

The Lockyer Creek Flood of January 2011: What Happened and How Should We Manage Hazard for Rare Floods

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Abstract:

The Lockyer Valley experienced a rare and damaging flood on the afternoon of the 10th January 2011. The lives of 19 people were tragically lost and many houses were destroyed.

The estimated annual exceedance probability (AEP) of the rainfall in some parts of the catchment was rarer than 1 in 1000. Many parts of the catchment upstream of Helidon and Grantham received rainfall with an AEP of rarer than 1 in 200.

There are many lessons to be learnt from this tragic flood event in regard to flood risk management. The flood event highlighted the need to consider residual risk in managing floodplains. Can we class the loss of life associated with this event as tolerable if the annual probability of occurrence is only 1 in 1000 ?

The policy for managing flood hazard for development proposals and planning schemes in Queensland would suggest that this risk is acceptable and tolerable. SPP 1/03 recommends that "development maintains the safety of people on the development site from all floods up to and including the Defined Flood Event".

However, the National Emergency Risk Assessment Guidelines would appear to be in conflict with Queensland flood risk management policy. Based on a risk assessment under these guidelines, this risk is not acceptable and should be managed.

So, how should councils consider the hazards associated with floods rarer than the 1% AEP flood event ? How can councils identify these hazards in the first place ? How do we educate policy makers to understand the full spectrum of flood risk management ?

The legacy of this flood should be to challenge the way that flood risk is managed in Queensland.

Introduction

The flood event that occurred on the afternoon of Monday 10th January, 2011 devastated communities, destroyed lives and simply washed away property. The event was tragic. A total of 17 lives were lost with two other persons never found, presumed dead.

As a community of flood risk managers, we must ask ourselves some serious questions as a result of this flood. How and why did so many people die ? What could have prevented these deaths ? Did the 'system' fail this community ?

Some of these questions are matters for the Queensland Floods Commission of Inquiry and the coronial inquiry. Hence, this paper will focus on the following questions:

- What happened to cause such flood hazard ?

- As risk managers, is this disaster 'acceptable' or even 'tolerable' ?
- What can we learn from this event ?

To address these questions, this paper provides some details on the flood event, an assessment of the probability of the event and discussion on what should be the legacy of this flood for flood risk management in Australia.

The Lockyer Valley

The Lockyer Creek catchment is located approximately 75km west of Brisbane. The regional city of Toowoomba sits at the top of the range forming the western boundary of the catchment.

The catchment down to the junction with the mid Brisbane River is 3,000 km². The catchment within Lockyer Valley Regional Council area is 2,300 km². The catchment of the Upper Lockyer Creek down to Grantham (710 km²) and that of the whole Lockyer Creek catchment are shown in Figure 1.

It is apparent that the Upper Lockyer Creek catchment has a typical bowl shape with similar travel times of 15km to 25km to Grantham for many of the tributaries.

