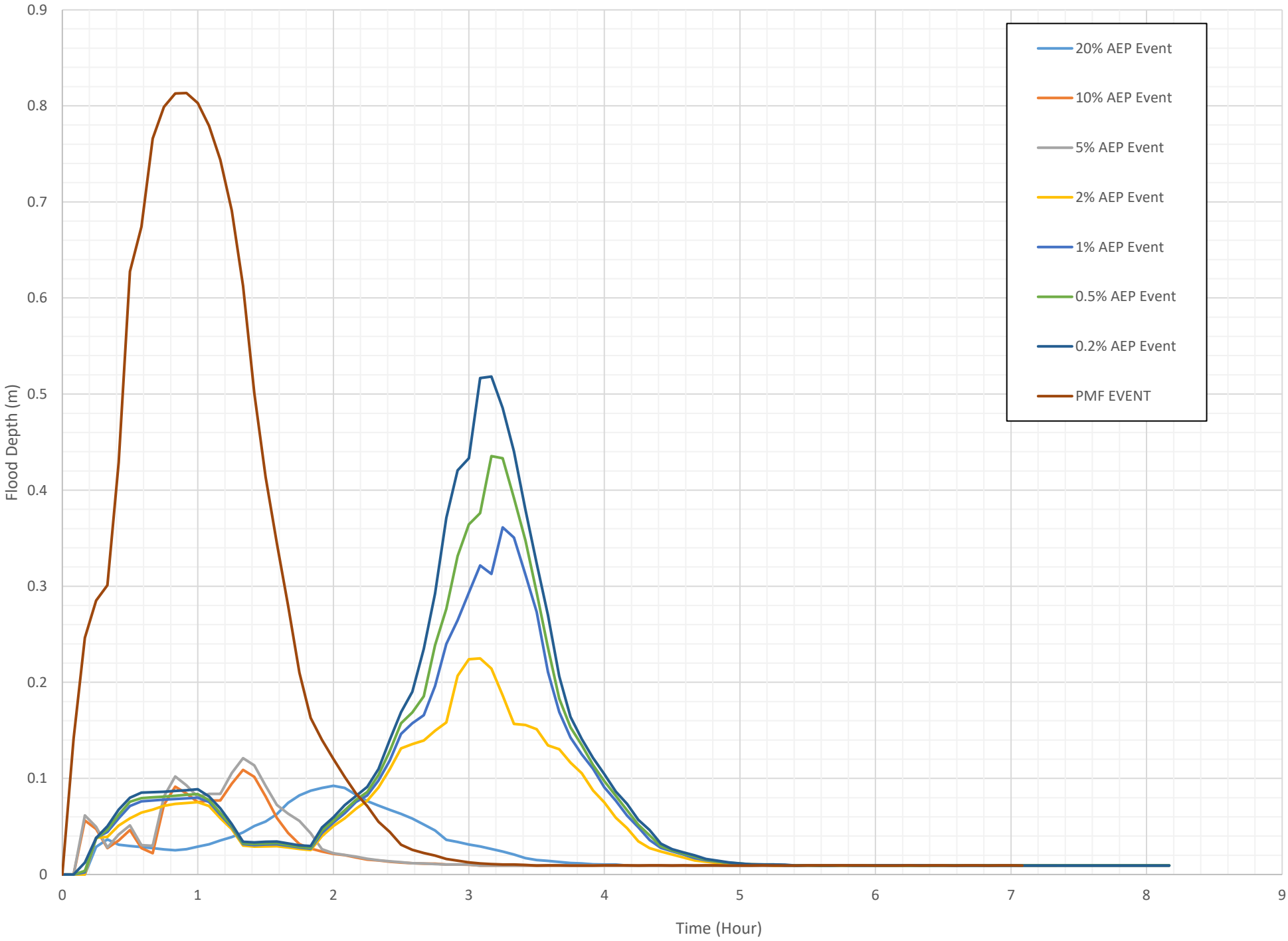


FIGURE D32
HEWITTS CREEK CATCHMENT
LOCATION 32: BEACON AVENUE



Appendix E

Appendix E. APRIL 2024 EVENT ANALYSIS

E.1. Overview

In April 2024, parts of the Wollongong region, including the study area, experienced a reasonably significant rainfall event. Council received feedback from the community regarding the impacts experienced during the event, including damage to property. These details from the community, as well as data from rainfall gauges and photographs were gathered following the events in order to analyse the event and understand its severity. This analysis can assist in further validating the results produced from the established modelling suite. The outcomes of this analysis are presented in the following sections.

