Paradise Dam Preparedness Review

Report 1: 2019-20

Queensland Government

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Content

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This report has been prepared using data collected from a diverse range of sources, many of which use unique methodologies and individual collation processes. It is therefore possible that some inconsistencies may be present despite the best efforts of the Office of the Inspector-General Emergency Management to validate and align the raw data utilised throughout this report.

Front cover image:
Aerial view looking downstream of the Paradise Dam spillway.
Photo credit: Sunwater

Back cover image:
Paradise Spillway and apron.
Photo credit: Sunwater

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Research paper

A research paper is produced as result of a review report or is initiated by the Inspector-General Emergency Management. A research paper explores an issue, generates discussion and seeks best practice solutions.

Contact for enquiries and proposed changes

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19 December 2019

Queensland Government

Inspector-General Emergency Management

The Honourable Craig Crawford MP
Minister for Fire and Emergency Services
PO Box 15457
CITY EAST QLD 4001

Dear Minister

In accordance with your instruction of 26 September 2019, I present a report into Paradise Dam and the local community's readiness for another significant flood.

The report covers dam safety and risk-related issues, disaster management arrangements and community readiness. It does not cover the dam's structural issues, neither does it address recovery in the event of a potential dam failure.

The approach to the review has been collaborative and aimed at maximising community safety outcomes, whilst providing independent assurance to Government.

The recommendations in this report build on good practice and aim to enable the system to continuously improve to deliver greater public value for hazard-specific events.

Yours sincerely

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Acknowledgement

The Office of the Inspector-General Emergency Management acknowledges Aboriginal peoples and Torres Strait Islander peoples as the Traditional Owners and Custodians of this Country. The Office recognises their connection to land, sea and community. We pay our respects to them, their cultures, and to their Elders, past, present and emerging.

Contents

Executive summary

The Office of the Inspector-General Emergency Management (the Office) was tasked by the Minister for Fire and Emergency Services to undertake the 2019 Paradise Dam Preparedness Review (the Review) on 26 September 2019. Its purpose is to provide assurance about capabilities, preparedness and community readiness for any future event, and to strengthen disaster management arrangements.

The terms of reference cover dam safety and risk-related issues, disaster management arrangements and community readiness. They do not cover the dam's structural issues, neither do they cover recovery. The Minister for Natural Resources, Mines and Energy has also announced a separate, independent Commission of Inquiry to examine any structural and stability issues associated with Paradise Dam.[1]

The approach to the Review has been collaborative, in line with the Office's legislated functions of identifying and improving capabilities as well as reviewing and assessing effectiveness, cooperation, and performance as set out under Section 16C of the *Disaster Management Act 2003.* The aim has been to maximise community safety outcomes, whilst providing independent assurance to Government about the effectiveness of ongoing local and district disaster management arrangements. The review methodology has included a variety of collection methods, validation by experts, research and community engagement.

The responsibility for management and operation of dams in Queensland is clearly defined in the *Water Supply (Safety and Reliability) Act 2008*. Standards and guidance material are comprehensive and based on international best practice. Sharing of risk information is an expectation of the Standard for Disaster Management in Queensland, and this applies to the management and operation of referrable dams in Queensland.

Paradise Dam is a roller compacted concrete dam, on the Burnett River about 20 km north-west of Biggenden and 80 km south-west of Bundaberg. It was built between October 2003 and December 2005 for water supply (not flood mitigation) and has no flood gates [2]. On 16 December 2005, Sunwater took ownership of the dam. The dam was originally designed to safely pass a flood with an average recurrence interval of once in every 30,000 years.

The current strength of the Paradise Dam spillway is calculated to be well below safety guidelines, and the life safety risk is also calculated to be well above the guidelines' limit for what society is expected to tolerate if there was a failure. Sunwater assess that the dam's stability may be marginal in a 1 in 50-year event and that the likelihood of failure is significantly increased in a 1 in 200-year event. Technical reports from a variety of experts concur with the basis for this assessment. The most likely failure mechanisms are sliding or overturning of sections of the primary spillway or undermining of the sections by the scouring effect of floodwater on the geology just below the dam.

This assessment is the result of a series of events and investigations since 2013. Few records exist for the period immediately after the dam's construction in 2005 and before it filled in 2010. A 'flood of record' - the largest recorded at the site - occurred in 2013, damaging the area below the dam. Following this event, the dam regulator commissioned a Review of Dam Safety Management Actions. The review was conducted by the New South Wales Department of Public Works. The terms of reference for the Office's review specifically mention this report. Independent advice from a former NSW Dam Safety Committee Executive Engineer about the actions that resulted is that Sunwater acted

'responsibly and appropriately and in generally a timely manner' in addressing the technical and Emergency Action Plan advice.

After damage to the Paradise Dam in 2013, Sunwater acted to mitigate the engineering risk and undertook successively more in-depth measures and investigations as new information emerged. The review team considers that, following the flood in 2013, Sunwater has taken appropriate investigative action in a timely manner.

The review was provided details of Sunwater's forecasting and prediction systems. The system is informed by over 60 additional rainfall and river height gauges installed since 2013 to complement over 100 already there. A departmental technical assessment of the systems concluded that the gauges were calibrated in line with industry best practice, appropriate for use, and consistent with Bundaberg Regional Council's model. Stakeholders would benefit from having flood water travel times in dam failure scenarios better documented.

Sunwater continues to improve its systems and modelling but there appears to be insufficient consultation between councils and Sunwater when flood modelling is undertaken. Responsibilities and protocols for collaboration in flood modelling should be formalised. Both this and the documenting of flood water travel times are opportunities for improvement in Emergency Action Plans for all dams.

Sunwater's management and operation arrangements for Paradise Dam are documented through Standard Operating Procedures and an Operations and Maintenance Manual. It conducts operations from a centre in Brisbane staffed year-round. In an earlier review the Office found that the Ross River Dam had been operated both flexibly and in accordance with the manual, giving confidence about Sunwater's overall approach.

The primary document linking dam operators and the disaster management arrangements is the Emergency Action Plan. Its purpose is 'for dam owners to respond collaboratively with relevant stakeholders to manage the consequences of a dam hazard or emergency event'. For the Paradise Dam, the Plan has been updated since 2013 for a variety of reasons; some updates include changes to information about the risk, however, this occurs in several places and is not obvious. Using industry measures, there have been four significant changes in risk related to the stability of the dam from a baseline in 2011. These changes in calculation result from comprehensive risk assessments, mitigation works and better understanding since the 2013 flood of the geology, scouring and dam structure risks. The Standard for Disaster Management in Queensland expects information on risks to be shared and understood. The current risk posed by Paradise Dam to downstream communities is not obvious from the Emergency Action Plan. The review team concludes that risk has not been clearly communicated to stakeholders until after September 2019.

North Burnett Regional Council flood preparedness focusses upstream of Paradise Dam. Several measures, including an updated risk assessment, staff training and mitigation measures, are ongoing. North Burnett Regional Council has recently conducted a dam failure exercise. The level of disaster preparedness and planning of the North Burnett Local Disaster Management Group for the risk posed by Paradise Dam is assessed to be strong.

Bundaberg Regional Council is well aware of its flooding risk. It has adopted a conservative approach to land use planning. It has a comprehensive mapping system that allows evacuation planning, has conducted flood studies, has a sound approach to identifying and addressing risks, has improved, and continues to improve, its Local Disaster Management Plan and sub-plans, and has collaborated with Sunwater and North Burnett over warnings. Training initiatives are satisfactory, ongoing, and will be supported by the recent appointment

of a Queensland Fire and Emergency Services (QFES) Emergency Management Coordinator. Dam failure for Paradise Dam has not been included as an individual risk within the Bundaberg LDMP though, and this can be partly attributed to not understanding the risk. Overall, while small opportunities for improvement remain, this review rates disaster preparedness and planning of the Bundaberg LDMG for Paradise Dam as strong.

Sunwater has effective and collaborative relations with the two councils downstream of Paradise Dam. Despite this, both reported a perceived lack of understanding about the risk changes to Paradise Dam, until recently. Opportunities exist for Sunwater to build on recent information release strategies and reap the benefits of such a strategy in a disaster management context with external stakeholders and the community.

Bundaberg Disaster District coordinates state level support to both North Burnett and Bundaberg councils. The review covers a range of aspects of the District's understanding of risk and preparedness for response. Connection with State government agencies appears sound. The review team witnessed the District operating alongside a QFES Incident Control Centre during recent fires, exhibiting both good systems and strong relationships.

Community readiness was assessed through submissions from councils and Sunwater, observation of the Sunwater Community Reference Group, discussion with prominent individuals and community groups and a survey of 300 residents downstream of the dam.

Sharing information about hazards and risk is the basis for disaster management planning. Sunwater's focus is to provide communities with information about how dams work, what can be expected of a dam during a major event, and what a dam can and cannot do.

Community understanding is mixed, North Burnett's residents are mostly concerned with water security rather than dam safety. From Bundaberg, the review team heard of little community conversation about the dam and disaster preparedness, but the telephone survey identified that flooding was the most commonly mentioned disaster risk. One third of respondents had previously experienced floods and are generally more prepared, and newcomers appear less concerned. Flooding due to water coming from a dam was rated fourth highest risk below cyclones and bushfires.

Community preparation for disasters appears higher than it has previously been in the region. However, the telephone survey results showed a pattern seen in other surveys; high individual levels of confidence but lower levels of preparedness. The surveys show the potential benefits of further community engagement. Only 30% of respondents had sought or received disaster preparedness information in the last 12 months.

The 2013 floods have had a marked effect on both North Burnett and Bundaberg councils. Initiatives have been taken and lessons learned, as shown in planning, warning, mitigation and betterment measures. Enhancements and exercising following a District post-disaster assessment have also been carried out. A literature review of past events identified 20 lessons drawn from 22 overseas case studies from the US and the UK. Current guidance about dams and ongoing safety activities for the Paradise Dam demonstrate that they are already learned in Queensland or being learned.

In the longer term and outside the scope of the recommendations of this review, four other matters are worth considering; ongoing monitoring of initiatives, long-term community readiness, lessons for other dams, and broader considerations of the learnings beyond preparedness and response.

Findings and Recommendations

Methodology

#	Finding	#	Recommendation
1	*The future report from the Commission of Inquiry into Paradise Dam may contribute to a clearer understanding of community risk.*		

Dam safety

#	Finding	#	Recommendation
2	*Roles and responsibilities for dam safety are well defined.*		
3	*Dam safety standards and guidance material for dam owners in Queensland is generally comprehensive and based on international best practice.*		
4	*The Standard for Disaster Management in Queensland expects information on risks to be shared and understood.*		
5	*Sunwater took necessary actions to understand the risk of the spillway once information became known.*		
6	*Sunwater has, for all practical purposes, addressed all the actions from the Paradise Dam Flood Event of January to March 2013 – Review of Dam Safety Management Action Report for the Office of Water Regulation*		
7	*Sunwater's operational and management arrangements are consistent with guidelines and have been tested.*		
8 *9*	*In relation to the Burnett River system, there appears to be insufficient consultation between councils and Sunwater when flood modelling is undertaken.* *Modelled flood information available in the Emergency Action Plan is not in a format that can be easily used by public interactive mapping systems*	**1**	**To enable the community to have a shared understanding of risks and enhance community engagement, flood scenarios in Emergency Action Plans be published, and in a format that can be utilised by public mapping systems.**

10	*Protocols and responsibilities of Sunwater and Bureau of Meteorology for the transfer of forecast information involving a dam failure scenario to local government and other stakeholders during a flood event are not documented in the Emergency Action Plan (EAP).*	**2**	**To enable entities to have a shared understanding of forecast information for dam failure events during a flood, including flood wave travel time, speed and height, Emergency Action Plans contain protocols and responsibilities of relevant stakeholders for these aspects.**
11 *12* *13* *14*	*The strength of the Paradise Dam spillway is well below the required factor of safety rating.* *The life safety risk for Paradise Dam exceeds the limits set in the guidelines and is more than what society would tolerate* *The current risk of Paradise Dam is not obvious in the Emergency Action Plan or other easily available public documents, nor is it obvious how it has changed.* *SunWater has information about the risk to life of Paradise Dam. This has been reassessed a number of times since the dam was built.*	**3**	**To enable a shared understanding of the risk, changes in the risk profile of referable dams be clearly communicated by entities that own dams to stakeholders and the community likely to be affected. The communication process starts immediately after the change is identified, is tailored to its audience, makes clear the scale of the change, and is documented so that stakeholders and the community can make informed decisions for managing risks.**

Disaster management arrangements

#	Finding	#	Recommendation
15	*North Burnett Local Disaster Management Group (LDMG) are developing plans to increase community safety relating to a failure of the Paradise Dam.*		
16	*North Burnett LDMG have significantly enhanced their disaster management plans and preparedness levels since 2010.*		
17	*Bundaberg District Disaster Management Group (DDMG) have significantly enhanced their disaster management plans and preparedness levels since 2013.*		
18	*Bundaberg DDMG is developing an operational plan to increase community safety relating to a failure of the Paradise Dam.*		
19	*The North Burnett LDMG, Bundaberg LDMG and the Bundaberg DDMG are well-prepared to respond to a major riverine flood and/or failure of the Paradise Dam.*		
20	*Strong relationships exist between disaster management agency*		

	members; however, this does not automatically lead to information sharing occurring across some agencies.		
21	*Dam failure for Paradise Dam has not been included as a separate risk within the North Burnett Local Disaster Management Plan (LDMP).*	**4**	**To increase understanding of hazards and manage risks, dam failure for Paradise Dam be included as a separate risk within the North Burnett LDMP.**
22	*Both training and exercising are important components of risk awareness, preparedness and planning.*	**5**	**To increase shared understanding of risks and enhance capability integration and collaborative planning, both LDMGs participate in the exercising of the Paradise Dam EAP.**
23	*Downstream residents listed within the Paradise Dam EAP are not identified by the Local Government Area (LGA) they reside in.*	**6**	**To increase shared understanding of risks, enable coordinated plans and collaboratively engage with downstream community members, residents listed within a dam EAP be identified by the LGA they reside in.**
24	*Dam failure for Paradise Dam has not been included as an individual risk within the Bundaberg LDMP.*	**7**	**To increase understanding of hazards and manage risks, dam failure for Paradise Dam be included as a separate risk within the Bundaberg LDMP.**
25	*BRC have committed in principle to undertake the QERMF process as part of its LDMP review process.*	**8**	**To enhance shared capacity and collaboratively manage risk, the Chair of the Bundaberg LDMG use the QERMF process to determine if dam failure for Paradise Dam should be reported as a residual risk to the Bundaberg DDMG in this instance due to known changes in the risk profile.**
26	*Dam failure for Paradise Dam has not been included as an individual risk within the Bundaberg District Disaster Management Plan (DDMP).*	**9**	**To increase shared understanding of risks, ensure the coordination of plans and manage risks, dam failure for Paradise Dam be included as a separate risk within the Bundaberg DDMP.**
		10	**To enhance shared capacity and collaboratively manage risk, the Chair of the Bundaberg DDMG use the QERMF process to determine if dam failure for Paradise Dam should be reported as a residual risk in this instance due to known changes in the risk profile to:** • **the State Disaster Coordination Group (SDCG) in accordance with their responsibilities under the State Plan** • **QFES for ensuring the development of the state-wide risk assessment.**

Emergency communications

#	Finding	#	Recommendation
27	*Many emergency communications channels for community readiness purposes exist across the Bundaberg Disaster District. Plans for their use have been tested.*		
28	*Strong emergency communication infrastructure exists across the Bundaberg Disaster District.*		
29	*Additional Emergency Alerts and associated polygons do not exist for a failure of Paradise Dam.*	**11**	**To ensure enhanced capability integration and enable timely community messaging Bundaberg LDMG in consultation with Sunwater develop additional Emergency Alerts and associated polygons for a Paradise Dam failure and load these on to the disaster management portal.**
30	*The audible warning siren at Paradise Dam may assist in delivering emergency warnings to residents immediately downstream.*	**12**	**To enable the community to make informed choices about disaster management, Bundaberg and North Burnett regional councils and Sunwater undertake a community-informed audible test of the Paradise Dam siren.**

Community readiness

#	Finding	#	Recommendation
31 *32*	*Flooding due to water coming from the dam does not feature as a significant risk in the minds of those surveyed.* *Due to a lack of information the community do not fully understand the risk from Paradise Dam and the reasons for it.*	**13**	**To enable the community to make informed choices about disaster management, and act on them, a joint Sunwater/council community engagement program be conducted to prepare the community downstream from Paradise Dam for events in the 2019/2020 storm and cyclone season, including the possibility of a Paradise Dam failure.**
		14	**To enable the community to make informed choices about disaster management, and act on them, Sunwater develop and deliver a sustainable long-term communication strategy on the community safety issues and risk profile connected with Paradise Dam. This is to be:** - **undertaken in collaboration with local and district disaster management groups, and** - **continued until the risk profile of the dam is in accordance with Queensland guidelines for dam safety** - **evaluated for its effectiveness.**

33	*Information about increased risk from the Paradise Dam has not effectively reached the casual/itinerant worker and tourism sector.*	**15**	**To enable the casual/itinerant worker and tourism sector, including those who do not have English as a first language, to make informed choices about disaster management, community engagement and communication strategies about Paradise Dam and floods in the Burnett river system be tailored to this sector.**

Lessons management

#	Finding	#	Recommendation
	Nil	**16**	**To enable entities in the sector to proactively work to achieve better results for the community, the recommendations and lessons of this review should be evaluated through the lessons management processes of entities involved in dam safety for their value and relevance.**

Conclusion

#	Finding	#	Recommendation
	Nil	**17**	**This report be returned to the Inspector-General Emergency Management to monitor, evaluate and report on progress and implementation of the recommendation(s) that are accepted in whole or in part by government.**

Introduction

This section explains the background to the review and the approach of the Office.

Background

On 24 September 2019 the Minister for Natural Resources, Mines and Energy announced that the storage level of Paradise Dam near Bundaberg would be reduced ahead of the 2019/20 wet season, to allow works to improve the dam's stability during extreme rain events.

Following the announcement, on 25 September 2019 an independent review was announced into Paradise Dam and the local community's readiness for another significant flood.

On 26 September 2019 the Minister for Fire and Emergency Services tasked the Office of the Inspector-General Emergency Management (the Office) to undertake the 2019 Paradise Dam Preparedness Review. The terms of reference are at Appendix A.

On 29 November 2019 the Minister for Natural Resources, Mines and Energy announced the Honourable John Byrne AO RFD would chair a transparent, fully independent inquiry into Paradise Dam structural and stability issues.

Purpose of the review

The purpose of this review is to provide assurance about capabilities, guide preparedness and community readiness for any future event, and to strengthen disaster management arrangements.

The review provides recommendations to guide preparedness for a future significant flood event affecting Paradise Dam in the Burnett river system.

Scope

The review aligns with the functions of the Office as outlined in section 16 of the *Disaster Management Act 2003* (the Act).

Legislative link

The following legislated functions of the Office have shaped the scope of this review: sections 16 (b), (c), (f), (g), (i), (j), and (k) of the *Disaster Management Act 2003* (DM Act 2003). Together they embrace the Office's functions to review and assess effectiveness, and to identify and improve capabilities of disaster management.

In scope

The review addresses the points prescribed in the terms of reference:

• implementation of advice provided in *Paradise Dam Flood Event of January to March 2013 Review of Dam Safety Management Action Report for the Office of Water Regulation* conducted by NSW Department of Public Works	Dam safety P.28 Appendix G Appendix H

• current information on the dam's safety and a timeline of the steps taken to obtain and verify this information	Dam safety P.20 Appendix F.
• the adequacy of Sunwater's forecasting and prediction initiatives	Dam safety P.29
• dam operations and management arrangements in place to prepare for the cyclone season	Dam safety P.31
• local disaster management group readiness	Disaster management arrangements P.34
• community readiness	Community readiness P.64
• communications between disaster stakeholders and more broadly with community stakeholders	Emergency communications P.56
• effectiveness of response preparedness	Disaster management arrangements P.51
• awareness and adoption of lessons learnt from other events	Lessons management P.72 Appendix C. Appendix D.
• such other matters as the Inspector-General Emergency Management considers necessary.	Future thinking P.77

The review team has consulted with Sunwater (the dam owner), the Local Disaster Management Groups of North Burnett and Bundaberg, the Bundaberg District Disaster Management Group, Queensland Fire and Emergency Services (QFES), the Queensland Police Service (QPS), and other relevant entities and State agencies to inform the review. A full list of those consulted is at Appendix B.

Out of scope

The review has not included:

- issues associated with the design, engineering, and structure of the dam unless they contribute to in-scope items
- assessment of the options for reducing the risk of dam failure
- the effects and consequences of planned water releases from the dam
- long term impacts of infrastructure damage
- consequential disaster management planning for an area that has been impacted by a dam break, including recovery
- insurance for damage issues
- Disaster Recovery Funding Arrangements (DRFA) payout issues particularly applicable to primary producers and householders.

The review team has not conducted or facilitated internal agency operational debriefs or community meetings as part of this review, however has attended community reference group meetings coordinated by Sunwater as observers to gain insights.

Commission of Inquiry into Paradise Dam

The terms of reference of the Commission of Inquiry into Paradise Dam chaired by the Honourable John Byrne AO RFD, build on those of the Paradise Dam Preparedness Review, as regards the safety of the dam. More clarity may emerge about the risk the dam poses to downstream residents from Justice Byrne's inquiries. It is important that any new

information on risk to the community is taken into account in community engagement initiatives.

Finding
The future report from the Commission of Inquiry into Paradise Dam may contribute to a clearer understanding of community risk.

Methodology

The approach to the review has been collaborative, and aimed at maximising community safety outcomes, whilst providing independent assurance to Government about the effectiveness of ongoing cross-sector efforts in disaster management.

The review team has made efforts to ensure that aspects of the Standard for Disaster Management in Queensland (the Standard), and applicable learnings and lessons have been drawn to stakeholders' attention to inform their planning for a future flood event.

Data collection

The review team used the following collection methods:

- invited submissions from key agencies across the sector
- held qualitative, face to face interviews and discussions with individuals from key agencies, disaster management groups and members of the community
- attended planning workshops, a disaster management group meeting and observed an exercise
- sought and analysed documents originating from NSW Public Works Department, GHD, the Sunwater Technical Review Panel, Sunwater, Bundaberg and North Burnett councils
- commissioned a community survey.

Validation

Technical documents were provided to the Office. The team sought advice from independent technical expertise on both dam safety and flood hydrology. These include:

- dam safety from a former Executive Engineer, New South Wales Dam Safety Committee
- flood hydrology from Water Planning and Coastal Sciences, Department of the Environment and Science, Queensland.

Research

A literature review identified lessons learned from other events, and recommendations both from previous Office reviews, and other reviews relating to dams. Lessons were drawn from the Lessons Learned from Dam Incidents and Failures website run by the US Association of State Dam Safety Officials, and the UK's Arup group of consultants and technical specialists. Recommendations from the Australian Disaster Inquiries Database were also considered. Results of this research are shown at Appendices C and D and referred to later in the report.

Community insights

As with all emergent reviews conducted by the Office, it was important to understand the change of risk and what this might mean for the community. The review team collected community views and perspectives regarding the preparedness for a future event through four approaches:

- attendance and observation of Sunwater Community Reference Group meetings, chaired by Major-General Richard (Dick) Wilson (Retired), AO
- a community telephone survey of residents downstream of the Dam, based on an all-hazards approach to disaster management and awareness in general, undertaken by an independent market research company
- discussions with elected officials at Federal, State and local level
- nine informal interviews with representative community members and groups.

Report structure

The report introduction starts with the background to the review and the approach of the Office in conducting it. It describes the methodology through which evidence was gathered.

The dam safety section addresses the first four points of the terms of reference that fall within Sunwater's remit. It covers current information on Paradise Dam safety, implementation of advice provided in 2013 in the NSW Department of Public Works report, Sunwater's forecasting and prediction initiatives, and dam operations and management. Appendices E, F and G provide further detail.

The disaster management arrangements section addresses the fifth, and eighth points in the terms of reference relating to arrangements by authorities for managing disasters. It covers local and district disaster management group readiness and response preparedness.

The emergency communications section addresses the seventh point of the terms of reference, about communications between disaster stakeholders and more broadly with community stakeholders. It covers the three related components of the Standard: public communication, communication systems and warnings.

The community readiness section addresses the sixth point of the terms of reference, about how communications are received in the community and the readiness of the community. It covers understanding of risk and draws on the survey commissioned by the Office for this review on the readiness of the community downstream of Paradise Dam.

The lessons management section addresses the ninth point of the terms of reference, about awareness and adoption of lessons learnt from other events. Appendices C and D provide further detail.

The future thinking section addresses the tenth point of the terms of reference, about other relevant matters.

Dam safety

Dams are assets, but they can also be hidden liabilities.[3]

This section addresses the first four points of the terms of reference that fall within Sunwater's remit. It covers:

- **current information on Paradise Dam safety**
- **implementation of advice provided in 2013 in the NSW Department of Public Works report**
- **Sunwater's forecasting and prediction initiatives**
- **dam operations and management**

Appendices E, F, G and H provide further detail.

Background to dam safety in Queensland

Roles and Responsibilities

The Queensland Government is responsible for the regulation of referable water dams in Queensland through the *Water Supply (Safety and Reliability) Act 2008 (*Water Supply Act 2008).[4] This act is administered by the Department of Natural Resources, Mines and Energy (DNRME) whose responsibilities include applying safety conditions to referable dams.[5]

A dam owner has the responsibility for the safety of their water dam and complying with the Water Supply Act 2008. Owners must have an effective dam safety management program in place to minimise the risk of a dam failing and to protect life and property.[6] Owners must also undertake a failure impact assessment[7] to determine if their dam is a referable dam. These are submitted to DNRME.

A dam is considered referable if two or more people would be at risk in the event of failure. If a dam is referable, owners must have an Emergency Action Plan (EAP).[8] An EAP ensures that protocols and procedures are in place between dam owners, local governments and disaster management groups to minimise any risk of a dam hazard or emergency event involving the dam.[9]

The Queensland State Disaster Management Plan (State Plan) also outlines roles and responsibilities of agencies that participate in the Queensland disaster management arrangements. Sunwater's roles and responsibilities are outlined in Appendix E.

Finding

Roles and responsibilities for dam safety are well defined.

A register of referable dams is maintained by DNRME.[10] They undertake audit programs to ensure compliance and regularly review dam safety risks against current standards to identify, prioritise and manage risks accordingly.[11]

Guidelines for dam safety in Queensland

Dam owners may be liable for loss and damage caused by the failure or escape of water from a dam.[12] The Queensland Government has guidelines in place to protect the community and minimise any risk from dams. These include the following.

Queensland Dam Safety Management Guidelines[13] provide construction and management guidance to assist dam owners to safely manage their dams and minimise risk of dam failure. This includes the requirement to have an approved EAP by DNRME.

Emergency action plan for referable dam guideline provides guidance to assist in the development of an effective and approved EAP.[14]

Guidelines on Acceptable Flood Capacity for Water Dams[15] specify certain minimum safety standards for referable dams. These include an acceptable flood capacity that a referable dam should be built to, and life safety risk limits that are tolerable to individuals and society. Societal limits of tolerability consider the principle that a dam whose failure would cause higher loss of life should be designed to a proportionally higher standard compared to a dam whose failure would result in fewer lives lost.[16]

Guideline for failure impact assessment of water dams[17] establishes whether a dam is considered referable. If referable, the dam is assigned a failure impact rating category based on the number of people at risk.

These guidelines often refer to complying with Australian and International standards; in particular the Australian National Committee on Large Dams Inc. (ANCOLD) guidelines.

ANCOLD is an Australian based non-government, non-profit and voluntary association of organisations and individual professionals with a common technical interest in dams. They prepare and issue guidelines that are widely used in Australia and provide consistency across the dams industry.[18] ANCOLD also has ties to the International Commission on Large Dams (ICOLD).

For the purpose of this review the review team have considered these ANCOLD guidelines.

ANCOLD - Guidelines on Design Criteria for Concrete Gravity Dams (2013)[19]
ANCOLD - Guidelines on Risk Assessment (2003)[20].

Finding
Dam safety standards and guidance material for dam owners in Queensland is generally comprehensive and based on international best practice.

Standard for Disaster Management in Queensland

The Standard sets expectations for all, including dam owners, about how risk relates to risk mitigation. According to the Standard, stakeholders should have a shared understanding of, and ready access to, risk information for all types of events.[21] Risk assessments should be integral to the mitigation, preparedness, continuity, response and recovery planning processes and documentation. Hazard mitigation and risk reduction should be embedded in all levels of planning and into core business across all phases of disaster management, including the management of shared residual risk. Hazards and risks should be identified and assessed regularly in collaboration with stakeholders, and the assessment used by the entity to develop plans for all phases of disaster management. Risk assessments should use plain language explanations,[22] be readily accessible and communicated to the communities to which they relate. Risk modelling should be available to inform disaster operations including public information and warnings.[23]

Finding
The Standard for Disaster Management in Queensland expects information on risks to be shared and understood.

Paradise Dam safety

About the dam

Paradise Dam is located approximately 20 km north-west of Biggenden and 80 km south-west of Bundaberg on the Burnett River. The dam wall straddles the Bundaberg Regional Council/North Burnett Regional Council boundary which is marked by the Burnett River in this area. The Dam was designed and built by the Burnett Dam Alliance between October 2003 and December 2005.

The Dam was officially opened and commissioned on 7 December 2005. In December 2005 its owner, Burnett Water Pty Ltd, became a wholly owned subsidiary of Sunwater Limited (Sunwater).[24]

Paradise Dam is now owned and operated by Sunwater, a Queensland Government owned corporation.[25] The shareholding ministers of Sunwater are the Deputy Premier, Treasurer and Minister for Aboriginal and Torres Strait Islander Partnerships, and Minister for Natural Resources, Mines and Energy.[26]

The dam is a water supply dam and, while all dams provide some attenuation or mitigation of floods, it is not a prescribed flood mitigation dam and does not have flood gates. When the dam fills, excess water flows over the spillway into the Burnett River below. The primary purpose of the dam is to supply water for irrigation. However, water is also supplied for urban, industrial and mining use.

The dam is a referable dam under the Water Supply Act 2008. It has a Category 2 failure impact rating, meaning that more than 100 people would be at risk if the dam failed. The dam was designed to safely pass up to a 0.0033% probability flood in any one year. To put that in context, it is intended to safely pass a flood event with an average exceedance interval of once in every 30,000 years (annual exceedance probability).

Water overtopping the spillway impacts both Bundaberg Regional Council and the North Burnett Regional Council. These two councils make up the Bundaberg Disaster District. The EAP identifies only a small number of properties in North Burnett are impacted, while Bundaberg Regional Council can be severely impacted.

The dam filled for the first time in March 2010. Since filling it has experienced a number of floods. The most notable was in late January 2013 as a result of ex-Tropical Cyclone Oswald. During this event, the dam's spillway was overtopped by 8.65m at the flood's peak. Flooding as a result of ex-Tropical Cyclone Oswald resulted in 5,500 evacuations in North Bundaberg.

Construction

The Paradise Dam spillway is a concrete gravity structure; the primary construction material is roller compacted concrete. The roller compacted concrete technique became popular in the 1970's. It allowed dams to be built in a timelier and more cost-effective way than conventional structure concrete dams. This technique is now commonly used for mass gravity dam applications. Roller compacted concrete dams are constructed using a series of horizontal continuous shallow layers of compacted concrete, called lifts. Construction of the Paradise Dam consists of a primary and secondary spillway. These are divided into sections of roller compacted monoliths, identified in the colour red in the following diagram. For the purpose of this report both spillways are referred to as "the spillway".

