Data and Methodology

WESTERN DOWNS REGIONAL COUNCIL

Western Downs Floodplain Risk Management Study

Data and Methodology

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1 INTRODUCTION

This report describes the collation, review and acquisition of a wide range of data used in the Western Downs Floodplain Risk Management Study (FRMS). This includes previous studies, planning documents and hydraulic, demographic and property data for the purposes of understanding flood risk in the study area and identifying potential management measures.

This report also describes the methodology for a number of quantitative assessments used in the study (including hydraulic impact, evacuation capability, flood damages and cost benefit assessments). An overview of the methodologies sufficient to inform option appraisal and decision making is provided in the main body of this report; additional detail is included in the appendices for further reference, if required. Results of these assessments are not included here; they have been reported alongside the various options and scenarios in the other reports which make up the FRMS.

This report is one of several that make up the FRMS as shown by the document map presented in Figure 1-1.

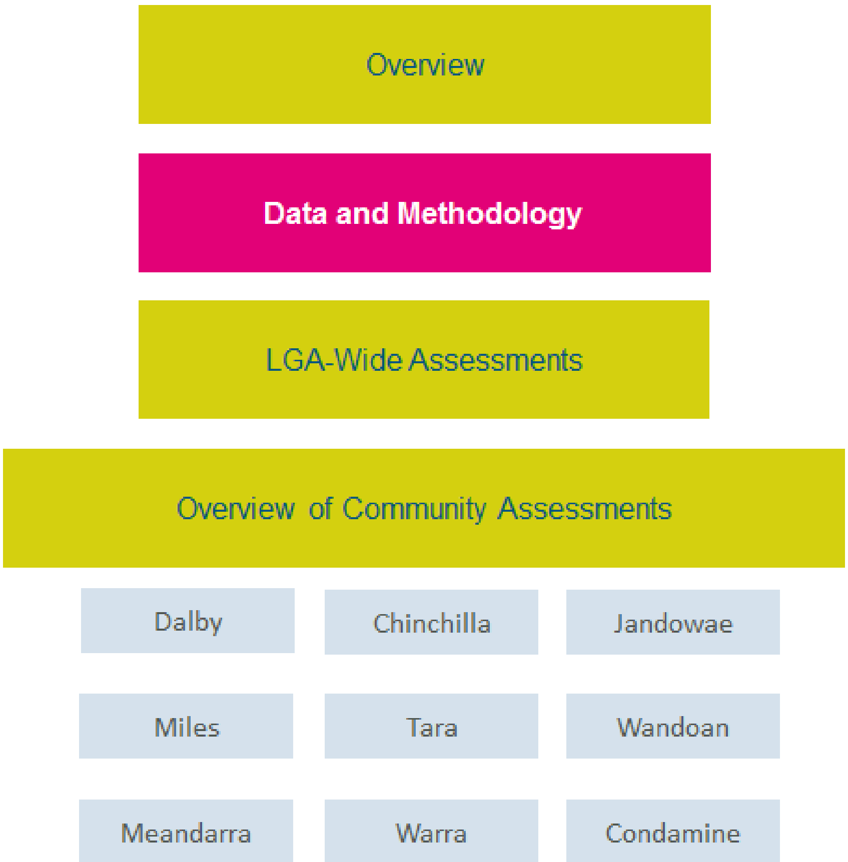


Figure 1-1 FRMS Document Overview

2 DATA REVIEW

2.1 Previous Studies

The Western Downs Regional Council was established in 2008 following the amalgamation of five previous local government areas. As such no single study was prepared before 2008 which addressed flood risk across the region as a whole.

The most significant studies of note were undertaken for Dalby and were reviewed as part of the current study. The 1986 study in particular, provided historical context for floodplain management options considered for Dalby. The studies are as follows:

- Dalby Region: Flood Management Study (Munro, Johnson & Associates, 1986); and
- Myall Creek Flood Study, Dalby (SKM, 2007).

2.1.1 Western Downs Planning Scheme Review

Following the formation of Western Downs Regional Council, Council commissioned new hydrologic and hydraulic modelling of 6 key centres across the region, those being:

- Dalby;
- Chinchilla;
- Miles;
- Tara;
- Jandowae; and
- Wandoan.

The studies were commissioned to inform the emerging Planning Scheme for Western Downs and were undertaken by Water Technology (Water Technology, 2011, 2012). For the purpose of the FRMS these recent studies by Water Technology are collectively referred to as the 'PSR'.

The PSR presents design flood results in graphical format. Design floods are statistical-based events that have a particular probability of occurrence. For example, the 1% Annual Exceedance Probability (AEP) event is the best estimate of a flood that has a 1% (i.e. 1 in 100) chance of occurring in any one year (on average). Table 2-1 relates various AEP events to the equivalent Average Recurrence Interval (ARI) events.

Table 2-1 Design Event Categories

Annual Exceedance Probability (AEP)	Approximate Average Recurrence Interval (ARI)
1%	100 year
2%	50 year
5%	20 year
10%	10 year
20%	5 year
50%	2 year

For all towns other than Dalby, the PSR was the first study which has mapped flood risk within the towns. Assessments were also undertaken which incorporated future allowances for increased rainfall intensities resulting from potential climate change.

2.1.2 Use of the PSR in the FRMS

Outputs from the PSR have been used to define existing risk in this FRMS. Where necessary, for the purposes of this study, the hydrologic and hydraulic modelling has been extended to include additional flood events and used as the basis from which to develop revised models which consider structural mitigation options.

Of particular note the following two key general extensions have been made:

- Derivation of 50%, 20% AEP (2 and 5 year ARI) hydraulic models along with the PMF for all localities; and
- Application of hydrologic techniques and obtained LiDAR data to derive hydraulic models for Warra, Meandarra and Condamine.

Appendix A contains the specifics of the hydrologic and hydraulic updates undertaken for the FRMS.

2.2 Demographic Data

Demographic data was used to inform the evacuation capability assessment and to understand the vulnerability of the various communities to flood risk. General household statistics and statistics on community vulnerability were extracted from the 2011 Census for use in the FRMS.

2.3 Property Data

No community wide property or floor level surveys exist for any of the towns within Western Downs. To assist with the quantitative assessment of flood damages and cost-benefit assessments, property databases were created for Dalby, Chinchilla and Jandowae with reduced scope databases for Miles, Tara, Warra, Condamine and Meandarra. The databases were populated with data obtained from site visits and online sources such as Google Street View on whether properties were residential or commercial/industrial. Information on whether a property was ‘high-set’ or ‘low-set’ was also gathered in the same way. Full details on the database creation are provided in Section 3.3.2. The reduced scope databases generally only located property within flood extents with little additional detail.

2.4 Historical Data

A separate report was prepared which reviews historical flood information across the region, with particular emphasis on the 2010/11 flood events. This report is included as Annex A of the FRMS. Community specific documents also summarise flood history, where available in each of the assessed townships.

3 QUANTITATIVE ASSESSMENTS

This section provides an overview of the key quantitative assessments used in the FRMS, in particular hydraulic impact, evacuation capability, flood damages and cost-benefit assessments. Additional detail is provided in the appendices for further reference, as required.