E.2. Rainfall Data

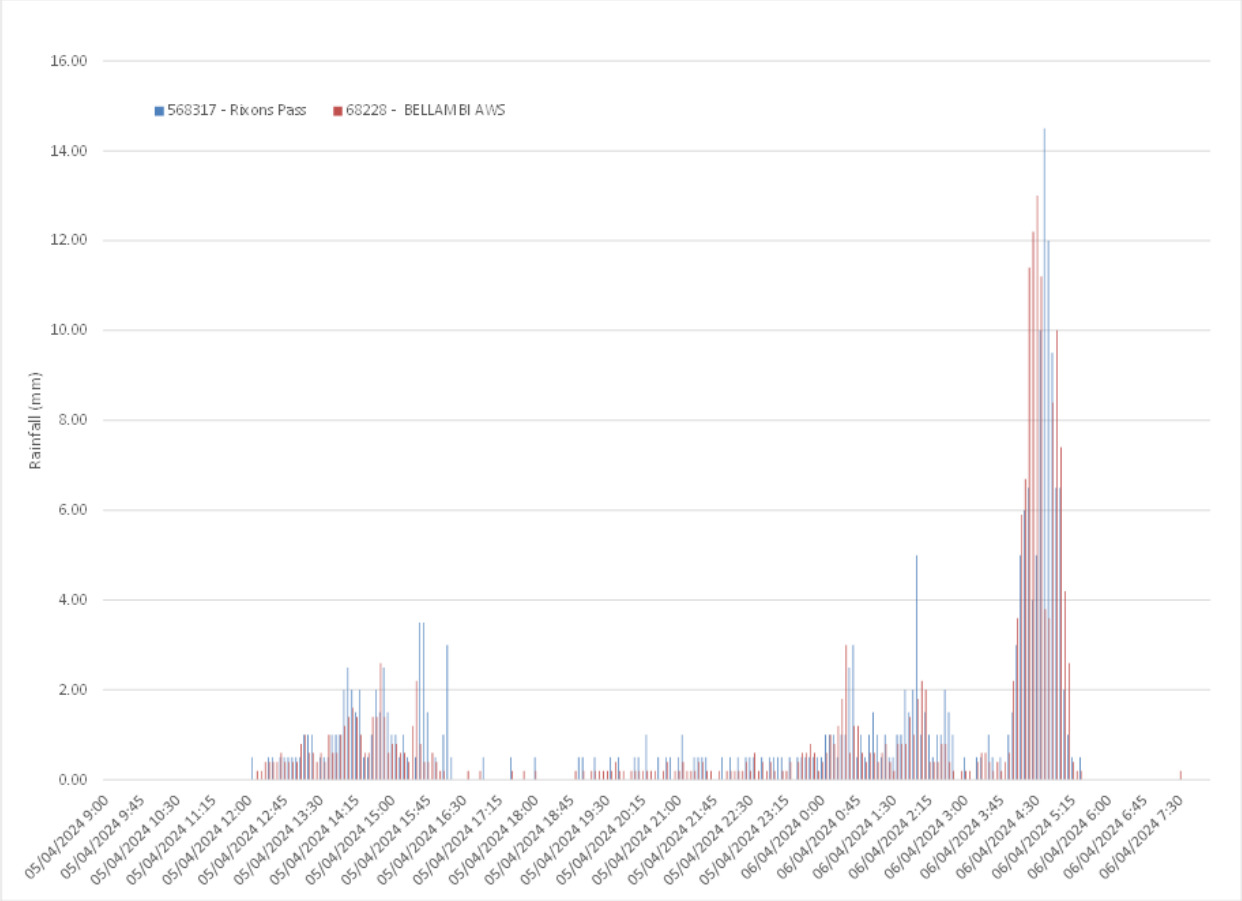
Given the short response time (that is, the time from rainfall to flooding occurring) for the catchment, sub daily rainfall information in the form of pluviograph data is essential to understanding the event. The closest available pluviograph rainfall gauges are located to the south of the study area (Map E1) at Rixon Pass and Bellambi AWS. The recorded hyetograph data is provided on Graph E1.