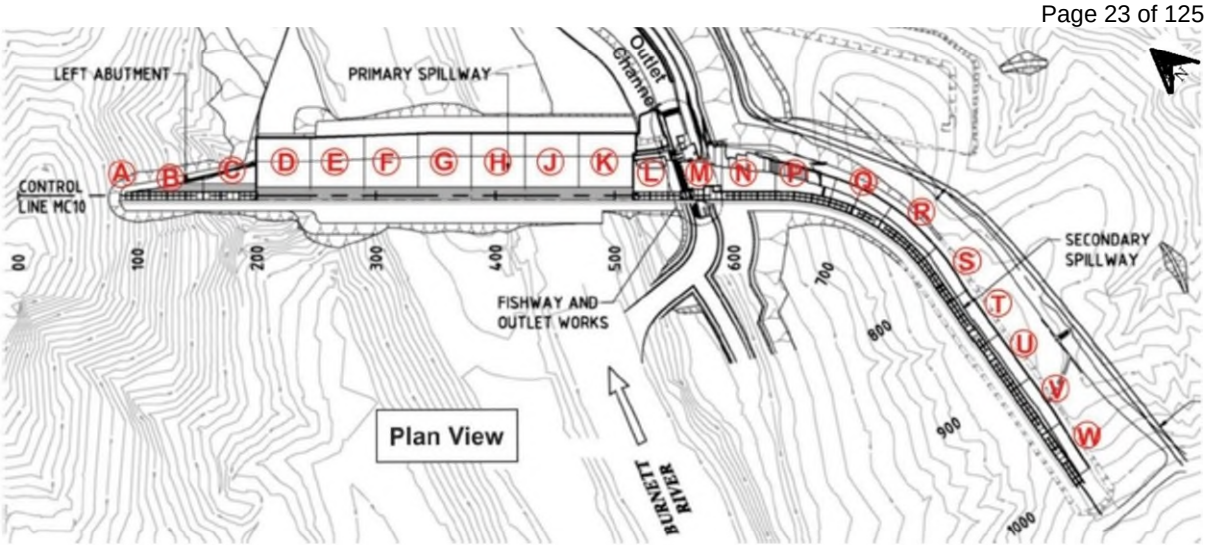
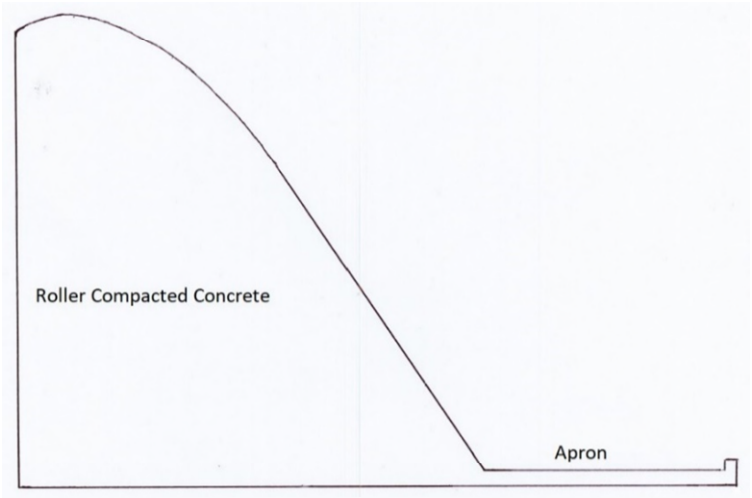


Diagram of the Paradise Dam spillways from above showing the monoliths.

Along the base of the primary spillway is a 20-metre-long spillway apron. This is intended to protect the toe of the spillway from impact of overtopping floodwaters and to reduce the energy flow onto the exposed rock and the river bed downstream.



Cross section of spillway showing the spillway apron.

Risk of failure

No dam is risk free, however society expects infrastructure to serve its purpose without imposing undue risk to the public.

Describing dam safety risk is complex. This review uses two industry-recognised ways to do this:

- the “factor of safety” which is a measure of the sliding stability of the dam under particular failure modes.
- the “life safety risk” which relates to tolerable risk limits acceptable to society.

Determining factors of safety and risk profiles require consideration of the full range of flood events possible at the dam from the minor to the rarest and most extreme. Flood magnitudes used in assessing factors of safety and risk profiles are regularly expressed according to the probability of an event happening or being exceeded in any given year. In this report the review team describes it two ways:

- as a percentage, for example a 1% probability of an event happening or being exceeded in any given year
- expressed as an Average Recurrence Interval, for example a 1-in-100-year event. (This method is now discouraged as people may think if it has already happened it won't happen again in the timeframe. This is not the case.)[27]

Factor of safety

Factor of safety, put simply, is the ratio of forces keeping the dam in place to the force that would cause sliding, overturing and subsequent failure. A factor of safety of 2.0 means that a dam is twice as strong as the force applied from the water in it. A factor of safety of less than 1.0 indicates failure would likely occur.

Forces that keep the dam in place include the weight of the dam, pressure from water downstream of the dam (tailwater level) and the strength of the dam to resist sliding (shear strength). Forces that destabilise the dam include pressure from water upstream of the dam (which will be stronger as levels rise) and uplift pressures from seepage through the dam and foundations (which are reduced through a dam drainage system).

Current ANCOLD guidelines[28] recommend a variation of minimum factors of safety according to escalating flood events:

- 1.5 for events considered "usual". That is more frequent than a 2% probability of happening in any given year (1-in-50-year event)
- 1.3 for events considered "unusual". That is between a 0.05% and a 2% probability of happening in any given year (between a 1-in-50-year and a 1-in-2000-year event)
- 1.1 for events considered "extreme". That is for events considered less frequent than a 0.05% probability of happening in any given year (less frequent than a 1-in-2000-year event).[29]

Stability analyses to derive factors of safety for Paradise Dam were undertaken in September 2019.[30] The dam has a factor of safety of greater than 1.5 for floods just up to a 10% probability of event happening in any one year (1-in-10-year event). For rarer flood events the dam falls below the recommended minimum factor of safety. For an event similar to the 2013 floods, classified as a 0.5% probability of happening in any given year (1-in-200-year event) the factor of safety is only around 1.1; it should be at least 1.3.

Finding

The strength of the Paradise Dam spillway is well below the required factor of safety rating.

Life safety risk

For the purpose of a referable dam, life safety risk refers to three tests for tolerable risk. The first is to satisfy an individual risk tolerance that is set to be lower than census statistics on background life expectancy in Australia. The second is to satisfy a societal risk tolerance, based on knowledge of how communities around the world have responded to catastrophic human-derived disasters, which requires progressively safer dams as the likely fatalities of a dam failure rise. The third is to satisfy "As Low as Reasonably Practical" or ALARP principle to test that efforts to improve safety reach a point where it is impractical to go any further. Put simply, society would expect the Paradise Dam to pose no risk of fatality to communities living downstream for a usual flood event. However, as the flood event became more severe, the tolerance for life safety risk increases. Tolerable risk is something dam owners need to review on an ongoing basis.

Guidance is available to dam owners on conducting risk assessments to better understand the likelihood and consequences of dam failure. Limits of tolerability of loss of life are provided in guidelines for different probability events.

For example, the tolerable limit for a 0.1% (1-in-1000-year event) probability event happening in any given year would be probable loss of life of 1. For a 0.001% (1-in-100,000-year) probability event the tolerable limit for probable loss of life is 100 people.

In July 2019 the risk of failure for Paradise Dam was re-assessed, as were the life safety risks. They were assessed at much higher than the tolerable limits in the Queensland Government guidelines on dam safety, as set out below:

> The risk of fatality for a 0.1% (1-in-1000-year event) probability failure event has a probable loss of life of 65 people. The guidelines state this should be less than 1.
>
> For Paradise Dam a probable loss of life of 120 people was assessed for a 0.05% (1-in-2000-year) probability failure event in any given year. The guidelines limit for 120 fatalities is for a 0.001% probability flood (a 1-in-100,000-year event). This is much higher than accepted tolerability limits.

Finding
The life safety risk for Paradise Dam exceeds the limits set in the guidelines and is more than what society would tolerate.

Probable loss of life per year
Expanding on the probable life safety risk, Sunwater describes life safety risks for Paradise Dam by a value representing the "Probable loss of life per year". The lower the value, the less risk. This is a calculation based on the number of expected fatalities directly resulting from the failure multiplied by the probability of the failure event.

To describe this simply, if a dam was assessed that:

- it would only fail in an extreme flood event
- this extreme flood event and subsequent dam failure had a probability of 0.01% occurring in any one year (1-in-10,000 -year event)
- the failure would directly result in 100 fatalities.

The dam's life safety risk would be assessed at 0.01. This is calculated as, 100 being the fatalities multiplied by the probability being 0.0001 (expressed as a decimal).

The actual calculation is more complex. It considers the sum of all dam failure modes, with variable probabilities of failure for varying flood levels, and varying downstream consequences.

The following table shows how the annualised probable loss of life has changed over time for Paradise Dam. The figures have been calculated as a result of comprehensive risk assessments, mitigation works and better understanding since the 2013 flood of the geology, scouring risks and dam structure.

March 2011	Jan 2015	Jun 2016	Jan 2018	Sep 2019
0.00013	0.031	0.034	0.094	0.195

This information has been calculated by the dam operator for this particular dam, but is not available to disaster management planners. When these figures are graphed (see Figure 1),

the calculated risk to life has grown significantly, 6-fold between January 2015 and September 2019 and 1500-fold between March 2011 and September 2019.

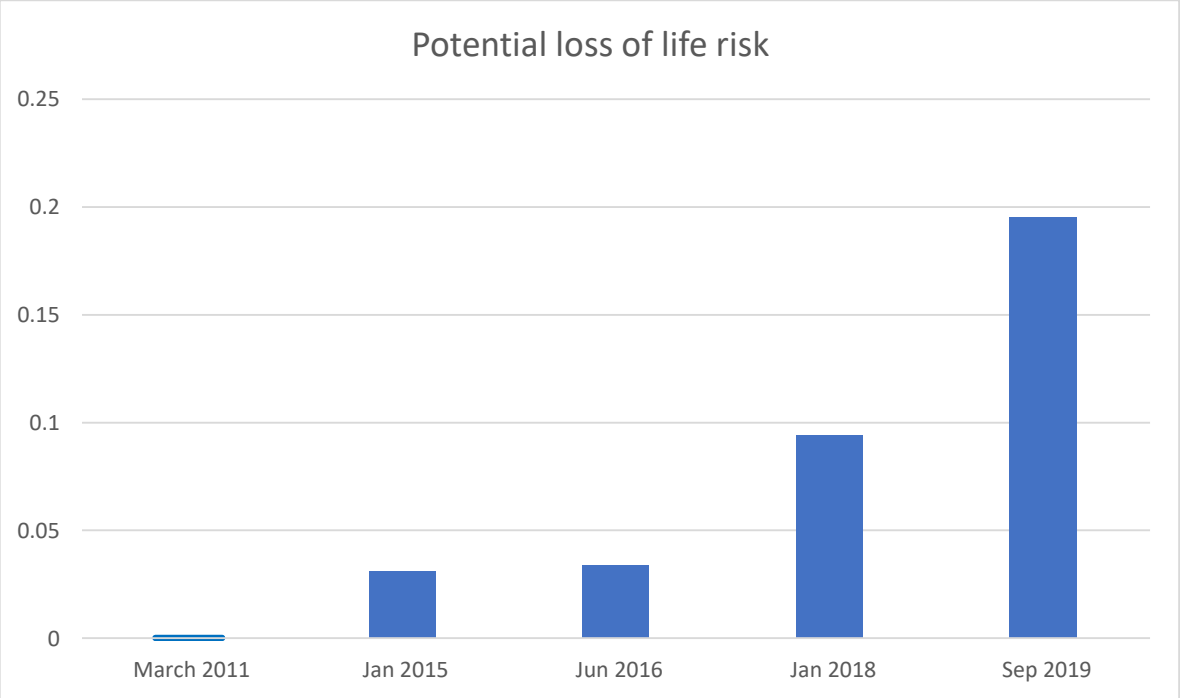


Figure 1: Graph showing the change of potential loss of life probability over time

Finding

SunWater has information about the risk to life of Paradise Dam. This has been reassessed a number of times since the dam was built.

Since 2017, Sunwater has been using a specialised modelling tool called HEC-LifeSim for estimating potential life loss. The tool is publicly available software from the United States Army Corps of Engineers. It is designed to simulate the entire warning and evacuation process resulting from catastrophic floods.[31] Sunwater uses this tool to better understand the potential loss of life based on decisions that individuals in the community are likely to make. The review team was provided with a demonstration of this tool. There are lessons for the broader disaster management sector from the use of loss of life modelling by Sunwater for community response to warnings. The Australian Red Cross advise that the concept is well used in the Asia-Pacific region.

Profile of what would cause a dam failure

In 2012 Paradise Dam was considered one of Queensland's safest dams. This was based on a Comprehensive Risk Assessment conducted in 2009 and then updated in 2012. The dam was designed to safely pass the probable maximum flood, which is the most severe flood that could theoretically occur. However, the damage that resulted in 2013 was not proportional to the flood which is now regarded as a 1-in-200-year event. As a result of the 2013 flooding, severe scouring to the underlying geology occurred immediately downstream of the apron at each end of the spillway and the apron itself was damaged. The apron sill was destroyed over almost the entire spillway width. Scouring is considered a problem because of the potential for undercutting of the dam structure which could cause dam failure in a flood event.

Since 2013 a significant number of investigations have taken place to understand the safety of the dam. These are outlined in Appendix F. Investigations have often resulted in the identification of other risk factors that have needed further investigation or confirmation.

In July 2019, GHD, working for Sunwater, identified the most likely cause of failure of Paradise Dam as a sliding within the primary spillway monoliths. Put simply, this would be failure along one of the roller compacted concrete lift joints resulting in a section of the spillway sliding away. The second most likely cause was undermining of the primary spillway due to future scouring.

To put a failure of Paradise Dam in perspective, it would require a "substantial" flood event. Sunwater describes the dam's stability as 'maybe marginal (i.e. metastable[1])' at a 1-in-50-year probability flood, and the likelihood of dam failure to be 'significantly increased' in a 1-in-200-year probability of a flood. Technical reports that the review team have seen are the basis for this assessment.

An event similar to that experienced in late 2010 should not be a concern of failure, however the dam should no longer be considered safe to pass floods with a magnitude similar to that experienced in January 2013, when the dam reached an elevation of 76.25m.

The below table shows all the likely failure mechanisms of the dam.

Failure Description	% Contribution
Sliding of Primary Spillway monoliths through RCC (shear)	51%
Undermining of Primary Spillway monoliths due to overflow scour, below apron	35%
Sliding of Secondary Spillway monoliths through / below the foundation	5%
Undermining of Primary Spillway monoliths due to scour at the toe, through the apron	4%
Undermining of Secondary Spillway monoliths due to loss of apron	3%
Sliding / overturning of Secondary Spillway monoliths through RCC (shear)	2%
All other failure modes	<1%

Risk contribution by failure mode

The effects of a dam failure

Failures of any dam are theoretically possible under a range of flood conditions. A failure would result in a flood wave and an increase in flooding (extent, depth and velocity) downstream over any that would already be occurring.

The comparative scale of flooding downstream of a dam failure would depend on the event. If failure occurred for an event the dam was originally designed to withstand (a probable maximum flood) the difference would be relatively minor due to the large scale flooding. The EAP shows that the effects of flooding from a 'sunny day failure' of Paradise dam - a dam failure without an accompanying flood - affects only around 70 households downstream. Both a probable maximum flood and a sunny day failure are unlikely events. However, as the flood event becomes more probable the effect of a dam failure would be more noticeable. Sunwater has mapped a number of events such as the 2013 floods to show the

[1] stable provided it is subjected to no more than small disturbances

difference in flooding of a spillway failure. This information has been provided to Bundaberg Regional Council.

Timeline to understand the current risk

Key events and actions have led to an understanding of the current risk of Paradise Dam failing. These are outlined in Appendix F. The timeline is less clear of events in the years during and immediately after the construction of the dam.

The situation changed after the flood of 2013, when Sunwater took successively more in-depth measures. Investigations of the engineering implications of the floods increased as new information emerged.

The review team considers Sunwater has taken appropriate investigative action in a timely manner as more information became available.

Finding

Sunwater took necessary actions to understand the risk of the spillway once information became known.

Actions to mitigate the risk

Since the unexpected damage from the 2013 flood, actions to mitigate the risk have been taken. Initially emergency repairs were done to withstand a late 2013 flood event. This was followed by works to mitigate any immediate path to failure such as repairs to downstream scour holes, spillway apron and rock foundations. This was followed by planning that involved more major engineering works. Key aspects of this planning and actions taken are identified in the timeline in Appendix F.

Review of Dam Safety Management Actions

Following the flood of record event in 2013 the former Queensland Department of Water and Energy (DEWS) commissioned the independent review "Paradise Dam Flood Event of January to March 2013 – Review of Dam Safety Management Action Report for the Office of Water Regulation".

The purpose of the review was to examine the dam safety management actions taken prior to, during and after the flood, to determine what lessons could be drawn to improve dam safety procedures and other matters considered relevant.[32]

The 2013 review identified a number of actions to be undertaken. The review team classified these actions into two categories, ones that directly relate to dam safety in general and those that relate specifically to the EAP.

The actions relating to dam safety in general were often technical in nature. For this reason, the review team engaged independent advice.

The independent advice stated *"Sunwater has acted responsibly and appropriately in responding, in generally a timely manner, to the recommendations of the review given the practices available in 2013/14. In addition, Sunwater has appropriately evolved its subsequent investigations and upgrade program in accordance with updated practices."*[33]

Refer to Appendix G for details.

The actions from the 2013 review that related to the EAP were assessed by the review team. Between the 2013 flood event and October 2019, the EAP for Paradise Dam had been revised 12 times. In 2019 alone there have been three revisions and another proposed.[34]

The review team considers Sunwater has addressed all these actions. For further details refer to Appendix H.

Finding

Sunwater has, for all practical purposes, addressed all the actions from the Paradise Dam Flood Event of January to March 2013 – Review of Dam Safety Management Action Report for the Office of Water Regulation.

Sunwater's forecasting capabilities

Sunwater provided the review team with details of their forecasting and prediction systems.

To estimate run-off from the catchment, Sunwater use a Unified River Basin Simulator (URBS). They have a number of calibrated rain-fall models for their upstream dams as well as an overarching model for Paradise Dam. The Paradise Dam model has been calibrated to each of the flood events that occurred in December 2010, January 2013 and March 2017.

The Bureau of Meteorology (the Bureau) also uses URBS which simplifies data sharing, between Sunwater and the Bureau. Both have been working closely together to continuously improve flood warning services and ensure consistency between their respective models. During a recent exercise of Paradise Dam, URBS was demonstrated. The review team observed a high level of interaction between Sunwater and the Bureau, which supported forecasts being consistent.

To collect observations of conditions during a rain event, a network of rain and water level gauges cover the catchment. Since the 2013 flood event the number of gauges has increased significantly, with over 60 gauges installed across the Burnett catchment. See Appendix I for a map of gauges in the catchment.

In 2018, Sunwater implemented a Flood Early Warning System which was observed by the review team. This is used to consume a range of Bureau data including forecast rainfall, soil moisture information and observations from the gauge network.

Sunwater has a hydrological model that covers the entire catchment, including tributaries downstream of the dam. This is used to model flows entering the reservoir of Paradise Dam and the subsequent discharge over the spillway. Hydraulic modelling has been done for various discharge scenarios. These are used as a planning tool to estimate the likely downstream flood extents, water depths and velocities. These three elements are important in understanding the risks.

Sunwater has modelled a number of flooding events, including those that have already occurred such as the 2013 flood. They also have modelled other possible flood events based on the likelihood of them occurring, including the probable maximum flood. These outputs include both a spillway failure and no spillway failure. They have been provided to Bundaberg Regional Council to compare against their models and incorporate into their systems.

Bundaberg Regional Council only recently became aware that Sunwater had developed new hydrological models. The 2012 Queensland Floods Commission of Inquiry Final Report Recommendation 2.8 stated "When commissioning a flood study, the body conducting the

study should check whether others, such as surrounding councils which are not involved in the study, …. are doing work that may assist the flood study….". Bundaberg Regional Council advised they may have had information to improve the Sunwater model if they had known at the time that a new model was being developed.

Finding
In relation to the Burnett River system, there appears to be insufficient consultation between councils and Sunwater when flood modelling is undertaken.

The Standard expects information on risks to be shared. The review team notes that a number of modelled flood events are included in the EAP as maps. The format of this document is a PDF. Although including these events in the EAP provides value, it is only available in PDF format which limits it being used by other systems. For example, there are many public interactive mapping systems that could display this information if it was also shared in a suitable format.

Finding
Modelled flood information available in the Emergency Action Plan is not in a format that can be easily used by public interactive mapping systems.

Recommendation
To enable the community to have a shared understanding of risks and enhance community engagement, flood scenarios in Emergency Action Plans be published, and in a format that can be utilised by public mapping systems.

The review team sought technical advice from the Director, Water Planning and Coastal Sciences Department of the Environment and Science, Queensland to validate the forecasting information. The advice was:

> *"The hydrology models are calibrated (hydrograph shape, event flood volume, peak discharge) to an acceptable standard consistent with industry best practice using the most recent information and are appropriate to use for flood forecasting and design flood assessments. The model parameters are within the expected acceptable ranges.*
>
> *The hydraulic model used is TUFLOW. It is an accepted industry product for this application. The results presented seem reasonable and are in accordance with what would be expected to see. Sunwater stated that there is reasonable agreement between Bundaberg Shire Council planning hydraulic model and the Sunwater model. It would be reasonable to expect some differences given the different scales of operation and questions being addressed by the models.*
>
> *The travel times for flood waves from the Dam have been assessed by Sunwater using historical information, hydrological modelling and hydraulic modelling. The three methods give similar estimates of travel time. Sunwater stated that assessment of travel times under failure modes were done using the TUFLOW hydraulic model. This assessment has concluded that the travel times for Dam failure scenarios are similar to natural flood wave movement for 2013 flood (within 5%). This information however was not documented."*

The travel times, speed and height of a flood wave from a dam failure emerged as critical information during the planning workshop on 11 November 2019 that the review team observed. The methodology used to calculate the predicted flood wave travel times for a

spillway failure is not documented, making its calculation less apparent to disaster managers. But it is the analysis of this methodology that is most important to planners. The predicted flood wave travel times for a spillway failure should be readily available to them.

The technical expert identified a further critical action. There is a need to ensure that protocols and responsibilities for the transfer of forecast information during a flood event and a transition into a dam fail scenario are clearly documented. The review team acknowledges that the Bureau is not responsible for modelling or flood forecasts of dam failure scenarios, however expects that the Bureau would support SunWater to ensure consistent messaging in case of such a scenario.

Finding
Protocols and responsibilities of Sunwater and Bureau of Meteorology for the transfer of forecast information involving a dam failure scenario to local government and other stakeholders during a flood event are not documented in the EAP.

The EAP contains an early section on roles and responsibilities. These include the legislative responsibility for councils to ensure information about an event is promptly given to the district disaster coordinator. The EAP is less clear on how specific modelling and timing information will be transferred before and during an event to stakeholders outside Sunwater. The review team considers that given the public interest about a potential dam failure, both modelling information and travel times for dam failure scenarios should be documented. As the singular document covering a dam, the EAP should cover both information-sharing issues.

Recommendation
To enable entities to have a shared understanding of forecast information for dam failure events during a flood, including flood wave travel time, speed and height, Emergency Action Plans contain protocols and responsibilities of relevant stakeholders for these aspects.

Paradise Dam operation and management arrangements

Documented procedures

Sunwater's management and operation arrangements for Paradise Dam are documented through Standard Operating Procedures and an Operations and Maintenance Manual. The Department of Natural Resources, Mines and Energy (DNRME) has advised that the Standard Operating Procedures and Operations and Maintenance Manuals for Paradise Dam are consistent with their regulations.

These documents provide the dam operators with instructions and guidelines for how the dam and associated equipment is to be operated and maintained. Sunwater updated their Standard Operating Procedures in early 2019. Sunwater advised the Operations and Maintenance Manual was currently being reviewed and expected to be completed by the end of November 2019. Sunwater advised the review of this manual was intended to address the current risk situation, reflect industry best practice and where possible align this manual to the other manuals of Sunwater's dams.

Sunwater advised of the routine work activities they have done to prepare for the upcoming wet season. Some of these activities include verifying emergency contact names and telephone numbers, training, and ensuring all flood operations equipment is working. Information and timings of Sunwater's inspection and maintenance activities were also provided.

The 2013 independent review "Paradise Dam Flood Event of January to March 2013 – Review of Dam Safety Management Actions" identified that Sunwater's documented procedures for dam safety were considered sound and in accordance with accepted industry good practice.[35] These are included in Appendix G and H.

Dam operations

Sunwater has an operations centre located in their Brisbane office. Emergency operations of Paradise Dam and other Sunwater dams are undertaken through this operations centre. The centre also monitors weather and safety related incidents.

Sunwater advised the centre operates 365 days a year and has an on-call roster as part of business as usual monitoring. This escalates through a series of activation levels based on weather forecast and dam safety risk. Fatigue management was considered by Sunwater as part of the Sunwater exercise on 3 December 2019.

Earlier this year the Office conducted a review into the 2019 Monsoon Trough Rainfall and Flood Event.[36] The review looked into the operation of the Ross River Dam which was coordinated through this operations centre. The review found the Ross River Dam was operated in accordance with the EAP and a flexible approach to implementation of the EAP was undertaken.[37]

During the three months of this Paradise review, the team observed Sunwater's efforts to ensure the dam operations were aligned with the disaster management arrangements. Evidence of their activities included a briefing to Bundaberg Local Disaster Management Group (LDMG) with changed risk information, a workshop with disaster management stakeholders to consider the changed risk, and an exercise. One outcome of the workshop was an agreed trigger-point for an evacuation decision and a skeleton whole-of-sector integrated action summary. The exercise was extended beyond Sunwater's pre-season, internal exercise, to include disaster management groups and whole of government stakeholders. The review team witnessed the Operation Centre in action during this exercise.

Finding

Sunwater's operational and management arrangements are consistent with guidelines and have been tested.

Emergency Action Plan

Emergency Action Plans are plans outlining procedures for dam owners to respond collaboratively with relevant stakeholders to manage the consequences of a dam hazard or emergency event.[38]

Each referable dam must have an EAP. Guidelines exist identifying the requirements of an EAP as well as the approval process and those involved.[39] Each plan is specific to the unique circumstances of the dam.[40]

The Paradise Dam EAP has been revised 12 times since 2013. Revisions reflect legislative requirements and updates to contact and notification lists. Updates have also been made in relation to a change in risk. For example, the July 2014 EAP does not mention overturning or sliding of the monoliths. It is mentioned in the March 2015 EAP. The October 2017 EAP further adds the probability of this happening. Many of these EAPs also include scour damage.

The September 2018 EAP mentions that if significant scouring was occurring in a future event then the need for evacuations should be considered by disaster management authorities. The February 2019 EAP goes further and also mentions sliding as a failure mechanism that would require an evacuation.

Changes in the EAP for Paradise Dam do reflect a changed understanding of its stability, and the changed risk to downstream communities. However, the review team found the risk is documented in a number of different places, and that it is not clearly evident without detailed comparison between different versions of the EAP. Earlier this report outlined values for the change of annual loss of life probability over time. Including these values in the EAP may provide a better understanding of the current risk and any changes that may have occurred.

Finding

The current risk of Paradise Dam is not obvious in the Emergency Action Plan or other easily available public documents, nor is it obvious how it has changed.

As mentioned earlier the purpose of EAPs are *"plans outlining procedures for dam owners to respond collaboratively with relevant stakeholders to manage the consequences of a dam hazard or emergency event*". [41] The Standard expects information on risks to be shared. Risk management is a key priority in the State Plan. Without risk information, stakeholders cannot properly carry out the risk analysis and planning activities outlined in the State Plan. As the consequences of a dam failure are managed through the disaster management arrangements, all stakeholders involved in the planning for a dam failure event need to understand the risk. This will enable them to plan accordingly and before a response is required. Sunwater is of the view that it has shared the change in risk during briefings in December 2015, November 2016 and February 2019 to members of the LDMG and DDMG. But sharing may not automatically lead to understanding.

Recommendation

To enable a shared understanding of the risk, changes in the risk profile of referable dams be clearly communicated by entities that own dams to stakeholders and the community likely to be affected. The communication process starts immediately after the change is identified, is tailored to its audience, makes clear the scale of the change, and is documented so that stakeholders and the community can make informed decisions for managing risks.

Disaster management arrangements

This section addresses the fifth, and eighth points in the terms of reference relating to arrangements by authorities for managing disasters. It covers:

- **Local and district disaster management group readiness**
- **Response preparedness**

Preparedness and Planning

The Standard identifies that preparedness and planning include all activities undertaken prior to an event to mitigate the impact of the event on the community. Planning also occurs in the response and recovery phases. Under the Standard, preparedness and planning consists of two components, namely Planning and Capability Integration.

Planning considers all phases of disaster management and describes the response, continuity of operations, Government services and recovery from the emergency. Planning involves key stakeholders and addresses known hazards and risks, identifies priorities and responsibility for performing functions and provides for regular review.

The Capability Integration component specifically addresses the requirement to develop capabilities that work together in an integrated manner to achieve disaster management outcomes and is recognised in the Standard indicators across all shared responsibilities.[42]

COMPARISON OF PAST FLOOD EVENTS

December 2010
River Height - 7.95m @ Bundaberg
North Burnett - 26 houses damaged
Bundaberg - 190 houses damaged

January 2011
River Height - 5.76m @ Bundaberg
North Burnett – zero houses damaged
Bundaberg - 4 houses damaged

January 2013
River Height – 9.5m @ Bundaberg
North Burnett – 206 houses damaged
Bundaberg - 2,200 houses damaged
(5,500 residents evacuated in North Bundaberg)

Dams without gates, like Paradise, cannot make downstream flooding worse. But owners of referrable dams can advise downstream communities about the timing of water released from dam, and are in the best position to advise about any potential failure. Both dam owners and emergency management agencies have obligations to be prepared for emergencies that arise at the sites of dams and for the flooding that may result from the release of water. The development of appropriate plans needs to involve dam owners, dam safety regulators and emergency management agencies, and should incorporate consultation with potentially affected communities.[43]

Local Disaster Management

North Burnett

Planning

Sunwater is a member of the North Burnett LDMG. Sunwater representatives regularly attend North Burnett LDMG meetings and exercises. The review team was advised that locally based Sunwater members are always very approachable and willing to provide support to North Burnett Regional Council (NBRC) on request. Sunwater provide the NBRC with updated EAPs for dams within the North Burnett Local Government Area (LGA). These EAPs provide important information relating to individual dams, including detailed flood maps.

With respect to the Paradise Dam EAP, reviews of the EAP by North Burnett LDMG over the past few years have only required updating of contact details for downstream residents. As part of this EAP review process, a preformatted Emergency Alert was developed, along with an associated messaging polygon. Further details relating to this Emergency Alert are detailed later in this report.

During the initial period of this review, NBRC was in the process of reviewing the latest draft of the EAP for Paradise Dam to fully understand the newly identified risks. As a result of these new risks NBRC commenced actions to update its own Local Disaster Management Plan (LDMP), as well as develop a Paradise Dam operational disaster plan to better manage potential risks to its small number of downstream residents. This operational plan will include early evacuation messaging and the management of immediate relief activities, such as temporary sheltering of any displaced persons. There is a possibility of 50-80 itinerant workers on a property five kilometres from the dam wall, dependent on the time of season. These people would have no family or other support.

Finding
North Burnett LDMG are developing plans to increase community safety relating to a failure of the Paradise Dam.

The North Burnett LDMG Disaster Risk Register lists risks in the form of risk statements and provides treatment options for these risks. Riverine flooding is one example of this. At the time of this review NBRC acknowledged that this register was not a complete list of its risks. Some undocumented risks are local knowledge held by Council staff. NBRC had already initiated action to address this issue at the time of this review.