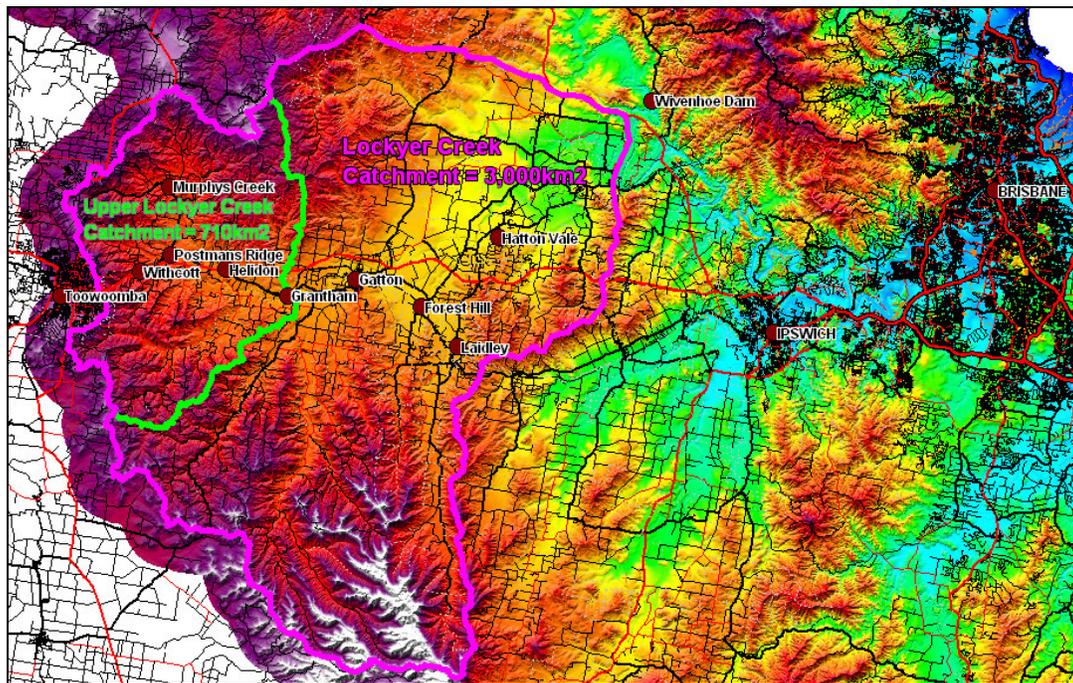


Figure 1: Catchments of Upper Lockyer Creek and Lockyer Creek

Lead-up to flood event

The period leading up to 10th January, 2011 included very wet December and early January. The catchments were very wet and infiltration losses were at a minimum.

On the afternoon of Sunday 9th January (the day before the event), rainfall fell over most of the catchment and resulted in a relatively small flood event. This event was probably less than a 20% AEP event in most parts of the catchment. For the residents

Flood behaviour

The wet catchments of the western Lockyer Creek area responded quickly to these intense rainfalls. Creek levels rose dramatically on the base of the recession from the previous flood the night before.

There are not any flood gauges on Lockyer Creek upstream of Helidon. Here, the catchment is already 370 km² and includes the towns of Murphys Creek, Postmans Ridge and Withcott. At this flood gauge, levels rose from 5m at 2:20pm to 13m at 2:50pm at which time, the gauge failed. That represents a rise of 8m in 30 minutes or equivalent to 1m every 4 minutes. This gauge record is probably from where the somewhat inaccurate "8m wall of water" phrase came.

Of note, the highest rate of rise was between 2:30pm and 2:40pm when the gauge rose from 7m to 11m. This is a rate of 1m every 2.5 minutes.