3.1 Hydraulic Impact Assessment

Hydraulic impact assessments are a standard approach to quantifying changes in flood behaviour as a result of potential changes in the floodplain (including impacts on depth, velocity, duration of inundation). Any structural flood risk mitigation measures, like levees, are designed to impact on flood behaviour. It is vital such hydraulic impacts, both positive and particularly any unforseen negative impacts are understood.

Existing flood behaviour is as defined by the flood models developed for the PSR which represent existing floodplain conditions. As part of the FRMS, the PSR models have been converted from MikeFlood software to TUFLOW software and used to simulate potential changes in the floodplain for Dalby, Chinchilla and Jandowae to determine the hydraulic impact (positive or negative) for various flood management measures. The conversions were undertaken in order to use some of TUFLOWs advanced features which are suited to flood risk management.

For management measures requiring cost benefit assessment, the full range of flood event magnitudes are modelled (the 50% AEP (2 year ARI) flood to the PMF) to quantify the reduction in damages for a range of event probabilities. Impacts have been mapped for the 10% and 1% AEP events to shown the impacts over a range of flood magnitudes.

For each management measure assessed, maps have been provided in the community specific reports, showing the key hydraulic impacts.

3.2 Flood Evacuation Capability Assessment

3.2.1 Aims of Assessment

Evacuation capability assessments consider the ability of people within the floodplain to evacuate safely during a flood event and to estimate the capacity for a community to evacuate safely. The QLD State Government (2011) dictates that all Councils have an Evacuation Sub-plan as a component of the Local Disaster Management Plan. The Evacuation Guidelines (QLD Govt., 2011), outline the six stages of an evacuation and considerations for each of these stages:

- Planning;
- Decision;
- Warning;
- Withdrawal;
- Shelter; and
- Return.

This report focuses primarily on the planning stage for an evacuation for communities within WDRC. Modelling undertaken as part of the *PSR* (Water Technology, 2012) and supplemented by additional modelling for this study has been used in the assessments.

The evacuation capability assessments aim to achieve the following objectives:

- To inform the Local Disaster Manager Groups (LDMG) evacuation planning process;
- Identify and assess risks to safe evacuation during flood events within WDRC; and
- Provide locality specific information and recommendations for incorporation into the Evacuation Sub-Plan.

It is recognised that no two floods are the same and depending on where the rain during a particular event falls, the resulting flood levels and times of inundation may vary for different parts of the town from event to event. The assessment is therefore considered to be 'high-level' and to be used as a guide rather than a fixed rule. It is also not a detailed evacuation plan, although much of the information and output can be used to inform response planning.

3.2.2 Assessment Methodology

Flood evacuation capability assessments have been undertaken using a timeline approach as recommended by QLD Evacuation Guidelines (QLD Gov., 2011). The state guidelines are strategic in nature and do not detail specifics about how such as assessment should be undertaken. Therefore the timeline approach developed by the NSW State Emergency Service (SES) (Opper, 2010) and frequently used in flood risk management studies has been applied.

The assessment methodology combines information on flood behaviour from flood models with estimates of flood prediction time, human behavioural factors, vehicle flow rates and safety allowances. For the purposes of the assessment both the PMF and 1% AEP design flood events have been used.

Each community, for which an assessment is undertaken, is divided into a number of evacuation sectors. Sectors are geographical areas defined based on a review of the design flood behaviour and the location of evacuation routes and centres. Each sector is assumed to evacuate to a common evacuation centre using a single evacuation route. Evacuation routes represent major roads which link a sector to an evacuation centre. They do not account for feeder roads which access the primary evacuation route.

The assessment has two main components:

- A '*Time Required*' assessment to determine the time required for a successful evacuation from each sector.
- A '*Time Available*' assessment which looks at the flood behaviour and estimates the time available for evacuation from each sector before the evacuation route is cut by floodwater.

A comparison of the time required against the time available allows for identification of sectors for which complete evacuation may be constrained by time. The assessment can be used to help prioritise which areas of a community should be notified first in the event of a flood. The two main components of the assessment are summarised below with further detail provided in Appendix B.

Assessment of Time Required

Following the delineation of evacuation sectors, for each sector the properties inundated during the PMF and 1% AEP flood events were mapped, representing the maximum number of properties that require evacuation. All properties within the PMF and 1% AEP flood extents affected by flooding were included and not just those inundated above floor level. Census data on population and vehicle ownership was then obtained from the Australian Bureau of Statistics survey (ABS, 2011) and was used to estimate how many people require evacuation from each sector and how many vehicles will be used during the evacuation.

A database of evacuation centres was supplied by WDRC. For communities where a timeline assessment was undertaken, the locations of the evacuation centres were compared against design flood behaviour in order to ascertain their suitability as flood shelters[1].

Ideally, evacuation centres should have PMF flood immunity but it is recognised that this criterion is not always practical, particularly for large areas of flat terrain. In such instances reaching an appropriate evacuation centre may involve crossing large areas of the floodplain and exposing the residents to an unacceptable level of risk.

The evacuation routes have been selected as major roads from a sector to an evacuation centre. The Evacuation Guidelines (QLD Govt., 2011) stipulate the following vehicle capacities for evacuation routes.

Table 3-1 Evacuation Route Capacity

Route Condition	Capacity (Vehicles/ Hour)
Normal – Fine weather with normal traffic control.	300
Enhanced – Emergency response agencies intervene to increase route capacity. Traffic management strategies may include: traffic controlled intersections, contra flow, banning vehicles towing caravans and trailers.	450
Disrupted – Heavy rain with possible vehicle breakdowns, traffic accidents, land slips, minor flooding across road, etc.	120

For the purposes of the timeline assessment, *'normal'* route conditions have been assumed.

The time required to complete a successful evacuation has been calculated as the sum of the following elements which are based on those from the Evacuation Guidelines (QLD Govt., 2011):

- *Prediction Time* - The time from the start of the storm to when it is apparent that a significant flood event may occur. A guideline value of 6 hours is assumed based on (Opper, 2009).
- *Decision Time* - The time required to make an informed decision to evacuate, including the mobilisation and deployment of resources. A guideline value of 6 hours is assumed based on (Opper, 2009).

[1] Further considerations as to the specifications required of a flood evacuation centre are given in "The Operational Planning Guidelines for Local Disaster Management Groups (QLD DES., 2006)". It is recommended that the facilities of the evacuation centres suitable for flood shelters within the Western Downs area be reviewed to ensure compliance with these guidelines.

- *Warning/Acceptance Time* - The time required to inform all dwellings that evacuation is required. This is estimated based on the time taken to warn residents so that the evacuation route is kept at the desired route capacity. An acceptance time of 2 hours is assumed based on guideline values (Opper, 2009).
- *Total Travel time* – The time required for vehicle movement for a full evacuation of the population within an evacuation sector to a safe location. Total travel time commences following the receipt and acceptance of the first warning i.e 2 hours after the warning and runs concurrently with remaining Warning/Acceptance time.

A full description of these parameters is provided in Appendix B.

Assessment of Time Available

The total available time for evacuation is marked along a timeline; the timeline commences when the storm starts and ends when evacuation is no longer possible due to road closures, or when everyone is safely evacuated.

The WDRC hydraulic models have been used to identify when evacuation routes are first inundated by floodwater and hence determine the time available for evacuation from the start of the storm. The PMF and 1% AEP design flood events have been used for this purpose and it is assumed that a road is cut when the flood depth is 0.1m or higher.