Failure of Paradise Dam is specifically identified as a hazard within the North Burnett LDMP. Dam failure is also identified in the Disaster Risk Register, but dam failure for Paradise Dam is not specifically identified as a risk. Up until now only Cania Dam Failure has been included in the risk register as there was a belief within the North Burnett LDMG there were no at-risk residences downstream from Paradise Dam within the NBRC LGA. The LDMG have committed to including Paradise Dam failure as a risk in the LDMP and Disaster Risk Register.

Finding
Dam failure for Paradise Dam has not been included as a separate risk within the North Burnett LDMP.

Recommendation
To increase understanding of hazards and manage risks, dam failure for Paradise Dam be included as a separate risk within the North Burnett LDMP.

Modelling for flood forecasting is a Bureau responsibility, while river modelling for flood mapping purposes is generally a council responsibility. NBRC has initiated the process of developing a detailed LDMG Flood Action Plan (and NBRC Internal Disaster Response Procedure), which will provide trigger points and a checklist of actions to be undertaken across the area at different stages during a flood event. NBRC has identified the need to workshop riverine flooding across the North Burnett area, including the reclassification of trigger levels at forecast locations and discussions around flash flooding for Monto. The Bureau has committed to work together with councils to help them review and reclassify their flood classifications to ensure they represent the impacts to the community. Confirming these trigger levels and understanding the flash flooding for Monto will enhance the LDMG's preparedness and response activities (e.g. warnings/alerts and evacuations). Once

predictive modelling is developed, the LDMG will come together to finalise the Flood Action Plan.

A meeting is scheduled with the Bureau for January 2020 to discuss flood services. The meeting is an extension to the regular Council-to-Council meeting for the region, and will include all councils in the Burnett as well as the Mary and Burrum/Cherwell catchments. It will focus on the Bureau's flood scenario service, flood classifications and Enviromon training. Predictive modelling will not be a focus of this meeting, although it may highlight the need to explore this further.

So far, the development of this LDMG Flood Action Plan has focused on floods from Monto through to Mingo Crossing, where the majority of NBRC residents are located. However, due to information provided by Sunwater relating to the potential increase in dam failure risk for Paradise Dam, this new risk along with the short section of riverine flooding downstream of Paradise Dam, will be included in the Flood Action Plan.

Past flooding events in the Burnett Catchment have identified opportunities to improve flood modelling and forecasting for sections of the Burnett River. NBRC has identified a need for river modelling to be produced for the Burnett River from Gayndah (Claude Wharton Weir) to Paradise Dam. NBRC has also identified a need for a river gauge on the Burnett River downstream from the Barambah Creek inlet. This modelling and additional gauge will help the LDMG identify earlier triggers for evacuating residents downstream from Paradise Dam and provide additional warning and evacuation timeframes. NBRC has committed to discussing these needs with Sunwater and the Bureau with a view identifying the feasibility of actioning them. The review team notes recommendations for improving the flood warning gauge network in NBRC have also been identified in the “North Burnett Regional Council Network Investment Plan”, prepared by the Bureau for the QRA in 2017.

The 2018 State Plan provides guidance about risk reduction and includes reference to the Queensland Emergency Risk Management Framework (QERMF). The Standard also recognises that hazard identification and risk assessment is a fundamental for disaster management planning. The North Burnett LDMG are committed to working through the QERMF with a view to updating the North Burnett LDMP. As part of this process North Burnett LDMG will consider identifying any residual risks.

Residual risk is the risk that is beyond the capability and/or capacity of the Local or District community or communities and existing disaster management arrangements to treat or mitigate.[44] As part of the risk management process disaster management groups should consider if any of their risks are beyond their capacity to treat or mitigate and are therefore residual risks. As a risk treatment option, residual risks can be transferred to and/or shared across supporting disaster management groups (i.e. District and State levels). This process should be outlined in disaster management plans, with any residual risks identified in these plans. The North Burnett LDMP does not currently address the residual risk consideration process and does not identify any residual risks.

Significant improvements to the North Burnett LDMP have occurred due to the LDMP (and associated sub-plans) being tested in real events such as the floods of 2010, 2011, 2013 and 2015. This included a major upgrading to the LDMP in 2016 where in-depth community engagement was undertaken as part of this process. Since 2016 the North Burnett LDMP (and sub-plans) have been tested in a real event, namely Tropical Cyclone Debbie (2017).

North Burnett LDMG, in collaboration with Sunwater also tested the Cania Dam EAP through a dam failure exercise. Although this exercise did not relate to Paradise Dam, it provided the

North Burnett LDMG with the opportunity to work through a dam failure event scenario in collaboration with Sunwater. It also allowed the LDMG to gain an understanding and appreciation of how an EAP correlates with the North Burnett LDMP, as well as the importance of early warnings and response actions for the downstream population.

As a long-term risk reduction and mitigation process, NBRC implemented new restrictions to its planning and building schemes after the 2013 flood disaster requiring all new building developments to be a minimum of 300 millimetres above the 2013 flood height levels. To date, this has had no impact on any NBRC residences downstream from Paradise Dam. The Queensland government has guidance material for adapting Queensland homes to be flood resilient through the "Flood Resilient Building Guidance for Queensland Homes".[45]

Finding

North Burnett LDMG have significantly enhanced their disaster management plans and preparedness levels since 2010.

Capability Integration

Modern emergency planning requires a close integration between dam safety planning and general community emergency management planning. Dam owners, emergency managers and dam safety regulators must share information and develop strategies to reduce the impacts of floods caused or affected by dams.[46]

With a population of around 10,000 as compared to about 95,000 in Bundaberg, capacity and capability are an ongoing challenge for NBRC when it comes to disaster management activities. The NBRC employs one part-time Disaster Management Officer (DMO), with some disaster management roles and responsibilities being absorbed by other NBRC staff members into their normal duties. However, with four residences and one orchard within the North Burnett region located downstream from Paradise Dam, this capacity is unlikely to hinder the capability of NBRC to prepare for a Paradise Dam failure.

The NBRC has a very positive working relationship with locally based Sunwater representatives, including those on the North Burnett LDMG. However, it is seeking improved levels of communication from Sunwater about the risk changes to Paradise Dam. Improved communications may have helped address community perceptions of these risks. It also would have helped the NBRC Disaster Management Officer (DMO) to sooner identify the four residences and one orchard packing shed within its area located downstream from Paradise Dam.

Although Sunwater provided the NBRC with information about the new stability issue for the Paradise Dam wall in September 2019, including the risk changes, it was identified that the NBRC did not fully understand the nature of the issue and the reasons for it. NBRC understood that core samples had been taken which identified structural weakness in Paradise Dam, but in October 2019 were still waiting for more information from Sunwater to gain greater clarity on the issue with the dam.

Sunwater have undertaken training with NBRC staff in how to read and understand its dam EAPs. However, the involvement of NBRC in previous Sunwater exercises for the Paradise Dam EAP is less clear. Participation in exercises is a useful enabler of risk awareness and the inclusion of risk information in disaster management planning.

It was also identified that the list of downstream residents within the Paradise Dam EAP did not identify which LGA they reside in. Although this practice is not required in an EAP it could have assisted the NBRC DMO in identifying which residents within its area were

located downstream from Paradise Dam. In turn, this would have enhanced a shared responsibility to support these residents before, during and after a disaster event.

Finding
Strong relationships exist between disaster management agency members; however, this does not automatically lead to information sharing occurring across some agencies.

Finding
Both training and exercising are important components of risk awareness, preparedness and planning.

Recommendation
To increase shared understanding of risks and enhance capability integration and collaborative planning, both LDMGs participate in the exercising of the Paradise Dam EAP.

Finding
Downstream residents listed within the Paradise Dam EAP are not identified by the LGA they reside in.

Recommendation

To increase shared understanding of risks, enable coordinated plans and collaboratively engage with downstream community members, residents listed within a dam EAP be identified by the LGA they reside in.

With the assistance of QFES and QPS, yearly Disaster Coordination Centre training and exercises for LDMG members are undertaken in the North Burnett area. A review of the training needs analysis for North Burnett LDMG members and advisors (and NBRC staff) identified that, overall, disaster management training was being undertaken. Many members and advisers (and NBRC staff) have well exceeded core training courses and inductions relevant to their respective disaster management roles. A review of the training needs analysis also identified that some members and advisors have a need to undertake further mandatory training; about Queensland Disaster Management Arrangements, Evacuation, and Recovery.

The QFES Emergency Management Coordinator (EMC) position that covers the North Burnett LDMG had been vacant for part of 2019, with support being provided from a neighbouring EMC. The commencement of the newly appointed EMC on 11 November 2019 will assist in this training being provided.

NBRC has seen over 50 staff member changes in the past 12 months. This has resulted in significant knowledge and experience being lost. The loss of corporate and local knowledge, such as this, should be a matter for consideration in the council's business continuity planning. Training and exercising are important to help new staff gain an understanding of disaster management arrangements. LDCC and DDCC staff training had been arranged for mid-November 2019 but was cancelled due to major bushfires. A commitment to reschedule this training has been made.

NBRC also has formal Council to Council (C2C) arrangements in place to enable experienced staff from councils within the Wide Bay Burnett Regional Organisation of Councils to provide support and relief to North Burnett Council for an event. Arrangements also exist for similar support and relief to be provided through the Local Government Association Queensland (LGAQ).

To support the NBRC with its limited capacity, Bundaberg Regional Council (BRC) agreed to service the NBRC flood gauges to maintain their functionality. BRC have committed to training NBRC in how to service these flood gauges to share servicing responsibility.

The North Burnett LDMG has encountered several disaster events since 2010 and have consciously undertaken many activities to improve its disaster preparedness and planning. When taking the Standard into consideration this review identified that, given its relatively small capacity and capability, the level of disaster preparedness and planning of the North Burnett LDMG for a future significant flood event affecting Paradise Dam is strong.

This review has provided some findings and recommendations relevant to disaster preparedness and planning which may afford the North Burnett LDMG with opportunities for further improvement.

Bundaberg

Planning

As is the case with the North Burnett LDMG, Sunwater is a member of the Bundaberg LDMG, with regular attendance by Sunwater representatives at Bundaberg LDMG meetings and exercises. The review team was advised that locally based Sunwater members are always very approachable and willing to provide support to BRC on request. Sunwater provide the BRC with information and advice around hazard identification and risk assessment.

The Paradise Dam EAP is a component of the Bundaberg LDMP, with the LDMG being invited by Sunwater to provide comment and feedback on each iteration of the EAP. Prior to any significant changes in the EAP, there is direct engagement with Sunwater and key LDMG representatives, and in particular, with the BRC Disaster Management Unit and the Executive Officer of the Bundaberg DDMG.

On-site familiarisation of Paradise Dam has been provided to Bundaberg LDMG and DDMG members by Sunwater. After the 2013 flood executive members of the Bundaberg LDMG and Bundaberg DDMG attended Paradise Dam to inspect both damage and repairs to the dam. Desktop exercises of updated versions of the EAP have also been undertaken to better understand and test the EAP.

During a disaster event, representatives from Sunwater are included in all meetings of the Bundaberg LDMG to provide content expertise on potential risks based on the Bureau's modelling and rainfall predictions. This practice aids in establishing regular and accurate dam reports during events.

Dam failure is identified in the Bundaberg LDMP[47], but dam failure for Paradise Dam is not specifically identified. BRC understand the resultant impact of a Paradise Dam failure on the Bundaberg area is flooding of the Burnett River downstream of the dam within the BRC reach of the Burnett River catchment.

However, BRC are aware there are several factors that may result in flooding in the BRC reach of the Burnett River. The extent of flooding impacts (regardless of cause) have been well captured in both the BRC Natural Hazard Risk Assessment and the Lower Burnett River Floodplain Risk Management Study (Flood Study). Flooding, regardless of cause, will be managed in accordance with the Bundaberg LDMP.[48]

The Bundaberg LDMP acknowledges several documents that inform local government policy for disaster management and specifically relate to hazards that may result in flooding impacts in the Bundaberg Regional Council area. Some of these documents are:

- Bundaberg Flood Mapping
- Function and threat specific plans as appropriate
- Bundaberg LDMP - Natural Hazard Risk Assessment Report.

Strategic documents of other infrastructure entities also inform local government policy. These include (but are not limited to):

- Sunwater – Paradise Dam Emergency Action Plan
- Sunwater – Fred Haigh Dam Emergency Action Plan
- Sunwater – Woongarra Storage Emergency Action Plan
- Sunwater – Isis Storage Emergency Action Plan.

The Bundaberg LDMP does not have specific evacuation plans with detailed actions (e.g. evacuation routes) for riverine flooding due to the multiple variations caused by different riverine flood options. However, BRC does possess the in-depth understanding, detailed mapping and ability to plan an evacuation in an event (i.e. Burnett River Flood Evacuation mapping system). BRC can comprehensively integrate map flood heights to floorboard levels for its residences and businesses.

This mapping can provide:

- evacuation zones, which have been identified and displayed visually on Bundaberg Regional Council's interactive mapping services
- division of sectors or suburbs located within large exposed areas, to enable management of warning and withdrawal activities
- evacuation routes and alternate evacuation routes
- all identified safer locations, such as evacuation centres and neighbourhood safer places, as well as pet-friendly facilities
- hospitals, aged care facilities, schools and other similar facilities which may require special attention or response
- emergency services and other key response agencies and locations
- hazardous sites
- critical infrastructure
- local government or other relevant boundaries.

Additionally, key data to support the disaster response is available within existing mapping, including:

- population and demographic data within each exposed area
- estimated evacuation timeframes for each evacuation zone either independently or concurrently with other zones
- evacuation route capacity and hazard immunity levels

- estimated percentage of exposed population requiring emergency accommodation.

BRC can also ascertain relatively accurate flood modelling and impact assessments for the Bundaberg community, including flood heights, water velocity and timings. Under its Evacuation sub-plan, this can be achieved utilising BRC's interactive mapping tools to create visual representations of hazards.

An in-depth explanation and demonstration of BRC's flood modelling tools and plans were provided to the review team. This provided a strong level of confidence in BRC's knowledge and capability to manage riverine flooding in the Bundaberg area. A copy of one of these flood modelling maps is provided in Figure 2.

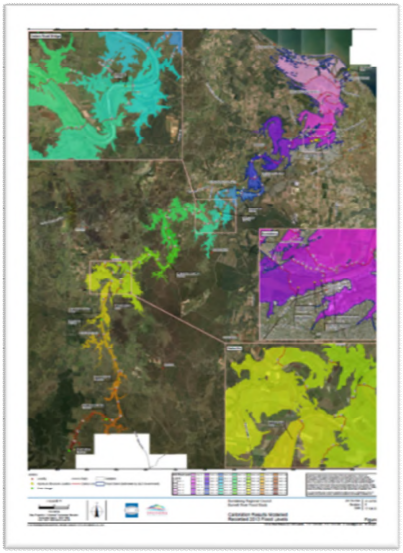


Figure 2

In conjunction with the above-mentioned flood modelling tools and plans the Bundaberg LDMG quickly develop an event specific evacuation plan. Bundaberg LDMG follow Queensland disaster management guidelines and training frameworks in developing these plans. Evacuation timeline assessment by BRC is based on the practices outlined in 'The Application of Timelines to Evacuation Planning'.

Significant improvements to the Bundaberg LDMP have occurred due to the LDMP (and associated sub-plans) being tested in real events such as the floods of 2010, 2011 and 2013. In support of the Bundaberg LDMP, the Burnett River Flood Plain Action Plan (preliminary version) was developed by the BRC in 2014. This was undertaken as a consequence of the 2013 floods. The purpose of this plan is to:

- provide BRC with an understanding of the nature and degree of flood risk across the lower Burnett River floodplain
- assess a range of floodplain risk management measures that could be implemented to reduce flood risks and increase community resilience to flooding
- provide flood risk information to inform land-use planning decisions and emergency management activities.

The Burnett River Flood Plain Action Plan led to BRC building four flood mitigation projects (evacuation route upgrades) utilising joint State and Commonwealth Government funding under the previous Natural Disaster Relief and Recovery Arrangements program (NDRRA), these being:

- Mount Perry Road, Bundaberg North
- Technology Park Flood Levee, Bundaberg North
- Fairymead Road, Bundaberg North
- Bartholdt Drive, Branyan.

BRC has also undertaken several other flood risk studies since the 2013 floods to improve their risk reduction/mitigation levels, namely:

- Bundaberg Flood Study (2013)
- Bundaberg Flood Risk Management Study (2014)
- Bundaberg Flood Protection Study (2015)
- Bundaberg 10 Year Flood Action Plan (2017)

With respect to Paradise Dam, the draft version of the most current EAP was provided to BRC for review and comment in November 2019. This draft included some information relating to the newly identified risks associated with Paradise Dam. At the time of the commencement of the Office's review, BRC did not fully understand these new risks and how a failure of Paradise Dam would change the flood risk for downstream properties as this information had not yet been provided by Sunwater. However, this information was provided to BRC in the lead up to a Sunwater exercise conducted on 3 December 2019.

In an initial verbal briefing provided to BRC management on 24 September 2019 Sunwater indicated that Paradise Dam was safe under normal conditions, however the dam could be at risk for a 2013 type flood event.

A follow-up meeting held by Sunwater on 2 October 2019, with executive members of the Bundaberg LDMG and Bundaberg DDMG provided additional information about Paradise Dam. This included verbal advice that delamination of 300mm concrete layers had occurred in the dam wall. Advice was provided at this meeting that water levels would be reduced to 42%, but information was not provided around how or on what basis this level was determined (e.g. community safety or water security). As the executive members of the Bundaberg LDMG and Bundaberg DDMG were not appraised of what a critical failure of Paradise Dam looked like, they were not able to fully understand the level of impact and plan community safety action triggers. BRC members subsequently requested information on the flood water levels, timeframes and impact areas from Sunwater in writing.

A change in risk of failure for Paradise Dam is now seen as an opportune time for the Bundaberg LDMG to review its current arrangements for management of riverine flooding. This situation provides opportunities to further review and refine the triggers for LDMG activation, decision and notification times for evacuations, effects on evacuation routes and evacuation centre locations. With the provisioning of additional information and collaboration from Sunwater, relating to the potential increase in dam failure risk for Paradise Dam, this new risk along with riverine flooding downstream of Paradise Dam has been included in a Flood Action Plan currently developed by BRC. This new action plan was successfully tested during a desktop exercise conducted by Sunwater on 3 December 2019.

Dam failure has been identified as a residual risk within the Bundaberg LDMP, with a key focus on a 'sunny day failure' and the impact on residences and communities closer to the dam (i.e. not Bundaberg City itself). Failure of individual dams, including the Paradise Dam, have not been nominated as individual risks within the LDMP. Given the recent advice from Sunwater, Paradise Dam now carries a noticeably greater risk of dam failure for the Bundaberg LDMG. Therefore, BRC have committed to including Paradise Dam failure as a risk in the Bundaberg LDMP and the Disaster Risk Register.

As part of its previous risk assessment and management processes undertaken using ISO 31000:2009 – Risk Management and the National Emergency Risk Assessment Guidelines (NERAG) the Bundaberg LDMG have identified its residual risks and listed them within its LDMP. Dam failure is not currently listed as a residual risk in the LDMP, however riverine flooding is. These residual risks have been shared across the Bundaberg DDMG as a risk treatment option.[49] BRC has now committed in principle to undertake the QERMF process as part of the Bundaberg LDMP review process. This process will assist BRC to review its residual risks. The QERMF process will be prepared with assistance from members of the Bundaberg DDMG and key LDMG agencies.

Finding
BRC have committed in principle to undertake the QERMF process as part of its LDMP review process.

Finding
Dam failure for Paradise Dam has not been included as an individual risk within the Bundaberg LDMP.

Recommendation
To increase understanding of hazards and manage risks, dam failure for Paradise Dam be included as a separate risk within the Bundaberg LDMP.

Although the above recommendation specifically relates to Paradise Dam, all councils would benefit from undertaking the QERMF process, in collaboration with their LDMGs, to formally reassessing the risk of referable dams within their LGA and document this process.

Recommendation
To enhance shared capacity and collaboratively manage risk, the Chair of the Bundaberg LDMG use the QERMF process to determine if dam failure for Paradise Dam should be reported as a residual risk to the Bundaberg DDMG in this instance due to known changes in the risk profile.

The Bundaberg LDMG has tested its LDMP (and sub-plans) on at least 14 occasions since 2013, including real events and organised exercises. The real events were TC Marcia (2015), TC Debbie (2017) and the Deepwater bushfires (2018). A large variety of exercise types have been deliberately undertaken by BRC to ensure that an all hazards approach is considered as part of their exercise program.

With respect to land use planning and building restrictions, prior to the 2013 event the Bundaberg Planning Scheme utilised a 2% Annual Exceedance Probability (AEP) flood for land use management on the Burnett River flood plain. BRC's current hazard evaluation report for flood now uses the 1% AEP as the basis for land use planning and lower AEP (0.2% - 0.5%) for community infrastructure.[50] This is a conservative move, bringing Bundaberg into line with other councils that typically use a 1% AEP measure.[51] At the time of the 2013 flood event BRC had already commenced the process of reviewing this planning scheme. As part of the 2013 disaster recovery process a Temporary Land Use Planning Instrument (TLPI) was implemented. The main outcomes of the TLPI were:

- defining a Flood Hazard Area pursuant to section 13 of the Building Regulation 2006
- setting of new minimum habitable floor levels for areas affected by Burnett River flooding
- allowing an increase in overall building height for dwellings that were proposed to be raised or constructed to a higher level to increase flood immunity
- facilitating repair works to sites and structures by making such development exempt.

The way in which future flooding was addressed was influenced by the adoption of this TLPI into the final planning scheme document. Following on from the TLPI, BRC adopted its new Planning Scheme and flood hazard area mapping in October 2015. These provide longer-term controls to ensure building and development in the Bundaberg region respond to the risk of flooding. Examples of longer-term controls include Flood Hazard Area Maps, Flood Hazard Overlay Codes, Flood Planning Control Property Report and Limited Development Zoning.

In the 2013 event, significant damage was sustained to infrastructure and property from flood induced scouring. This is emphasised by the $150 million in NDRRA funding provided for public infrastructure damage sustained in the 2011 and 2013 events. This flood-induced scouring was most severe in North Bundaberg where approximately 16 sink holes formed in the urban area causing major structural damage to homes, roads and outbuildings. Using the advice of technical experts BRC developed its *Improving Dwelling Resilience to Flood Induced Scour - Guidelines for Dwellings Constructed within a Flood Hazard Area* to assist designers in formulating improved flood resilient dwelling outcomes.

Planning for resilience has also been a feature in BRC's disaster management efforts. In May 2018 the Burnett Catchment Flood Resilience Strategy was formally released under Resilient Queensland, which is the implementation plan of the Queensland Strategy for Disaster Resilience. The Resilience Strategy has received several professional accolades including a Resilient Australia-Government Award (Queensland) and several awards conferred by the Planning Institute of Australia (Queensland division).

The Resilience Strategy was developed in partnership with the Queensland Government (with the Queensland Reconstruction Authority (QRA) as lead agency) and the four local councils which comprise the Burnett River Catchment. Two of these local councils are BRC and NBRC. Under the Natural Disaster Resilience Program (NDRP) a Regional Resilience Coordinator was established. The benefits of an ongoing approach to such roles is apparent in the experience of other councils and has been flagged by the Australian Red Cross.[52] A number of resilience initiatives have been commenced under the Burnett River Catchment Flood Resilience Strategy, such as:

- council collaboration for flood warning infrastructure
- response and recovery training for frontline personnel
- resilience through community leadership
- LiDAR (Light Detecting and Ranging) coverage in the Burnett flood catchment
- flood warning infrastructure and markers project
- increased information sharing and collaboration
- agriculture, land management and environmental stewardship
- strategy actions in progress.

Capability Integration

Until September 2019 significant collaboration had occurred between stakeholders to extensively review the Paradise Dam EAP and the Bundaberg LDMP. This included the open sharing of flood mapping and Sunwater working collaboratively with BRC to develop messages and polygons to deliver Emergency Alert warnings to downstream residents. The stakeholders involved in this process understood the need to have a shared responsibility to ensure community safety. This shared responsibility was further reinforced through training.

However, as previously outlined in this report some information relating to the risk posed by Paradise Dam was only reported to BRC management on 24 September 2019, with further information provided to the Bundaberg LDMG and DDMG on 2 October 2019. BRC are seeking improved levels of communication at the earliest opportunity to enable BRC to better (and sooner) understand the risk to its communities.

Sunwater have subsequently consulted and collaborated more closely with BRC, providing a rapid and open exchange of data and modelling. This information was associated with a potential failure of Paradise Dam and its effect on top of flooding associated with an event like that of 2013. This information-sharing and collaboration included BRC and Sunwater

working together to develop triggers for the updated Paradise Dam EAP. Sunwater also engaged with key BRC representatives in relation to the use of its audible warning siren and associated warning messages to incorporate them into the updated Paradise Dam EAP.

This review has identified earlier that information about changes in risk have important implications for others. Opportunities exist for Sunwater to build information about changes in risk into its routine communications with stakeholders. If taken up, these opportunities may also lead to increased public confidence and greater community safety.

With respect to improving disaster management knowledge, regular training and exercising of Bundaberg LDMG members is undertaken in partnership with QFES and the Bundaberg DDMG Executive Officer (XO). A review of the training needs analysis for Bundaberg LDMG members and advisors identified that, on the whole, training was being undertaken, with many members and advisers (and BRC staff) having well exceeded core training courses and inductions relevant to their respective disaster management roles. However, it also identified that some members and advisors have a need to undertake further mandatory training requirements; particularly about evacuation and recovery.

As is the case with North Burnett LDMG, the QFES EMC position that covers the Bundaberg LDMG had been vacant for part of 2019, with support being provided from a neighbouring EMC. The commencement of the newly appointed EMC on 11 November 2019 will assist in this training being provided.

The recent issue regarding the integrity of Paradise Dam has seen the Bureau, Sunwater and BRC work collaboratively to provide enhanced decision-making support to manage this issue. This includes:

- A tailored weekly report for the Burnett River catchment upstream of Paradise Dam which includes 7-day rainfall forecasts with medium to longer term rainfall outlooks, disseminated by email and supported by verbal briefings
- Ongoing work with Sunwater to:
    - Carry out due diligence checks on the Burnett flood model to ensure consistency
    - Share critical thresholds, key rainfall triggers, impacts information and an understanding of lead time required for evacuations to ensure enhanced decision support from the Bureau
    - Develop a Communications Protocol to activate during an event based on key triggers
    - Participate in exercises to practice and improve developed procedures
    - Host a workshop at the Bureau to further understand the most appropriate rainfall forecast data to use for hydrologic purposes
- Activating enhanced procedures throughout the 2019/20 wet season and beyond.

As previously outlined in this report Sunwater has been using LifeSim since 2017 to simulate impact (including loss of life) in catastrophic floods. To help develop LifeSim BRC provided Sunwater with its building footprints. As LifeSim can run a scenario-based flood model with vehicular evacuation plans to support best planning BRC identified that it would benefit from this technology. By inputting its locally developed data into LifeSim and then using LifeSim itself, BRC can be better informed about evacuation planning. This sharing can also value add to LifeSim and provide additional benefits to Sunwater. The benefits of sharing LifeSim with BRC is currently being scoped by Sunwater.

For the 2013 event it was estimated there were more than 7,500 affected persons with many properties either damaged due to tornado activity or flood water inundation. At the flood peak, there were approximately 2,000 persons within BRC-operated evacuation centres. The construction of the Bundaberg Multiplex by BRC, post 2013, delivers an increased, scalable and more efficient capacity for provisioning short-term support to displaced persons unable to shelter with family and friends. This enables State agencies (e.g. Department of Communities, Disability Services and Seniors (DCDSS), QRA and the Department of Housing and Public Works (DHPW)) and Commonwealth agencies (e.g. Centrelink) to provide improved outreach and case management activities, leading to a more rapid commencement of recovery actions.

The Bundaberg LDMG has encountered several disaster events since 2010 and have consciously undertaken extensive activities to improve its disaster preparedness and planning. When taking the Standard into consideration this review identified that, given its moderate capacity and capability, the level of disaster preparedness and planning of the Bundaberg LDMG for a future significant flood event affecting Paradise Dam to be strong.

This review has provided some findings and recommendations relevant to disaster preparedness and planning which may afford the Bundaberg LDMG with opportunities for further improvement.

District Disaster Management

Bundaberg

Planning

All agency representatives of the Bundaberg DDMG understand the need to have a shared responsibility to ensure community safety. Since 2010 extensive work has been undertaken by members of the DDMG to improve information sharing, gathering situational awareness (e.g. additional flood monitoring equipment) and reducing risks associated with Paradise Dam (e.g. structural work to the dam post 2013 flood, improved public communications, messaging and flood predictions).

Sunwater representatives are included in the Bundaberg DDMG as an advisor and have a high attendance rate at DDMG meetings. The executive of the Bundaberg DDMG advises that it has developed a professional working relationship with locally based representatives from Sunwater. This relationship has resulted in open communications being promoted and practised. Improvements in the information exchange processes between Sunwater and DDMG have continually grown since the 2010/2011 disaster events. This has benefitted the planning, preparation and response phases of subsequent flood-related events.

In addition, during weather events the Chair of the Bundaberg DDMG advises that discussions and meetings are held between Sunwater and DDMG representatives, both formally and informally. These discussions are held to determine potential risks associated with significant flooding.

The DDMG regularly receive updated EAPs from Sunwater relating to referable dams within the Bundaberg Disaster District. These EAPs provide important information relating to these dams, such as detailed flood maps and identified alert levels. The Chair of the Bundaberg DDMG advised that for the DDMG, understanding and desktop exercising of the Paradise Dam EAP has been very successful in determining response strategies at a district level.

Since 2010 significant improvements to the Bundaberg District Disaster Management Plan (DDMP) have occurred due to the DDMP (and associated sub-plans) being tested in real

events such as the floods of 2010, 2011, 2013 and 2015. Referable dams and water storage facilities are listed in the Bundaberg DDMP as critical infrastructure requiring consideration for risk assessment. Dam failure is included in this DDMP as an identified hazard, but dam failure for Paradise Dam is not specifically identified as a hazard.

Major riverine flooding is included in the DDMP as an identified hazard**.** The DDMG is well prepared for major riverine flooding, with substantial knowledge and experience gained through the flood events of 2010, 2011, 2013 and 2015. Since 2010, enhancements in disaster prevention / mitigation, preparedness and planning programs by the North Burnett and Bundaberg LDMGs, as well as the DDMG member and advisory agencies, have occurred. These enhancements have enabled the DDMG to be well placed to manage major riverine flooding. Many of these enhancements are documented throughout this report.

Risk management processes conducted by the DDMG have been undertaken in accordance with the National Emergency Risk Assessment Guidelines (NERAG), which complies with Risk Management Standard AS/NZS ISO 31000:2009.

Utilising the NERAG processes, the Bundaberg DDMG developed a detailed district risk register incorporating risk identification, risk analysis and risk evaluation. These risks are not a duplication of those identified by the North Burnett and Bundaberg LDMGs. It addresses only those risks that will significantly impact on the local government area to such a degree that the risk requires transferring to, or sharing with, the DDMG. The risks, including their evaluation, analysis, assessment and treatment are contained in in the Bundaberg DDMP.[53] These risk management processes have previously been identified as an example of good practice by the Office.

Finding
Bundaberg DDMG have significantly enhanced their disaster management plans and preparedness levels since 2013.

Although dam failure is included in the Bundaberg DDMP as an identified hazard, dam failure is not specifically listed as a district level risk. The risk evaluation and treatment factors for a dam failure are like those of a significant riverine flood, which is included as a risk in the DDMP. As part of the QERMF process, residual risk at both a local and district level will be addressed. Dam failure could therefore be considered a risk for the DDMG. The Bundaberg DDMG has not undertaken the process of identifying and elevating any district level residual risks to the State level.