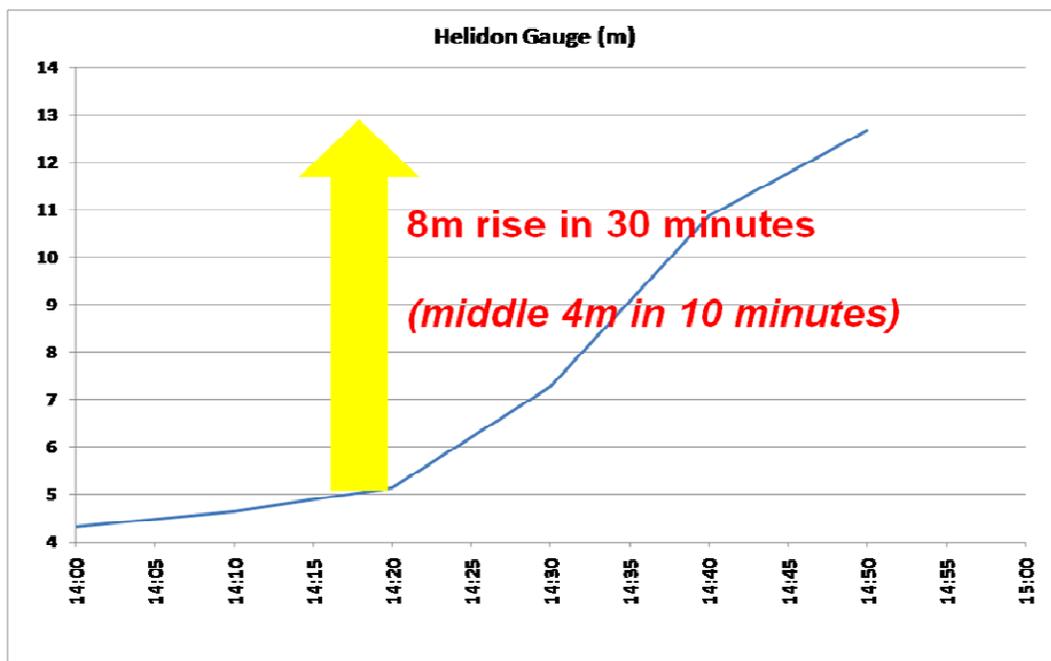


Figure 3: Helidon Flood Gauge Levels

Creek changes during event

The flood resulted in very high velocities in the creek. This resulted in much of the riparian vegetation along the Lockyer Creek and upper tributaries being stripped from its roots during the flood event.

The debris load within the water column probably contributed to the loss of riparian vegetation. Large trees felled upstream most probably contributed to the debris loads on riparian vegetation further downstream.



Figure 4: Upper Lockyer Creek Riparian Vegetation Pre (L) and Post (R) Flood

Flood modelling of event

SKM is currently carrying out the Lockyer Creek Flood Risk Management Study. This study was originally planned, prior to the flood event, to be undertaken some time in 2011/2012 financial year. Following the event, the study was started immediately.

The first part of the study involved the development of a complex two-dimensional (2D) TUFLOW flood model. The study area was represented by five 2D domains all dynamically linked. The 2D domains ranged in cell size from 7m x 7m to 40m x 40m. The largest domains included representation of Lockyer Creek as a network of over 400 open channels.

A hydrological model of the catchment was created using RAFTS-XP. Over 230 sub-areas represent the 2,300 km² catchment.

There was a scarcity of rainfall gauges in the upper catchment. As well, the rainfall cell discussed above moved across the catchment with highly variable intensities. Due to the difficulties in properly representing the rainfall temporal and spatial distributions across the catchment, rainfall radar images were used to derive rainfall inputs.

SKM has developed techniques which enable rainfall radar images to be converted to individual rainfall temporal patterns for each sub-area in the hydrological model. Dr Phil Jordan (SKM) performed this work to create over 230 individual temporal patterns. The rainfall totals and peak intensities were scaled to match the rainfall recorded at point locations where available.

Numerous trials were carried out aimed at matching the observed flooding behaviour. Interviews with residents identified over 500 flood levels. Approximately 280 of these points were surveyed, ranging vertically from 250 mAHD to 70 mAHD.

The 2D/1D flood model matched 80% of the points to within 0.5m and 60% of the points to within 0.25m. While this level of accuracy is not high, it reflects the complexities of modelling such a flood (high debris loads, varying roughness and structures collapsing during event) on a steep floodplain.

There were difficulties in matching the fast rate of floodwater rise but more so with the fast rate of flood recession for the event in the upper Lockyer Creek floodplain area. The gauge at Helidon indicated a rate of flood recession almost as steep as the very fast rate of rise. The model rate of recession was much slower (approximately half of that recorded).

The suspected reason for this is the change in the creek roughness during the flood event. It is apparent from aerial photography before and just after the flood event that the almost complete loss of riparian vegetation along the creek changed from a hydraulic roughness of approximately 0.10 to 0.04 (see photos above).

While attempts were made to vary hydraulic roughness in the creek with velocity-depth product using TUFLOW, this was not successful due to the inability to estimate the relationship between $V \times D$ and Manning's n .

Flood hazard during event

The 2D flood modelling and mapping allowed a representation of the hazards on the floodplain at the peak of the flood event. Velocity-depth product has been used in this paper as a proxy for flood hazard.

Flood hazard for the town of Grantham is presented in Figure 5 below in order to provide some context for the discussion on flood hazard management in rare flood events. $V \times D$ products of more than 3 m^2/s were experienced in the much of the Grantham town area with some areas above 5 m^2/s .