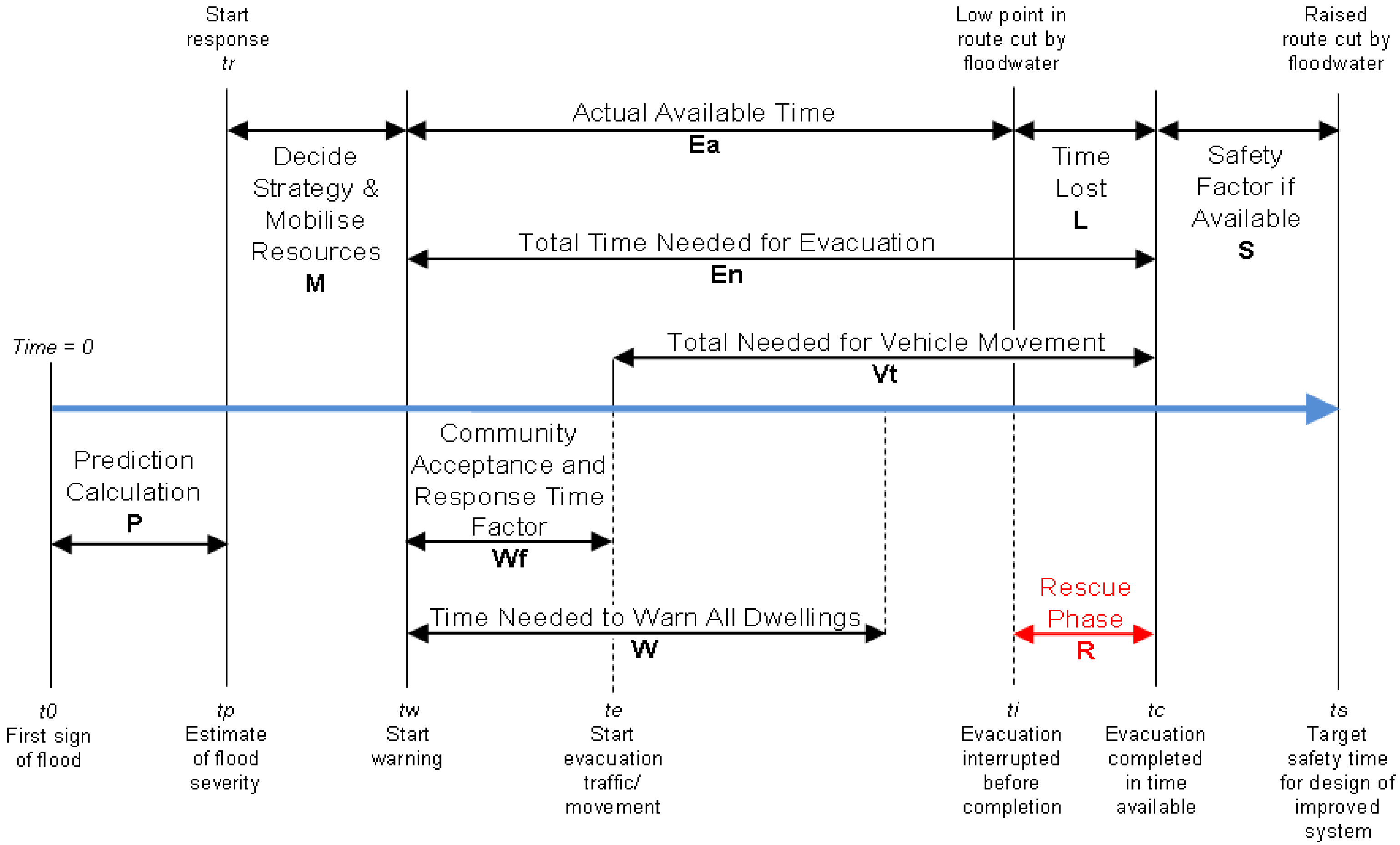
3.2.3 Key Assumptions

There are a number of assumptions underlying the evacuation capability methodology. These include:

- <u>Sector-level assessments have not explicitly included resources and timelines for special needs areas such as hospitals, caravan parks or nursing homes.</u>
  These areas will require additional resources and time to evacuate safely. These special needs areas must be assessed by the LDMG on a case-by-case basis and incorporated into the Evacuation Sub-Plan.
- <u>Flood data is based on modelled, design flood behaviour.</u>
  The assessment has been completed on a single design event. The associated flood behaviour is not necessarily typical of all flood events and cannot be relied upon to 'predict' time of inundations and road closures during an actual flood event. The PMF event has been used for the assessment, as such representing a maximum upper limit number of flood affected properties that require evacuation.
- <u>Residents within population sectors behave the same way.</u>
  Population sectors are grouped together due to common requirements, such as similar time of flood inundation or same evacuation route required. However, when grouped, there is the underlying assumption that all residents in that group will behave in the same manner during evacuation. The inclusion of evacuation routes is also important. In the evacuation timeline assessment, it is assumed residents evacuate only along the designated routes. Therefore, it is vital that the routes included are accurate, relevant and include sufficient detail to provide an accurate representation of roads likely to be used during an evacuation.

3.2.4 Key Outputs

The key outputs from the assessments are the delineated evacuation sectors along with information on the time required for evacuation and the time available for evacuation. Where applicable, recommendations are made for potential improvements. Where an assessment has been undertaken for a sector, a graphical illustration of the timeline incorporating the components of the ‘time required’ and ‘time available’ assessments is provided. An example timeline is shown in Figure 3-1.



Note: S will be negative value (safety factor <0) when *ti* occurs earlier than *tc*. S will be zero when all available time needed (En) is used. Only when *ti* occurs after *tc* does a Safety Factor begin to accrue. The magnitude of S has to be determined by reference to the capacity to cope with uncertainty and interruptions. The time elements are not drawn to scale in this diagram,

Source: (Opper *et al*, 2009)

Figure 3-1 Example Timeline

3.3 Flood Damages Assessment

3.3.1 Introduction

A baseline assessment of flood damages is required in order to assess the potential for any future mitigation measure to reduce these damages. In this way a reduction in damages from the baseline can be considered a benefit. Benefits of floodplain management measures can then be compared against the costs associated with the planning, design, construction and maintenance of such a measure. Such measures are only economically viable if the benefits exceed the cost (i.e. the ratio of benefits to costs is greater than 1.0).

Flood damages are classified as tangible or intangible depending on whether it is practical to assign monetary values, as shown in Figure 3-2. Tangible damage for example may be damage to buildings and contents whereas intangible damage may the loss of sentimental items or ill health as a result of the flooding.

Tangible damages can also be split into direct damages such as loss of building contents and indirect damages such as loss of industrial production or tourism.