After the 2013 flood event, dam failure has been a topic of conversation between the DDMG and Sunwater to determine appropriate coordinated response strategies for this possible scenario. Since early October 2019 and through consultation with Sunwater, North Burnett LDMG and Bundaberg LDMG, the Bundaberg DDMG has developed a greater understanding of the increased community safety risk associated with the Paradise Dam.

Finding
Dam failure for Paradise Dam has not been included as an individual risk within the Bundaberg DDMP.

Recommendation
To increase shared understanding of risks, ensure the coordination of plans and manage risks, dam failure for Paradise Dam be included as a separate risk within the Bundaberg DDMP.

Recommendation
To enhance shared capacity and collaboratively manage risk, the Chair of the Bundaberg DDMG use the QERMF process to determine if dam failure for Paradise Dam should be reported as a residual risk in this instance due to known changes in the risk profile to:

- *the State Disaster Coordination Group (SDCG) in accordance with their responsibilities under the State Plan*
- *QFES for ensuring the development of the state-wide risk assessment*.

The Chair of the Bundaberg DDMG advises that, in general, it does not formally review EAPs. Section 352HC of the Water Supply Act 2008 is a discretionary provision that provides that the Chair of a district group may review an EAP for consistency with the DDMP. The DNRME Emergency Action Plan for Referable Dam Guideline 2017 shows that it is not compulsory. Notwithstanding this, the following process was undertaken by the Chair of the Bundaberg DDMG in response to the recent review of Paradise Dam EAP:

- The dam owner provides a copy of the EAP to the Chair of local and district disaster management groups.
- The dam owner and the LDMG collaboratively assess the EAP for consistency with the LDMP (e.g. downstream messaging and communications).
- If the EAP is consistent with the LDMP, a notice is given to the dam owner to this affect and a copy is forwarded to the Chair of the DDMG for noting. In this instance no further action is required of the DDMG.
- If the EAP is not consistent with the LDMP, then the dam owner and LDMG work together to addresses the inconsistencies. If this is achieved a notice is given to the dam owner identifying this and a copy is forwarded to the DDMG for noting, with no further action being required of the DDMG.
- If the EAP is not consistent with the LDMP and both parties are unable to reach a solution to make it consistent, this issue is escalated to the DDMG for their attention and any necessary intervention/assistance.

On 11 October 2019 the Chair of the Bundaberg DDMG received a copy of Paradise Dam EAP (issue 10.0) for review. On 22 November 2019 the Chair of the Bundaberg DDMG advised Sunwater that no formal review of the plan was conducted by Bundaberg DDMG, however the contact information of DDMG representatives contained in Appendix 3 (Notification Group) was reviewed and acknowledged as correct. The Chair of the DDMG further acknowledged that in consultation with the Disaster Management Officers from Bundaberg and North Burnett Regional Councils, a copy of this EAP was provided to both LDMGs for review.

Both Bundaberg and North Burnett LDMGs are engaged with Sunwater in a collegiate way as part of a review process for the latest Paradise EAP to ensure consistency with their respective LDMPs.

On 2 October 2019 information was provided to the DDMG by Sunwater about new dam failure risks associated with Paradise Dam. Following on from the Sunwater exercise conducted on 3 December 2019 it was determined that the failure of this dam would be included as a new risk by the DDMG with a formal risk assessment to be undertaken.

The change in risk of failure of the Paradise Dam presents an opportunity for the DDMG to review its current arrangements for management of riverine flooding. Additionally, to further

refine the triggers for activation, decision and notification times for evacuations, effects on evacuation routes and evacuation centre locations.

Members of the Bundaberg DDMG in collaboration with staff from Bundaberg and North Burnett Regional Councils commenced developing a district operational plan to address a Paradise Dam failure. This plan was based on an extreme weather event that triggers the integrity of Paradise Dam. A draft version of this operational plan was sufficiently tested during the Sunwater desktop exercise held on 3 December 2019 and is expected to be formally adopted by the DDMG around 20 December 2019.

Finding
Bundaberg DDMG is developing an operational plan to increase community safety relating to a failure of the Paradise Dam.

The DDMG over the past five years has conducted and participated in several exercises to assess its capability and capacity:

- Exercise 'Pick Up' (2014) tested the newly developed Air Services Coordination Plan in response to a sudden flood disaster.
- Exercise 'Cow Bell' (2014) tested DDMG and LDMGs in a sudden disaster which impacts the communications infrastructure.
- Exercise 'Airborne' (2017) explored the capacity and interoperability of the Sunshine Coast, Gympie, Maryborough and Bundaberg DDMGs (and the State Disaster Coordination Centre (SDCC)) to respond and support aviation management during a large-scale disaster event across multiple disaster district.
- Exercise 'Tahliye' (2019) explored evacuation management during a disaster event.

In October 2019 the Department of Transport and Main Roads (DTMR) conducted a discussion-based exercise in Bundaberg as part of its annual pre-cyclone season preparedness program. The exercise explored the disaster management arrangements between DTMR and external stakeholders during a disruptive event. The exercise looked at the impacts of localised flooding with major flood warnings in place which impact on various DTMR locations and the travelling public.

District level plans have also been tested in real events, including TC Marcia (2015), TC Debbie (2017) and Deepwater Fires (2018). A number of lessons for improvement were identified through these events and have been outlined in the Lessons Management section of this report.

Capability Integration

Desktop exercising of the Paradise Dam EAP by Sunwater is carried out as EAPs are updated. Part of this process is to ensure all stakeholders are clear on roles and responsibilities for hazard specific disaster operations. Executive representatives from the DDMG are invited by Sunwater to attend Paradise Dam EAP exercises.

Representatives from Sunwater are included in all (extraordinary) meetings of the DDMG during a disaster event, to provide content expertise on potential risks based on flood modelling and rainfall predictions. During disaster events Sunwater provides regular dam reports that assist the DDMG with developing plans and enacting response activities. This information-sharing also assists all district level stakeholders to become familiar with early warning procedures developed by Sunwater relating to dam water levels and potential flooding risks.

Bundaberg DDMG and both LDMGs have a strong collaborative approach; the by-product of a willingness of all stakeholders to build and maintain strong professional relationships. The review team witnessed this strong collaborative approach first-hand during the combined response to the Woodgate/Buxton fires in November 2019.

Regular disaster management training of DDMG members and advisors is undertaken in collaboration with QFES. A review of the training needs analysis for Bundaberg DDMG members and advisors identified that on the whole training was being undertaken, with many members and advisers having exceeded core training courses and inductions relevant to their respective disaster management roles. It also identified that a few members and advisors have a need to undertake further mandatory training requirements.

A body of work has already been commenced by the newly appointed QFES EMC to ensure training is conducted for Bundaberg DDMG members in line with the Queensland Disaster Management Training Framework (QDMTF).

Since the 2013 floods, effective disaster planning and preparedness of aged care providers across the Bundaberg Disaster District has been a priority for the Bundaberg DDMG. The DDMG in collaboration with both LDMGs have undertaken considerable effort to improve disaster plans and preparedness of aged care facilities across the disaster district. This has included:

- Establishing a district level aged care service provider committee
- Conducting a full-day information forum for aged care service providers
- Undertaking direct and ongoing interaction and support to individual aged care facilities
- Recommending changes to emergency/disaster management plans, practices and regulations for aged care service providers in Queensland.

The Queensland Ambulance Service (QAS) have introduced yearly contact with vulnerable person-based agencies (e.g. aged care facilities) to view their evacuation plans and provide advice. Last year (2018) was the first time this approach was undertaken in Bundaberg. QAS found some of the agencies were a bit apprehensive about this approach. QAS has identified that Bundaberg has 15 aged care homes of varying levels, including independent living centres and is continuing to liaise with aged care facilities below the Paradise Dam that have been identified as vulnerable to flooding. Bundaberg LDMG and BRC are aware of these annual contacts by QAS with aged-care based agencies and the evacuation plan viewings. Given Queensland-wide initiatives to address the need for all aged care providers to plan and exercise for evacuation to a similar safe establishment, identified in the Cyclone Debbie Review, this initiative is significant.

DHPW has a Regional Disaster Management Plan that details operational arrangements in response to an event. This plan enables temporary housing solutions to be provided upon request where a large-scale loss of housing stock has occurred. DHPW have committed to swiftly developing an operational plan that supports the updated EAP and other operational plans. This DHPW operational plan will support a more proactive and longer-term response, relief and recovery to a major flood event in the Bundaberg Disaster District where flood heights may exceed that of 2013 and the repatriation of displaced persons may be delayed or extended for a considerable timeframe.

As a result of the 2013 foods events, Maritime Safety Queensland (MSQ) developed and implemented its *Extreme Weather Contingency Plan for Gladstone*, which covers a number

of water ways including the Burnett River. The aim of this plan is to provide for the safety of vessels and their operation during extreme weather events. Under this plan personal safety is always deemed to be of prime importance. Given the recent advice around the risk change to Paradise Dam, there is value in testing the *Extreme Weather Contingency Plan for Gladstone* in an exercise for the Burnett River this cyclone season.

DCDSS has a Bundaberg District Human and Social Recovery Plan. The purpose of this plan is to describe the actions that the Queensland Government and its partners will take to reduce the human and social impacts of disaster. It provides a model for how district and local stakeholders will engage to assess impacts and deliver coordinated services.

A new co-located emergency services facility in Bundaberg was established at higher flood-free ground by QAS and QFES after their facilities were flooded in 2013. Their respective business continuity plans have been developed to better respond to flooding in Bundaberg City.

The Bundaberg DDMG has experienced several disaster events since 2010 and have consciously undertaken many activities to improve its disaster preparedness and planning. When taking the Standard into consideration this review identified the level of disaster preparedness and planning of the Bundaberg DDMG for a future significant flood event affecting Paradise Dam to be strong.

Overall, the review team found a well-organised and proficient level of preparedness and planning across the District. One community member told the review team, that in their view the community is very prepared now with LDMG, DDMG and media relationships and experiences gained from 2010 and 2013 events. They went on to say that in their view very good work has been undertaken locally around flood preparedness and mapping, which would hold the community in good stead for any future flood. This review has provided some findings and recommendations relevant to disaster preparedness and planning which may afford the Bundaberg DDMG with opportunities for further improvement.

When looking to the future, any structural modifications to Paradise Dam may not be completed until 2025. Consequently, the heightened level of risk associated with Paradise Dam could remain for the duration of that period. A focus on long-term disaster management planning and preparedness for Paradise Dam will therefore be required by all stakeholders. This will include a sustained level of vigilance, ongoing risk assessment and collaboration.

Response preparedness

Under the Standard, disaster response operations are focused on stabilising the impact of a disaster on a community. This includes a range of life, property and environment-saving activities and life dependant restoration activities. At a system level the effective management of disaster response operations is dependent on the performance of command, control, coordination and cooperation, operational information and intelligence management systems and resource management.[54]

The review team looked at the level of preparedness to undertake disaster response operations in accordance with the Standard.

Local Disaster Management

Both Bundaberg and North Burnet councils' local disaster management plans outline the roles and responsibilities for disaster response activities, including overall local disaster coordination. They provide an outline of requirements for response, such as:

- early activation of the LDMG and LDCC and the likely triggers
- warning systems, public education, and community information
- functional and event-specific operational plans
- coordination of disaster operations (including evacuations)
- management and deployment of resources and supplies
- timely and accurate reporting
- media management. [55]

Combined, the plans cover the full geographic area likely to be affected by any flood from the dam.

Bundaberg LDMG has developed an operational plan to manage a dam wall failure at Paradise Dam. This plan was developed to complement the latest Paradise Dam EAP and other operational plans (e.g. MSQ, DTMR, DHPW, North Burnett LDMG and Bundaberg DDMG). The newly developed Bundaberg LDMG operational plan was sufficiently tested during a desktop exercise conducted by Sunwater on 3 December 2019.

North Burnett LDMG is in the final stage of developing an operational plan to manage the effects of a dam wall failure at Paradise Dam. This operational plan will complement the Dam's latest EAP and the operational/action plans of the Bundaberg LDMG and Bundaberg DDMG. It will also complement individual disaster plans being established for the four downstream residences and one orchard.

In preparation for forecast disaster events, both local groups gather information from many sources to develop intelligence products and gain situational awareness and to understand the potential impact on communities. Sources include emergency services, Sunwater, the Bureau, community members, council staff, LDMG member agencies and the DDMG. [56] As an aid to gaining situational awareness, the Bundaberg LDMG also monitors the community's interaction with BRC's Emergency Management Dashboard and Interactive mapping pages during disaster events (not just flooding), Facebook and Webpage usage.

In preparation for a large-scale evacuation, BRC have significantly increased its capability to provide immediate sheltering for evacuees with the construction of the Bundaberg Multiplex. This facility has been designed for this purpose. It has also increased short-term accommodation options through improvements to RV camping grounds, like the Bundaberg Recreation Precinct, throughout its area. However, it is anticipated that a request for assistance will be lodged with the Bundaberg DDMG seeking support from DHPW if medium to long-term temporary housing support for evacuees is required.

The review team observed strong cooperation between councils during the course of this review. North Burnett typically activates for events simultaneously with Bundaberg and the District. Both councils activate their LDCC for a disaster event. North Burnett additionally readies the coordination centres for its six support groups. The establishment of support groups/sub-groups to assist the LDMG with its business reflects good governance.[57] Both councils' supporting LDMGs are well versed in disaster response due to experiences gained, skills developed, and learnings applied from flood events that have occurred over the past nine years.

District Disaster Management

The Bundaberg DDMP outlines the arrangements within the Bundaberg Disaster District to provide whole-of-government planning and coordination capability to support local

governments in disaster management. Additionally, the DDMP provides an outline of requirements for response, including:

- roles and responsibilities
- warning notification and dissemination, including Emergency Alert text and voice messages
- activation and triggers for response
- establishment of a district disaster coordination centre
- operational reporting
- disaster declarations
- functional and operational plans
- requests for assistance, air support, and supplies and equipment
- resupply and emergency supply.[58]

The Bundaberg DDMG utilise various information sources to assist it in preparing for and responding to riverine flooding and dam failure events. These include:

- Bureau of Meteorology tools (e.g. river height gauges, rainfall gauges, predictive flood modelling)
- Local community information
- Emergency services information
- Engagement with LDMGs
- EAP flood mapping
- LDMG Flood Portal mapping
- Sunwater tools (e.g. dam levels)
- SDCC Situational Awareness Platform
- Reports from the SDCC.

The DDMG also utilise different methods to assist it in understanding the potential risks to communities downstream from Paradise Dam. These include:

- Sunwater briefings
- co-location of the Bundaberg DDCC and Bundaberg LDCC (promotes the sharing of information across both centres)
- deployment of a satellite DDCC in the North Burnett to enhance information sharing and collaboration with the North Burnett LDCC.

To assist the DDMG in its response preparedness capability, DDMG representative agencies develop their own plans and implement improvement measures. For example, DTMR have recently identified that currently the Bruce Highway between Childers and Gin Gin has no Road Condition Information Signage (RCIS) to aid in proactively managing closures of this highway due extreme flooding, including the failure of Paradise Dam. Road condition signage is identified as part of the Bruce Highway Road Operations Improvement Project being undertaken by DTMR. The installation of eight RCIS between Gympie and Gin Gin, plus associated cameras to enable active management of the highway and advanced closure, is being considered by DTMR.

DTMR have also developed a traffic management plan that identifies alternate transport routes in the event transport infrastructure (e.g. roads and bridges) is impacted by disasters,

such as major flooding, in the Bundaberg disaster district. This plan includes the long-term impact from a Paradise Dam failure.

District capability

On 14 November 2019 the Inspector-General Emergency Management visited the QFES Bundaberg Incident Command Centre (ICC) responsible for controlling the Woodgate fire and the evacuation of Buxton.

The ICC had been established at the recently-built combined QFES/QAS facility in south Bundaberg. The fire-fighting element was spread across a single room within the QFES part of the complex.

In a meeting room adjacent to the ICC the main elements of the DDCC had been established, including the District Disaster Coordinator (DDC), the XO, support staff and, separately, an officer in the QPS liaison role. A liaison Office from Bundaberg Council was also present.

The QFES ICC Commander was also the regular QFES DDMG representative, ensuring good relations and a free flow of information between the ICC and District.

The centre was operating smoothly, exhibiting good systems and relationships, and demonstrating the attributes of good practice by liaison officers as outlined in recommendations of the 2018 Queensland Bushfires Review.

Results of a telephone survey, conducted for the purpose of this Review, identified that 85% of respondents were confident that the official local response to a disaster event would be effective and coordinated. From observations made and through contact with community representatives throughout this review the review team supports this high level of confidence.

As already outlined in this report Sunwater conducted an exercise on 3 December 2019 in line with the updated Paradise Dam EAP. The aim of this exercise was to test plans and provide assurance about organisational readiness for any large flood event along the Burnett River downstream from Paradise Dam, with a focus on increased dam safety risk. Agency representatives from the LDMGs and the DDMG attended this exercise. Representatives at a state-level also attended, including the State Disaster Coordinator. A NBRC representative was unable to attend the exercise on the day but had engaged in exercise development activities leading up to the exercise. The plans tested included the updated Paradise Dam EAP and the operational/action plans of the local and district disaster management groups and individual agencies.

The exercise highlighted two main learnings. The importance of coordination of public messaging between Sunwater and council was highlighted by an exercise artificiality. Its importance was known to all participants but unable to be fully tested. The exercise highlighted the significance of activation levels. The terms used to describe levels of activation of disaster management response are the same as those for the activation of the Emergency Action Plan. Both draw their authority from different sources; the *State Plan* and the *Emergency action plan for referrable dams guideline* respectively. The exercise showed

that the activation level of the EAP, according to water-level triggers agreed with local government, can be different from the response activation level that disaster management groups, and Sunwater as an organisation, can choose. The difference in activation levels can lead to perceptions of poor coordination. Those involved should acknowledge the difference that can arise between the activation level of the dam's EAP based on risk, and organisational activation levels, based on readiness.

The exercise provided the review team (and the State Disaster Coordinator) with a level of confidence and assurance that the local and district disaster management groups and member/advisor agencies had the plans, knowledge and commitment to manage a large flood event for the Burnett River and Paradise Dam. This included the management of a dam failure associated with Paradise Dam.

Finding

The North Burnett LDMG, Bundaberg LDMG and the Bundaberg DDMG are well-prepared to respond to a major riverine flood and/or failure of the Paradise Dam.

Emergency communications

This section addresses the seventh point of the terms of reference, about communications between disaster stakeholders and more broadly with community stakeholders.

The Standard identifies that emergency communications both within and across agencies, is paramount to effective operations. Under the Standard, emergency communications consist of three components, Public Engagement, Communications Systems and Warnings.[59]

- Public engagement (including public information and public education) is foundational to all disaster management activities. It is a two-way process in which entities and the broader community work together to understand, prepare for, respond to and recover from disasters.[60]
- Effective communication systems are necessary for disaster operations. Communication systems include any means or methods used by entities to share critical information.[61]
- The ability for the community to take appropriate action in the event of a disaster is vitally important to reducing the risk of loss of life and property. Warnings include any communication to the broader community that enable this.[62]

Public engagement

In addition to the Standard, the Department of Natural Resources, Mines and Energy Emergency Action Plan for Referable Dam Guideline 2017 sets expectations for Dam Owners:

> Dam owners are encouraged to work in partnership with local governments to incorporate relevant dam EAP information into local disaster management community awareness and resilience programs.[63]

Sunwater provides residents with information and education around how dams work. This program has evolved over several years, following different weather events. The focus is to provide communities with information about how dams work, what can be expected of a dam during a major event, and what a dam can, and cannot, do.

As part of Sunwater's community education program, a survey was undertaken by ReachTel in 2017 to help inform the development of the program and associated resources. A high-level overview of this is contained in Sunwater's 'Be Rain Ready' Final Report. Sunwater has taken learnings from this report, gathered feedback at its dam open days, as well as from council workshops in 2018, to assist in improving its community education resources and early warning messaging. Sunwater's community education resources - 'Be Rain Ready' and most recently the 'dam savvy' education program and digital Council toolkits - have also been made available and promoted to the downstream community more broadly. Sunwater has also partnered with local councils and emergency service groups on a range of dam open days and 'Get Ready' events designed to raise awareness and knowledge about how dams work and to prepare for and keep informed during storm season. Sunwater's website "Stay informed" section includes information on the Sunwater App, as well as catchment maps and links to the Bureau and Council websites.

As part of its annual cyclone season preparedness program Sunwater undertake community engagement with residents downstream of Paradise Dam to inform and test communication systems and deliver community education messages. As part of this process the Bundaberg LDMG and Bundaberg DDMG have consistently been involved in the development of communications arrangements between Sunwater, LDMGs and downstream residents.

Those residents immediately downstream of the dam receive targeted attention. They include in North Burnett four residences and one packing shed on an orchard. NBRC staff have committed to work with those four residences and the orchard owner to ensure they understand the risks associated with Paradise Dam and to develop individual disaster plans for flood and possible dam failure scenarios. These plans will include:

- flood mapping
- evacuation triggers and timings
- evacuation route options (including air rescue, as a last resort)
- evacuation shelter options
- communication strategies.

Under Sunwater's EAP for Paradise Dam, residents located immediately downstream are personally contacted to educate them on the EAP, flood level triggers, evacuation triggers, timings and locations, and Emergency Siren alert meanings. As at December 2019, BRC, Sunwater and NBRC are developing a community education flyer and intend to conduct biannual dam failure drills for both residents and primary producers in this zone. The flyer will include emergency messaging methods (including audible siren) and recommended emergency actions. For primary producers, this community education flyer will form part of an employee's induction package. To support BRC in this education and preparedness activity, NBRC have committed to engaging with those residents and primary producers who reside within Bundaberg council area but are located close to North Burnett. NBRC has engaged with the one orchard owner located downstream from Paradise Dam. Further engagement will involve the development of an individual disaster plan for a major flood and failure of Paradise Dam, which will form part of their business continuity plan.

Each year BRC, in collaboration with representatives from their LDMG, undertake a broad community education and preparedness program to engage with persons across its area. BRC do this before summer to better prepare its community for the cyclone/storm season. Newsletters, social media posts and commercial media messages are key methods utilised for this program. BRC have undertaken annual Get Ready community engagement and education opportunities at local events. For example, OceanFest (Storm Tide preparedness), Day for Daniel (emergency kit planning), Neighbourhood Centre "Get Ready" presentation, Givelda evacuation route public meeting and primary school disaster preparedness curriculum activities. Additionally, as part of its Burnett Catchment Resilience Strategy, BRC have directly engaged with aged care facilities within its area to improve their business continuity.

The Burnett River Flood Plain Action Plan (preliminary version) was developed by the BRC in 2014, after the 2013 floods, and is currently available online through the BRC website. This Plan provides the community with detailed flood maps for the whole of the Bundaberg LG area, including high resolution mapping of the 2013 floods with colour coded water level heights, and details of four major evacuation route upgrades in Bundaberg City.

BRC flood gauge mapping was made public in December 2013 to better inform the community about their flood risk. This flood modelling was made public through the BRC

website providing individuals with a platform that enables them to model the flooding on their specific locations. This mapping includes building footprints, local infrastructure (i.e. roads, bridges, sewerage, stormwater and water networks), temporary local planning instruments and imagery from previous flood events.

The review team observed the BRC to have developed extensive flood modelling maps. However, there was some concerns raised with the review team that little mapping existed for areas outside of Bundaberg City. It was also suggested simpler flood maps could help the general community understand their level of threat from flooding and a dam failure.

This report has already shown that BRC are very well placed to identify and map those communities further downstream on the Burnett River that are most vulnerable to major flooding. This has resulted from the high-quality flood mapping and evacuation tools developed by BRC since 2013.

Presentation to groups form a further part of Bundaberg's public engagement work. Audiences include aged-care facilities, retirement villages and nursing homes, tourist operators via Tourism Queensland, backpacker hostels, business forums and networking groups. Display presentations are also conducted at expos and shopping centres. Disaster management material is also distributed through the Chamber of Commerce network and in languages other than English. In the case of an evacuation, the Bundaberg LDMG Communications Team will work closely with the Evacuation Centre Managers to provide daily briefings and manual information displays.

NBRC, in collaboration with other LDMG agencies, regularly undertake activities to educate and inform its community about disaster preparedness. In the lead up to the cyclone/storm season each year NBRC undertake an increased community education program to prepare the community for this season. Newsletters, social media posts and commercial media messages are key methods utilised for this program.

To help the community better understand the works planned for the Paradise Dam Improvement Project, community drop-in centres were held by Sunwater in September and October 2019. Sunwater also established a dedicated phone number and email to respond to public queries. Additionally, Sunwater have utilised its public website to provide community information around Paradise Dam. This has included the release of Community Updates. These public engagement activities by Sunwater, cover the Bundaberg and North Burnett areas.

The Paradise Dam Community Reference Group was established by Sunwater in late October 2019 to support Sunwater in its role of implementing the Paradise Dam Essential Works and Dam Improvement Program. It supports the associated communication to, and consultation with, the broader communities and stakeholders with an interest in Paradise Dam, and provides insight into a diverse range of perspectives on community safety and water security. Discussions with this Community Reference Group have included ideas for improving future community education programs and practises relating to Paradise Dam.

The review team heard one idea that 3D graphical models of riverine flooding and also of a failure of Paradise Dam would help the community better understand how these events affect their properties and businesses. The review team observed that the NBRC Dashboard currently provides interactive flood mapping for its three main flood prone townships (i.e. Gayndah, Mundubbera and Monto), with these online maps depicting various flood levels. The dashboard also provides flood mapping for the 2013 (1:200) flood event. This flood mapping enables individuals to identify flooding for their specific locations in these three

townships. Opportunities exist for further public engagement and promotion around these online maps, which may assist in addressing some of these community requests.

Councils and Sunwater are committed to engaging with businesses and primary producers downstream from Paradise Dam commencing November/December 2019 to better educate and prepare them for a major flood and/or dam failure. This engagement includes the development of individual disaster plans for those businesses and primary producers to be impacted early by a Paradise Dam failure. As already outlined in this report, NBRC have committed to engaging with those downstream primary producers who reside within the Bundaberg area but are located close to North Burnett area.

The above programs and practices demonstrate that Sunwater undertakes a level of community education for Paradise Dam, and other dams it operates in Queensland. However, this process does not appear to have allayed community concerns around the perceived lack of information being provided publicly about the problems associated with Paradise Dam. The following section on Community readiness shows this, and that there is a need for more information.

Communications systems

The Bundaberg LDMP Sub-Plan B (*Communications Plan*) outlines the various methods utilised to communicate disaster-related education and information to the community. These include:

- social media, and emergent media opportunities
- brochures and pamphlets in all services centres
- TV and radio including commercial media
- BRC e-mail system
- the Emergency Alert SMS message system (when approved)
- letterbox drops and door knocking in key strategic areas
- the Wireless Institute Civil Emergency Network (WICEN).

To this list North Burnett adds, in its subplan, methods suited to its size and decentralisation. They include community notice boards and networking through community organisations. These communication strategies should enable these community members to be well informed and well placed to prepare for and respond to a flood and/or dam failure event.

Under the Bundaberg LDMP Sub-Plan B, community messaging for disaster events will be managed by BRC's Communications Team, a member of which will also undertake the role of Public Information Officer within the Local Disaster Coordination Centre. All available modes of communication will be utilised to ensure maximum saturation of messaging is achieved from the typical media streams through to community meetings and face-to-face individual engagement. The review team heard from community members that commercial media in particular, plays a vital role in getting community messages and warnings out to the community in disasters. Local radio played an important role in getting community messages and warnings out in the 2013 floods.

In addition to the communication modes included in their sub-plans, both BRC and NBRC have implemented their own Emergency Management Dashboards. These are utilised to display announcements and warnings for disaster events occurring in the respective local government area. Both dashboards are promoted as the local points-of-truth for disaster messaging to communities, with messaging being shared across support agencies. Both councils have also linked the Sunwater website to their dashboards. For BRC the dashboard

system is cloud hosted to provide additional redundancy. As NBRC's dashboard is a newly developed tool, it is yet to be formally included in the *Public Information and Warnings* sub plan. NBRC are committed to undertaking this action as part of its review of this sub plan.

Bundaberg LDMG has also established the 'Wardens' program within its respective small communities that frequently become isolated in floods. This program has identified individuals (i.e. Wardens) residing in these communities who become the conduit of information between the community and the LDMG in the times of disasters. Wardens are equipped with either fixed or portable radio communications as a redundancy. NBRC are currently in the process of establishing their wardens and has already sourced radio equipment for them. Further enhancement of their skills through the Australian Institute for Disaster Resilience Volunteer Leadership program [64] might be worth consideration.

Sunwater has revised its communication processes to ensure earlier and additional notifications to subscribers and promotes its emergency notification service annually. Residents living within 15 kilometres downstream of a Sunwater dam have the opportunity to register for Sunwater's Emergency Notification Service. If a resident's property is outside the notification zone, residents can still access operational and emergency updates by downloading the Sunwater app or through Sunwater social media channels.

Sunwater's early warning guideline includes messaging triggers when Paradise Dam is near full capacity, if forecast rainfall over the dam catchment indicates a spill is possible and when the dam starts spilling water to ensure residents have sufficient time to take necessary action. For Paradise Dam, these have been revised, updated and tested in December 2019.

Sunwater has developed a multi-channel, common warning strategy, utilising feedback from Councils. It includes common language and consistent messaging, for downstream residents. This involves improved communication tools using SMS messaging, the Sunwater mobile app, social media, radio alerts and emergency alert messaging. The review team found Sunwater's website also includes information on the Sunwater app, as well as catchment maps, current dam heights, and links to the Bureau and Council websites.

The free Sunwater app (released in 2015 and upgraded in 2018 and 2019) was developed as an additional communication tool to provide timely and accurate notifications of potential dam outflows and emergency notifications when Sunwater dams are spilling water and during extreme weather events.

Sunwater is also committed to ensuring communities downstream from Paradise Dam are provided with sufficient and understandable information for those people to be able to make informed decisions in the event of a spill from the dam. Sunwater seeks to complement Council messaging through the use of social media channels to share information posted by the LDMG during an emergency event. The aim is to ensure messaging reaches as broad an audience within the community as possible; to support them in making informed decisions in the event of a spill from a dam. As an additional communication mode, Sunwater has now installed an audible speaking siren at Paradise Dam.

As is the case with many other areas of Queensland, the Bundaberg disaster district suffers from communication system disruptions during disaster events. This creates information-sharing problems between stakeholders and disaster management groups, that has the potential to reduce response levels in a disaster.

In addressing this issue, the Bundaberg DDMG conducted exercise Cow Bell in 2014. This exercise included a test of the communications infrastructure. One key recommendation

identified the need to improve radio communications networks across the disaster district. As a consequence, DDMG and LDMG member agencies undertook actions to enhance their own internal communications capabilities and redundancies (e.g. satellite phones and Digital Radio Network). Other redundancy communication options utilised by members and advisors of local and district disaster management groups include UHF and VHF radio communications with key community representatives in isolated areas. The disaster management groups have also identified and successfully field-tested the capability of the local voluntary WICEN to provide an additional communications redundancy for the disaster district.[65]

Telstra and Optus have provided the Bundaberg DDMG with an outline of their communications redundancy measures around riverine flooding, such as battery backup times, generator sites and alternate towers. As part of these redundancy measures Telstra have plans that enable the deployment of 'Cells on Wheels' (COWs) within the Bundaberg disaster district. This includes the rapid deployment of COWs by air or road.

Finding
Many emergency communications channels for community readiness purposes exist across the Bundaberg Disaster District. Plans for their use have been tested.

Finding
Strong emergency communication infrastructure exists across the Bundaberg Disaster District.