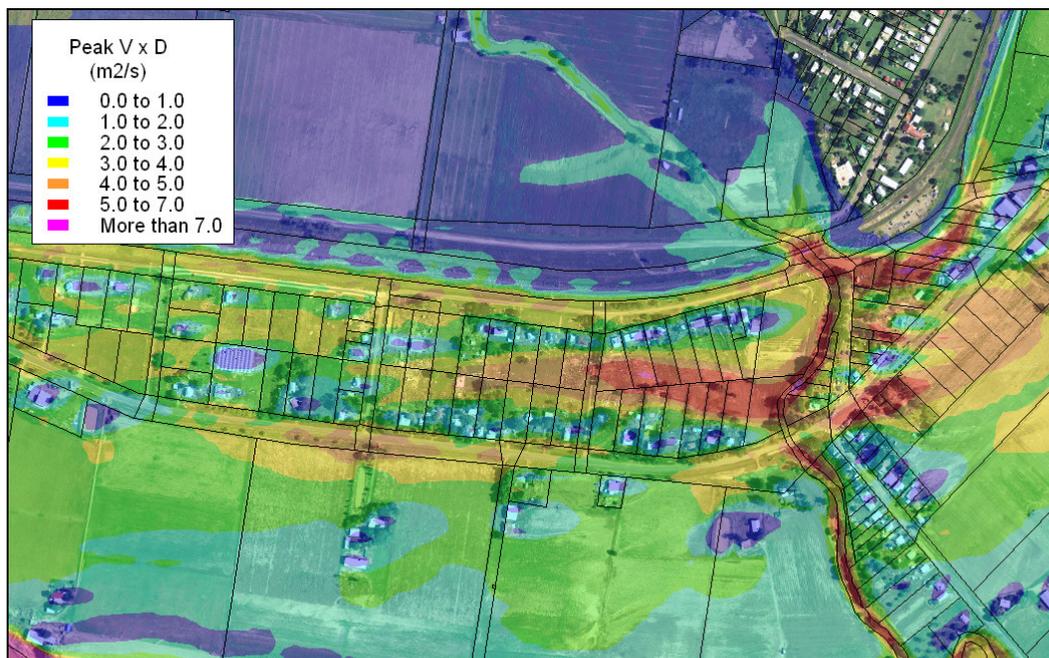


Figure 5: Peak Modelled $V \times D$ at Grantham 10th January 2011

Loss of life and property damage

This paper provides some commentary on the scale of property damage and loss of life during the flood event. However, a more comprehensive assessment of these deaths and structural failures is warranted.

The official death toll from the flood event in the Lockyer Valley area (excluding the Toowoomba and Ipswich areas) is 17 people with another two people not found.

The Queensland Police provided a summary of these deaths and some description of how they occurred. Of particular note in considering the manner of death in this flood event is how many people died in their homes. There were only six of the 19 deaths resulting from people being in vehicles (five attempting to evacuate and one attempting to cross a flood road).

A staggering 13 of the 19 people killed (70%) were washed out of their houses, disappeared as the house was washed away or drowned in their house.

Fitzgerald et al (2010) assessed the 73 recorded flood deaths in Australia over the 12 year period from 1997 to 2008. This assessment indicated that approximately 50% of deaths related to motor vehicle use (e.g. crossing a flooded road). A further 25% of deaths were attributable to *"inappropriate or high-risk behaviour during floods"* (e.g. children playing in a flooded creek) and another 16% were associated with attempts to swim or wade across flooded waterways. The study concluded that *"the vast majority of deaths in Australia (>90%) that occur as a result of floods occur because of the choices made by the individual; choices to engage in inappropriate risk-taking behaviour or to enter flooded waterways either by foot on in a vehicle."*

Based on a cursory assessment of the 19 lives lost in the Lockyer Valley on that fateful Monday afternoon, it would appear that only 30% were as a result of *"choices to engage in inappropriate risk-taking behaviour or to enter flooded waterways either by foot on in a vehicle"*. As mentioned above, a very high proportion of 70% of the people killed were in their homes at the time of the flood. Based on the data supplied in Fitzgerald et al (2010), not one of the 73 people killed by floods between 1997 and 2008 was in their home at the time of the flood.

