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REVIEW OF NORTH TRALEE FLOOD STUDIES

FINAL REPORT

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1. INTRODUCTION

This study has been prepared by WMAwater on behalf of Queanbeyan City Council (Council) and serves as an independent peer review of a number of studies undertaken for the North Tralee site (the site).

The site is proposed to be developed for employment, open space and conservation purposes, however parts of the site are known to be subject to flooding.

This study provides Council with independent advice as to the suitability of previous studies prepared for the site, in regards to flood related information and the accuracy of the Flood Planning Level (FPL) for the subject land.

1.1. Objectives

The aim of this study is to review the flooding components of the following studies undertaken for the North Tralee Study Area:

- *Flood Study and Riparian Corridor Assessment Jerrabomberra Creek - Brown Consulting, Jan 2010* (the Brown Study);
- *Tralee LES Jerrabomberra Creek Flood Study - URS Australia, Aug 2003* (URS Study)*; and*
- *North Tralee LES 2011 (Appendix B) – Northrop Consulting, 2010*

In particular, advice is sort as to the suitability of the Brown Study being used as a basis to inform a FPL for the North Tralee site consistent with relevant NSW legislation and policy requirements. The Brown Study produced a hydraulic model of the site to model flood behaviour which extended some distance both upstream and downstream of the site. This region is defined throughout this report as 'the study area'.

1.2. Background

The site is part of a larger parcel of land known as 'Tralee' that was considered for residential rezoning in the early 2000's. A Local Environmental Study (LES) was prepared for the entire site at that time (comprising land known as North Tralee and South Tralee). However due to the close proximity to Canberra Airport, the site at North Tralee is no longer being considered for residential development. Instead, the site is now proposed to be developed for employment, open space and conservation purposes as noted earlier.

A planning proposal to rezone the land at North Tralee for employment/light industrial uses was submitted to the NSW Department of Planning in May 2014 and a Gateway determination was issued to Council on 28 May 2014.

A number of studies have been prepared for Council and by various proponents to investigate flood behaviour at Tralee. Not all of these studies have covered the entire site with a number investigating only parts of the site.

The Brown Study (2010) was prepared by Brown Consulting for the proponents and covers the entire area subject to the rezoning proposal. Study findings include flood maps for the 100 and 500 year ARI events and the Probable Maximum Flood (PMF).

Council wish to determine to suitability of the Brown Study (2010) for determining the sites FPL and have sought independent advice in respect to the flood liability of the site. Development is proposed to only occur where land is located above the flood planning level, and it is important this level be accurately defined. The ‘flood planning level’ as defined under Council’s local environmental plan is the 1:100 ARI (average recurrent interval) plus a 0.5 metre freeboard.

In addition to the Brown Study (2010), other studies (see Section 1.1) have been made available for review to help inform Council of the site’s flood liability.

1.3. Study Area

The Study Area is located in the south western corridor of Queanbeyan NSW within the Jerrabomberra Creek catchment immediately upstream of the NSW/ACT border. The Jerrabomberra Creek catchment upstream of the Study Area is approximately 82 km^2 of predominately, rural and natural land uses. The Study Area follows Jerrabomberra Creek from Lake Jerrabomberra in the upstream to Lanyon Drive in the downstream.

The disused Goulburn-Bombala Railway and its embankment form a significant hydraulic feature at the downstream end of the site. A wooden trestle bridge forms the Railway crossing of Jerrabomberra Creek. This bridge was noted in the Brown Study to be supported by six sets of three wooden piers and approximately 38 metres long. A second break in the railway embankment is located approximately 200 metres south of this bridge.

2. STUDY REVIEWS

2.1. Brown Consulting Study (2010) - Study Review

Brown Consulting were commissioned to undertake an investigation of the flood behaviour of Jerrabomberra Creek at Tralee for the proposed Tralee North and The Poplars development areas. The investigation was part of the South Jerrabomberra Masterplan.

The objectives of the Brown Study were:

- Review of available existing information;
- Review and assessment of previous investigations into Jerrabomberra Creek and the development areas;
- Determine current flooding situation for the 100 and 500 year Average Recurrence Interval (ARI) storm events and the Probable Maximum Flood (PMF);
- Determine limitations on the proposed development due to flooding;
- Investigate cut and fill options to maximise developable area and minimise impact on Jerrabomberra Creek and minimise flooding impacts.