Warnings

In risks to the community that involve a failure of the Paradise Dam an agreement has been reached for Sunwater to provide initial community messaging using a single polygon from the Paradise Dam wall to the mouth of the Burnett River. This covers residences in both Bundaberg and North Burnett regional councils. This collaborative approach saw Sunwater assume responsibility for issuing Emergency Alerts for dam failure, rather than adopting the traditional approach of warning for a specified number of kilometres downstream from the dam. The preformatted Emergency Alert and an associated messaging polygon were developed in collaboration between Sunwater, BRC, NBRC, QFES and DDMG and uploaded to the SDCC via the disaster management portal. It was tested on both 20 November 2019 and 3 December 2019. Other community messages, and siren triggers are developed collaboratively by Sunwater and both regional councils. This process encourages uniformity in messages and timings of messages, alerts and warnings.

Under this arrangement with Sunwater the Bundaberg LDMG have the responsibility of providing any additional community warnings (including Emergency Alerts as an option) for the affected area. This approach streamlines the warning process for all residents downstream of the dam, provides consistency in messaging, and avoids the potential for confusion and duplication with the initiating emergency warning. With the recent risk change for Paradise Dam, BRC are considering pre-formatted additional warnings for inclusion in the operational plan for a Paradise Dam failure.

With respect to flooding for the Burnett River, the Bundaberg LDMG develop their Emergency Alerts and associated polygons based on intelligence gathered for individual events. This intelligence includes Bureau forecasts, river heights and flood mapping quickly developed utilising real-time data from river gauges downstream from Paradise Dam (e.g. Walla Weir) and other tools.

Finding
Additional Emergency Alerts and associated polygons do not exist for a failure of Paradise Dam.

Recommendation
To ensure enhanced capability integration and enable timely community messaging Bundaberg LDMG in consultation with Sunwater develop additional Emergency Alerts and associated polygons for a Paradise Dam failure and load these on to the disaster management portal.

Sunwater's Emergency Notification Service provides notifications and warnings about its dams to registered downstream residents. This can also be accessed through the Sunwater app or through Sunwater's social media channels. Downstream residents are informed regularly by Sunwater as an emergency event unfolds. The initial communication will generally be 24 to 48 hours before an outflow where Sunwater has enough Bureau forecast rainfall information to confirm that there will be an outflow from the dam. At each trigger of the EAP, a downstream notification action is taken to send updated information to residents affected. Sunwater can also pre-emptively activate triggers in the EAP. If forecast modelling shows an outflow will occur, Sunwater will activate the appropriate trigger.

The review team found that residents living in the immediate vicinity of Paradise Dam receive messages from Sunwater about water being released from the dam or when it goes over the wall. However, not all of these residents received the Sunwater messages during the 2013 flood event. Telecommunication infrastructure damaged during the 2013 event may have contributed to this outcome. Nevertheless, this issue was overcome by Sunwater staff based at Paradise Dam being very proactive and personally informing and checking on the welfare of nearby residents, and substantial process changes have been made since 2013.

The audible speaking siren now at Paradise Dam is designed to alert residents in the immediate vicinity of the dam about a dam failure. The activation of this siren would be accompanied with a radio broadcast and/or an Emergency Alert text message. Sunwater advised that although only silent testing of the sirens had been undertaken to date, they have committed to distributing factsheets about the siren by the end of 2019 and undertaking a full test of the siren in collaboration with the two regional councils. This test would be undertaken as soon as individual disaster plans had been developed with the residents immediately downstream from the dam.

Finding
The audible warning siren at Paradise Dam may assist in delivering emergency warnings to residents immediately downstream.

Recommendation
To enable the community to make informed choices about disaster management, Bundaberg and North Burnett regional councils and Sunwater undertake a community-informed audible test of the Paradise Dam siren.

Emergency Alerts and audible sirens are not the only tools used by Sunwater to communicate warnings and messages in a disaster event. It utilises multiple communication methods to enhance its capability to deliver public warnings and messages. These include the Sunwater mobile app, social media, radio alerts and other SMS messages. Sunwater are also mindful of the need to ensure consistent messaging is used and collaborate with the LDMGs and DDMG to ensure this occurs.

As covered in the Public engagement section, for those residents immediately downstream from the dam, this review identified the critical need for them to evacuate well before the emergency siren had been activated to ensure their safety and lives. This is due to poor mobile phone reception in the area to receive messages/alerts and evacuation routes being compromised early by rising flood waters.

To provide greater safety for residents immediately downstream, the operational plans being developed by the LDMGs and DDMG, will focus on ensuring these residents have safely evacuated well before any forecast dam failure occurs and before evacuation routes are blocked by flood waters.

The sections above outline various methods used by both councils to communicate disaster warnings to the local community. They include the use of the council dashboards. These mediums enable ongoing connectivity with the community through a disaster event.

Warnings communicated throughout the BRC are developed by the Bundaberg LDMG, based on information obtained from various reliable data sources, such as:

- Bureau of Meteorology forecasts and warnings
- Sunwater data (e.g. dam water heights)
- SDCC Situational Awareness Platform, intelligence products and QERMF mapping tools
- river and rain gauge network via the Bureau and *Enviromon*
- intelligence from North Burnett Regional Council (e.g. rainfall and river heights in the Burnett River upper catchment)
- subject matter experts (e.g. Bundaberg LDMG members and advisors).

The review team heard from community members that both the LDMGs and DDMG are good at delivering messages and community warnings. As one member stated,

> *Disaster management leaders are freely available to speak to commercial media and put community messages out. The thing is for people to leave earlier due to messages and warnings. The LDMG and DDMG do that very well*.

The review team also heard from members of the community that the use of multiple information and warnings mediums helps inform about disasters. Door knocks, radio messages, text messages, social media, apps and the possible installation of a siren for high risk flood areas were mentioned in this context. Receiving information direct from local emergency management personnel (e.g. police) was also a very helpful practice.

During this review the team heard that throughout the 2013 flood event in Bundaberg disaster messaging was well managed, with good information being provided by local disaster management agencies. The 2013 event has educated the public of the importance of listening to warnings and messages. The Bundaberg Chamber of Commerce identified that, as a result of the emotional effects on many community members from the 2013 event it is important in any future events to make people aware of floods without making them afraid. Having effective but responsible community messaging is therefore crucial. Early, regular and reliable advice is also very important. Social media can be very effective in this regard, but it needs to be well managed.

Community readiness

This section addresses the sixth point of the terms of reference, about how communications are received in the community and the readiness of the community.

For this review the review team looked at the level of community readiness in accordance with the Standard. The Standard's outcomes for public engagement set expectations for community readiness: [66]

- Communities are empowered through timely public information and through education initiatives to prepare for, respond to, and recover from disasters
- Public engagement outcomes have a positive effect on the action taken by the community across all phases of disaster management.

The action that communities should take to be ready is further developed in the 'Get Ready Queensland' program. Its website's headline topics include 'finding your council', 'alerts and warnings', 'understand your risk' and 'get prepared'. This section looks at two of these: Understanding of risk and community preparedness.

The review has already covered the councils' and other authorities' efforts to provide information on these topics. To gauge the success of these and wider take-up of preparedness actions, the review team commissioned a telephone survey of downstream residents, attended the Sunwater Community Reference Group and conducted informal interviews with representative community members and groups.

Understanding of risk

According to the Standard, hazard identification and risk assessment are fundamental to effective disaster management and forms the basis for disaster management planning and programs. Hazard identification and risk assessments should be iterative and regularly reviewed to ensure planning is based on up-to-date accurate data. Risk assessments should use plain language explanations, be readily accessible and communicated to communities to which they relate.[67] The community impact of floods affected by dams, including dam-break floods, can be greatly reduced if communities have recognised the risk beforehand.[68]

This review sought to understand the extent to which the community understands the increased risk of a dam failure. This risk is based on the extent to which dams influence floods. All dams on waterways impose a range of permanent effects on the natural stream flows and typically change the peak, timing and duration of floods. At one end of the spectrum are those structures (such as dams with uncontrolled spillways) that have minimal capability to modify flows. In these cases, the flow modifications are typically a lessening of the flood peak accompanied by a lengthening of flood duration (see Figure 3a). This effect can vary considerably depending on catchment size, dam storage capacity, rainfall intensity and the dam storage level at the onset of a flood.[69]

Dams may also have the potential to fail and the subsequent dam-break floods can cause substantial damage downstream. The effect of dam failure on flood flows is illustrated in Figure 3b. Dam-failure floods involving a risk to life are rare events, but failure usually causes extremely rapid rises in downstream flood levels and often these rises occur with little or no effective warning especially if the population at risk is close to the dam.[70]

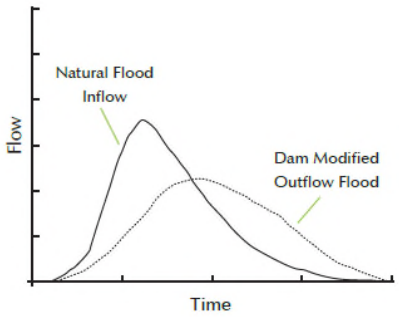


Figure 3a

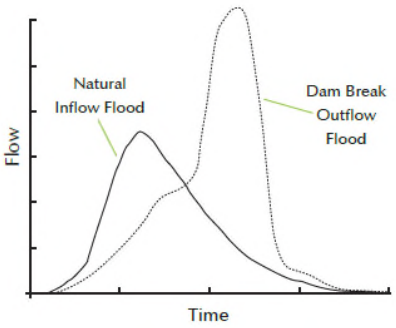


Figure 3b

During the initial phase of this review the review team engaged with community representatives to gauge the community's understanding of any issues or concerns held about Paradise Dam and downstream riverine flooding. For the Bundaberg region and its substantial primary production industry, the weather – rather than the dam - was a constant topic of conversation. Between 2013 and 2015 it was the centre of conversation due to the 2013 floods. However, since 2015 the review team heard that community discussions around flooding have diminished. The current drought helped to change the community conversation from the concerns of future floods to the need for good rain.

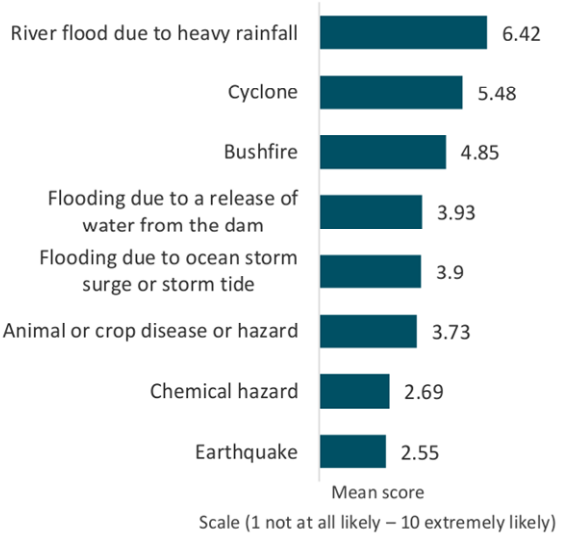
The recent and unexpected release of water from Paradise Dam is a new community conversation, especially given the drought. The review team heard that water security and its financial effect for primary production was the key focus of the conversations for Paradise Dam in the Bundaberg region. Most North Burnett residents were concerned with water security and the financial costs associated with it (i.e. agricultural farming). Only a few residents immediately downstream of the dam were concerned about community safety.

The review team heard that those residents living just downstream of Paradise Dam have a good understanding of their susceptibility to major riverine flooding risk, having been exposed to it in 2010 and 2013. Residents' understanding of a dam failure risk was not as strong. Dwellings immediately downstream were safe in the 2013 event (e.g. the first downstream dwelling was safe by about 5 metres). However, this is not guaranteed for a dam failure event. The need to rapidly evacuate to higher ground, should one occur, is understood.

The telephone survey asked questions about top-of-mind perceived risks. Respondents were asked to describe in their own words the disaster events or hazards they believe are most likely to impact their community. Flooding was by far the most commonly mentioned disaster risk (83%). After this, cyclones were identified as a likely event by 34% of respondents. Other risks were nominated by fewer than one in five respondents, the most common being bushfire (19%), fire (13%) or storms (7%). 3% nominated tornados while 2% mentioned risks associated with the dam wall or a water release from the dam.

Respondents were also asked to rate the likelihood of a range of disaster events occurring in their community in a range between 'not at all likely' (1) and 'extremely likely' (10). The disaster perceived as being most likely to occur was river flooding due to heavy rainfall, which received an average likelihood rating of 6.42. The perceived likelihood of other

disaster events occurring are detailed in the chart. Flooding due to release from water from the dam was rated 3.93.



The review team notes that it is not possible for substantial amounts of water to be released from Paradise Dam as it is not a gated dam. However, the rating of 3.93 does indicate community perceptions about the relative risk of flooding from the dam.

Finding
Flooding due to water coming from a dam does not feature as a significant risk in the minds of those surveyed.

This relative lower rating of the risk of flood due to release of water from the dam contrasts with other themes heard during the review. Throughout this review the review team repeatedly heard that many residents strongly suspected there was a problem with the dam but did not fully understand what this problem was. In addition, residents strongly expressed the view that they did not fully understand why there was a problem and why the water was suddenly being released from the dam.

Some residents sought more open communication, as information about the issues with Paradise Dam had not been fully provided to the community.

Finding
Due to a lack of information the community do not fully understand the risk from Paradise Dam and the reasons for it.

Recommendation
To enable the community to make informed choices about disaster management, and act on them, a joint Sunwater/council community engagement program be conducted to prepare the community downstream from Paradise Dam for the 2019/2020 storm and cyclone season, including the possibility of a Paradise Dam failure.

These community concerns reinforce the value of all agencies providing regular and reliable public information. Get Ready Queensland's website page 'Understand your risk', makes the connection with risk and preparedness.

> *It's only when you understand your risk that you are able to take the necessary steps to reduce the impact of a natural disaster on your wellbeing, home, family, finances and business*.[71]

Providing communities with a proper understanding of the risks associated with Paradise Dam gives residents the opportunity and time to prepare and respond to disaster events, and contributes to greater community confidence. The opportunity for conveying the changing risk was covered earlier in the section on Paradise Dam safety and operational and management arrangements. Councils were previously unable to review or mitigate the increased risks associated with the dam as they were not aware of the change to the risk level in 2015. It would appear that this may only have become apparent after September 2019.

The importance of reporting changes of risk to stakeholders and the community is already addressed in the dam safety section of this report with a recommendation provided around this issue.

Sunwater, in particular, would benefit from developing and delivering a sustainable long-term communication strategy, that informs the community of the issues connected with Paradise Dam and ensures they are aware of the community safety risks associated with the dam as they change over time.

Recommendation
To enable the community to make informed choices about disaster management, and act on them, Sunwater develop and deliver a sustainable long-term communication strategy on the community safety issues and risk profile connected with Paradise Dam. This is to be:

- *undertaken in collaboration with local and district disaster management groups; and*
- *continued until the risk profile of the dam is in accordance with Queensland guidelines for dam safety*
- *evaluated for its effectiveness.*

Community preparedness

To ensure public comment was captured for the review, MCR, an established market research firm was engaged to undertake a telephone survey of 300 people aged 18 years and over living downstream of Paradise Dam.

The telephone survey was undertaken across late October and early November 2019, and used a quantitative approach to measure community awareness and understanding of local disaster risks, arrangements and preparedness. It was also used to measure community confidence levels around disasters. The survey largely covered people living in parts of the Bundaberg LGA, namely Bundaberg City, Burnett Heads, Moore Beach, Branyan, Sharon, Gooburrum, South Bingera, Pine Creek, Bungadoo, Oakwood, Delan, Givelda, Electra, Booyal, South Kolan, Maroondan, Rubyanna and Wallaville. It also included the small community of Coringa within the North Burnett area. For further information on the Survey refer to Appendix J.

The survey identified that 89% of respondents were confident in their understanding of the local disaster risk to themselves and their property. It further identified that most respondents (82%) had experienced a disaster in the community where they currently reside, with 66% of respondents surveyed indicating that they had experienced a river flood due to heavy rainfall. However, a lower percentage (15%) had experienced flooding due to the release of dam water. Those respondents who were not confident in their understanding of the local disaster risk to themselves and their property indicated their reasons for this were:

- not having enough information about local risks
- being unaware of the risks
- feeling unable/unaware on how to prepare appropriately.

A combination of confidence and experience suggests that the community downstream of Paradise Dam should be generally prepared for disasters, but lacks knowledge about the specifics of floods resulting from release of water from a dam.

The MCR telephone survey also provided information about the preparedness of the community. The survey report identified that for those residents surveyed:

- 93% were confident they were prepared for and could respond to a disaster
- 64% had prepared (either in part or full) an emergency kit.

This level of preparedness action was mirrored in other behaviours. Of all the disaster preparation behaviours tested, respondents were most likely to report having prepared (either in part or in full) an emergency kit for responding to a local disaster event (64%). Around one in two reported having prepared the following:

- an evacuation plan (56%)
- a household emergency plan (54%)
- a plan for what to do with family pets or other animals in an evacuation (48%)
- an evacuation kit (46%).

The review team did not find a directly comparable baseline or standard against which to benchmark these results. The closest is a *Queensland Regional Household Survey* (QRHS), conducted in 2012, which included measures for household disaster preparedness and resilience. Although this household survey didn't specially categorise results for Bundaberg and North Burnett areas, it did provide results for Wide Bay residents (which includes these two areas). The whole area has a similar demographic and geographic character, and is often is affected by the same events. The results provided in the household survey identified that for Wide Bay residents in 2012.

- 82.8% believed they were prepared or very prepared for a natural disaster.
- 27.8% had items stored as an emergency kit.

While a direct comparison of these two surveys is not possible, the indications are that, since 2012, that has been a generally increased level of disaster preparedness.

The telephone survey results about warnings and disaster advice were, again, broadly encouraging. Most respondents (72%) indicated that they would know where to access accurate and reliable information during a disaster situation. 19% said they would not know where to access disaster information, while 9% were unsure. Four in ten respondents (44%) reported that they have registered to receive at least one emergency information or alert system. 25% of all respondents have registered to receive emergency information or alerts from the Bureau of Meteorology, 17% from other weather apps or forecasters, 13% from utility providers and 12% from their insurance company.

The Dashboard on BRC website is promoted as the online location to access locally-based disaster information during an event: a local point of truth for Bundaberg. Extensive community engagement has been undertaken by BRC throughout its Lower Burnett Floodplain Risk Management Study and ongoing promotion of the Dashboard and interactive flood mapping tools. BRC told the review team that this had increased the community's awareness of flood mapping tools. However, results of the MCR telephone survey identified that while 56% of residents would go to council website for more information about a disaster, only 10% of respondents would be most likely to go there. Only 6% would be most likely to go to a local council Facebook page.

Findings from the MCR telephone survey suggest that people do receive information. It indicated that 87% of respondents were confident they would receive adequate information or warnings about a potential local disaster event and 72% would know where to get disaster advice. These results indicate there is an opportunity for BRC to continue to publicly promote its Dashboard as a priority source of community information in a disaster.

In 2019 BRC has separately conducted its own survey at local events, to assist Bundaberg in determining the level of community readiness of residents within its area. From this BRC based survey it was identified that:

- 28% of respondents would go to Council for information in a disaster, with the radio, TV and Internet coming in close behind
- cleaning up around the yard / house and tying down loose items was the main preparation activity
- having an evacuation plan was not a high preparatory activity
- Bundaberg is susceptible to cyclones
- "If it's flooded forget it" was very well known
- only 28% of respondents knew the SES contact telephone number.

From the perspective of this review, the results of this BRC based survey suggests additional education is required in the promotion of individual/family evacuation plans, the BRC Dashboard as a local point of truth, and the SES contact telephone number. These surveys are regarded as good practice, and would be worth repeating following any joint community engagement program.

Local emergency managers within BRC have partnered up with local non-government organisations to better deliver community readiness outcomes. These local non-government organisations include Uniting Care, Lifeline, Australian Red Cross and the Salvation Army. As an example, Lifeline supported the delivery of flood mapping information to vulnerable people. The effect of this partnership also resulted in a 20-fold increase in the use of the BRC interactive flood mapping in the lead-up to significant rain events.

The review team heard from informal interviews, stories that supported the increased readiness shown in the telephone survey results. Interviewees told the review team that the evacuation of people in Bundaberg from roofs would not be required again as the community has learnt from the 2013 floods and would now take more notice of evacuation warnings and messages. From the informal interviews the review team identified two important perspectives relating to community preparedness in the Bundaberg area.

The first perspective is that those residents affected by the 2013 disasters and still residing in the Bundaberg area are generally better prepared for and more resilient to flood events. As one community representative stated to the review team,

> *They learnt a lot from the 2013 event. TC Marcia in 2015 certainly showed people were prepared, as they stocked up well in preparation*.

TC Marcia in 2015 also demonstrated that schools and businesses were prepared. The review team heard that schools closed, and community messaging went out in a timely manner. Some businesses used Facebook and text messaging to tell clients about their business closing in preparation for the cyclone. This mirrored what the schools and other agencies and businesses did.

The second perspective is that those residents not affected by the 2013 floods or arrived in the Bundaberg area post the 2013 floods are generally less concerned about and less prepared for a flood event.

These two perspectives also apply to businesses and primary producers in the Bundaberg area. From a resilience perspective, Bundaberg businesses, in general, have improved readiness since 2013. The review team heard that some now use cloud-based data storage.

This allows them to recover or relocate very quickly and re-establish their businesses. The Hinkler Shopping Centre was flooded in 2013 but now has a greater level of business resilience due to flood mitigation measures undertaken. One business had learnt from the 2010 flood event in Bundaberg and ensured in the 2013 event they had enough stock. This business was able to supply other local businesses that didn't have enough supplies.

The telephone survey did not cover business resilience but the comments across informal community interviews indicates that the events of 2013 and others have led to improved disaster recovery capabilities of businesses in Bundaberg, especially those who were flood affected in 2013.

One sector that seemed less prepared is the tourist or temporary visitor sector. There is a casual population of up to 8,000 backpackers in Bundaberg in winter, with around 2,000 to 4,000 out on farms working each day. Most of these are from overseas and do not have English as their first language. The review team heard there is currently limited interest in Paradise Dam by the tourist sector. An informal '4 out of 10' score was provided for the current level of tourist and backpacker preparedness for a flood event. However, during recent disaster events the review team was also advised that two daily briefings were provided by Tourism and Events Queensland to inform disaster management groups. This information was then shared with other tourism related stakeholders to better inform them of matters relating to backpackers and other visitors to Queensland.

The review team acknowledges that BRC has engaged with tourist operators via Tourism Queensland and with backpacker hostels and distributed disaster management material in languages other than English.

When it comes to communicating with, and warning, backpackers about disaster events there is a level of shared responsibility. Backpackers have a level of self-responsibility to be informed and prepared. However, others, such as contractors, farmers, hostel owners, local councils and tourism-related stakeholders also have a responsibility. The review team heard there is no common structure in place for coordinating advice to backpackers. This requires further consideration. One respondent expected it would improve in 2020 with additional effort being undertaken in that area by the tourism sector. A 'Crisis Ready' app is being developed to increase community visitor readiness for disasters.

Finding
Information about increased risk from the Paradise Dam has not effectively reached the casual/itinerant worker and tourism sector.

Recommendation
To enable the casual/itinerant worker and tourism sector, including those who do not have English as a first language, to make informed choices about disaster management, community engagement and communication strategies about Paradise Dam and floods in the Burnett river system be tailored to this sector.

Engaging and educating a community about its disaster risks helps the community to be properly prepared and ready to respond to disasters. Due to the nature of the risk for Paradise Dam, both short term and long-term planning for community readiness is needed. This will require disaster management stakeholders to use a comprehensive communication strategy to engage with the community. This communication strategy should be developed in a cooperative and co-delivered manner. Some elements should be delivered immediately; others should endure for a sustained period. As some community members are still

emotionally recovering from past disaster events and may become distressed by any warnings, the communication strategy will require sensitivity in its delivery to those affected.

Lessons management

This section addresses the ninth point of the terms of reference, about awareness and adoption of lessons learnt from other events.

Appendices C and D provide further detail.

According to the Standard, lessons management promotes continuous improvement across all levels of disaster management.

Local Disaster Management

North Burnett

Lessons process and activities from the 2013 event

From the 2013 floods North Burnett identified a number of key lessons from which they applied learnings. The majority of these learnings have already been detailed in this report, including:

- constructing a dedicated LDCC at Gayndah
- establishing an independent digital radio network to improve communication redundancies between disaster management groups
- installing additional river and rainfall gauges across the Burnett catchment area to provide enhanced forecasting and flood modelling (further details provided in the Bundaberg learnings)
- employing a part-time Disaster Management Officer within NBRC
- pre-deployment of the Satellite DDCC to Gayndah
- completely overhauling the North Burnett LDMP (including extensive community consultation).

Other learnings from 2013 not yet outlined in this report are:

Flood Marker Project: To better educate the North Burnett community in understanding how a flood event could impact the community NBRC has initiated a Flood Marker Project. This project will see flood markers in key locations around the Gayndah and Mundubbera townships which indicate the flood level in their street, relevant to the forecast location. This will assist residents to understand where the water will come to in their street and provide them with the tools to make informed decisions, thereby increasing their resilience.

Grab and Go Kits: The creation of LDMG support group Grab and Go kits was undertaken. These kits contain paperwork, stationery, maps, etc. to enable the set-up of Support Group disaster coordination centres.

Evacuation Centre Kits: Communities within North Burnett area are often isolated in floods. Deployment of locally based Australian Red Cross staff and resources to its six evacuation centres is therefore hindered. NBRC created Evacuation Centre Kits for rapid deployment of staff and resources.

Biggenden Evacuation Centre Upgrade: The township of Biggenden is more susceptible to stranded motorists than any other town in the North Burnett area. Accordingly, additional toilet shower facilities and an upgrade to the kitchen has ensured the Biggenden Memorial hall is better suited as an evacuation centre.

Many of these learnings were tested during TC Marcia (2015) and found to be highly beneficial.

Lessons identified and learned from events after 2013

To improve increased information sharing and situational awareness in an event between the North Burnett LDMG and Bundaberg LDMG arrangements are being canvassed to embed a staff member in the Bundaberg LDCC for future events (e.g. exchange of flood information and mapping).

The following learnings were gained from Cyclone Marcia (2015) and Cyclone Debbie (2017):

- school closures – linked to the *Dashboard* for better community messaging
- video messaging – installing multi-media capability in the LDCC to enable event specific video messaging (e.g. message from the council Mayor)
- Bureau of Meteorology flood classifications – need for greater clarity around the Bureau's flood terminology to better inform the community (still in progress)
- road information - road closures linked to the *Dashboard* to better inform the community
- LDCC roles and responsibilities – establishing easy to understand LDCC roles and responsibilities sheets for staff to follow
- improved mapping – provisioning more in-depth maps into the LDCC that detail flood plains, gauge locations, sub-basins, etc.

Bundaberg

Lessons process and activities from the 2013 event

For BRC a learning from the 2013 disaster event was that they did not possess a granular understanding of what flood classifications on the Burnett River height gauge at Bundaberg City centre (Targo Street) meant to the city of Bundaberg (i.e. unaware of the spatial footprint and the exposure of people and the built environment to flooding based on this river height gauge).

The development of the BRC interactive flood mapping since 2013, provides more granular detail of the Burnett River flood plain downstream of Paradise Dam. This enables residents to plan their own evacuation in a way that hasn't been achievable in the past.

Additionally, BRC's calibrated hydraulic flood model (developed in 2013) utilises data from five historical flood events (i.e. 1942, 1971, 2010, 2011 and 2013). When compared with actual survey data and aerial data, BRC now has a high level of confidence in action triggers that have been nominated (e.g. evacuation triggers).

As outlined earlier in this report, following the 2013 Burnett River flood event BRC undertook a flood risk management study known as the Burnett River Floodplain Action Plan. The plan was developed between August 2013 and June 2014 and was underpinned by a comprehensive two-year flood modelling and mapping study of the Burnett River between Paradise Dam and the river mouth at Burnett Heads. The development of this plan included

a significant community consultation process, with important information being provided by a local Community Reference Group and Technical Reports.

The purpose of the Plan was to:

- provide council with an understanding of the nature and degree of flood risk across the lower Burnett river floodplain
- assess a range of floodplain risk management measures that could be implemented to reduce flood risks and increase community resilience to flooding
- provide flood risk information to inform land-use planning decisions and emergency management activities.

The Burnett River Flood Plain Action Plan led to BRC applying for substantial joint State and Commonwealth funding under the NDRRA program for flood mitigation projects. This ultimately led to BRC undertaking four key projects. These projects have been previously outlined in the Preparedness and Planning section of this report.

In addition, the BRC has completed a further 15 betterment projects between 2013 and 2015, utilising the NDRRA funding. These include:

- Bundaberg Multiplex and emergency power (evacuation centre)
- Branyan Drive culvert upgrade (flood evacuation route)
- Wallaville-Goondoon Road upgrade (flood evacuation route)
- Kendalls Flat Weir (infrastructure protection)
- Millbank Waste Water Treatment Plant development (infrastructure protection).

Not all members of the community are aware of these mitigation projects. Community engagement by the review team heard from one community leader that no flood mitigation measures had been put implemented in Bundaberg since 2013, other than flood warnings.

The dependence on a flood warning network for the Burnett Catchment to provide real time data to support decision making by the Bundaberg LDMG highlighted a need to ensure that it is maintained to the highest standard. In response the BRC now conduct its own annual maintenance program for the flood warning network on the Lower Burnett. As already outlined in this report, about 60 additional rainfall gauges and river height gauges have been installed across the Burnett Catchment. BRC also work in partnership with NBRC to assist with maintenance of those gauges located in the Upper Burnett. The delivery of accurate and reliable data from the flood warning network for the Burnett Catchment data supports the:

- identification of flood and rainfall gauges
- warnings system significantly upgraded
- wardens network
- repeaters for radio communications.

The flood warning network (and associated mapping system) has undergone three major revisions, the most recent being to provide redundancy in an emergency event. This system has become fundamental for both community preparedness and providing residents with decision-making tools to ensure their safety during flood events. The system is cloud-hosted to ensure that it remains fully operational in a catastrophic event. The capacity of the system can be rapidly amplified to manage increased demand.

This system was the first of its kind for a local council in the southern hemisphere designed as a public education tool to improve community resilience to extreme flooding, and developed in partnership with Uniting Care Community (UCC). Immediately post 2013, UCC provided training on this tool to 300 trauma-impacted residents, with the system being more widely released in December 2013 to reduce flood-induced anxiety within the community.

Lessons identified and learned from events after 2013

Since 2013 Bundaberg has not been adversely affected by disaster events, however agencies from the Bundaberg LDMG continue to apply lessons learned from the 2013 event, as well as other events outside its boundaries.

District Disaster Management

Bundaberg

Lessons process and activities from the 2013 event

A full and in-depth post disaster assessment review was undertaken by the DDMG after the 2013 tornados and extreme floods. Opportunities for enhancement were identified in this review, with actions implemented to address these. An examination by the review team of the Post Disaster Assessment Report for Ex TC Oswald indicated that all recommendations for action at local and district levels had been completed.

Due to the complexities around many of these recommendations, considerable time has been required since 2013 to address them to a satisfactory level (e.g. telecommunications option in the North Burnett).

Lessons identified and learned after the 2013 event

Like the 2013 event, a full and in-depth post disaster assessment review was undertaken after the 2015 floods associated with TC Marcia. Enhancement opportunities were identified in this review and detailed in the Post Disaster Assessment Report for TC Maria. The review team identified that the recommendations for action at local and district levels were completed. These included:

- including the earlier pre-deployment of the Satellite DDCC into the DDMP to provide improved support to the North Burnett LDCC
- DIEMS training provided to DDMG members before storm season to improve situational awareness and information sharing across agencies
- examination of satellite TV channel Imparja's Cyclone Warnings protocols
- DTMR and DoE DDMG representatives incorporate learnings from TC Marcia into procedures in relation to the assessment / closure of schools and buses routes.