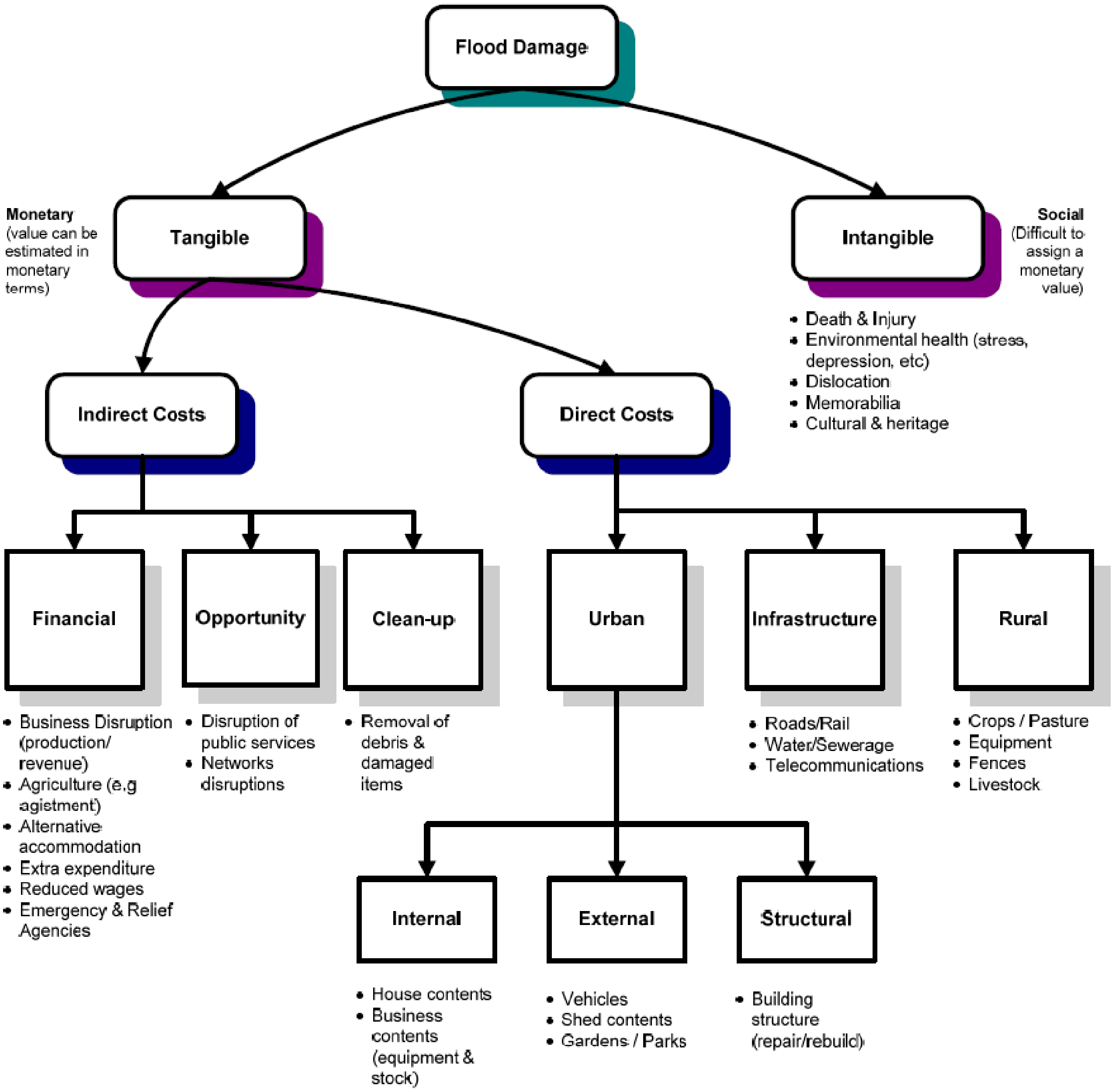


Figure 3-2 Breakdown of Flood Damages

Damages are derived using modelled design flood events ranging from relatively frequent events up to the largest event believed possible (the Probable Maximum Flood). Damages are calculated for each modelled design event and then the annual average damages (AAD) are derived from this. As a structural flood mitigation measure will be designed to be in place for many years then the annual average damages and multiplied by the number of years for which such schemes are designed for – typically 100 years. A discount factor is applied whereby AAD are reduced year on year when projected into the future. This is standard economic practice and can be thought of as society's willingness to value something more at present than in the future.

3.3.2 Methodology for Calculation of Tangible Damages

The flood damage assessment employed in this study follows current best practice within Queensland and are based on the following approaches:

- ANUFLOOD (Smith and Greenaway 1992) which provides stage-damage curves for a number of property types and classes.
- Rapid Appraisal Method (RAM) for Floodplain Management (VDNRE 2000) which provides recommendations on appropriate adjustments to the ANUFLOOD data.
- Queensland Government guidance on the assessment of tangible flood damages (NRM 2002) which contains further recommendations for applying ANUFLOOD in Queensland studies.

The methodology used to estimate flood damages is discussed in detail in Appendix C. An overview of the general methodology applied for each community assessment is provided below.

Establishment of Property Database

For each community assessment where flood damages have been estimated, a property database has been developed. The property dataset identifies properties within the community and classifies them as either residential or commercial/industrial. Furthermore each identified property was determined as being either high-set or low-set. A combination of site visits use of available imagery and assumptions were used in the determination of these factors. Areas of each community judged to be at greatest risk of flooding received the greater focus when determining these factors. The distinction between high-set and low-set was arbitrary with a building considered as high-set if the difference between ground and floor level was sufficient to park a car. Non high-set buildings were classified as low-set which included both slab on ground and low raised buildings.

LiDAR data was used to establish the ground elevation at each property and all low set properties were assumed to have a floor level 0.3m above ground and all high set properties 2m above ground.

Direct Internal Damage Estimation

Peak modelled flood levels for design flood events ranging from the 2 year ARI to the Probable Maximum Flood were extracted at the location of each property in the property database. A comparison of the flood levels with the assumed property floor elevation allowed for an estimate of flood depth above floor level for each design flood event.

Stage-damage relationships or curves which relate property damages (internal building structure and contents) to the stage (depth) of water were used in the assessment with separate curves for residential and commercial property. These stage-damage curves are approximations based on average values and house types. It would not be valid therefore to consider the resulting estimated damage at a single property but rather the results should be assessed at community level.

The stage-damage curves adopted in this study are based on those recommended for use in Queensland with damage values adjusted to present day (2012) values using the Consumer Price Index (CPI).

Indirect Damage Estimation

An allowance for indirect damages has been made based on NRM (2002) guidance in which indirect residential and commercial damages are assumed to be 15% and 55% of direct damages respectively.

External/Below Floor Damages

An allowance for external damages to items such as mowers and washing machines has been made based on NRM (2002) where the flood height is lower than the habitable floor height. A nominal damage value with an upper limit of $1412 has been applied to properties with below floor level flooding.

Structural Failure

Structural failure of a building is separate to internal structural damage (such as built-in cupboards, internal walls, and wiring) which is included in the stage-damage curves.

Structural failure results from a combination of flood depths and velocities. Even at shallow depths, velocities greater than 2m/s can lead to scour of the foundations. Conversely, at low velocities with depths greater than 2 metres, damage to light framed buildings from water pressure, flotation and debris loads can occur.

Typically, such damage is considered likely to occur when the velocity-depth product is greater than 1 m^2/s (NRM, 2002).

Based on these criteria, structural failure of building has been assumed for properties experiencing any of the following flood conditions:

- Velocity – depth product > 1 m^2/s; or
- Depth (above floor) > 2 metres; or
- Velocity > 2 m/s.

It should be noted that 'structural failure' does not necessarily mean complete destruction of the building. Structural damages have been nominally based on $20,000 per property, which is consistent with previous studies.