Map E1: Rainfall Gauge Locations



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Graph E1: Rainfall Hyetograph– April 2024 Event

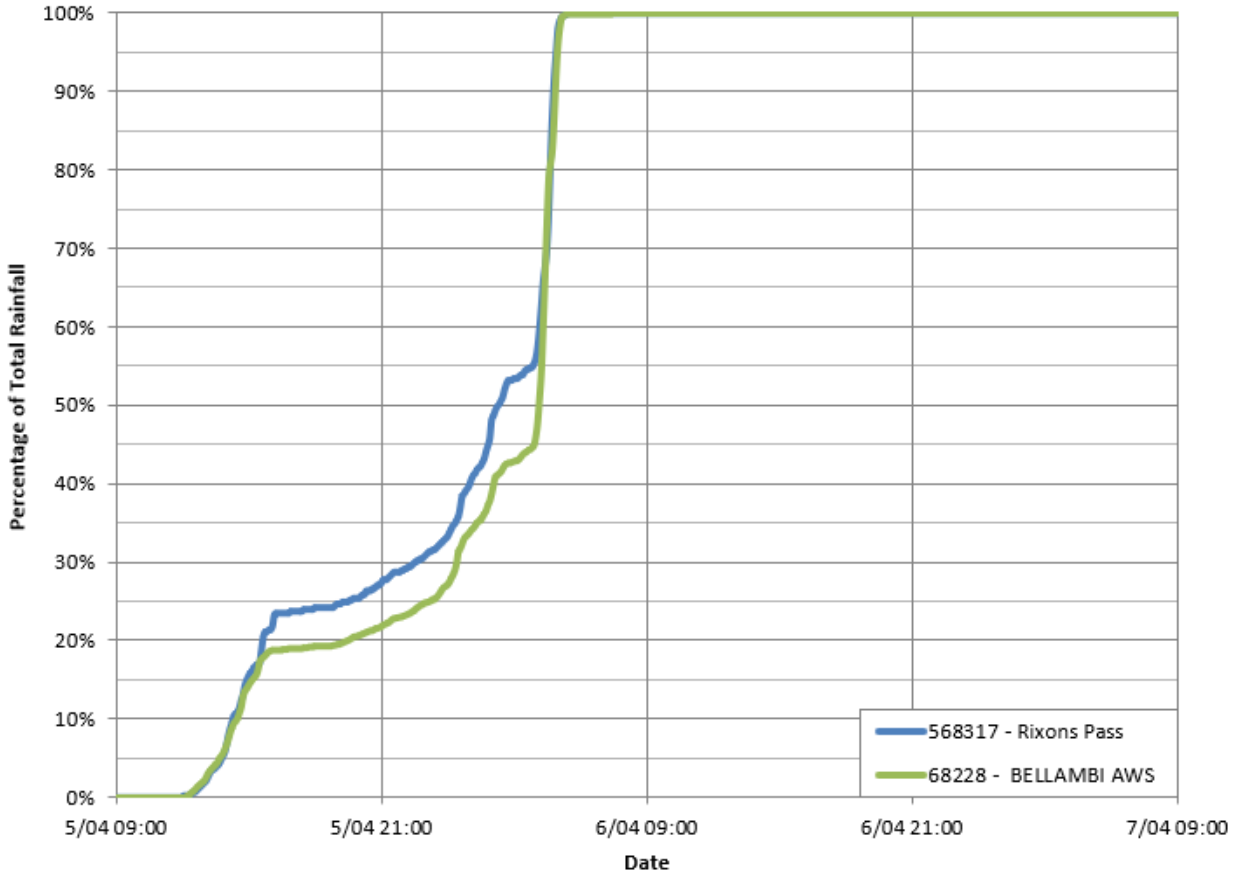


The rainfall record at both gauges demonstrates a similar pattern, including intense periods of continuous rainfall on 5th April between 12pm and 4pm (Rixon Pass - 45mm, Bellambi - 36.4mm), a similar period on 6th April between 12am and 3am (Rixon Pass - 43mm, Bellambi - 31mm), and a final larger burst on the 6th April between 4am and 5:30am (Rixon Pass - 94mm, Bellambi - 107mm). A slightly larger total rainfall was recorded at Rixon Pass (210.50m) compared to Bellambi AWS (194.6mm).

A comparison of the cumulative rainfall is provided on Graph E2. The comparison shows that while both gauges recorded similar patterns and total rainfalls, during the event the Rixon Pass gauge generally experienced higher rainfall intensity.