As mentioned above the Brown Study was commissioned to investigate options with regard to cut and fill measures to maximise the developable land area. These measures were not supported by Council or the relevant Government agencies and were therefore not undertaken. Accordingly, it is only those parts of the Brown Study that provide information in respect of the existing flooding behaviour of the subject land that require review as part of the current study.

2.1.1. Hydrology

The Brown Study investigated using Flood Frequency Analysis (FFA) for stream gauge (410743) to determine design flows for the study area, however concluded that the total record period (26 years) is too short to provide an accurate 100 year flow estimate. Whilst this is a reasonable assumption, it failed to mention that the 2 year to 20 year ARI design flow estimates are likely reasonable and could be used for hydrologic model calibration. FFA is the preferred method of determining design flows where available data allows for it.

Instead of FFA, the Brown Study (2010) utilised the hydrologic model XP-Rafts (Version 7) with typical regional model parameters to determine design flows. Details on selected model parameters indicate that reasonable hydrologic parameters have been used. Model parameters include:

- ARBM loss model with parameters recommended in the ACT Planning and Land Authorities Water Sensitive Urban Design Code (March 2008);
- Reasonable percent imperviousness;
- Reasonable catchment slopes; and
- Typical Manning's values for both impervious and pervious land uses.

However, the Brown Study (2010) does not provide information on how catchment routing was modelled which can significantly impact on peak flows.

2.1.1.1. Hydrology Results

The Brown Study (2010) hydrologic model design flows have been compared to the FFA undertaken as part of the Tralee LES study (2003). As mentioned previously, FFA performed on a 26 year record period, likely provides reasonable flow estimates for design flows up to and including the 20 year ARI. Table 1 presents a comparison of flows from these two studies. Comparison of the Brown Study (2010) hydrologic model flows to the Tralee LES (2003) FFA derived design flows for the 10 and 20 year ARI events indicates that flows are similar. This provides confidence in the Brown Study (2010) hydrologic model design flows.

Table 1: Comparison of design flows at the NSW/ACT boarder (m³/s)

	10 year ARI	20 year ARI	50 year ARI	100 year ARI
Brown Study (2010) XP-Rafts Model Flow	165	213	270	322
FFA - Tralee LES (2003)	152	212	317	423
PRM	145	186	254	305

To add further robustness to the design flow estimates the Brown Study (2010) calculated design flows via the Probabilistic Ration Method (PRM) for comparison. The PRM flows were found to be similar to the flows determined from the hydrologic model for all examined ARI. This comparison can be seen in Table 1.

As the 10 and 20 year ARI Tralee LES study (2003) FFA flows and the PRM flows are similar to the hydrologic model design flows, WMAwater conclude that the Brown Study hydrologic assessment and design flows are reasonable and suitable for use in design flood hydraulic modelling. Hence, they are also suitable for determining FPLs.

2.1.2. Hydraulic Modelling

The Brown Study (2010) utilised a two-dimensional hydraulic model (SOBEK) to define design flood behaviour for the study area. The model was not calibrated.

The model grid cell size has not been specified in the report, and two models with varying grid cell sizes (5 m and 10 m) were made available for the study review. Selection of grid cell size is important for the definition of in-bank conveyance. A 10 m model grid would likely lack the definition required to accurately model the Jerrabomberra Creek in-bank for the study area.

Model inflow boundaries were situated downstream of Jerrabomberra Lake and on the small tributaries within The Poplars and Tralee North development areas. The downstream model boundary was modelled as a constant water level boundary upstream of Lanyon Drive.

Roughness coefficients were determined from Section D5.06.9 of Queanbeyan City Council – Development Design Specification D5 Stormwater Drainage Design and from Hydraulic Design of Flood Control Channels, Engineer Manual published by the US Army Corps of Engineers. A roughness coefficient of 0.04 was used in the modelling for the in-bank area and overbank overland flow. WMAwater notes that a Manning's of 0.04 is towards the lower end of what would be considered acceptable and a higher roughness (0.05) should be considered if no hydraulic model calibration is undertaken. The URS study indicated that '*Vegetation in the main creek channel largely comprises grasses and shrubs with scattered trees along the banks'* (see Section 2.2) which would indicate a higher roughness than that selected. Selection of a higher roughness would be considered conservative and best practise for an uncalibrated model.

2.1.2.1. Topographical and Survey Data

The Brown Study notes that topographical and survey data for the study area was obtained from various sources throughout the history of the site. The Brown Study (2010) notes, that 'detailed survey of the creek will be undertaken for the detailed design stage of the development with flood extents to be recalculated.' This indicates that Brown Consulting themselves anticipate revision of the study's 100 year flood level, and associated FPL (100 year ARI level + 0.5m). Furthermore, the quality of the Aerial Laser Scanned (ALS) ground survey is not known with the Brown Study (2010) noting that the ALS data had been 'manually adjusted', with no mention of confirming the ALS data with survey data made. It is common practise to ensure the accuracy of the ALS with survey data.