Damage to Infrastructure

It is often difficult to estimate infrastructure damage due to flooding as it usually requires input from several agencies, which may or may not know the value of the asset nor the damage that is likely to sustain in a flood. For this study, infrastructure damage is assumed to be 15% of total direct damage, which is consistent with similar studies.

3.3.3 Annual Average Damages

Damage values per community can be estimated for each modelled ARI event by summing the damages at every property and including the allowances for infrastructure damage. As the ARI is a measure of frequency of occurrence the damage values can be combined for each event to provide the Annual Average Damages (AAD). AAD represents the estimated tangible damage sustained every year on average over a long period of time.

3.3.4 Intangible Damages

Intangible damages incorporate direct and indirect impacts for which there is no commonly agreed method of evaluation (EMA, 2002). Intangibles compose of things without market value i.e. cannot be bought or sold, which makes their dollar value difficult to calculate. There are a number of intangible costs of flooding to the community including the following:

- Loss of life and limb;
- Inconvenience;
- Isolation/evacuation;
- Stress and anxiety;
- Disruption; and
- Health issues.

In the absence of reliable cost estimates associated with intangible damages, a multiplier can be applied to the Benefit-Cost ratio of a mitigation measure. For example, a rule of thumb that has been used in NSW is to adopt a multiplier of two (2), i.e. a mitigation measure should have a minimum B/C ratio of 0.5 if it is to be considered further.

3.3.5 Benefit of a Mitigation Option

The total benefit of a mitigation option is calculated based on the difference in AAD, and adjusted to present worth, using a Net Present Worth Factor of 14.77. This factor is based on a 50 year design life and a 7% discount rate.

3.3.6 Benefit-Cost Ratios

The overall financial viability of a measure is initially assessed by calculating the monetary benefit-cost ratio. The procedure for calculating benefit-cost ratios is outlined below:

1. Calculate annual average damages with and without the measure in place.
2. Calculate the average annual benefit associated with the measure (i.e. the annual average damages avoided with the measure in place).
3. Convert the average annual benefit to a present value benefit using discounting (see Box 1).
4. Calculate the whole life cost of the measure.
5. Calculate the monetary benefit-cost ratio. (total benefit/total cost).

Box 1 - Present Value and Discount Factors

Discounting monetary values which occur in the future is common economic practice on project appraisal and can be summarised by the phrase "*a dollar today is worth more than a dollar tomorrow*". Benefits of a flood defence scheme (damages avoided) accrue into the future and these future benefits need to undergo an adjustment to present day values. This adjustment is termed discounting.

Discounted annual average damages across the design life of the scheme or period of assessment are then summed to give the present value benefit.

This assessment is similarly applied to scheme costs although typically most of the capital costs will be at the start with only maintenance and repair costs occurring into the future. The whole life (present value) costs of a scheme are compared to the benefits to obtain the benefit cost ratio.

4 FLOODPLAIN MANAGEMENT MEASURES

Floodplain management measures have been assessed at the community level and are categorised into the following general groupings:

- Structural Flood Mitigation Measures;
- Land Use and Development Control Measures; and
- Emergency Planning and Response Measures including Community Awareness.

As consideration and assessment of measures is specific to each community the methodology employed varies between each community assessment. For that reason the relevant community section should be referred to for the specific methodology employed.

The level of assessment applied to each community is applied in accordance with a framework detailed in the ‘Community Overview’ document of the FRMS. The level of assessment applied is in accordance with the level of risk and determines the breath of management measures considered for each particular community.

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APPENDIX A: HYDROLOGIC AND HYDRAULIC MODEL UPDATES

Hydrology

Peak flow estimates were derived for Dalby, Chinchilla, Jandowae, Wandoan, Tara and Miles as part of the Flood Study (Water Technology, 2011, 2012).

Summary of Method

For Chinchilla, Jandowae, Wandoan, Tara and Miles the flows were derived in the way summarised below:

- An at site flood frequency analysis (FFA) was undertaken for the Dogwood Creek at Gil Weir gauge.
- Regional flood frequency estimates were derived for all 5 towns using the regional regression equations derived by Palman and Weeks (2009).
- Regional flood frequency estimates were scaled for each town using the ratio of the regional flood frequency estimate for Gil Weir and the site specific FFA at Gil Weir.

Peak flows were derived by Water Technology for the 10%, 5%, 2% and 1% AEP (10, 20, 50 and 100 year ARI) events.

For Dalby a separate combination of techniques was employed. In short a RAFTS model was developed and the output hydrographs from the model were scaled to fit peak flow discharges derived from a regional flood frequency analysis. The regional flood frequency analysis involved conducting individual FFAs on gauging stations within the vicinity of Myall Creek and plotting the resulting 1% AEP peak flow against catchment area. A visual ‘best-fit’ was performed to estimate a 1% AEP peak flow for Myall Creek at Dalby using conservative assumptions. Discharges for lower order events were estimated through scaling of corresponding design discharges for the Condamine River at Warwick. Full details are provided in Appendix E of the Dalby Flood Study (Water Technology, 2012).

FRMS Updates

Peak flows for the 50% and 20% AEP (2 and 5 year ARI) events were not supplied for the towns with the exception of Dalby. These were therefore derived by BMT WBM using the same technique as outlined above. Gil Weir estimates of the 50% and 20% AEP (2 and 5 year ARI) peak flows were taken as $124m^3/s$ and $524m^3/s$ respectively based on an FFA prepared for the FRMS using the Flood Study techniques. For Dalby, the 50% and 20% AEP flows were contained as inflows within the supplied hydraulic models and so these flows were extracted and used in the FRMS.

The Chinchilla model has the added complexity of two inflows as follows:

- Charley’s Creek “major”
- Rocky Creek “minor”

In the Flood Study hydraulic model, each inflow has an “A” and “B” variant. The B run is identical to the A run except for a scaling factor applied to adjust the hydrograph.

The FFA produced a single peak flow and it was therefore necessary to split this flow across the two inflows. Documentation on the methodology applied in the Flood Study was limited and therefore the following approach was adopted for the 50% and 20% AEP flows:

- Run the Rafts model using IFD parameters to obtain the 50% and 20% AEP hydrographs for Rocky Creek and Charley's Creek.
- Adopt the Rocky Creek hydrograph with no scaling.
- Scale the Charleys Creek hydrograph so that the peak coincides with the peak estimated using the FFA.

The supplied 10% AEP RAFTS model from the Flood Study was used as the basis for deriving the 50% and 20% AEP flows for Chinchilla. The 10% AEP model used IFD parameters rather than user defined intensities. It was noted that minor scaling was applied to the 10% AEP hydrographs when comparing those from the hydrologic RAFTS to those used in the hydraulic model – particularly for Charley's Creek. This scaling is not explained in the Flood Study but, as it is relatively minor, the direct flows from RAFTS for the 50% and 20% AEP events were used. (In all cases the 24 hour storm was used as the critical duration as per the Flood Study.)

Hydrographs for PMF events for all towns were contained in supplied hydrologic RAFTS models. These flows were extracted for use in the FRMS.

Warra, Meandarra and Condamine

Additional topographic LiDAR data supplied for use in the FRMS meant that these towns could also be hydraulically modelled. In order to undertake such modelling, design inflows were required to be estimated. For consistency, peak inflows at Warra and Meandarra were derived using the same techniques as for the 5 regional towns. Only the 1% AEP flow was derived as the assessments for these towns was of reduced scope in line with the level of risk. Inflows to the hydraulic model were simply ramped up until the peak flow was reached and then maintained at this flow until the models reached steady-state flow conditions. As such, a design hydrograph shape was not required.