Most recently, in 2019 Exercise Tahliye was conducted by the Bundaberg DDMG. This exercise simulated a storm tide event requiring a large-scale evacuation. It explored the capacity and roles and responsibilities of agencies to respond and support evacuation management during a disaster event. Exercise recommendations included:

- DDMG and LDMG members be continually reminded of the importance of their agency's attendance at exercises
- Executive Officer, DDMG provide training and more awareness to DDMG and LDMG members about the SDCC Situational Awareness Platform
- agency roles and responsibilities as outlined in the State Plan to be reinforced to agency members during scheduled DDMG and LDMG meetings

- Bundaberg LDMG conduct a field exercise involving the setup of the Multiplex as a functioning evacuation centre
- evacuation management continue to be a focus of local and district group exercises, to strengthen local and district capability.

Lessons identified and learned from previous dam events

A literature review of past events identified 20 lessons drawn from 22 overseas case studies from the US and the UK. Current guidance about dams and ongoing safety activities for the Paradise Dam demonstrate that they are already learned in Queensland, or being learned. Those with accountabilities for dams are either aware of their implications or are adopting actions to mitigate them. The review team identified a further 21 recommendations regarding dams from South Australia, Victoria and Queensland. Sixteen of these were from the 2012 Queensland Flood Commission of Inquiry. Some recommendations are specific, relating to particular dams - some with gates and do not apply to Paradise Dam.

Lessons are often drawn from recommendations that emerge from events. Such lessons and recommendations are shown at Appendices C and D. The review has not done an in-depth analysis of progress on the recommendations identified in other reviews. This will form part of another piece of work in respect to monitoring and evaluating the effectiveness of lessons and progress on recommendations previously delivered. The obvious point that emerges from this report on the Paradise Dam is that the recommendations here should be evaluated by all entities that own dams for their value and relevance to their individual circumstances. Only if this happens as a matter of course embraced by all entities will the intent of a lessons management program have been achieved.

Recommendation

To enable entities in the sector to proactively work to achieve better results for the community, the recommendations and lessons of this review should be evaluated through the lessons management processes of entities involved in dam safety for their value and relevance.

Future thinking

This section addresses the tenth point of the terms of reference, about other matters considered necessary.

This review report is delivered in December 2019. Options to address the long-term safety of Paradise Dam are still being studied, and are the focus of Building Queensland's detailed business case; some are predicted to continue for a further six years. The review terms of reference cover preparedness for a future flood event affecting the Paradise Dam in the Burnett River system. There are four matters outside the scope of recommendations that are worth consideration in that context.

The first is to monitor the implementation of ongoing actions. Stakeholders have identified a number of measures in preparation for a potential dam failure. Many of these have been captured by Sunwater on behalf of the disaster management system at a workshop on 11 November 2019 and at an exercise on 3 December 2019 conducted by Sunwater. It is not possible at this stage to provide assurance that all intentions have been acted on, or had the desired consequences. The intentions should be monitored for progress and completion.

The second is to focus on long term community preparedness. The telephone survey conducted for the purpose of this review shows a relatively higher level of preparedness compared with an earlier survey in the area. A community engagement campaign is planned, based on emerging risk information and preparedness messages. Ongoing monitoring may be needed to evaluate the success of this strategy over the next five years to establish whether the community remains aware of the risk and any changes associated with any future works.

The third applies more broadly to other referable dams across Queensland. If lessons are to be learned from this experience, a forward-looking program is needed to ensure lessons are captured and shared, and then applied as relevant to all referable dams across the State.

The fourth is to extend thinking to those aspects of disaster management outside the scope of this review. This review is focussed on response preparedness. But there are lessons in other aspects of the Prevention, Preparedness, Response, Recovery spectrum arising from the economic costs of a dam failure. The impact of drought and climate adaptation will see further interest and involvement by stakeholders around dam management. The review has not examined any of the impacts in the area of recovery. Importantly, and a feature of previous Office reviews is the need to ensure information is transferred effectively outside the time of crisis. Sunwater appears to have undertaken a lot of work to better understand risk (e.g. Paleo Study, New Flood Model, New Rainfall model, Life modelling). This work has not been readily visible to other stakeholders. Some of the information arising from this work may have better informed the LDMGs and councils in their planning. Councils' data may have also added value to some of this work. Stakeholders should look for opportunities to contribute to each other's modelling work. The review team has seen the potential value to both parties in a business-as-usual context.

Conclusion

Changed risk information about the Paradise Dam emerged in September 2019. Since then, there has been much effort by many to ensure that arrangements are in place so that the community downstream of the Paradise Dam will be as safe as it can be, if the dam were to fail.

If the dam fails, arrangements are in place to respond to this. However, the successful application of them is based on a number of influencing factors, for example time of day and the vagaries of circumstance. There is still ongoing work to be done; updating and exercising of plans, and community engagement need to be ongoing. Risk revision and flood modelling information must continue to be shared with stakeholders as it emerges. The implications of this information must be understood and acted on as necessary.

This report does not detail all the initiatives and works that have recently emerged. It will be up to those individuals and agencies themselves to determine their importance and ensure their completion against the range of business-as-usual priorities. This is in line with the Office's proposed Lessons Management Framework, which will ensure lessons identified are learnt.

Justice Byrne's Commission of Inquiry into Paradise Dam is due to report in April 2020. The terms of reference include the root cause of structural and stability issues, among other matters. It is important that the findings and recommendations of this IGEM review are revisited once his report is complete.

Recommendation

This report be returned to the Inspector-General Emergency Management to monitor, evaluate and report on progress and implementation of the recommendation(s) that are accepted in whole or in part by government.

Appendix A: Review terms of reference

REVIEW TERMS OF REFERENCE

Paradise Dam Preparedness Review

Purpose

Section 16C of the *Disaster Management Act 2003* provides the Inspector-General Emergency Management with functions including:

- to regularly review and assess the effectiveness of disaster management by the State, including the State disaster management plan and its implementation;
- to review, assess and report on performance by entities responsible for disaster management in the State against the disaster management standards;
- to report to, and advise, the Minister about issues relating to the functions above
- to make all necessary inquiries to fulfil the functions above.

In accordance with these functions, the Office of the Inspector-General Emergency Management will review and provide recommendations to guide preparedness for a future significant flood event affecting Paradise Dam in the Burnett river system. The review will cover:

- Implementation of advice provided in *Paradise Dam Flood Event of January to March 2013 Review of Dam Safety Management Action Report for the Office of Water Regulation* conducted by NSW Department of Public Works.
- Current information on the dam's safety and a timeline of the steps taken to obtain and verify this information.
- The adequacy of Sunwater's forecasting and prediction initiatives;
- Dam operations and management arrangements in place to prepare for the cyclone season
- Local Disaster Management Group readiness;
- Community readiness;
- Communications between disaster stakeholders and more broadly with community stakeholders;
- Effectiveness of response preparedness; and
- Awareness and adoption of lessons learnt from other events.
- Such other matters as the Inspector-General Emergency Management considers necessary.

Approach

The Office will consult with Sunwater (the dam owner), Queensland Fire and Emergency Services and other relevant entities and State agencies to inform the findings of the review.

Reporting

The review report will be based on relevant Shared Responsibilities of the Standard for Disaster Management in Queensland.

The review report will be provided to the Minister for Fire and Emergency Services. Before finalising the review report, the Office will consult with relevant entities on draft findings and recommendations.

Appendix B: Government agencies and local governments consulted

Commonwealth Agencies
Bureau of Meteorology
State Agency
Department of Aboriginal and Torres Strait Islander Partnerships
Department of Agriculture and Fisheries
Department of Communities, Disability Services and Seniors
Department of Education
Department of Environment and Science
Department of Housing and Public Works
Department of Local Government, Racing and Multicultural Affairs
Department of Natural Resources, Mines and Energy
Department of State Development, Manufacturing, Infrastructure and Planning
Department of the Premier and Cabinet
Department of Transport and Main Roads
Public Safety Business Agency
Queensland Ambulance Service
Queensland Fire and Emergency Services
Queensland Corrective Services
Queensland Health
Queensland Police Service
Queensland Reconstruction Authority
Queensland Treasury
Disaster Districts
Bundaberg Disaster District
Local Government Authorities
Bundaberg Regional Council
North Burnett Regional Council
Government Owned Corporations
Sunwater Limited
Other Agencies
Australian Red Cross

Appendix C: Lessons learnt from other events

Lessons identified - the Association of Dam Safety Officials; Arup

	Lesson	IGEM Comment Awareness and adoption
1.	All dams need an operable means of drawing down the reservoir	Paradise dam has this in an environmental control gate.
2.	Concrete gravity dams should be evaluated to accommodate full uplift	Considered in assessments of Paradise Dam stability. • The GHD memo (Dam Stability analysis 5 Sep 19) uses 50% uplift reduction as the best estimate but notes consideration has been given to uplift values as high as 60%. • The TRP (Report No2 23 September 2019) suggests that 80% may be appropriate for projecting to unusual and extreme reservoir levels.
3.	Dam incidents and failures can be fundamentally attributed to human factors	Under investigation
4.	Dam owners, engineers and regulators need to address public safety at dams	Ongoing
5.	Dams located in seismic areas should be evaluated for liquefaction, cracking, potential fault offsets, deformations, and settlement due to seismic loading	EAP contains the risk of earthquake, however the ICOLD has published research that shows no large dams have failed due to earthquake shaking. https://www.waterpowermagazine.com/features/featuredam-safety-and-earthquakes
6.	Dams should be thoroughly assessed for risk using a periodic risk review process including a site inspection, review of original design/construction/ performance, and analysis of potential failure modes and consequences of failure. The completed review supports a case for taking risk-informed actions at individual dams and for prioritizing actions for an inventory of dams.	Adopted by Sunwater
7.	Earth and rockfill embankment dams must be stable under the full range of anticipated loading conditions.	Not applicable to Paradise Dam
8.	Emergency Action Plans can save lives and must be updated, understood, and practiced regularly to be effective.	Ongoing
9.	Hazardous hydraulic conditions, such as hydraulic rollers, can occur at dams of all sizes.	Sunwater website covers Safety tips for visiting a dam or weir. Practice in the North America indicated good signage at and near dam facilities is critical.

10.	High and significant hazard dams should be designed to pass an appropriate design flood. Dams constructed prior to the availability of extreme rainfall data should be assessed to make sure they have adequate spillway capacity.	Apparent through the GHD reports submitted to IGEM. Addressed in relevant guidelines.
11.	Intervention can stop or minimize consequences of a dam failure. Warning signs should not be ignored.	Paradise Dam is fitted with warning technology and those in charge were aware of its importance.
12.	Many earth-cut spillways have been constructed in erodible material that can result in unsatisfactory performance and breaching of the spillway. The integrity of all earth-cut auxiliary spillways should be evaluated to ensure that the design storm can be safely passed.	Not applicable to Paradise Dam
13.	Regular operation, maintenance, and inspection of dams is important to the early detection and prevention of dam failure.	Ongoing
14.	Seepage along penetrations through embankment dams should be controlled using a filter diaphragm instead of anti-seep collars.	Technical advice: not applicable to Paradise Dam
15.	Site security is a critical aspect of dam safety that shouldn't be overlooked or disregarded.	Apparently in place through the review teams visits to Paradise Dam
16.	Stability of the dam foundation and other geologic features must be considered during dam design.	Ongoing consideration
17.	The first filling of a reservoir should be planned, controlled, and monitored.	Detailed guidance given in Queensland dam safety guidelines (DNRME, Feb 2002):
18.	The hazard classification of a dam can change over time (hazard creep).	Ongoing
19.	Uncontrolled vegetation on and around dams can hinder inspection and lead to serious structural damage, significant maintenance costs, and possible failure.	None apparent at Paradise dam
20.	Masonry blocks plucked out due to turbulence. Overtopping of the spillway walls. Lessons learnt: Spillway designs to ensure sufficient capacity so flows are discharged safely away from the dam	Apparently relevant and ongoing in work to address Paradise Dam construction issues.

Appendix D: Relevant recommendations

Recommendations from previous IGEM Office reviews

Report	Recommendation	Rec. No.
2015 Callide Creek Flood Review	Banana Shire Council investigate means to prioritise the commissioning of a fit-for-purpose flood study for high-risk areas across the Banana Shire to better inform flood risk management, including improved town planning. The outcomes of such a study should be available to the public and inform flood awareness campaigns, flood warnings, and building approvals.	Recommendation 2
	Banana Shire Council coordinates the development of a strategy to significantly enhance public education regarding local disaster management arrangements within the Banana Shire, focusing on key identified risks.	Recommendation 3
	SunWater provide downstream residents with easily understood information regarding operation of the dam, and the impacts that various outflows may have for them, in accordance with mapping prepared for the Emergency Action Plan. This information should be complementary to any information from the Banana Shire Council.	Recommendation 4
	The Department of Energy and Water Supply, in conjunction with SunWater, seek clarification of the dam owners' legal obligation to comply with Emergency Action Plans and, if required, investigate how a more flexible approach may be adopted.	Recommendation 5
	In accordance with recommendations of the BMT WBM report, the Banana Shire Council, SunWater, and the Bureau of Meteorology, under the stewardship of the Department of Natural Resources and Mines, jointly identify the requirements for a suitable gauge network for the Callide Valley to allow meaningful and timely flood warnings. The review should identify key stakeholders, examine potential funding sources and include a cost benefit analysis.	Recommendation 6
	Prior to September 2015, the Banana Shire Council develops a multi-channel warning strategy and associated public information campaign, including common language and consistent messaging, for the Banana Shire.	Recommendation 7
	Prior to September 2015, SunWater and the Banana Shire Council jointly develop a multi-channel, common warning strategy, including common language and consistent messaging, for residents downstream of SunWater assets within the Banana Shire Council, and clearly articulate procedures for dissemination	Recommendation 8
	As part of the above, both the Banana Shire Council and SunWater ensure Emergency Alert messages are pre-formatted, consistent, polygons are identified according to risk, and that they are tested and practiced with the State Disaster Coordination Centre.	Recommendation 9
	Local Disaster Coordination Centre capability and capacity should be reviewed to ensure adequate staffing arrangements are in place to fill key positions, and that operational protocols are known and practiced across all functions to provide redundancy. Assistance for review and necessary training	Recommendation 10

	should be sought from key Local Disaster Management Group member agencies.	
	The evacuation sub-plan component of the Local Disaster Management Plan should be reviewed, including any identified triggers for activation. Ideally, the plan should be tested in a live, multi-agency exercise prior to next summer	Recommendation 12
	State Disaster Coordination Centre considers requesting a representative from critical infrastructure owners be present as a liaison officer in the State Disaster Coordination Centre during activations for events that may impact on their assets.	Recommendation 13
Review of Seqwater and SunWater Warnings Communications Report 1: 2015-16	Seqwater and SunWater focus immediate attention and action on issues of collaboration with local disaster management groups, addressing information sharing, messaging responsibilities, terminology and timing. Actions should be implemented immediately.	Recommendation 1
	A committee be established, chaired by the Department of the Premier and Cabinet, reporting to the Queensland Disaster Management Committee. This committee will provide implementation of strategic dam safety and disaster management policy and coordinate the work program across the agencies and relevant entities.	Recommendation 2
	Review the Water Supply (Safety and Reliability) Act 2008 and the Emergency Action Planning for Referable Dams guideline to enhance effective communication.	Recommendation 3
	In accord with the outcomes of Recommendation 3, the Emergency Action Planning for Referable Dams guideline and the Queensland Local Disaster Management Guidelines are aligned to require dam operators, councils and local disaster management groups to collaborate in planning, and their plans reflect: • agreed warning and notification systems • the testing and exercising of agreed warning and notification systems.	Recommendation 4
	Responsibilities of all referable dam owners under the Water Supply (Safety and Reliability) Act 2008 are clearly articulated in the State Disaster Management Plan. The district and local disaster management guidelines are updated to include responsibilities for all referable dam owners and operators, councils and disaster management groups for notifying and warning the public; and require referable dam owners to be advisors to local disaster management groups where there are referable dams. We note the considerable variance in the capability of referable dam owners and this should be taken into consideration when developing plans.	Recommendation 5
	Any dam safety policy and strategies developed to improve warnings and notifications are regularly evaluated to assure effectiveness, in line with community expectations.	Recommendation 6
	Emergency Alert messages for dam related events are: • pre-formatted, consistent and current polygons are identified • content aligned with the Queensland Emergency Alert Guidelines • stored and practised in consultation with the State Disaster Coordination Centre.	Recommendation 7

	Seqwater and SunWater (and other referable dam owners where relevant) proactively engage with relevant local governments to develop and implement a community education and information program for identified communities at risk of dam release scenarios where the downstream flooding can be directly related to dam outflow.	Recommendation 8
Comment: Sunwater has provided responses that explain how they have addressed relevant recommendations. In their submissions, and through discussions with councils, and examination of related work, the Office is satisfied that the recommendations above have been addressed or are being addressed as part of the current planning.		
The Cyclone Debbie Review 2017-18	Relevant authorities should work with the tourism sector to clarify future arrangements for evacuation. In particular they should look closely at differentiating voluntary and directed evacuations in their messaging, ensure the differences are explained to the community in pre-season campaigns, and that necessary information is passed on to tourists.	Recommendation 8b
	Principles, applicable to all tourist budgets, covering liabilities for costs and shelter in the event of evacuation should be developed and promulgated as part of tourism marketing.	Recommendation 8c
	Intelligence: A strategy should be developed to improve the availability of information to decision-makers and other audiences. Information should be searchable, more specific, timely, and allow stakeholders to find what they want.	Recommendation 10
	Intelligence: Significant effort should be invested to provide disaster decision-makers at every level with a shared understanding of risks, the situation, and capability, so that they can agree the best decisions for the communities they serve.	Recommendation 11
Comment: The Office notes the progress made since the TC Debbie review to share information more widely across the sector. The findings from this review reinforce the recommendations from the Cyclone Debbie review and indicate that the sharing of modelled predictions should continue to be given priority.		

Other recommendations related to dams

State	Year	Inquiry Type	Disaster	Recommendation
VIC	2011	Independent	Flood	the state require dam owners and operators provide regular situational reports to the relevant control agency where dam issues may impact incident management.
VIC	2011	Independent	Flood	the state require that dam owners and operators inform the control agency and the Bureau of Meteorology about the management and operation of dams and weirs consistent with the flood warning requirements of the relevant river systems, including providing telemetry at sites as necessary. This may require the state proactively liaising with other states to ensure equivalent obligations are placed on interstate dam operators where the dam may impact Victorian communities.
VIC	2011	Independent	Flood	the state require that dam owners and operators inform people situated downstream of water storages if the owners/operators become aware of an immediate threat arising from the dam to the safety of those people. The

				owner/operators should provide this information as soon as the owner/operators become aware of the threat.
VIC	2011	Independent	Flood	the state require dam owners and operators to review storage operating manuals to incorporate lessons from the 2010-11 floods and make this information publicly available. The manuals should include a clear policy on dam surcharging and pre-release.
QLD	2012	Royal Commission	Flood	Toowoomba Regional Council and the Department of Environment and Resource Management should continue to co-operate to assess the referable dam status of existing detention basins and any future detention basins constructed in the West Creek and East Creek catchment areas.
QLD	2012	Royal Commission	Flood	As part of the longer term review of the Manual of Operational Procedures for Flood Mitigation at Wivenhoe Dam and Somerset Dam, the Queensland Government should consider the impact of possible upgrades of bridges downstream of Wivenhoe Dam on different operating strategies for the dam.
QLD	2012	Royal Commission	Flood	As part of the longer term review of the Manual of Operational Procedures for Flood Mitigation at Wivenhoe Dam and Somerset Dam the Queensland Government should consider whether the dam operators should be able to extend the drawdown of the lake beyond seven days in order to reduce downstream bank slumping
QLD	2012	Royal Commission	Flood	The Queensland Government and Commonwealth Government should ensure the existence and maintenance of a repository of data of the type used in flood studies. The database should include the types of data which the expert panel specified as needed for a comprehensive flood study. Councils, Queensland and Commonwealth Government agencies and dam operators should be able to deposit and obtain access to data.
QLD	2012	Royal Commission	Flood	The Queensland Government should consider whether North Pine Dam should be operated as a flood mitigation dam when it considers possible operating strategies and full supply levels as part of the longer term review of the Manual of Operational Procedures for Flood Mitigation at North Pine Dam.
QLD	2012	Royal Commission	Flood	Seqwater should, in creating the new Wivenhoe and North Pine flood mitigation manuals, comprehensively consider: • the amount of discretion that is able to be exercised by the flood engineers and the senior flood engineers, and the description of the circumstances in which such discretion may be exercised • the circumstances in which it might be appropriate to release water in advance of an impending flood on the basis of forecasts from the Bureau of Meteorology • if strategies of the form of strategy W2 and W3 in Revision 7 are included in the revised manual, or any strategy defined as a 'transition strategy', when and how those strategies should be implemented

				• if the concept of 'urban inundation' is relevant to the operation of the dam, how it should be defined, and if the definition involves diverse concepts, how those concepts can be related back to the strategies, so that flood engineers can reach a clear understanding of their objectives and primary considerations • if the concept of 'natural peak flow' is relevant, how it should be defined.
QLD	2012	Royal Commission	Flood	The Department of Environment and Resource Management should prioritise dam safety audits according to risk. The risk assessment should be informed by criteria including: • structure and materials used in construction • age of the dam • time since last inspection • occurrence of a flood event since last audit and the size of that flood event • population at risk if the dam were to fail • experience and capability of dam owner • dam owner compliance history • time since last audit.
QLD	2012	Royal Commission	Flood	The Queensland Government should legislate to oblige each owner of a referable dam to have an emergency action plan approved by the appropriate Queensland Government agency. Such plans should be reviewed periodically
QLD	2012	Royal Commission	Flood	Wide Bay Water should, in addition to its usual wet season preparations and maintenance, undertake the following activities in advance of each wet season: • conduct training for personnel on dam operation, including contingency plans for the situation in which one or more of the gates is inoperable • hold meetings of key personnel of Wide Bay Water involved in the operation of the dam during floods, which: • in addition to any other matters, inform staff about the current status of the gates, dam operation strategies and contingency plans for the situation in which one or more of the gates is inoperable • are recorded in minutes which document the information provided and are made available to all operational staff.
QLD	2012	Royal Commission	Flood	Seqwater should consider commissioning an investigation into the extent of cracking below the level of the upper gallery of Somerset Dam and the impact of any such cracking on the dam stability and, in turn, its operation.
QLD	2012	Royal Commission	Flood	The Department of Environment and Resource Management should prepare formal work procedures for the review of flood event reports created under emergency action plans and flood mitigation manuals. These should include procedures for: • making enquiries with the owners of referable dams that have catchments that have been subject to heavy rainfall (or where there is other reason to believe the emergency action plan has been

				triggered) as to whether the emergency action plans have been triggered • reminding owners of referable dams that have had emergency action plans triggered of their obligation to submit a flood event report • upon receipt of a flood event report, reviewing it, identifying any dam safety or other issues or areas where insufficient detail has been provided, raising those matters with the dam owner or other affected party and identifying appropriate remedial steps • raising any issues identified in the report that are beyond the expertise of the Department of Environment and Resource Management, or are likely to be of particular interest to another body, with the appropriate body • keeping a record of the process and results of the review of the flood event report • fixing an appropriate timeline for the completion of each of the above steps: the time required may depend on specific circumstances but must allow for any potential safety issues to be identified and remedied efficiently.
QLD	2012	Royal Commission	Flood	When commissioning a flood study, the body conducting the study should: • check whether others, such as surrounding councils which are not involved in the study, dam operators, the Department of Environment and Resource Management, and the Bureau of Meteorology, are doing work that may assist the flood study or whether any significant scientific developments are expected in the near future, and decide whether to delay the study • discuss the scope of work with the persons to perform the flood study as well as surrounding councils which are not involved in the study, dam operators, the Department of Environment and Resource Management, and the Bureau of Meteorology
QLD	2012	Royal Commission	Flood	The Queensland Government should ensure that all flood mitigation manuals include the requirement that those operating the dam during flood events hold current registrations as professional engineers.
QLD	2012	Royal Commission	Flood	The Queensland Government should ensure that, when it considers options for the operational strategies to be employed at Wivenhoe and Somerset dams, and North Pine Dam, it is presented with a wide range of options which prioritise differing objectives. The Queensland Government should determine the operational strategies by considering the implications of each option over a range of flood events for at least: • inundation of urban and rural areas • water supply security • dam safety • submerging of bridges • bank slumping and erosion

				• riparian fauna and flora.
QLD	2012	Royal Commission	Flood	The Department of Environment and Resource Management should conduct periodic dam safety information and education sessions with emergency management personnel including those from Emergency Management Queensland, local and district disaster management groups and local councils. Priority should be given to sessions if the Bureau of Meteorology forecasts a wet season with a greater than 50 per cent chance of above median rainfall.
QLD	2012	Royal Commission	Flood	Prior to each wet season, the Department of Environment and Resource Management should audit the compliance of each owner of a referable dam with the obligation to have an emergency action plan approved by the Queensland Government.
SA	2017	Independent	Storm	That the Flood Reform Task Group, as proposed by the Department of Environment, Water and Natural Resources, develop a business case for Cabinet, based on the dam safety discussion paper (Pisaniello & Tingey-Holyoak, 2016) which identifies options and a way forward to address dam safety in SA.

Appendix E: Sunwater's roles and responsibilities

Sunwater's roles and responsibilities from the Queensland State Disaster Management Plan.

Roles

- Monitor water, emergency events and incidents at local, district and state levels in collaboration with DNRME.
- Provide a liaison officer function to the SDCC to attend/provide information and advice on the impacts of bulk water supply and dam safety as they affect Queensland.
- Contribute to the DNRME situation reports for all levels during activation.
- Facilitate actions within, and across their Water networks in response to an emergency event or incident.
- Seqwater and SunWater manage their own emergency response arrangements and support is provided through the SDCC when required.

Responsibilities

- Operate their water supply infrastructure and dams according to emergency management protocols and relevant state legislation.
- Manage emergencies such that the safety of the public, employees and contractors and the minimisation of potential environmental harm and damage to assets is prioritised.
- Work with and provide timely and accurate information to State, District and Local disaster management groups where required to manage the consequences of a water supply or dam safety incident.
- Develops Emergency Action Plans (EAPs) for all of their referable dams as per legislative requirements.
- Provides notifications and warnings to population at risk immediately downstream of their referable dams as per actions contained within their approved EAPs.
- SunWater also provides dam releases notifications during emergencies or incidents through the free SunWater App to provide the community with up to date information on dam releases and other operational and community activities.
- Are actively responding to changing flood conditions and providing flood forecasts and advice directly to communities downstream of dams.
- SunWater operates an Operations Centre (Brisbane) to coordinate response to flood and dam emergencies for their storages. The Centre provides updated SITREPS when activated for the State, local government and emergency services. Senior Management and media team engagement is also available to the SDCC full stand up occasions.

SunWater operates their Operations Centre (Brisbane) to host its event operations team, network control and its incident and management teams. The centre provides updated SITREPS during emergencies and incidents for the State, local government and emergency services and will have senior management and media resources available to the SDCC as required.

Appendix F: Timeline

October 2003	Design and construction commenced by the Burnett Dam Alliance. One of the participants in the Alliance was Burnett Water Pty Ltd, the owner of the Dam. A trial embankment was built and tested during construction of the dam; this tested acceptable. Sunwater have subsequently advised normal practice would be to do this prior to construction so test results can influence design.
December 2005	Paradise Dam construction completed. Burnett Water Pty Ltd, became a wholly owned subsidiary of SunWater
16 December 2005	Sunwater became responsible for the ongoing management and operation of the dam.
January 2006	Core samples were taken from Monolith L by the Burnett Dam Alliance.[72] (Based on their enquiries made in late 2019, Sunwater advised they were unaware of the 2006 core testing until July 2019 when enquiries were made by Sunwater's design team with the original designer.)
December 2010 – April 2011	The dam experienced three major flood events.
	December 2010 flood – River Height - 7.95m @ Bundaberg – North Burnett - 26 houses damaged (Mundubbera & Gayndah) – Bundaberg - 190 houses damaged
	The peak in late 2010 (classified as a 1 in 30-year event) was almost 6 metres over the spillway. Sunwater advised that only limited damage was caused to the Dam and plans for repair works were made.
January 2011 flood	– River Height - 5.76m @ Bundaberg – North Burnett – zero houses damaged – Bundaberg - 4 houses damaged
March 2011	Life Safety Risk assessed at 0.00013 loss of life probability per year (the review team calculate these and others to a 1 loss of life probability equivalent. In this case it is 1 loss of life probability per 7,692 years 4 months).
2012	Paradise Dam was classified as only one of two Sunwater dams that completely satisfied the DNRME acceptable Capacity Guidelines.
January 2013	Highest ever recorded flooding for Bundaberg as a result of ex-Tropical Cyclone Oswald. Flood peak above crest of spillway - 8.65 metres. At the peak of the flood close to 5 times the dam's capacity was assessed as flowing over the spillway in one day.

	In total more than 20 times the dam's capacity was assessed as flowing over the spillway. – River Height – 9.5m @ Bundaberg – North Burnett – 300 houses damaged (Mundubbera & Gayndah) – Bundaberg - 2,200 houses damaged – (5,500 residents evacuated in North Bundaberg) Severe damage resulted.
March 2013	Emergency repairs commenced to enable the spillway apron to withstand a late 2013 season flood event. Works to mitigate any immediate path to failure including downstream scour holes, spillway apron and rock foundations. Commencement of Dam Safety Review (brought forward from 2025).
May 2013	The former Department of Energy and Water Supply engaged NSW Public Works to perform an independent review to examine the dam safety management actions taken prior to, during and after the 2013 flood event at Paradise Dam, and to determine what lessons could be drawn from the experience, especially with regard to any need to improve dam safety procedures.
June 2013	Paradise Dam Spillway Flood Damage 2013 Interim Design Report completed Commencement of "Paradise Dam Flood Event of January to March 2013 Review of Dam Safety Management Actions" commissioned by the former Department of Energy and Water Supply. Completion of emergency repairs to enable the spillway apron to withstand a late 2013 season flood event.
22 August 2013	The former Department of Energy and Water Supply review of "Paradise Dam Flood Event of January to March 2013 – Review of Dam Safety Management Actions" released.
October 2013	Comprehensive Dam Safety Inspection completed.
October 2014	Dam Safety Review completed, and findings submitted to the Dam Safety Regulator. This included early revised assessment of dam safety risks and potential failure modes post 2013 flood. Independent Technical Review by Sunwater's insurer commissioned. This concluded that "damage to the primary spillway following the 2013 flood would not be expected for a structure designed and constructed to modern design standards". The report also noted that there were "limited construction records to confirm exact details of issues."

	Commencement of Comprehensive Risk Assessment.
2 December 2014	Horizontal cored holes drilled in monoliths F and G.
15 December 2014	Independent inspection of cored holes.
30 December 2014	Cored holes inspection results reported to Sunwater.[73]
January 2015	Comprehensive Risk Assessment commissioned in October 2014 completed. This placed the dam above the Limit of Tolerability for failure due to the risk of downstream scouring undermining the integrity of the spillway structure, and other risks. This means the risks were unacceptable. The primary spillway (monolith K) did not meet dam stability requirements for a 0.05% chance of flood in any given year (or a 1 in 2 000-year event). The Comprehensive Risk Assessment identified structural and non-structural improvements to be considered and incorporated into Sunwater's Portfolio Risk Assessment. The 2015 Sunwater's Portfolio Risk Assessment included four stages of improvement. Stages 1&2 to commence 2015, Stage 3 to commence in 2023 and Stage 4 to commence in 2025.

Stage 1 Improvement Project – improved emergency response (non-structural measures), with literature review undertaken, and progressing to further emergency management improvements and Emergency Action Plan initiatives across Sunwater's portfolio (2015 to 2018)

Stage 2 Improvement Project – strengthening the base of primary spillway monoliths (D&K), completed August 2017

Stage 3 Improvement Project – proposed secondary spillway improvement works (subsequently merged with Stage 4, and comprising the current Paradise Dam Improvement Project)

Stage 4 Improvement Project – proposed primary spillway improvement works (subsequently merged with Stage 3, and comprising the current Paradise Dam Improvement Project).