Also of note is the lack of information related to detailed survey of the disused Goulburn-Bombala Railway and associated infrastructure. The Railway forms a significant hydraulic feature at the downstream end of the site, and likely is a control influencing the site's flood levels. Correct modelling of this structure is essential to the accurate modelling of flood behaviour and in particular, peak flood levels, from which the FPL is derived.

A key feature of the Railway infrastructure is a wooden trestle bridge that forms the Railway crossing of Jerrabomberra Creek. This bridge was noted in the Brown Study (2010) to be supported by six sets of three wooden piers and 'approximately' 38 metres long, however, the Brown Study (2010) has modelled this structure (in 1D) as 31 m long. There is also an error with modelling of the southern bridge span, with the 1D invert modelled as higher than the crest level of the railway. This removes flow conveyance through this significant bridge span (modelled as 15 m x 2 m) until the level of the Railway embankment is overtopped, which, once this occurs, does not require a 1D model element as flow can pass freely over the embankment in 2D.

Additionally, no detail has been given about a 'second break' in the railway embankment mentioned in the Brown Study (2010) which is located approximately 200 metres south of the bridge. This structure is modelled in 1D as two 5 m wide non-enclosed flow paths through the Railway. The URS Study (2003) provides details of this structure (see Section 2.2) which are in conflict with that modelled as part of the Brown Study (2010) which would over estimate flow conveyance through this structure.

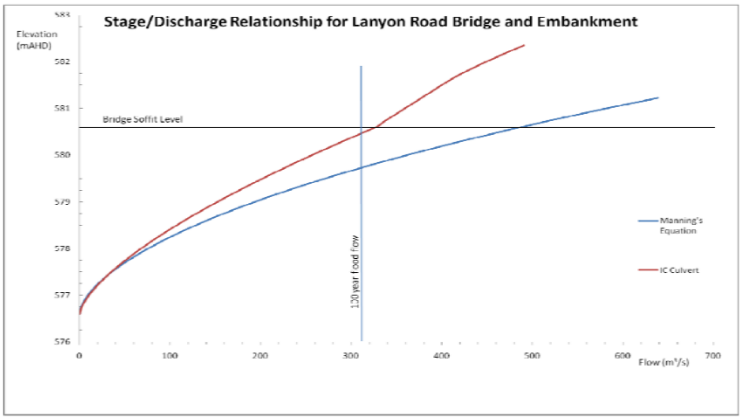
Due to the importance of these structures on flood behaviour, it is recommended that detailed survey be undertaken for the bridge, the railway embankment crest level within the flood extent, and for the southern 'break in the railway'. The railway embankment has been modelled as overtopped in various locations, the occurrence of which could significantly impact on upstream flood levels.

2.1.2.2. Model Boundaries

The upstream inflow boundaries are positioned in suitable locations so as to not impact on results in the area of interest at the site.

The downstream model boundary was modelled as a constant water level boundary upstream of the Lanyon Drive Bridge, which along with the Goulburn-Bombala Railway, likely forms an important flow control. The bridge was reported in the Brown Study (2010) as not being modelled for the following reasons:

- *The bridge at Lanyon Drive was not included in the model due to a lack of data downstream of the road embankment and the assumption that the bridge was designed to accommodate the 100 year peak flood flow;*
- *The flow capacity of the bridge and embankment was calculated from pencil-drawn hand measurements were provided on 10 September 09 by Brown Consulting (ACT);*
- *A simple stage/discharge relationship based on the sketched details of the Lanyon Drive Bridge was developed using Manning's Equation – the channel under the bridge deck was found to have capacity of 487 m³/s, well in excess of the 313 m³/s developed in XP-RAFTS and used in the SOBEK modelling;*
- *Culvert entrances were also modelled using the program IC Culvert –this program calculated that the bridge has the capacity to accommodate the 100 year flow below the soffit level of the bridge;*
- *A graph showing these calculated stage/discharge relationships is presented below;*