PUBLIC EXHIB

Graph E2: Cumulative Rainfall – April 2024 Event

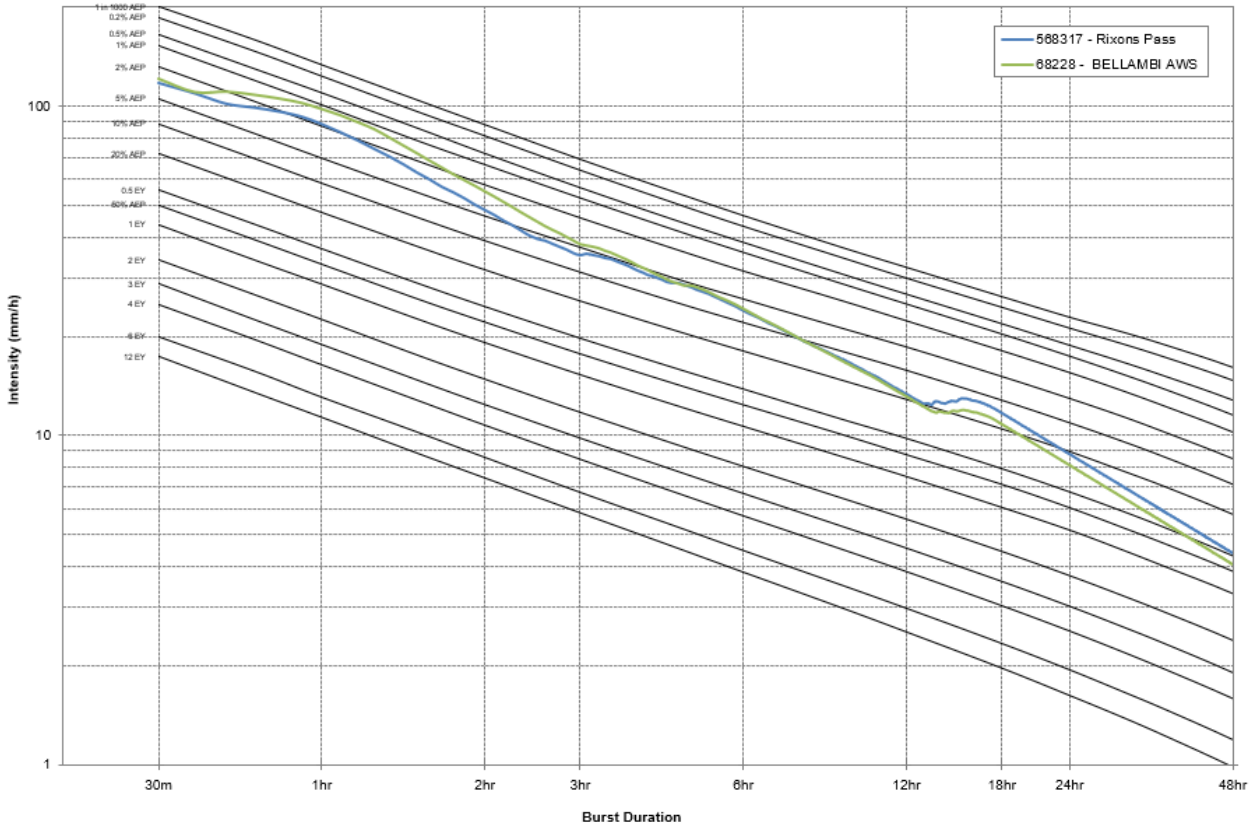


The recorded rainfall was compared to the design intensity frequency duration rainfall data available from the ARR datahub (Graph E3) to determine the probability of the recorded rainfall for different durations. At the 1 hour duration the recorded rainfall from Rixons Pass is comparable to just below a 1% AEP event. As the durations increase the probability of the recorded rainfall reduced to approximately a 20% AEP at the 24 hour duration.

A design flood is produced from a combination of aspects including rainfall, antecedent conditions, rainfall losses, and catchment critical duration. The probability of each of these can vary, however considering the rainfall, it is likely that the April 2024 flood events was between a 5% and 1% AEP event.

PUBLIC EXHIB

Graph E3: Cumulative Rainfall – April 2024 Event



E.3. TUFLOW Model Results Verification

A significant event presents a good opportunity to validate the performance of the modelling suite by comparing reports of flooding impacts against the model results. It also serves to understand the likely size of the flood relative to modelled design events. Council received 26 reports of impacts associated with the April 24 event, these were compared against the model results for the 1% AEP design event. All impacts reported by the community appear to be replicated by the design 1% AEP extend, verifying that the design modelling provides a reliable representation of flood behaviour across the study area and can be used to identify areas subject to flood risk. The comparison is provided on Figure E1 and E2, locations and details of the reported impacts are shown.