The flood occurred on a Monday afternoon during school holidays. When it is considered that a fraction of the population were away from their homes (and the area), it is possible that the death toll could have been higher.

Furthermore, if it was not for the bravery and skills of the SES and other rescuers, the death toll would have been higher. A total of 47 people were rescued by boat and 43 people were rescued by helicopter.

A total of 120 houses were structurally damaged by the flood. Many of these were either totally destroyed during the flood event or were deemed to be structurally unsound as a result of the flood and subsequently demolished.

A short summary of the property and infrastructure damage caused by the flood is presented below:

- 2,300 houses inundated;
- Approximately 1,000 cars swept off roads;
- 40 of 48 council-owned bridges damaged;
- 1100km of 1400km of council-owned roads damaged.

Probability of flood event

The estimation of the probability or rarity of this flood event is just that – an estimate. Due to a relatively short period of rainfall records in the region, especially short duration pluviograph records, the accuracy of rainfall intensities rarer than 1% AEP is not high.

Furthermore, the only flood gauge that adequately measured the flood (Helidon gauge) has only 85 years of data and does not include the significant event of 1893. A flood frequency analysis of the peak flows recorded at this gauge indicates that the January 2011 flow of 3,700 m³/s would have an exceedance probability of 0.25%. There is a low level of accuracy associated with the flow estimate of 3,700 m³/s and the flood modelling carried out to date would suggest that the flow may have been in the order of 4,200 m³/s. This would have an exceedance probability of 0.2%.

While the flood gauge at Gatton is much longer and includes the 1890's, this gauge is located downstream of Grantham and includes the large tributaries of Ma Ma Creek and Tenthill Creek. Due to the 10th January flood event being concentrated on the upper Lockyer Creek catchment with little flow from either Ma Ma Creek or Tenthill Creek catchments, the flood was estimated to be approximately a 1% AEP event at Gatton.

CRCForge rainfall depths have been used to simulate a range of design floods for the study area. The results of these simulations provide some guide to the probability of the flood event. At Grantham, the resulting peak flows and levels of the January 2011 flood event lie above the 0.2% (1 in 500) AEP event and just below the 0.05% (1 in 2000) AEP event.

Hence, based on available evidence, the probability of the flood at Helidon and Grantham is estimated to be approximately 0.1% AEP with bounds of 0.2% and 0.05% AEP.

Guidance from Queensland state planning policy

In Queensland, State Planning Policy (SPP) 1/03 sets out the State's interest in ensuring that the natural hazards of flood, bushfire, and landslide are adequately considered when making decisions about development.

At the start of the policy, the following position statement of the Queensland Government is presented *"The Queensland Government considers that development should minimise the potential adverse impacts of flood, bushfire and landslide on people, property, economic activity and the environment"*.

It is not a comprehensive policy on flood risk management as it is specifically focussed on managing future risk (i.e. that associated with future development on the floodplain). The management of existing flood risk and residual flood risk are not part of the scope of SPP 1/03.

Hence, it is recognised that SPP 1/03 is a policy for application when land is subject to development applications and when planning schemes are made. However, the Lockyer Creek flood event provides an opportunity to assess how well SPP 1/03 would have performed in managing flood risk.

To conduct this assessment, it is necessary to create a hypothetical scenario in which the towns of Grantham and Withcott were developed under the guidance of SPP 1/03. In reality, these towns were established many decades ago when our collective understanding and appreciation of flood risk management were less than today.

The specific objectives of SPP 1/03 that warrant consideration are:

- The minimisation of the adverse affects of flooding.
- The adequate consideration of flood hazard when making decisions about development

In the hypothetical scenario of Grantham being developed since 2003, an application of SPP 1/03 would have resulted in much of the inundated part of town being classified as within a 'natural hazard area' as it would be within the bounds of the 1% AEP flood (assuming that was adopted as the DFE). Residential development would have been permitted in areas of medium hazard with floor levels of habitable rooms above the 1% AEP flood levels.

However, it is clear from this application that any hazards associated with rarer floods do not require management or consideration. The focus on hazard management in SPP1/03 stops at the 1% AEP flood (assuming that it was adopted as the DFE) for residential development.