- *The flow elevation was not estimated at the bridge, however it was calculated at 581.0 m AHD approximately 50 metres upstream of the bridge – this would result in a water level at the bridge of below the soffit of 580.6 m AHD which would not result in backwater effects, which is in line with the assumption that the bridge is designed to allow passage of the 100 year flood;*
- *The stage discharge relationship at the bridge was approximated using a normal depth boundary condition upstream of the bridge in both existing and developed model runs for consistency;*
- *The SOBEK model has the limitation that the boundary condition to the flow must be in line with the model cells. Incorporation of the bridge did not allow this without additional downstream ALS data; and*
- *Given the level of accuracy of the ground surface data used in the hydraulic modelling*

(which was not based on actual survey data but estimates based on elevation modifications made in 12d) the minor inaccuracies to the flow downstream of the site caused by modelling the Lanyon Drive Bridge and embankment in this manner will not impact on the accuracy of the results.

Point six (6) above mentions that because water levels are determined not to reach the bridge soffit, no backwatering upstream of Lanyon Drive will occur. However, it is not the case that flood levels must reach the level of the bridge soffit for backwatering to occur as expansion/contraction losses and various other losses associated with bridges and their embankment can cause significant backwatering upstream.

It is recommended that additional survey data of Lanyon Drive Bridge and downstream be obtained and incorporated into the hydraulic model.

2.1.2.1. Model Calibration

The hydraulic model has not been calibrated. It is best practise to calibrate a hydraulic model, particularly when determining design flood levels used to develop FPLs.

It is recommended that the hydraulic model be calibrated using available historic flood information to ensure accuracy of the selected parameters and model results.

2.2. Tralee LES Jerrabomberra Creek Flood Study – Study Review

The Tralee LES Jerrabomberra Creek Flood Study by URS Australia (2003) has been reviewed.

Of note is Section 10.2.2 – Infrastructure and Other Issues which is reproduced below:

- *The main railway crossing over the Creek comprised an old wooden bridge, approximately 38 m long with six sets of three wooden piers, of which three sets are located within them channel. The Creek was not flowing at the time of the inspection by URS.*
- *Pipe culverts (4 x 2.35 m diameter) have also been recently installed within the railway embankment, approximately 170 m south of the bridge. It is understood that Railway Infrastructure Corporation (RIC) installed the culverts to replace a bridge structure previously at that location, and the culverts were designed to provide similar flood discharge capacity to the original bridge (pers. comm. Stuart McCarthy). These culverts act to provide additional waterway opening areas within the embankment during extreme flood events.*
- *The Creek channel banks within the Tralee North site comprises near vertical batters, frequently as much as 4 m high, resulting from on-going erosion during high flow events. It is reported that considerable volumes of silt have been deposited within areas of the creek downstream (Dept. Housing, 1984).*
- *Vegetation in the main creek channel largely comprises grasses and shrubs with scattered trees along the banks. The floodplain overbank areas generally comprise grasses and low shrubs.*

The report indicates a 100 year ARI peak flood level at the Goulburn-Bombala Railway of 583.95 mAHD. This is higher than the 100 year ARI level determined in the Brown Study (2010) which likely relates to a number of the issues highlighted in Section 2.1.

2.3. North Tralee LES 2011 (Appendix B) – Study Review

Appendix B of the North Tralee LES study by Northrop Consulting (2010) has been reviewed. The study provides little additional relevant information from a flooding perspective.

3. CONCLUSIONS

After reviewing the Brown Study (2010) hydrology, WMAwater conclude that the design flows, including the 100 year flow, determined as part of the Brown Study (2010) are suitable for use in design flood modelling.

Review of the Brown Study (2010) hydraulic model indicates that the model requires review and that detailed survey of the disused Goulburn-Bombala Railway and associated infrastructure should be undertaken for incorporation into the model. In particular, the Jerrabomberra Creek bridge crossing, the southern ‘break in the railway’, and the railway crest over the width of the floodplain should be surveyed and incorporated into the model.

Additionally, survey of Lanyon Drive Bridge and downstream should be undertaken so that the hydraulic model can be extended further downstream to model the potential impacts of Lanyon Drive on upstream flood levels.

The hydraulic model should then be calibrated using available historic flood information to ensure accuracy of the selected parameters and model results.

4. REFERENCES

Brown Consulting
1. **Flood Study and Riparian Corridor Assessment Jerrabomberra Creek**
Queanbeyan City Council, January 2010.

URS Australia
2. **Tralee LES Jerrabomberra Creek Flood Study**
Queanbeyan City Council, August 2003.

Northrop Consulting
3. **North Tralee LES 2011 (Appendix B)**
Queanbeyan City Council, September 2010.

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.

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 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

	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:

- $ 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

	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.