The locations of reported impacts are clustered along Hewitts Creek upstream of Lawrence Hardgrave Drive, in the north west of the catchment and Thomas Gibson Creek, in the north east. This may suggest that rainfalls were more significant in these portions of the catchment. Other areas may have also been impacted, including the Slacky Creek area; however, these were not reported to Council.

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Debris was recorded at a number of locations throughout the catchment following the April 2024 event. As no detailed measurements were captured, it is not possible to validate the factors documented in Council's Conduit Blockage Policy, however the evidence does suggest that there is merit in having the policy. Photography provided by Council is shown in Photo E 1 and Photo E 2.



Photo E 1: Slacky Creek at Black Diamond Place, Bulli
Source: https://www.facebook.com/groups/1506743279573394



Photo E 2: Slacky Creek at Princes Highway, Bulli

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Figure E 1: April 2024 Event Reported Impacts – Upstream Hewitts Creek area

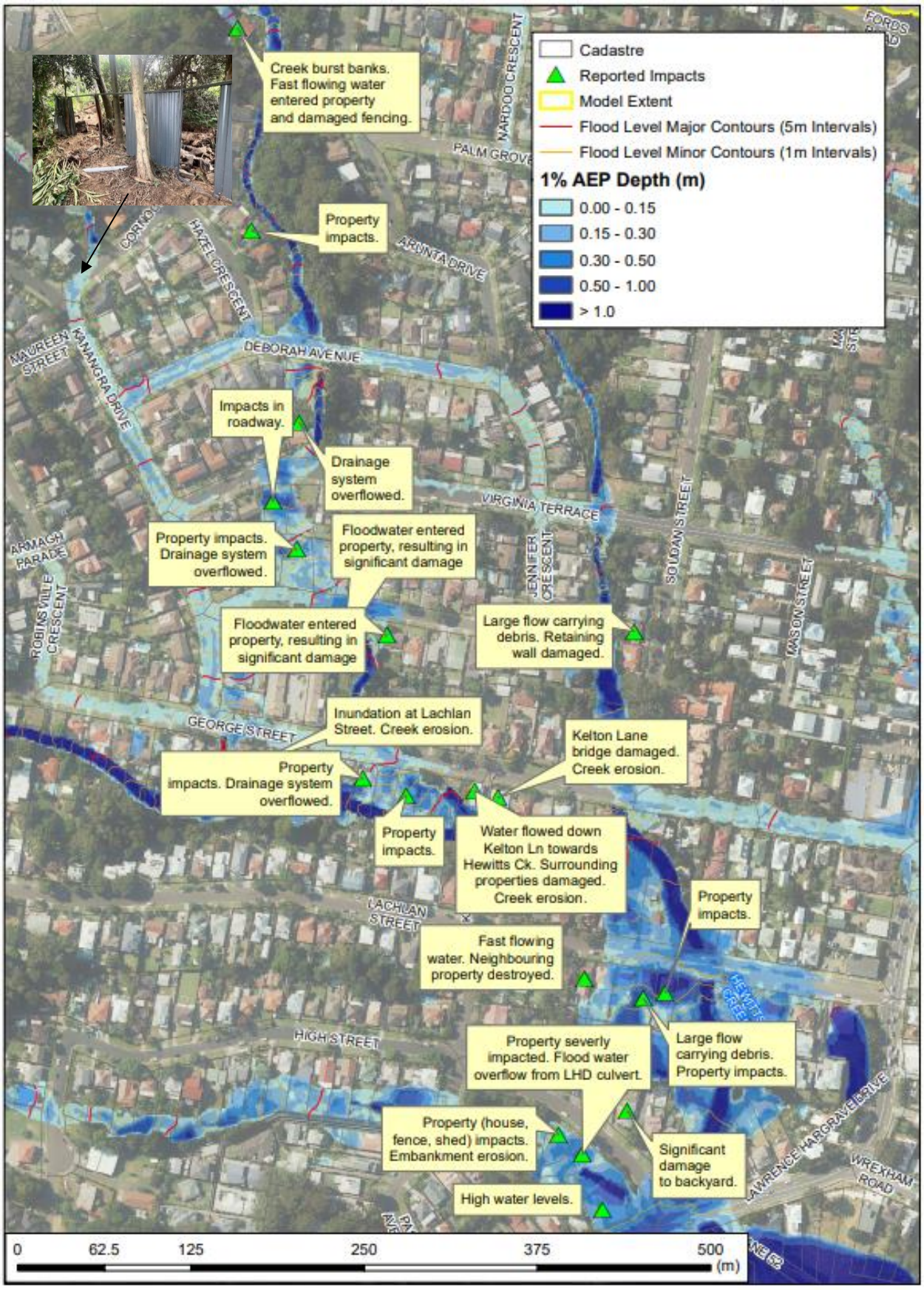
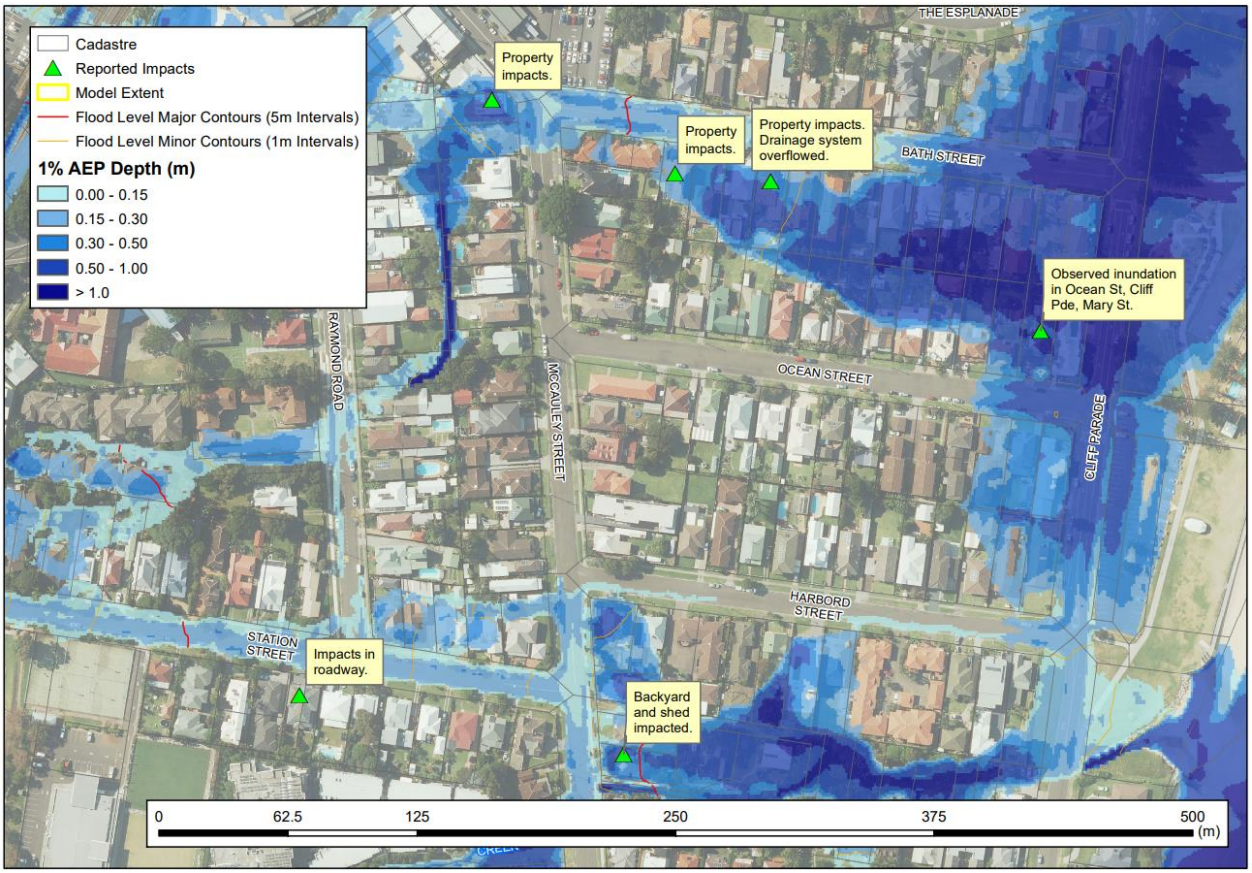


Figure E 2: April 2024 Event Reported Impacts – Thomas Gibson Creek area



PUBLIC EXHIBITION