Challenges for flood risk management

The obvious challenge for flood risk management emerging from this flood event is how to account for the hazard associated with flood events rarer than the 1% AEP flood event. The management of this risk category is often referred to as residual risk.

It is also one of the most overlooked elements of flood risk management. Commonly, the approach to residual risk management is one of acceptance or at least tolerance. The implied acceptance of residual risk comes from an often incorrect assumption that the consequences vary somewhat linearly with probability. Hence, rare floods (say 0.2% AEP or 1 in 500 AEP) are viewed as highly unlikely to occur and, if they do occur, that consequences are just 'bad luck'.

However, in light of the damage, destruction and deaths caused by this flood event, questions over the tolerance of this level of risk need to be raised and considered.

The best guidance available for assessing the tolerance of such risks is embodied within the National Emergency Risk Assessment Guidelines (EMA, October 2010). This paper was produced in November 2011. However, a revised version of this document is due for publication in early 2012. NERAG provides a process for assessing risk as either intolerable, tolerable (subject to reducing the risk to as low as reasonably practicable) or acceptable. The 'as-low-as-reasonably-practicable' or ALARP principle is demonstrated below in Figure 9 taken from NERAG (EMA, October 2010).

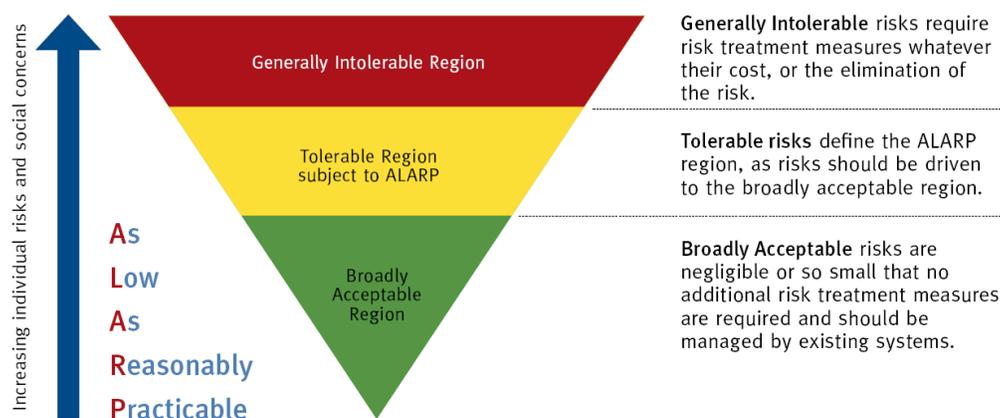


Figure 6: ALARP Principle (reproduction of Figure 9 from NERAG, EMA 2010)

Applying the risk assessment process to this particular flood event yields interesting results. In order to simplify the application, the area of interest was defined as the Helidon to Grantham section of the Lockyer Creek floodplain.

Firstly, the consequences need to be defined. NERAG provides guidance on consequence rating through consideration of a number of aspects of the event including effects on people, environment, infrastructure, governance etc. Table 1 below shows the consequences of major and catastrophic events (other categories in NERAG include moderate, minor and insignificant).

Table 1: Assessment of Severity of Flood Consequences

Aspect	Major	Catastrophic
People	Multiple loss of life (mortality > 1 in 100,000), health system overstressed, large numbers of displaced people (more than 24 hours).	Widespread multiple loss of life (mortality > 1 in 10,000), health system unable to cope, displacement of people beyond ability to cope.
Public Administration	Governing body absorbed with managing the event, public administration struggles to provide merely critical services, loss of public confidence in governance, media coverage beyond region or jurisdiction.	Governing body unable to manage the event, disordered public administration without effective functioning, public unrest, media coverage beyond region or jurisdiction.
Environment	Severe impairment or loss of ecosystem functions affecting many species or landscapes, progressive environmental damage.	Widespread severe impairment or loss of ecosystem functions across species and landscapes, irrecoverable environmental damage.
Social Setting	Reduced quality of life within community, significant loss or damage to objects of cultural significance, impacts beyond emotional and psychological capacity in large parts of the community.	Community unable to support itself, widespread loss of objects of cultural significance, impacts beyond emotional and psychological capacity in all parts of the community.
Infrastructure	Mid-term to long-term failure of significant infrastructure and service delivery affecting large parts of the community, initial external support required.	Long-term failure of significant infrastructure and service delivery affecting all parts of the community, ongoing external support at large scale required.
Economy	Financial loss 1-3% of the	Unrecoverable financial loss > 3% of