For Condamine, the peak flow of the historical flood of 2010/11 was used in place of a design flood event. This flood event was the largest on record and required the town to be evacuated twice in succession. As for Warra and Meandarra no hydrograph shape was required as the Condamine model was ran until steady-state flow conditions were achieved at the peak flow.

Peak flows for Warra Meandarra and Condamine are summarised below:

- Warra 1% AEP Peak Flow: Coranga Creek 1,163m^3/s; Jandowae Creek 603m^3/s.
- Meandarra 1% AEP Peak Flow: 848m^3/s.
- Condamine 2010/2011 event peak flow: 5,820m^3/s.

Hydraulics

Dalby, Chinchilla and Jandowae

The MIKEFLOOD Dalby, Chinchilla and Jandowae hydraulic models as used in the Flood Study were converted to TUFLOW to allow additional modelling and assessments to be undertaken for the FRMS.

The principal changes to the hydraulic models were a reduction in the resolution (increase in model cell size) to allow for improved run times. This was necessary to allow efficient testing of structural mitigation options in required timeframes.

For Dalby and Chinchilla the modelled cell size was increased to 20m and for the smaller Jandowae model it was 10m.

Checks were undertaken to ensure that the updated model results were comparable to the MIKEFLOOD results. Other than minor differences, the model results showed no notable disagreements.

Inflows to the model used the same hydrographs as the Flood Study models. However the orientation and location of the inflows underwent minor adjustments to more appropriately align with flow directions. For Jandowae in particular the inflow to the model was adjusted to correspond to the channel. The supplied model had some of the inflow entering below the dam and therefore was overstating flow in this area.

The models were ran for the full set of AEP events (those supplied and those derived): 50%, 20%, 10%, 5%, 2% 1% AEP and the PMF events.

Warra, Meandarra and Condamine

New hydraulic models were developed for Warra, Meandarra and Condamine as part of the FRMS. These models were simplified to accord with the nature of the assessment for these towns. Inflows were ramped up until the estimated peak inflow was achieved and this was maintained until steady-state flow conditions were observed in the model. LiDAR data was used as the basis of the topographic data in the model and a uniform roughness value was set.

The purpose of the models was to map the approximate extent, depth and hazard of a significant flood event (design or historical) and this in turn would then assist with emergency planning and response.

APPENDIX B: PARAMETERS USED IN EVACUATION ASSESSMENT

Prediction Time (P)

Prediction time is one of the most significant parameters in the evacuation capability assessment. It is also one of the most uncertain, relying on a combination of quantitative data, such as stream gauge and pluviograph readings, and qualitative assessments such as lead-up storm behaviour. In addition, the following, conflicting objectives must be balanced:

- Late prediction may not allow sufficient time for safe evacuation of residents; whilst
- Early prediction may result in unnecessary evacuations. As well as the associated cost and inconvenience, residents may be less likely to heed evacuation advice in the future.

Within the Western Downs Region prediction time is informed by a combination of predicted and recorded rainfall and river height information, provided by the Bureau of Meteorology (BoM). This is limited to Dalby, Chinchilla and Condamine.

Resource Mobilisation Time (M)

Resource mobilisation time is the amount of time it takes the SES to assess the severity and likelihood of a flood event, formulate a response strategy and mobilise resources. The resource mobilisation phase occurs prior to commencement of evacuation.

Warning Time (W)

Warning time accounts for the time required to inform all dwellings that evacuation is required. During flood events there are many warning dissemination methods available, such as door knocking or a variety of mass broadcast means including:

- Radio;
- Television;
- Sirens;
- Telephone; and
- SMS notification.

Within the ‘Evacuation Timeline’ framework (Opper, 2004) door knocking is the only warning method considered for assessment. This is due to the timeframes and successful response to the evacuation warning message associated with the mass broadcast methods being largely unknown. Due to these current unknowns, the above listed mass broadcast methods are not considered further during the evacuation planning process.

Using the door knock approach, the resultant warning time (W) is proportional to the number of dwellings requiring warning, the number of door knock teams and their efficiency. Based on field testing by the SES (Opper, 2004), a door knock efficiency of 12 houses/hour/team has been used for this assessment.

$$WarningTime(W) = \frac{DwellingCount}{(TeamCount \times TeamEffeciency)}$$

Community Acceptance and Response Factors (Wf)

Following delivery of an evacuation warning, experience has shown that people require time to firstly accept the warning and secondly organise themselves prior to evacuating. To accommodate for this, the 'Evacuation Timeline' methodology includes both warning acceptance and warning lag factors. As prescribed by Opper (2004), one hour has been adopted as the respective warning acceptance and warning lag factors. Within the context of this assessment, the combination of these warning factors mean that residents do not evacuate a dwelling until two hours after being issued of an evacuation warning via door knocking.

Evacuation Time (En)

The evacuation time represents the required time to complete a full evacuation of all people, using cars as the primary means of transport, assuming no unexpected impediments (L).

$$EvacuationTime(En) = Acceptance\&ResponseTimeFactors(Wf) + VehicleMovementTime\ (Vt)$$

Required Time For Vehicle Movement (Vt)

Following community acceptance of an evacuation warning, the time required for vehicle movement represents the time needed to complete a full evacuation of all people, using cars as the primary means of transport. Assuming sufficient door knock teams, such that evacuation routes are at their vehicle flow rate capacity, calculation of *Vt* requires consideration of the number of cars evacuating, the vehicle flow rate along a given evacuation route and an additional traffic safety factor, allowing for the time needed to attend to a serious traffic incident.

$$VehicleMovementTime(Vt) = \frac{VehicleCount}{VehicleFlowRate} + TrafficSafetyFactor$$

Within the 'Evacuation Timeline' approach (Opper, 2004), a vehicle flow rate of 600 vehicles/lane/hour and the traffic safety factors listed in Table A-1 are recommended.

Table B- 1 Evacuation Traffic Flow Traffic Safety Factors

Base Time (hrs)	Safety Factor (hrs)	Total Time Required for Vehicle Movement (Vt)
1	1	2
2	1	3
3	1	4
4	1.5	5.5
5	1.5	6.5
6	1.5	7.5
7	2	9
8	2	10
9	2	11
10	2.5	12.5
1	2.5	13.5
12	2.5	14.5
13	3	16
14	3	17
15	3	18

Source: (Opper, 2004)

Available Evacuation Time (Ea)

The actual available time for evacuation (*Ea*) is defined as the time until evacuation route closure occurs (*ti*), due to inundation of the evacuation route by floodwater.

Following closure of an evacuation route, where the calculated vehicle movement time (*Vt*) exceeds the time available for evacuation (*Ea*), rescue operations (*R*) will need to be initiated. Rescue operations represent a failed evacuation.

$$VehicleMovementTime(Vt) > AvailableEvacuationTime(Ea) = FailedEvacuation$$

Rescue Phase (R) and Lost Time (L)

As mentioned above, if evacuation routes close before evacuation is complete, it will be necessary to rescue isolated areas. There are no guidelines for estimating how long rescue may take; factors involved, such as provision of boats and helicopters, are completely different to factors used to estimate vehicle evacuation. Therefore, for the purposes of this assessment, the rescue phase is defined as the amount of ‘lost evacuation time’. The rescue phase is calculated as the difference between the time when evacuation should have been completed and the time when evacuation is interrupted.