Life Safety Risk revised to 0.031 loss of life probability per year, (1 loss of life probability per 32 years 3 months) being a significantly greater risk than the March 2011 value of 0.00013.

February 2015	Paradise Dam experienced a flood event that resulted in a peak of 2.58m above the spillway. Impacts were assessed, and no action was required
May 2015	Planning and design of Stage 2 Dam Improvement Project commenced. This was to address the most significant risks identified in the January 2015 Comprehensive Risk Assessment. Two core samples taken from the crest of the Left Abutment (Monolith C) and the Secondary Spillway (Monolith N).

November – December 2015	Results of samples drilled in May 2015 indicated poor quality lift joints with less than 10% of the joints encountered being bonded.
January 2016	Paradise Dam Numerical Study of Scour Potential Report – "*As a summary, the numerical estimates of future scour potential clearly show the need for remediation works on both the primary and secondary spillway."*
April 2016	Revised Dam Safety Review completed. This review confirmed the need for improvement works that were already underway to strengthen the base of primary spillway. The Revised Dam Safety Review identified that due to the scouring effects critical flood loads for the primary spillway were assessed between a 0.2% and 0.1% chance flood event happening in any one year (or between a 1 in 500 and 1 in 1000-year event). The Revised Dam Safety Review also identified limitations in test data for the roller compacted concrete shear strength parameters.
June 2016	Revised Comprehensive Risk Assessment completed with input from the April 2016 Revised Dam Safety Review. This identified similar risks to the Comprehensive Risk Assessment completed in 2015 with a slight increase in risk. It identified the potential failure of roller compacted concrete layers for an event larger than a 0.001% chance flood event happening in any one year (or a 1 in 10,000 events. However, the risk from scouring was still the highest risk. Life Safety Risk revised to 0.034 loss of life probability per year, (1 loss of life probability per 29 years 5 months) a similar risk to the January 2015 value of 0.031.
April 2017	Planning for next stages of Dam Improvement Project resulted in Stage 3 and 4, Dam Improvement Projects to be combined.
August 2017	Stage 2 Dam Improvement Project completed. This involved strengthening the base of primary spillway monoliths D & K by the addition of reinforced concrete protection and anchor bars.
December 2017	Sunwater commenced drafting of Preliminary Business Case for combined Stages 3 and 4 Dam Improvement Project.
January 2018	Sunwater commenced consultation with Building Queensland on options for draft Preliminary Business Case. Life Safety Risk revised to 0.094 loss of life probability per year (or 1 loss of life probability per 10 years 8 months), being a greater risk than the June 2016 value of 0.034.

June 2018	Preliminary Business Case completed for combined Stages 3 and 4, Dam Improvement Project. Preliminary Business Case options considered included the construction of a new dam downstream of the existing dam site, upgrading of existing Paradise Dam infrastructure, a reduction in capacity of the existing dam and decommissioning of the dam.
October 2018	Commencement of detailed review of the stability and shear strength of the dam and spillway to inform basis Detailed Business Case for combined Stages 3 and 4, Dam Improvement Project.
December 2018	Initial findings indicated an elevated risk due to a new failure mode from low shear strength of RCC lift joints. Pending further validation, studies and testing.
January 2019	State approved Building Qld to lead Paradise Dam Improvement Program, with target of a late 2020 completion date.
May - June 2019	6 x 61mm diameter vertical cores taken from the Secondary Spillway (Monoliths Q, S, V). 10 x 150mm diameter horizontal cores taken from the Secondary Spillway and Left Abutment (Monoliths B, C, N, P, Q, R, S, U)
July 2019	Paradise Dam Spillway Improvement Project Preliminary Design Report incorporated the results of samples taken in 2006.[74]
August – September 2019	Laboratory testing of core samples. Further reviews and geotechnical investigations undertaken. Independent Technical Review Panel workshop. Revised understanding of dam stability, increased risk of roller compacted concrete shear failure. Sunwater advised they commenced discussions with Government in early September 2019. Life Safety Risk revised to 0.195 loss of life probability per year (or 1 loss of life probability per 5 years 2 months), being a significantly greater risk than the January 2018 value of 0.094.
20 September 2019	Sunwater commenced lowering the level to 42% capacity.
25 September 2019	IGEM Review announced.
November 2019	TatroHinds Report confirms basis for earlier GHD assumptions for modelling, although is slightly more optimistic about lift bonding assessments.
29 November 2019	An independent inquiry will be held into Paradise Dam with Honourable John Harris Byrne AO RFC as Chairperson and Commissioner, and Emeritus Professor John Phillip

	Carter AM FAA FTSE FRSN FIEAust FAIB as Commissioner.

Appendix G: 2013 Review – Actions related to dam safety in general

Following are the actions that relate to dam safety from the "Paradise Dam Flood Event of January to March 2013 – Review of Dam Safety Management Actions" commissioned by the (former) Department of Energy and Water Supply, and undertaken by NSW Public Works in 2013.

Recommendation	Advice from Sunwater on Implementation	Independent Technical Expert engaged by IGEM comment on Implementation
First Term of Reference		
5. It is desirable that the Sunwater standards, notably DS13, be amended to better cover the spillways of dams including the energy dissipation zone. SOP 19 would benefit from inclusion of training on case studies of gravity dam failures and their causes and consequences, and on case studies of damages to gravity dam energy dissipators and of rock scour	DS13 was amended to Rev. 2 dated February 2014 and included techniques for inspecting dam spillways and inspecting dam energy dissipation zones (see HB#2487193). DS13 has subsequently been updated numerous times, with the current version being HB#2487044. Section 4.3 of this document includes techniques for Dam Spillway Inspections including the energy dissipation zone. In November 2013 the training course material was revised to incorporate case studies of gravity dam failures and their causes and consequences, and to include case studies of damage to gravity dam energy dissipators and of rock scour. Sunwater has been unable to locate the 2013 version of SOP19.	Sunwater have substantially amended their inspection Standard DS13 to comply with PWD's request to better cover spillway inspections as advised in Sunwater's response. Further additions to the current version (Jan 2019) could be made including: • Section 4.3-Replacing second set of dot points with "The operator must inspect the entire surface and walls of the spillway with the aid of binoculars or drones if necessary" and move dot points 4 to 6 to the relevant further subsections of the Standard; • Section 4.3.1-Add a line on looking for spillway training wall movements, misalignment; • Section 4.3.2-Add a line on looking for spillway wall movements, misalignment; • Section 4.3.3-Add a line on looking for gate damage, deterioration and excessive leakage. Add a line on looking for cavitation damage; • Section 4.3.4-Put "(i.e. cavitation damage)"after "..pitted areas"; • Section 4.3.5-In entrance channel section, include line on wall failure, movement, misalignment. In spillway discharge channel section, include line on malfunctioning drains I endorse Sunwater's last comment on having updated its training materials (i.e. SOP19) to include relevant case studies of gravity dam failures and damage to spillway dissipators, as I have been Sunwater's training course presenter for many years and I updated the course materials at their request to include relevant case studies after the 2011/13 Queensland floods and regularly update the materials as any new events occur.

Recommendation	Advice from Sunwater on Implementation	Independent Technical Expert engaged by IGEM comment on Implementation
6. It is desirable that Sunwater review its procedures for assessing the potential for rock scour at its dams, particularly those dams with high specific power discharges (peak power per metre length of spillway crest). If not already estimating rock scour should become part of the assessment procedure for those dams with high specific power discharges.	Whilst specific reviews of procedures cannot be verified, Sunwater does undertake assessments on a case by case basis. Sunwater undertook assessments for potential rock scour in relation to other dams where this was an identified risk, including dams with high specific power discharges. Procedures for assessing the potential for rock scour are determined on a site by site basis. For example, the October 2018 assessment of rock scour at Burdekin Falls Dam utilised two methods: the eGSI method and the Rock Mass	I am aware of, and have been involved in discussions of, the Burdekin Dam spillway scour study which was a “state of the art” extremely comprehensive study. I have also been involved in other Sunwater dam risk assessments in recent years where spillway capabilities were closely examined and, as such, can endorse, to a reasonable extent, that Sunwater determines on a site by site basis its needs for assessing the potential for rock scour at its dam spillways.
7. It is desirable that the potential for further rock scour at Paradise Dam is estimated carefully before the coming wet season and the work is reviewed by an independent peer reviewer recognized for knowledge of and experience in rock scour estimation methodologies. The peer reviewer should be involved from the outset so as to comment on the analysis scenarios and approach. The outcome of the work should include a “best estimate” result. As a minimum the work should cover a range of flood magnitudes and two configurations: • The configuration of the rock surface downstream of the dissipator as it will exist on completion of Phase 2 remedial works • The situation where the dissipator apron has been subsequently destroyed and removed by floodwaters.	A rock scour assessment using the Annandale method was undertaken prior to the 2014 wet season to assess the potential for further rock scour (see section 8.1 in HB#2487344). This assessment covered a range of flood magnitudes between 1.5 and 1:1,000 AEP and included a "best estimate" result. The work was peer reviewed, with the peer reviewer involved from mid-2013. After the 2014 wet season further work was undertaken to assess the potential for rock scour. A physical hydraulic model was constructed and tested in three configurations to provide calibration data for the Comprehensive Scour Model (CSM). Flows modelled between 1:200 and 1:10,000 AEP. This work was completed as part of the 2016 Dam Safety Review (DSR, Section 12.10.1.6). The scour potential is reported in “Final report Paradise Dam Scour Potential from Erik Bollaert 18 Jan 2016 (complete report and appendixes)”, HB#1991619. The main elements of the peer review are included in TRP report No.4 (HB#1856772), Section 8, principally “Section 8.2 Primary Spillway”. The peer reviewers also reported in TRP report No. 1 (HB#2125307), No. 2 (HB#1512226) and No. 3 (HB#1675033). The 2016 Dam Safety Review was also peer reviewed. The configurations examined included after the phase 2 remedial works and with the dissipator apron removed during a flood. The model provided a "best estimate" result. The assessment of potential for rock scour required a physical hydraulic model to be constructed to provide input data. This was unable to be undertaken prior to the 2014 wet season, but was subsequently completed as set out above.	Sunwater has adequately undertaken rock scour assessments of the spillway using appropriate investigators, reviewers and techniques pertinent to the time. Note that in recent years there have been improved guidelines for investigation, improved analysis techniques and further results of investigations and analysis which have tempered somewhat the 2013/14 results (see GHD July 2019 report).

Recommendation	Advice from Sunwater on Implementation	Independent Technical Expert engaged by IGEM comment on Implementation
8. It is desirable that the stability analysis of critical dam monoliths is refined before the coming wet season and the work is reviewed by two independent peer reviewers, one recognized for knowledge of and experience in gravity dam stability analysis and one a recognized specialist in rock mechanics (unless a suitable person highly skilled in both fields can be found). The peer reviewers should be involved from the outset so as to comment on the analysis scenarios and approach. The outcome of the work should include “best estimate” results as well as results of traditional standards-based analyses. At this stage it appears the analyses should give consideration to: • The selection of analysis methodology and safety criteria for gravity dam stability • The outcomes of the rock scour analyses under the preceding point • The latest knowledge of foundation geology • A further review of the stabilizing forces provided by tailwater • Any proposed reliance on passive anchors, including the consideration that the load capacity cannot be monitored in the long term.	A stability analysis of critical dam monoliths was undertaken prior to the 2014 wet season. This is reported in Final report - Paradise Dam Spillway Flood Damage 2013 Interim Design Report - June 2013 (HB#2487324), Sections 7.1 and 7.2. The main elements of the peer review are included in TRP report No. 4 (HB#1856772), principally “Section 9 Stability Analysis of the Dam’s Monoliths” and Appendix B “TRP's Letter of 30 December 2014 on assessment of RCC cording and core testing”. This analysis was updated as more data was obtained and in early 2016 was reported in "Stability Analysis for Paradise Dam – AECOM Report Rev 01 dated 13 April 2016" HB#1945933. The final stability analysis included a "best estimate" base case and a sensitivity case. Each of the five considerations identified in the advice were considered. The stability analysis was peer reviewed by three independent peer reviewers. These peer reviewers were involved from mid- 2013 and had extensive expertise in: • gravity dam's stability analysis; • geotechnics; and • spillway hydraulics. Core drilling and other geotechnical field work and analysis was required in order to complete the stability analysis. As a result, a further stability analysis was not completed until after the 2014 wet season.	Appropriate stability analyses were undertaken of the dam monoliths under the oversight of appropriate peer reviewers as recommended by PWD with this initial work completed in 2014 (the slight delay was caused by the need to obtain further site geomechanical information). As above, these works have been consolidated by further investigations and analyses

Recommendation	Advice from Sunwater on Implementation	Independent Technical Expert engaged by IGEM comment on Implementation
9. It is desirable that the risk assessments be updated when results from the preceding two work items are available. Consideration should be given to these aspects of the risk analyses: • In addition to the failure pathway in the interim design report there should be a parallel failure pathway involving destruction of the dissipator apron by abrasion and the energy of the overflow • An event tree branch for the probability of sliding, given deep scour to the dam toe, should be included • The results from the scour and stability analyses should inform the probability of deep scour and the probability of sliding • The reasoning underlying the selection of the risk analysis values needs to be fully documented.	By December 2013 a risk assessment workshop had been conducted. The results of this workshop were provided to the Technical Review Panel (TRP) and DSR for review. Feedback received validated the output of Sunwater's updated risk assessment. The feedback received was incorporated in the Jan 2015 CRA report (HB#2487773). Updated risk assessments were completed as part of the 2016 Comprehensive Risk Assessment and are reported in "Paradise Dam Phase 2 – CRA", HB#1961274. The updated risk assessment: • incorporated the results from the rock scour assessment and the stability analysis referred to above into the "best estimate" and sensitivity cases (Part 14); • identified and analysed all potential failure modes (Part 5), including as the result of destruction of the dissipator apron; • contained an event tree analysis (Parts 5.4 and 5.5),	The risk assessment for the dam have been progressively updated since 2013 with further investigations and analyses culminating in June 2016 CRA report and subsequently updated in the July 2019 Preliminary Design Report
10. It is desirable that the results of the updated risk assessment inform Sunwater's level of preparedness for the coming wet season and level of surveillance at the dam in the event of a flood. A precautionary approach should be taken having regard to these facts: • The analyses have wide uncertainty • It is not reasonably practicable to know exactly what is happening in the energy dissipation zone during a flood event • Public safety would potentially be at risk.	By December 2013, the results of the updated risk assessment had preparedness for the 2014 wet season and level of surveillance at the dam in the event of a flood. For example, as a result of the updated risk assessment, in December 2013 an Apron Slab Integrity Monitoring System was installed in eight of the 21 primary dissipator slabs ("Complete Report – Paradise Dam Primary Spillway Apron Capping Slab Phase 4A Design Report – December 2013" HB#1500335, Section 4.7). This system supported Sunwater's assessments and monitoring of dam failure. Sunwater's level of preparedness and level of surveillance was as per its standard procedures, as updated.	Sunwater reacted to PWD's report in an appropriate precautionary manner by using risk assessment results to update its procedures in targeting appropriate surveillance (i.e. new monitoring systems installed, and inspection procedures updated) and preparedness measures for coming flood seasons

Recommendation	Advice from Sunwater on Implementation	Independent Technical Expert engaged by IGEM comment on Implementation
11. The reservations of Sunwater's independent peer reviewers regarding the value of analyses before the coming wet season, as proposed in our preceding advices, need to be fully heard and carefully considered. Resolution of those reservations lies outside the scope of this review.	Sunwater's independent peer reviewers provided input to Technical Review Panel report No. 1 in October 2013 (HB#2125307) in relation to the value of the recommended analyses before the coming wet season.	The input of appropriate peer reviewers was sought and taken on board before the 2014 flood season as recommended by PWD
Second Term of Reference		
5. An opportunity for improvement of practices/procedures for any future events exists in the risk assessment process with regard to: • Documentation of the risk assessment, particularly as regards the description of failure mechanisms and the reasoning which underlies probability values; • Assigning "best estimate" risk values. If Sunwater sees reasons to take a precautionary approach, that should be done after the "best estimate" risk assessment results are available • Use of event trees primarily, but also fault trees if appropriate, to fully define failure mechanisms; and • Bolstering engineering judgment by science and world experience of dam performance to the maximum practicable extent	Sunwater has significantly improved its risk assessment process since the early 2000s when the flood risk related to Sunwater dams was revised and the ANCOLD guidelines were updated. At Paradise Dam, comprehensive risk assessments (***CRAs***) were completed in 2009 (HB# 890472), 2012 (HB#1275870), January 2015 (HB# 1685006) and June 2016 (HB# 1961274). The June 2016 CRA (HB#1961274) included: • description of failure mechanisms and reasoning underlying probability values (Part 5); • "best estimate" and sensitivity cases (Part 14); and • the use of event trees (Parts 5.4 and 5.5). The peer reviewed analyses which underpinned the updated risk assessments facilitated the incorporation of learnings from other events. Another example of Sunwater considering these issues across the portfolio of its dams is outlined within the Portfolio Risk Assessment (HB# 2219947). Sunwater's in-house experience from other events is also continually incorporated in risk assessment processes and to improve practices and procedures for future events. For example, revisions to the EAP have incorporated learnings from events such as Callide Valley in 2015.	As recommended by PWD, Sunwater has undertaken several risk assessments of Paradise Dam since the 2013 floods, as more investigation and research techniques material became available, each with an increasing level of depth and sophistication to match current best practice (see June 2016 CRA report and July 2019 Preliminary Design Report).

Recommendation	Advice from Sunwater on Implementation	Independent Technical Expert engaged by IGEM comment on Implementation
6. Given what is now known about the performance of the dam in floods, there would appear to be an opportunity of improving SOP 42, and possibly other guidance documents, with respect to: • Ensuring that a dam safety engineer makes a site inspection as a matter of urgency after a report of damage which is potentially a dam safety incident as defined by the regulator. • Specifying that "time to notify" under DS 2 of the development permit conditions runs from the date of the engineer's inspection provided the damage is confirmed as a "dam safety incident" • Specifying who is responsible for initiating notification of the regulator and seeing that it is made within the required time of seven days.	Sunwater's records indicate that SOP42 was updated by September 2013 in response to this recommendation. However, Sunwater has been unable to locate the 2013 versions of SOP42.	Sunwater have incorporated PWD's recommendations to set out responsibilities for the prompt inspection and reporting of dam safety incidents. However, the PWD recommendation to inform the regulator of a dam safety incident within seven days does not appear in current versions of SOP42.

Recommendation	Advice from Sunwater on Implementation	Independent Technical Expert engaged by IGEM comment on Implementation
Fifth Term of Reference		
1. It is desirable that the feasibility of improvements at the dam, and to other infrastructure, be investigated as part of the Phase 3 work. These are improvements which may assist dam safety management generally and which may reduce the time required for any future remediation in particular. Some key matters to be examined are: • Increasing the flow capacity of culverts on the normal southern access road to the dam to reduce the likelihood of wash-outs. • Improvements to the right bank access at the dam that would avoid destruction of the access in every large flood. • Improvements that could provide early access to the left bank at the dam for a) Inspecting personnel and b) heavy equipment needed for remediation work. • Subject to the outcome of the preceding point, provision of safe access down the left bank to the left end of the dissipator apron. • Measures to prevent ingress of gravel or other debris to the environmental flow gate chamber. • Measures to safeguard the hydraulic rams that are designed to open the environmental flow gates. • Measures to better protect the electric power system used to operate release facilities and to reduce the time required for repair in the event power is lot in floods. • Improvements which would allow a greater release discharge without disrupting any potential future remediation work in the energy dissipation	Sunwater completed a Comprehensive Risk Assessment (HB#1961274) and Dam Safety Review (HB#1904372) as part of the Phase 3 work, which included assessing the feasibility of improvements at the dam and to other infrastructure. • The road crossing and culverts on the normal southern access road to the dam were repaired by the local Council in mid-2013. These repairs included extra concreted rock protection on the downstream side which is where the washout occurred. This reduced the likelihood of wash-outs and facilitate better access. It is noted that one lane of the crossing was always available after the flood so access for the dam repairs was not adversely impeded. • Improvements to the right bank access at the dam were assessed, but none were considered practical due to the terrain. • Culverts across the discharge channel in the stream bed were installed to improve access to the left bank. Other options to improve early access to the left bank were assessed. However, no permanent access options down the left bank to the left end of the dissipator apron were identified. • Measures to prevent ingress to environmental flow gate chamber were assessed but have not been implemented. • Measures to safeguard the hydraulic rams that are designed to open the environmental flow gates were assessed but have not been implemented. These potential improvements have been further considered in current studies, see Section 9.9.3 of Paradise Dam Spillway Improvement Project Preliminary Design Report (GHD, July 2019 [HB#2464363]). • Electrical switchboards have been moved to higher elevations, where possible. For example, the main incomer board is now located on the right abutment crest. • Improvements which would allow a greater release discharge have not been considered.	Some of the PWD dam safety management recommendations have been timely completed (i.e. road culvert strengthening, installation of discharge channel culverts, raising of electrical switchboards) but others have been discounted as impracticable (i.e. left and right bank access improvements, upgrading environmental flow gate chamber, increasing release discharge capacity) or are included (i.e. safeguarding environmental flow gate hydraulic rams) as part of the upcoming Spillway Improvement Project

Appendix H: 2013 Review – Actions related to the Emergency Action Plan

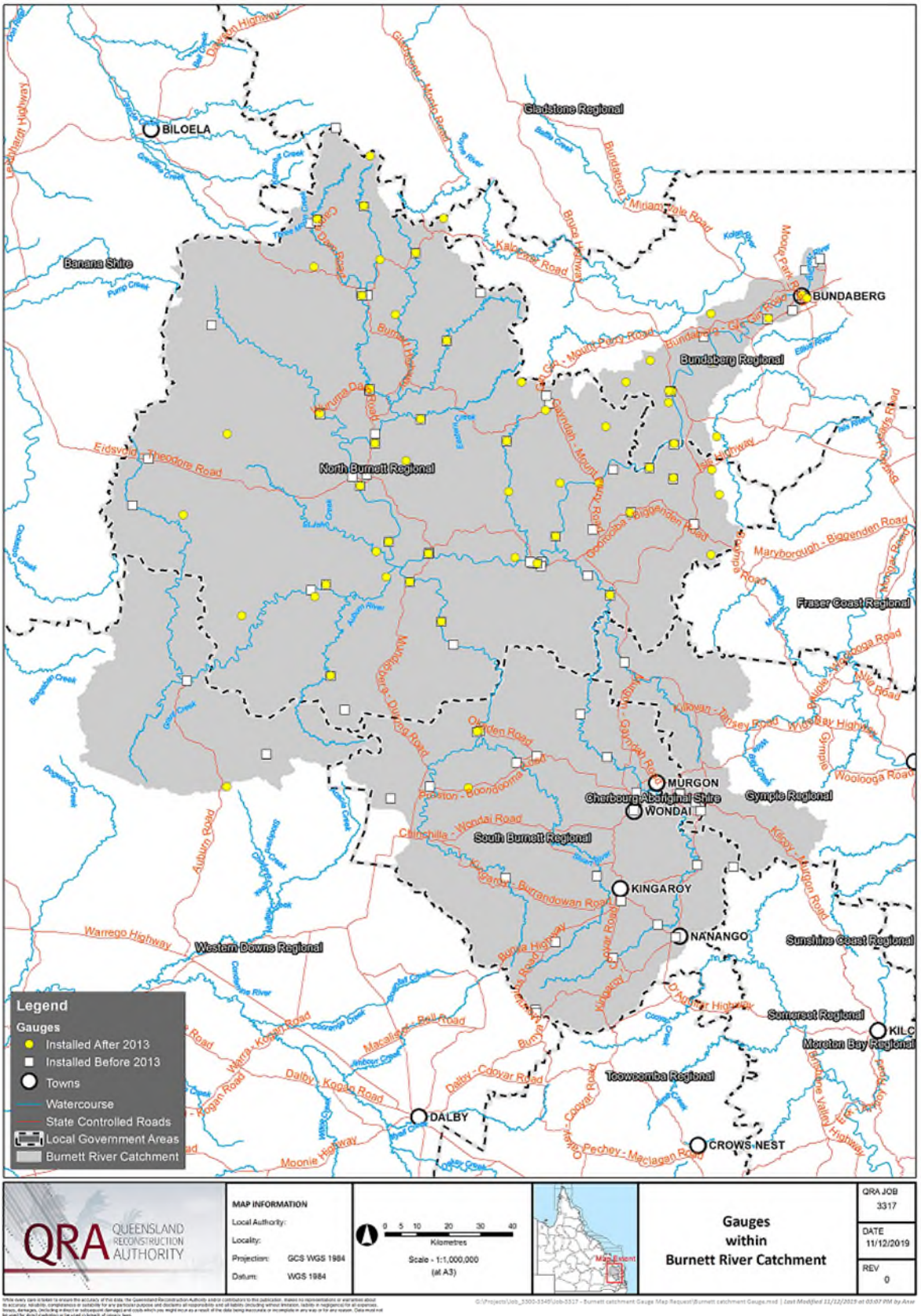
Following are the actions from the “Paradise Dam Flood Event of January to March 2013 – Review of Dam Safety Management Actions” that relate to the Emergency Action Plan.

Recommendation	Advice from Sunwater on Implementation	Comment on Implementation
Second Term of Reference		
7. There is an opportunity to improve procedures by Sunwater training its personnel to enter sufficient words in the “Message” field of Communication Records to enable others to comprehend the subject of the communication.	Sunwater revised its Emergency Event Coordinator and Dam Safety Training material by October 2013, to ensure that all EAP personnel were trained to enter sufficient information of the conversation in the "Message" field of the record of communication page in the EAP to enable others to comprehend the subject of the communication.	Emergency Management Improvement Project included improved planning and partnering with disaster management agencies (improved warnings and emergency management), communication and education, training and testing, and establishment of a dedicated Sunwater operations control centre.
Third Term of Reference		
4. The EAP should be revised to allow for the risks which are now known to exist at Paradise Dam. In particular, response plans should be devised for possible future damage scenarios	The EAP was revised in November 2013 (HB#2483124) to allow for the risks which were then known to exist at Paradise Dam. Response plans were devised for possible future damage scenarios. For example, section 4 included a new part which dealt with Modes of Dam Failure and Probable Emergency Responses. The revised EAP was approved by the Regulator.	Mode of Dam failure was incorporated into the November 2013 EAP
Fourth Term of Reference		
2. If the advice under the first Term of Reference is followed, it is desirable that the EAP is revised to take account of the findings of the analyses proposed under that TOR.	The EAP was revised in November 2013 and approved by the Regulator. This EAP revision incorporated the findings of the analyses proposed under the first Term of Reference.	This relates to Action 10 in regard to updated risk assessments and surveillance which are included in the latest EAP.
3. It is desirable that Sunwater work together with the disaster management groups in an effort to make the EAP more user friendly and to maximise the effectiveness of evacuation.	In the November 2013 revision of the EAP, Sunwater worked with disaster management groups to make the EAP more user friendly and to maximise the effectiveness of evacuation. For example, Roles and Responsibilities were checked and Alert levels were re-worded to be in line with QFES terminology (i.e. Stage 1 changed to Lean Forward).	The format of the EAP has changed since 2013 and much easier to read.

Recommendation	Advice from Sunwater on Implementation	Comment on Implementation
4. It is desirable that the EAP be revised to better deal with redundant systems for emergency management.	The revision of the EAP in November 2013 considered the need for redundant systems for emergency management. For example, radio was added into the communications section for situations where poor mobile phone reception exists. Email address were also added to downstream residents and a new layout, which make the information easy to read, was incorporated. Sunwater has also revised its emergency management response since 2013 to better deal with redundant systems. For example, the 2017 update has a communications failure section which was a learning from the 2015 Callide review.	The current EAP includes communications failure.
5. It is desirable that the EAP be revised to provide better information on assets and resources which may be required for emergency management	The EAP was revised to incorporate a page listing equipment available during an emergency (p39)	Appendix C1 lists equipment available during an emergency response.
6. It is desirable that the EAP be reviewed to remove any content that is not applicable to Paradise Dam	The revision of the EAP in November 2013 removed content that was not applicable to Paradise Dam. The EAP is only relevant for Paradise Dam.	Content not relevant to Paradise Dam was not found.
7. It is desirable that there be a list of acronyms and their meaning immediately after the table of contents	The revision of the EAP in November 2013 incorporated a list of acronyms and their meaning immediately after the table of contents (see section 1, page 3).	See section 1.2 of current EAP
8. It is desirable that the EAP be revised to make clear statements about the need for continuous attendance of surveillance personnel at the dam	The revision of the EAP in November 2013 incorporated clear statements about the need for continuous attendance of surveillance personnel at the dam. The Inspections page, which outlines the types of inspections that are carried out at the dam, was checked (p44), and the action for DDO was included to state "inspect the dam continually" once EAP active to Lean Forward (p58)	See section 3.5 Emergency inspections and monitoring.
9. It is desirable that the EAP be revised to make clear statements about the urgency for inspections by a dam safety engineer	The revision of the EAP in November 2013 incorporated clear statements about the urgency for inspections by a dam safety engineer. For example, flow charts were amended and updated (see page 21/22), changing the wording from "ARRANGE Inspection of the Dam" to "ARRANGE Inspection of the Dam as soon as possible, when safe to do so"	See section 3.5 Emergency inspections and monitoring.
10. It is desirable that the EAP be revised to give better guidance on the reporting by personnel at the site of changed conditions at the dam	The inspection sheets that the DDO (on site personal) use to report on conditions, visual inspections and readings at the dam were updated in the 2013 EAP to assist with this (p74).	EAP includes a list of triggers and actions which include reporting

Recommendation	Advice from Sunwater on Implementation	Comment on Implementation
11. It is desirable that consideration be given to revision of the EAP to give guidance on the impact of releases from the dam on downstream access and residents	The revision of the EAP in November 2013 incorporated downstream residents' contact requirements and details in section 3, pages 3A to 3C.	Population at risk is also identified from various maps in the EAP
12. It is desirable that the EAP be revised to provide more useful information on available access modes and routes to the dam	The revision of the EAP in November 2013 provided more useful information on available access modes and routes to the dam, for example, alternate access routes and travel distances.	This is included in the 2013 EAP, see section 7
13. It is desirable that the EAP be revised to provide a more accurate definition of incremental flood effects	The revision of the EAP in November 2013 incorporated failure and non-failure flood cases, providing a more accurate definition of incremental flood effects. Inundation plans from the 2011 flood and Burnett River Flood Study were also incorporated.	This is included in the various maps.
14. It is desirable that consideration be given to the value of 2D inundation modelling and to the preparation of more accurate mapping on which to plot inundation extent	2D modelling and inundation modelling was utilised in the updated risk assessment process, which culminated in the 2016 Comprehensive Risk Assessment (HB#1961274, Part 6).	The use of 2D modelling has been confirmed.
15. It is desirable that the EAP be revised to remove any inappropriate or outdated references	The revision of the EAP in November 2013 removed inappropriate and outdated references.	EAP has been regularly reviewed and an opportunity to remove any outdated references.