	government sector's revenues requiring major changes in business strategy to (partly) cover loss, significant disruptions across industry sectors leading to multiple business failures and loss of employment.	the government sector's revenues, asset destruction across industry sectors leading to widespread business failures and loss of employment.
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A non-exhaustive assessment of the flood event against these six aspects is presented below:

- In regard to the effect on the local population, this event was highly significant. The population of the Lockyer Valley is approximately 37,000. Hence, a total of 19 deaths results in a very high ratio of 1 per 2,000 (applied across the Australian population, this equates to approximately 11,000 deaths). Based on the table above, this would equate to a catastrophic event.
- In regard to public administration, the state and local government was absorbed with managing the event but was able to manage the event. Based on the table above, this would equate to a major event.
- The environment was significantly affected with many kilometres of riparian vegetation lost. Based on the table above, this would equate to a major event.
- In the absence of a detailed assessment of social impacts (which is well beyond the scope of this paper), the event would be estimated to fall into the major category above for Social Setting.
- The infrastructure damage would most likely be classified in the major category listed above. Four bridges were destroyed, sewerage systems were inoperable for many days, roads were significantly damaged.
- The local economy has been significantly affected. On a state basis, the flood event represents a reduction in state GDP of 2.75% (2010/2011) to 0.75% (2011/2012) based on the Queensland Government State Budget 2010-11 – Mid Year Fiscal and Economic Review. A flood levee was introduced and the floods on a state-wide basis changed the economic focus of the state to some degree. Again, in the absence of a detailed economic analysis, this flood would be classified as major consequence at a local level.

Based on the above, the consequences of the flood in the Lockyer Valley matched between the 'catastrophic consequence' and 'major consequence' categories.

In order to estimate the likelihood of this flood event, the results of the flood modelling for this event compared to the modelled flood behaviour for a range of annual exceedances was assessed. While the accuracy of rainfall intensity predictions for events rarer than 1% AEP may not be high, there is sufficient evidence to suggest that this event was rarer than the 0.3% (1 in 330) AEP event but probably not as rare as the 0.03% (1 in 3300) AEP flood event. Hence, based on the likelihood table provided in NERAG, this flood event would be classified as "unlikely".

It needs to be recognised that the rarity of this flood event varied considerably along the valley. At Gatton, which is only 10km further downstream, the probability is estimated to be in the order of 1% AEP. The assessment above relates only to the reach of Lockyer Creek from Helidon to Grantham.

Hence, the risk assessment has identified that the event was between major and catastrophic with a likelihood of "unlikely". The NERAG qualitative risk register (reproduced below) results in a "Medium Risk" to "High Risk" classification.

Likelihood Level	Consequence Level				
	Insignificant	Minor	Moderate	Major	Catastrophic
Almost Certain	Medium	Medium	High	Extreme	Extreme
Likely	Low	Medium	High	High	Extreme
Possible	Low	Low	Medium	High	High
Unlikely	Low	Low	Medium	Medium	High
Rare	Low	Low	Low	Medium	Medium
Very Rare	Low	Low	Low	Low	Medium
Almost Incredible	Low	Low	Low	Low	Low

Figure 7: Qualitative Risk Matrix (reproduction of Table 4 from NERAG, EMA 2010)

NERAG also provides guidance on the evaluation of the risks. The confidence of the risk assessment was categorised as high, due to the assessment being based retrospectively on an actual event.

Hence, based on the risk evaluation provided by NERAG below, the risk would be clearly identified as “Tolerable subject to the ALARP principle”. This does not imply that the risks are to be tolerated. Rather, it implies that measures and controls over the risk should be considered to see if it is possible to reduce the risk to the “Broadly Acceptable” region.