Safety Factor (S)

If the evacuation route closes after the time required for evacuation to complete, the difference between these times is referred to as a safety factor. The safety factor can help inform evacuation resource planning. For example, an area with a lower safety factor may be prioritised over an area with a large safety factor. In addition, the safety factor may be used to determine whether the evacuation sector is able to sustain an increased population when new developments are proposed. Although it is not suggested that a safety factor be eroded entirely, it does provide a semi-quantitative method for determining how much additional risk a community is prepared to take on due to development.

The safety factor, S, indicates how much extra time is available between the conclusion of evacuation and road closure. If S is negative, evacuation cannot complete.

APPENDIX C: DAMAGES

The stage-damage curves used by ANUFLOOD are based on the Sydney 1986 flood event and need updating to allow for temporal and regional variation. In accordance with RAM guidance (VDNRE, 2000), the damages implied by the existing ANUFLOOD stage-damage curves were increased by 60%.

An adjustment using CPI was then made to bring damage values to them to present day values.

Damages were estimated for both residential and commercial buildings across the range of modelled design flood events ranging from the 50% AEP (2 year ARI) flood to the Probable Maximum Flood (PMF). For the purposes of this study the PMF has an assumed ARI of 100,000 years (an annual exceedance probability of 0.001%).

Residential Damages

Residential stage damage curves developed for ANUFLOOD (1992) were used in this study as recommended by the Queensland Government Department of Natural Resources and Mines (2002). It is important to note that application of the ANUFLOOD stage-damage curves are only applicable if the number of properties to which the curve is applied is considerable (greater than 50). This is because the stage damage curve is an averaging procedure. Likewise, whilst damages are output on a property by property basis they should be treated as a lumped damage value at the community level. The NRM guidance note contains curves representing small, medium and large buildings.

The guidance recognises that in 'flood aware' communities, which receive sufficient flood warning, the actual damages may be significantly less than the potential damages due to the efforts of residents and volunteers ahead of the flood. Generally the worst case assumption is that nothing can be, or will be done to remove susceptible valuables from the area facing inundation. Whilst many communities within the Western Downs region are acutely flood aware, there are also many transient populations associated with factors such as the mining industry. Any adjustment for actual damages from potential damages will be judged on its own merits for that communities' individual assessment and where such an adjustment has been made this will be documented in the relevant community specific sections.

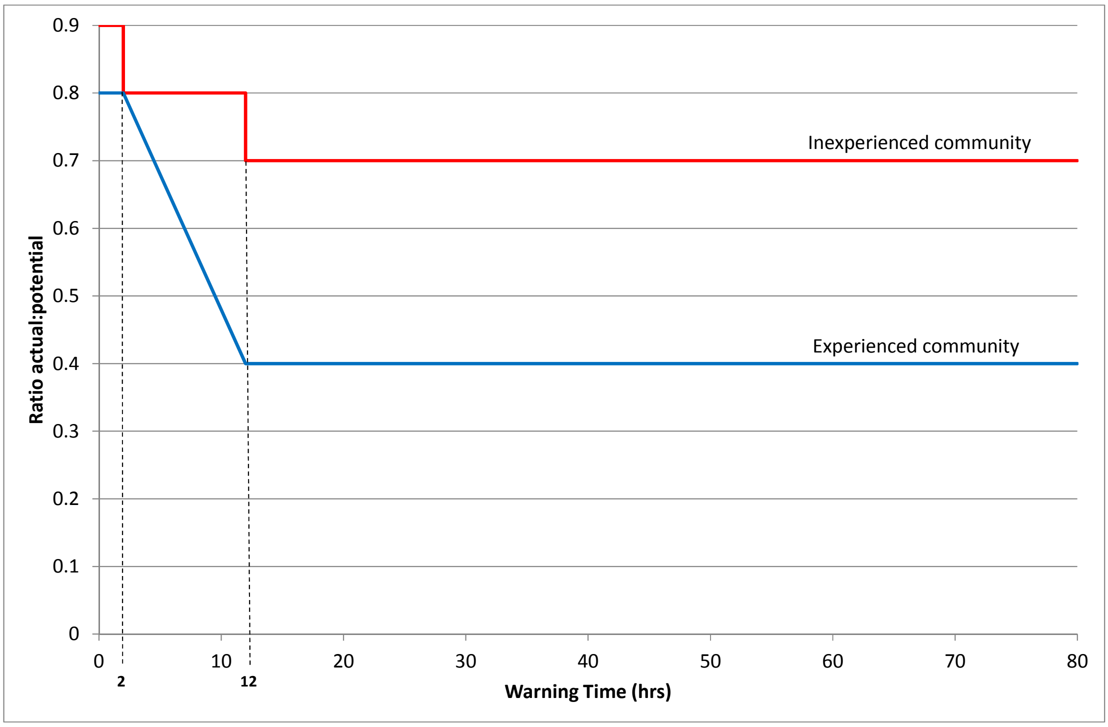

Figure C- 1 Relationship between Actual and Potential Damages

Reproduced from VDNRE (2000)

An allowance for damages for below floor flooding has also been included in the damage calculations. Many houses, particularly raised houses, have storage below the main floor level. Such areas may be used to store items such as movers and washing machines, which may be damaged, even if the main house has not been affected. As such, a value of $1,412 per property has been applied, as per NRM (2002).

Vehicles are excluded from this value for the following principle reasons:

- Vehicles are easily moved to higher ground; and
- Funding agencies are unlikely to justify a mitigation measure for which a large component of the benefits is derived from protecting cars.

Residential Damage Assumptions

Unless stated otherwise in the individual community specific sections, it is assumed that all residential houses are detached and of medium size for the purposes of the damage assessment. A medium house is assumed to have a floor area of between 80 to 140m2 and/or 3 bedrooms.

An allowance for indirect damages has been made based on NRM (2002) guidance in which indirect residential damages are assumed to be 15% of direct damages.

High-set residential properties are assumed to have a floor level 2m above ground level, for low set properties this reduces to 0.3m above ground level. For the purposes of this study topographic LiDAR data has been used to derive an estimate of ground levels at the property.

All monetary values have been adjusted to present day (2012) dollar values using the Consumer Price Index (CPI) weighted average across the eight capital cities (ABS, 2012).

The RAM Study (VDNRE, 2000) found that the residential stage damage curves produced by ANUFLOOD are out-dated and that the estimates are too low. They recommend that the curves be increased by 60%.

Commercial/Industrial Damages

For the purposes of this study no distinction is made between commercial and industrial properties. Commercial damage values have been applied to both.

Commercial stage-damage curves developed for ANUFLOOD (1992) for direct damages were used in this study. Unless stated otherwise in the individual town specific sections, it is assumed that all commercial properties are of medium size (186 to 650m2) and of medium (class 3) value.

Damage values were updated to present day (2012) values by adjusting for CPI (ABS, 2012).

An allowance for indirect damages has been made based on NRM (2002) guidance in which indirect commercial damages are assumed to be 55% of direct damages.