Likelihood Level	Consequence Level				
	Insignificant	Minor	Moderate	Major	Catastrophic
Almost Certain	Intolerable	Intolerable	Intolerable	Intolerable	Intolerable
Likely	Tolerable subject to ALARP	Tolerable subject to ALARP	Tolerable subject to ALARP	Intolerable	Intolerable
Possible	Broadly Acceptable	Broadly Acceptable	Tolerable subject to ALARP	Tolerable subject to ALARP	Intolerable
Unlikely	Broadly Acceptable	Broadly Acceptable	Tolerable subject to ALARP	Tolerable subject to ALARP	Tolerable subject to ALARP
Rare	Broadly Acceptable	Broadly Acceptable	Tolerable subject to ALARP	Tolerable subject to ALARP	Tolerable subject to ALARP
Very Rare	Broadly Acceptable	Broadly Acceptable	Tolerable subject to ALARP	Tolerable subject to ALARP	Tolerable subject to ALARP
Almost Incredible	Broadly Acceptable	Broadly Acceptable	Tolerable subject to ALARP	Tolerable subject to ALARP	Tolerable subject to ALARP

Figure 8: Risk Evaluation Table with High Confidence Level (reproduction of Table 6 from NERAG, EMA 2010)

In applying the ALARP principle to this flood event, it would indicate that if the consequences could be reduced to minor (within practical reason), this would result in an acceptable risk. This is indicated by the arrow in Figure 8 above.

The consequences table provided in NERAG identifies the following characteristics of a ‘minor’ event:

- Isolated cases of serious injuries, health system operating within normal parameters;
- Isolated cases of environmental damage, one-off recovery efforts required;
- Financial loss 0.1% to 0.3% of the government sector’s revenues requiring activation of reserves to cover loss, disruptions at business level leading to isolated cases of loss of employment;
- Governing body manages the event under emergency regime, public administration functions with some disturbances, isolated expressions of public concern, media coverage within region or jurisdiction;

- Isolated and temporary cases of reduced services within community, repairable damage to objects of cultural significance, impacts within emotional and psychological capacity of the community;
- Isolated cases of short-term to mid-term failure of infrastructure and service delivery, localised inconveniences.

Based on a preliminary assessment, it would appear possible to reduce the consequences of this flood to these levels. To do so would require very strict planning regulations that would prohibit development within high hazard areas for such a rare flood event. Infrastructure would need to be designed to cope with the flood forces and debris loads of such an event (currently, bridges should be designed to withstand the 1 in 2000 AEP flood forces). The local government and state government response would need to be very well conducted with sufficient resources on stand-by for such an event and a system of regular practice drills to ensure smooth operation of any emergency plan.

This is where the challenge lies for the management of residual risk. Is it practicable or possible to reduce consequences to these levels for an event with a probability of much less than 0.3% ?

If the Lockyer Creek Flood Risk Management Study had been carried out in 2009 and identified that much of Grantham would experience life-threatening hazards in 0.5% and 0.2% AEP flood events, what would have been our response ? Management measures may have included voluntary house purchase. But how many people would voluntarily sell their house on a 0.5% annual probability of a flood hazard ?

By way of comparison, the guidelines for managing risk to life associated with dam failure (ANCOLD, 2003) recommend that risk be managed in dam design and operation such that the loss of one life in a 0.01% (1 in 10,000) AEP event is considered as a tolerable risk. This comparison between the standards set for risk management in dam design and that of floodplain risk management warrants further assessment.

Conclusions and the Legacy of This Flood

The flood of that afternoon in January 2011 was a tragedy of a magnitude that should change the way that flood risk is managed in Queensland. Specifically:

- A risk-based approach to flood management should be adopted (and implemented) that considers the full range of flood hazards and likelihoods of flood events;
- More guidance needs to be provided on the level of consequence that is considered acceptable or tolerable in flood events rarer than 1%. Ideally, this would be consistent with the risk management approach for dam safety;
- Consider a state-wide approach to identifying areas in Queensland where flood hazards for rare flood events are likely to be unacceptable. These areas would then be assessed in further detail to define and manage these flood risks.

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