High-set commercial properties are assumed to have a floor level 2m above ground level, for low set commercial properties this reduces to 0.3m above ground level. For the purposes of this study topographic LiDAR data has been used to derive an estimate of ground levels at the property.

Dalby Customised Stage Damage Curves

NRM (2002) guidance also strongly recommends that local authorities develop their own data for use in damage assessments. This was undertaken as part of the assessment for Dalby by Munro, Johnson & Associates (1986).

The Dalby specific stage-damage curves were derived using information gathered from two surveys undertaken in Dalby:

- An urban property survey to identify property type (residential/commercial/industrial), floor height (high/low-set) and approximate building area for commercial and industrial properties; and
- A flood damage survey undertaken by an experienced valuer which involved detailed assessment of potential flood damage at a limited number of residential, industrial and commercial properties.

Stage-damage curves were developed for both residential and commercial properties using three intervals of above floor level flood depth. A nominal allowance of $500 per affected residential property was assumed as the indirect cost. Industrial properties were treated as commercial properties and these were classified into low, medium and high damage categories.

Figure B-2 compares the Dalby customised stage-damage curve with the ANUFLOOD curve. Both curves include direct and indirect damage components and are updated to present day values.

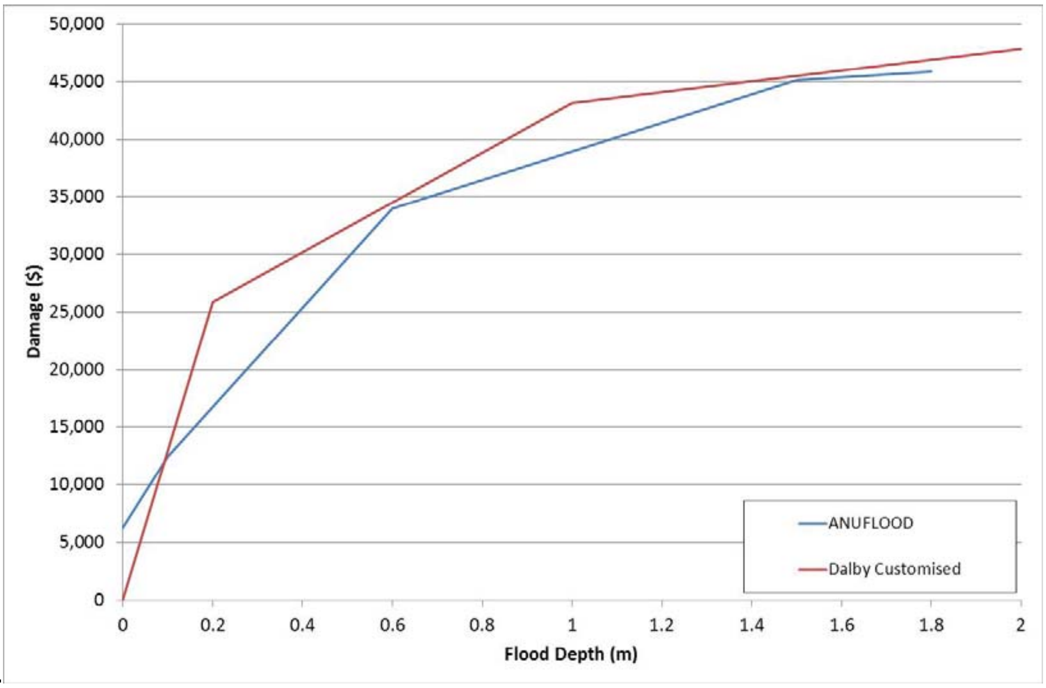

Figure C- 2 Comparison of Residential Stage Damages Curve

Whilst the overall curves shown in Figure B-2 are similar the following points are noted:

- ANUFLOOD damages are initially much higher as soon as floor level is reached when compared to the Dalby customised damages.
- Dalby customised damage curve shows damages are significantly higher per property for flood depths of 0.2m than for the ANUFLOOD curve.

Munro, Johnson & Associates (1986) also produced Dalby specific stage-damage data for Commercial/Industrial Damages. The stage-damage data was presented on a unit area basis. To facilitate a comparison with the ANUFLOOD data used in this study, a floor area of 418m^2 has been assumed which corresponds with the average value of the medium size class in the ANUFLOOD data. The data were also adjusted to present day values using CPI. The comparison is plotted in Figure B-3 where it can be seen that the two curves are similar.

As the customised stage-damage curves for Dalby are broadly similar to the ANUFLOOD stage-damage curves, the ANUFLOOD curves have been adopted for use in this study to retain consistency with curves used for other communities.

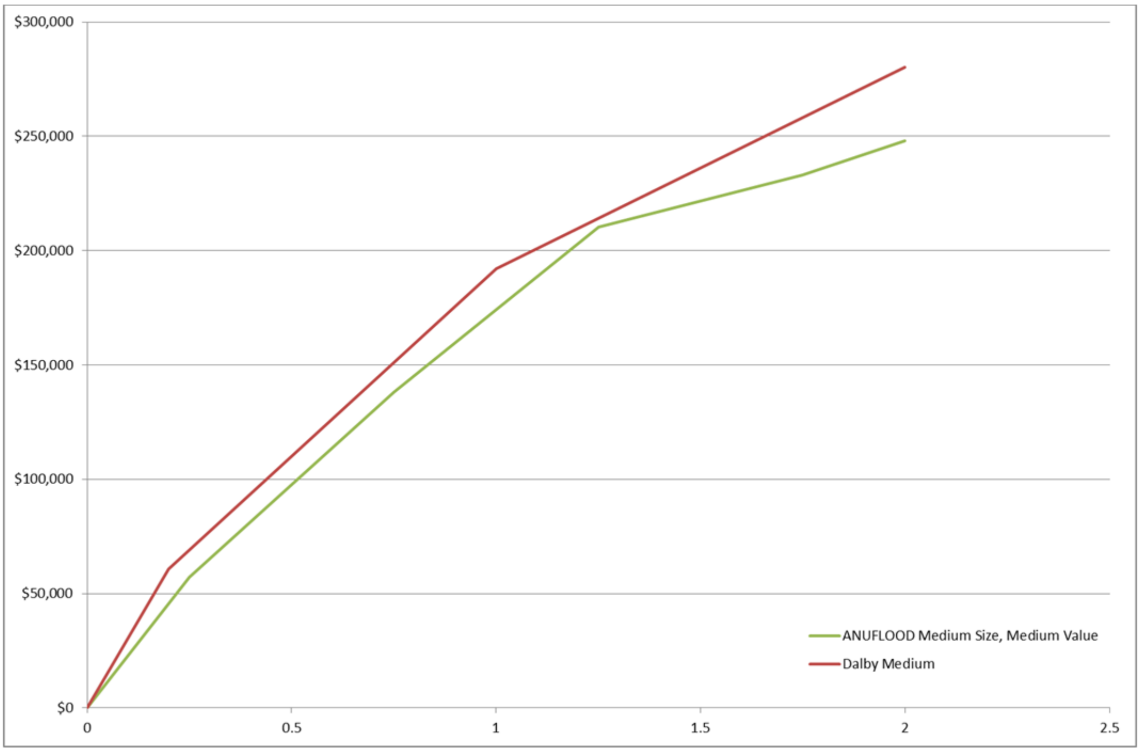

Figure C- 3 Comparison of Commercial Stage Damage Curves

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