Appendix I: Map showing gauges in the North Burnett Catchment

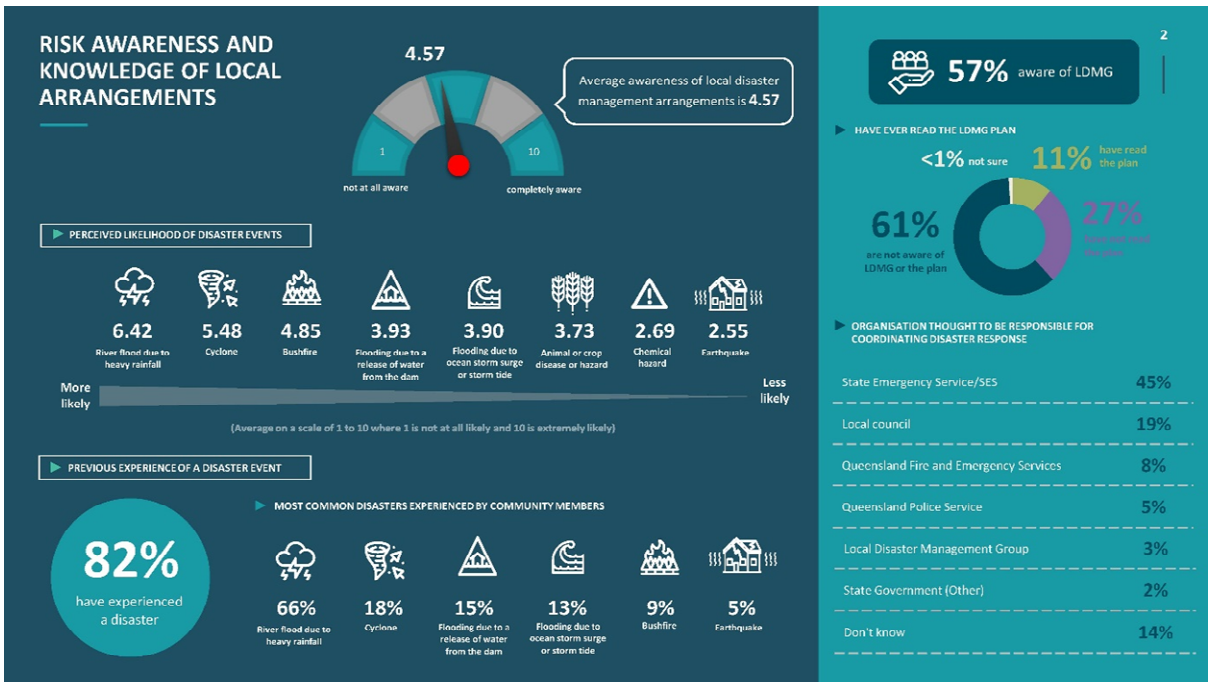


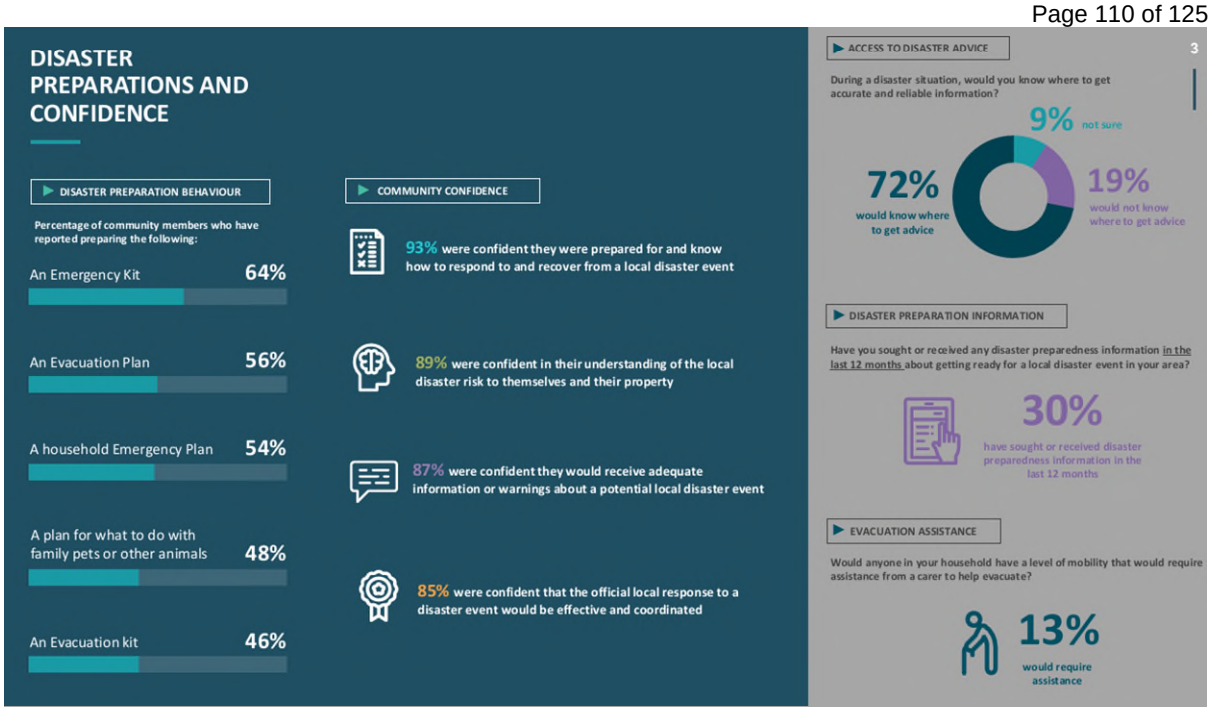
Appendix J: Quantitative Research with Community Members

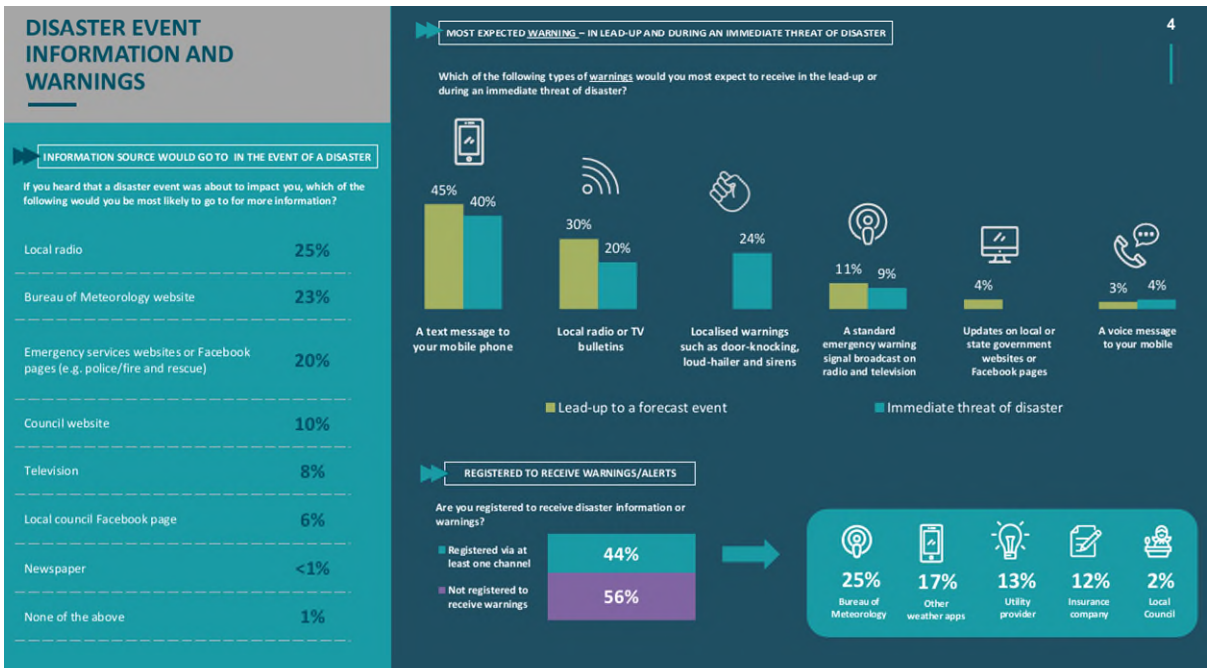
The following report was commissioned by the Office of the Inspector-General Emergency Management to inform and provide supporting evidence for this review. The full report is published on the Office's public-facing website: https://www.igem.qld.gov.au

2019 Paradise Dam Review Research with Community Members.

Market and Communications Research 2019




DISASTER PREPARATIONS AND CONFIDENCE
DISASTER PREPARATION BEHAVIOUR
Percentage of community members who have reported preparing the following:
An Emergency Kit 64%
An Evacuation Plan 56%
A household Emergency Plan 54%
A plan for what to do with family pets or other animals 48%
An Evacuation kit 46%
COMMUNITY CONFIDENCE
93% were confident they were prepared for and know how to respond to and recover from a local disaster event
89% were confident in their understanding of the local disaster risk to themselves and their property
87% were confident they would receive adequate information or warnings about a potential local disaster event
85% were confident that the official local response to a disaster event would be effective and coordinated
ACCESS TO DISASTER ADVICE
3
During a disaster situation, would you know where to get accurate and reliable information?
9% not sure
72% would know where to get advice
19% would not know where to get advice
DISASTER PREPARATION INFORMATION
Have you sought or received any disaster preparedness information in the last 12 months about getting ready for a local disaster event in your area?
30% have sought or received disaster preparedness information in the last 12 months
EVACUATION ASSISTANCE
Would anyone in your household have a level of mobility that would require assistance from a carer to help evacuate?
13% would require assistance


DISASTER EVENT INFORMATION AND WARNINGS
INFORMATION SOURCE WOULD GO TO IN THE EVENT OF A DISASTER
If you heard that a disaster event was about to impact you, which of the following would you be most likely to go to for more information?
Local radio 25%
Bureau of Meteorology website 23%
Emergency services websites or Facebook pages (e.g. police/fire and rescue) 20%
Council website 10%
Television 8%
Local council Facebook page 6%
Newspaper <1%
None of the above 1%
MOST EXPECTED WARNING – IN LEAD-UP AND DURING AN IMMEDIATE THREAT OF DISASTER
4
Which of the following types of warnings would you most expect to receive in the lead-up or during an immediate threat of disaster?
45% 40% A text message to your mobile phone
30% 20% Local radio or TV bulletins
24% Localised warnings such as door-knocking, loud-hailer and sirens
11% 9% A standard emergency warning signal broadcast on radio and television
4% Updates on local or state government websites or Facebook pages
3% 4% A voice message to your mobile
Lead-up to a forecast event
Immediate threat of disaster
REGISTERED TO RECEIVE WARNINGS/ALERTS
Are you registered to receive disaster information or warnings?
Registered via at least one channel 44%
Not registered to receive warnings 56%
25% Bureau of Meteorology
17% Other weather apps
13% Utility provider
12% Insurance company
2% Local Council

Appendix K: Definitions

TERM	DEFINITION
Activation	The commencement of a process or activity in response to a trigger. An activation is not a declaration, nor is it dependant on the declaration of a disaster situation (see definition for declaration). For example, activation of relief measure, as detailed in the Queensland Disaster Relief and Recovery Arrangements.
Activation (of Emergency Action Plan)	Actions undertaken by the dam owner as per the emergency action plan in response to a dam event if: 1. persons or property may be harmed, because of the event 2. a coordinated response involving two or more of the following relevant entities is likely to be required to respond to the event: • each local and district disaster management group for the emergency action plan • each local government whose local government area may be affected if a dam hazard event or emergency event were to happen for the dam • the Department of Natural Resources, Mines and Energy chief executive • another entity the dam owner considers appropriate i.e. Queensland Police Service, Queensland Fire and Emergency Services.[2]
Alert	A level of activation: a heightened level of vigilance due to the possibility of an event in the area of responsibility. Some action may be required. The situation should be monitors by someone capable of assess the potential threat.
All-Hazards Approach	This approach assumes that the functions and activities applicable to one hazard are most likely applicable to a range of hazards
Approved Emergency Action Plan	An emergency action plan that is approved under s 351i(1)(a) or taken to be an approved emergency action plan under s 352Q(2) of the *Water Supply (Safety and Reliability) Act 2008.*[3]
Australasian Inter-Service Incident Management System (AIIMS)	The nationally recognised incident management system used by emergency service agencies.

[2] Department of Natural Resources, Mines and Energy, 2017, *Emergency Action Plan for Referable Dam Guideline,* https://www.dews.qld.gov.au/__data/assets/pdf_file/0018/84015/eap-guideline.pdf.
[3] Department of Natural Resources, Mines and Energy, 2017, *Emergency Action Plan for Referable Dam Guideline,* https://www.dews.qld.gov.au/__data/assets/pdf_file/0018/84015/eap-guideline.pdf.

Briefing	The process of advising personnel of the details of the incident or event with which they will be dealing.
Capability	The ability to achieve a desired effect in a specific environment/context.
Capacity	The combination of all the strengths, attributes and resources available within an organisation, community or society to manage and reduce disaster risks and strengthen resilience. Capacity may include infrastructure, institutions, human knowledge and skills, and collective attributes such as social relationships, leadership and management.
Community	• A group with a commonality of association and generally defined by location, shared experience, or function. • A social group which has a number of things in common, such as shared experience, locality, culture, heritage, language, ethnicity, pastimes, occupation, workplace, etc.
Consequence	The outcome or impact of an event that may be expressed qualitatively or quantitatively. There can be more than one consequence from an event. Consequences are generally described as the effects on people, society, the environment and the economy.
Control	The overall direction of emergency management activities in an emergency situation. Authority for control is established in legislation or in an emergency plan and carries with it the responsibility for tasking other organisations in accordance with the needs of the situation. Control relates to situations and operates horizontally across organisations.
Coordination	The bringing together of organisations to ensure disaster management before, during and after an event. It is primarily concerned with a systematic acquisition and application of resources (people, material, equipment, etc.) in accordance with priorities set by disaster management groups. Coordination operates horizontally across organisations and agencies.
Coordination Centre	A centre established at State, district or local government level as a centre of communication and coordination during times of disaster operations.
Crest of Dam	The term crest of dam is often used when top of spillway and top of dam should be used for referring to the overflow section and dam proper, respectively.

Dam Hazard	Dam hazard, for a dam, means a reasonably foreseeable situation or condition that may: (a) cause or contribute to the failure of the dam, if the failure may cause harm to persons or property or (b) require an automatic or controlled release of water from the dam, if the release of the water may cause harm to persons or property. (Refer s 352A of the Water Supply (Safety and Reliability) Act 2008).[4]
Dam Hazard Event	An event arising from a dam hazard if persons or property may be harmed because of the event and (a) a coordinated response involving 2 or more of the relevant entities mentioned in paragraphs (b) to (d) of the definition relevant entity is unlikely to be required to respond to the event (b) the event is not an emergency event. (Refer s 352A of the Water Supply (Safety and Reliability) Act 2008).[5]
Damage Assessment	The process of collecting quantifiable data that enables the assessment of the impact of an event. Data collected could be used to inform Impact Assessments
Dam Safety Regulator	Unless otherwise specifically given a different meaning, references to the Dam Safety Regulator are to be interpreted as references to the Director-General of the Department of Natural Resources, Mines and Energy or the Director-General's delegate.[6]
Debrief	A meeting at the end of an operation with the purpose of assessing the conduct or results of an operation.
Declaration of a Disaster Situation	The formal procedure to enable declared disaster powers under the *Disaster Management Act 2003* (ss64-69) as required. Specific powers may be used to prevent or minimise loss of life, injury or damage.
Declaration of an Emergency Situation	An emergency situation declared under the *Public Safety Preservation Act 1986* (s5).
Declared Area	• For a disaster situation declared under s64(1) of the *Disaster Management Act 2003* – the disaster district, or

[4] Department of Natural Resources, Mines and Energy, 2017, *Emergency Action Plan for Referable Dam Guideline,* https://www.dews.qld.gov.au/__data/assets/pdf_file/0018/84015/eap-guideline.pdf.
[5] Department of Natural Resources, Mines and Energy, 2017, *Emergency Action Plan for Referable Dam Guideline,* https://www.dews.qld.gov.au/__data/assets/pdf_file/0018/84015/eap-guideline.pdf.
[6] Department of Natural Resources, Mines and Energy, 2017, *Emergency Action Plan for Referable Dam Guideline,* https://www.dews.qld.gov.au/__data/assets/pdf_file/0018/84015/eap-guideline.pdf.

	the part of the disaster district, for which the disaster situation is declared; or • For a disaster situation declared under s69 of the *Disaster Management Act* – the State or, if the disaster situation is declared for a part of the State, the part.
Disaster	A serious disruption in a community, caused by the impact of an event, that requires a significant coordinated response by the State and other entities to help the community recover from the disruption.
Disaster Management	Arrangements about managing the potential adverse effects of an event, including, for example, arrangements for mitigating, preventing, preparing for, responding to and recovering from a disaster.
Disaster Management Group	Means the state group, a district disaster management group or a local disaster management group.
Disaster Management Plan	The State group, DDMGs and LDMGs must prepare a plan (*State Disaster Management Plan*, District Disaster Management Plan and Local Disaster Management Plan) for disaster management in the state, disaster district and local government's area respectively.
Disaster Management Stakeholder	Any individual, group, corporation, business, organisation, agency, who may affect or be affected by a decision, activity or outcome of disasters or hazards and the approach to prevention, preparedness, response or recovery phases.
Disaster Management System	The Queensland disaster management system refers to the legislation, regulations, plans, standards, policies, technology systems, guidelines and associated publications in place to facilitate effective disaster management across the four phases of prevention, preparedness, response or recovery phases.
Disaster Operations	Activities undertaken before, during or after an event happens to help reduce loss of human life, illness or injury to humans, property loss or damage, or damage to the environment, including, for example, activities to mitigate the adverse effects of an event.
Disaster Risk	The potential loss of life, injury, or destroyed or damaged assets which could occur to a system, society or a community in a specific period of time, determined probabilistically as a function of hazard, exposure, vulnerability and capacity.

District Disaster Management Group (DDMG)	The group established under s22 of the *Disaster Management Act 2003*. The DDMG provides whole- of-government planning and coordination capacity to support local governments in disaster management and operations.
Escalation point	The point at which the capability and/or capacity of an entity to manage the current situation or event has been exceeded, resulting in an escalation to the next level of Queensland's disaster management arrangements for assistance, to continue to effectively manage the event.
Emergency Alert	A national telephone warning system that provides Australian emergency authorities with an enhanced ability to warn the community in the event of an emergency. The warning system is another tool available for organisations to issue emergency warnings. Emergency Alerts will be issued via landline and mobile telephones.
Emergency Event	An event arising from a dam hazard if persons or property may be harmed because of the event, and any of the following apply: i. A coordinated response where two or more of the relevant entities, mentioned in paragraphs (b) to (d) of the definition relevant entity, are likely to be required to respond to the event. ii. The event may arise because of a disaster situation declared under the DM Act. iii. An entity performing functions under the State disaster management plan may, under that plan, require the owner of the dam to give the entity information about the event. (Refer s 352A of the Act)[7]
Emergency Event Interim Report	An interim report on the performance of the dam and the functioning of the EAP during an emergency event, which is submitted to the chief executive prior to the end of the event at the request of the chief executive. (Refer s 352U(2)(a) of the Act)
Emergency Event Report	A report on the performance of the dam and the functioning of the EAP during an emergency event which is presented to the chief executive following the end of the event. ('End' of an emergency event means when the dam hazard giving rise to the event is no longer a risk to persons or property.)

[7] Department of Natural Resources, Mines and Energy, 2017, *Emergency Action Plan for Referable Dam Guideline,* https://www.dews.qld.gov.au/__data/assets/pdf_file/0018/84015/eap-guideline.pdf.

	(Refer s 352T(2) of the Act)[8]
Emergency Management	Emergency management is also used, sometimes interchangeably, with the term disaster management, particularly in the context of biological and technological hazards and for health emergencies. While there is a large degree of overlap, an emergency can also relate to hazardous events that do not result in the serious disruption of the functioning of a community or society.
Evacuation	The planned movement of persons from an unsafe or potentially unsafe location to a safer location and their eventual return.
Evacuation Centre	A building located beyond a hazard to provide temporary accommodation, food and water until it is safe for evacuees to return to their homes or alternative temporary emergency accommodation.
Event	An event means any of the following: • A cyclone, earthquake, flood, storm, storm tide, tornado, tsunami, volcanic eruption or other natural happening • an explosion or fire, a chemical, fuel or oil spill, or a gas leak • an infestation, plague or epidemic • a failure, or disruption to, an essential service or infrastructure • an attack against the State • another event similar to an event mentioned above. An event may be natural or caused by human acts or omissions.
Exercise	A controlled, objective-driven activity used for testing, practising or evaluating processes or capabilities.
Exposure	The elements within a given area that have been, or could be, subject to impact of a particular hazard. Exposure is also sometimes referred to as the 'elements at risk'.
Failure Impact Assessment	A process used under the Act to determine the number of people whose safety could be at risk should the dam fail. This assessment must be certified by a Registered Professional Engineer Queensland (RPEQ) in accordance with the Act.

[8] Department of Natural Resources, Mines and Energy, 2017, Emergency Action Plan for Referable Dam Guideline, https://www.dews.qld.gov.au/__data/assets/pdf_file/0018/84015/eap-guideline.pdf.

Failure Impact Rating	A failure impact rating is a measure of the population at risk should the dam fail. There are two categories for referable dams: • category 1: 2 to 100 people at risk if the dam were to fail • category 2: more than 100 people at risk if the dam were to fail.[9]
Functional Lead Agency	An agency allocated responsibility to prepare for and provide a disaster management function and lead relevant organisations that provide a supporting role.
Functional Plan	A functional plan is developed by lead agencies to address specific planning requirements attached to each function. Although the functional lead agency has primary responsibility, arrangements for the coordination of relevant organisation that play a supporting role are also to be outlined in these plans.
Hazard	A process, phenomenon or human activity that may cause loss of life, injury or other health impacts, property damage, social and economic disruption or environmental degradation. (United Nations Office for Disaster Risk Reduction, 2017)
Hazard mapping	The process of establishing geographically where and to what extent particular phenomena are likely to pose a threat to people, property, infrastructure and economic activities.
Impact assessment	The analysis of consequences of an event, including psychosocial (emotional and social), economic, natural and built environment.
Incident	An event, occurrence or set of circumstances that: • has a definite spatial extent • has a definite duration • calls for human intervention • has a set of concluding conditions that can be defined • is or will be under the control of an individual who has the authority to make decisions about the means by which it will be brought to an end.
Intelligence	The product of a process of collecting and analysing information or data which is recorded and disseminated as intelligence to support decision making.
Jurisdiction	The state or territory in which an agency, organisation or statutory position has authority or responsibility.

[9] Department of Natural Resources, Mines and Energy, 2017, Emergency Action Plan for Referable Dam Guideline, https://www.dews.qld.gov.au/__data/assets/pdf_file/0018/84015/eap-guideline.pdf.

Lean forward	An operational state prior to ‘stand up’ characterised by a heightened level of situational awareness of a disaster event (either current or impending) and a state of operational readiness.
Level of Risk (or risk level)	Magnitude of a risk, or a combination of risks, expressed in terms of the combination of vulnerability, consequence and their likelihood.
Levels of Activation	The Queensland Disaster Management Arrangements are activated using an escalation model based on the following levels: • Alert – a heightened level of vigilance due to the possibility of an event in the area of responsibility. Some action may be required and the situation should be monitored by staff capable of assessing and preparing for the potential threat. • Lean forward – an operational state prior to ‘stand up’ characterised by a heightened level of situational awareness of a disaster event (either current or impending) and a state of operational readiness. Disaster coordination centres are on standby, prepared but not activated. • Stand up – the operational state following ‘lead forward’ whereby resources are mobilised, personnel are activated and operational activities commenced. Disaster coordination centres are activated. • Stand down - transition from responding to an event back to normal core business and/or continuance of recovery operations. There is no longer a requirement to respond to the event and the threat is no longer present.
Liaison Officer	A person who liaises between a coordination centre and their home entity (e.g. SDCC and Energy Queensland) during disaster operations. Liaison officers communicate and coordinate their activities to achieve the best utilisation of resources or services provided to the centre (e.g. provide technical or subject matter expertise, as well as, capability and capacity of their home entity).
Likelihood	The chance of something happening whether defined, measured or determined objectively or subjectively, qualitatively or quantitatively and described using general terms or mathematically. (Standards Australia/Standards New Zealand Standard Committee, 2009).

Local Disaster Coordinator (LDC)	The person appointed as the local disaster coordinator under s35 of the *Disaster Management Act 2003*. The function of the local disaster coordinator is to coordinate disaster operations in the local government area for the LDMG.
Local Disaster Management Group (LDMG)	The group established under s29 of the *Disaster Management Act 2003*, in place to support Local Government in the delivery of disaster management services and responsibilities in preventing, preparing for, responding to and recovering from disaster events.
Local Disaster Management Plan (Local plan)	A plan prepared under s57 of the *Disaster Management Act 2003* that documents arrangements to manage disaster planning and operations with the local government area of responsibility.
Mitigation	Activities intended to reduce or eliminate risks or lessen the actual or potential effects or consequences of an event.
Monitoring	Continual checking, supervising, critically observing or determining the status to identify change from the performance level required or expected. Monitoring can be applied to a risk management framework, risk management process, risk or control. (Australian Emergency Management Institute, 2015)
Natural Hazard	Those which are predominantly associated with natural processes and phenomena. (United National Office for Disaster Risk Reduction, 2017)
Network	A group or system of interconnected people or things. (Australian Emergency Management Institute, 2015)
Offers of assistance	The offering of financial donations, volunteers, goods and services from individuals, corporations, businesses or organisations.
Operational Plan	An operational plan is a response plan which outlines a problem/concern/ vulnerability and identifies the appropriate action (what? who? how? when?) to address the situation. The operation plan sits within the disaster management plan and is developed after conducting a risk assessment.
Phases of Disaster Management	Prevention, Preparedness, Response and Recovery.
Place of Refuge	An alternative or in addition to evacuation where individuals shelter within their homes, workplace or with family/friends if considered safe to do so. (Queensland Disaster Management Guideline)

Plan	A formal record of agreed emergency management roles, responsibilities, strategies, systems and arrangements.
Planning process	The collective and collaborative efforts by which agreements are reached and documented between people and organisations to meet their communities' emergency management needs. It is a sequence of steps which allows emergency management planning to take place.
Policy	Provides a deliberate system of principles and statement of intent to guide decisions and achieve rational outcomes.
Population at Risk (PAR)	The number of people calculated under the failure impact assessment guideline, whose safety will be at risk if the dam, or the proposed dam after its construction, fails.[10]
Probable Maximum Precipitation (PMP)	The theoretical greatest depth of precipitation for a given duration that is physically possible over a particular drainage basin.[11]
Probable Maximum Flood	The flood resulting from PMP, snowmelt, coupled with the worst flood-producing catchment conditions that can be realistically expected in the prevailing meteorological conditions.[12]
Preparedness	The knowledge and capacities developed by governments, response and recovery organisations, communities and individuals to effectively anticipate, respond to and recover from the impacts of likely, imminent or current disasters.
Prevention	Activities and measures to avoid existing and new disaster risks.
Queensland's disaster management arrangements (the Arrangements)	Whole-of-government arrangements to ensure the collaborative and effective coordination of planning, services, information and resources for comprehensive disaster management.
Queensland Disaster Management Committee (QDMC)	The group established under s17 of the *Disaster Management Act 2003* and chaired by the Premier to make strategic decisions about prevention, preparedness, response and recovery for disaster events and to build Queensland's resilience to disasters.
Recovery	The coordinated process of supporting disaster-affected communities' psychosocial (emotional and social), and

[10] Department of Natural Resources, Mines and Energy, 2017, Emergency Action Plan for Referable Dam Guideline, https://www.dews.qld.gov.au/__data/assets/pdf_file/0018/84015/eap-guideline.pdf.
[11] Department of Natural Resources, Mines and Energy, 2017, Emergency Action Plan for Referable Dam Guideline, https://www.dews.qld.gov.au/__data/assets/pdf_file/0018/84015/eap-guideline.pdf.
[12] Department of Natural Resources, Mines and Energy, 2017, Emergency Action Plan for Referable Dam Guideline, https://www.dews.qld.gov.au/__data/assets/pdf_file/0018/84015/eap-guideline.pdf.

	physical wellbeing; reconstruction of physical infrastructure; and economic and environmental restoration.
Referable Dam	A dam, or a proposed dam after its construction will be a referable dam if: (a) a failure impact assessment of the dam, or the proposed dam, is required to be carried out under the Act (b) the assessment states the dam has, or the proposed dam after its construction will have, a category 1 or category 2 failure impact rating (c) the chief executive has, under s 349 of the Water Supply (Safety and Reliability) Act 2008, accepted the assessment. (Refer s 341 of the Act)[13]
Relevant Entities	Means each of the following under the emergency action plan for the dam: (a) the persons who may be affected, or whose property may be affected, if a dam hazard event or emergency event were to happen for the dam e.g. owners of parcels of farmland adjacent to the dam, residents of a township (b) each local group and district group for the emergency action plan; and each local government whose local government area may be affected if a dam hazard event or emergency event were to happen for the dam (c) the chief executive (d) another entity the owner of the dam considers appropriate e.g. the Queensland Police Service. (Refer to s 352A of the Act.)[14]
Residual risk	The disaster risk that remains, even when effective disaster risk reduction measures are in place, and for which emergency response and recovery capacities must be maintained.
Resilience	A system or community's ability to rapidly accommodate and recover from the impacts of hazards, restore essential structures and desired functionality, and adapt to new circumstances.
Response	Actions taken directly before, during or immediately after a disaster in order to save lives, reduce health impacts, ensure public safety and meet the basic subsistence needs of the people affected.
Risk	The concept of risk combines an understanding of the likelihood of a hazardous event occurring with an

[13] Department of Natural Resources, Mines and Energy, 2017, Emergency Action Plan for Referable Dam Guideline, https://www.dews.qld.gov.au/__data/assets/pdf_file/0018/84015/eap-guideline.pdf.
[14] Department of Natural Resources, Mines and Energy, 2017, Emergency Action Plan for Referable Dam Guideline, https://www.dews.qld.gov.au/__data/assets/pdf_file/0018/84015/eap-guideline.pdf.

	assessment of its impact represented by interactions between hazards, elements at risk and vulnerability. (Geoscience Australia)
Risk Assessment	An approach to determine the nature and extent of risk by analysing potential hazards and evaluation existing conditions of vulnerability that together could potentially harm exposed people, property, services, livelihoods and the environment on which they depend. (United Nations Office for Disaster Risk Reduction, 2017)
Risk Management	The systematic application of management policies, procedures and practices to the tasks of identifying, analysing, assessing, mitigating and monitoring risk. (Australian Emergency Management Institute, 2015)
Risk Management Framework	A set of components that provide the foundations and organisational arrangements for designing, analysing, assessing, mitigating and monitoring risk. (Australian Emergency Management Institute, 2015)
Risk Register	A table, list or other representation of risk statements describing sources of risk and elements at risk with assigned consequences, likelihoods and levels of risk. Risk registers are produced by risk assessment processes, summarising the outputs of these processes to inform decision making about risks. Risk registers record the identification, analysis and evaluation of emergency risks. (Australian Emergency Management Institute, 2015)
Service delivery	The act of providing a service or conducting an activity that is an entity's normal business.
Shared understanding	Knowledge and awareness of a situation, person, or thing, that is shared across and between different entities to provide a common frame of situational awareness.
Shelter in place	An alternative or in addition to evacuation where individuals shelter within their homes, workplace or with family/friends if considered safe to do so.
Situational awareness	Situational awareness or situation awareness is the perception of environmental elements and events with respect to time or space, the comprehension of their meaning, and the projection of their status after some variable has changed, such as time, or some other variable, such as a predetermined event. It is also a field of study concerned with understanding of the environment critical to decision makers.

Spillway	A spillway is a structure used to provide the controlled release of flows from a dam or levee into a downstream area, typically the riverbed of the dammed river itself.
Spillway Apron	A concrete floor at the bottom of a spillway to prevent soil erosion from heavy or turbulent flow.
Stand Up	The operational state following 'lean forward' whereby resources are mobilised, personnel are activated, and operational activities commenced. Disaster coordination centres are activated.
State Disaster Coordination Centre	A permanent state level operational facility located at the Emergency Services Complex, Kedron, Brisbane.
State Disaster Management Plan (State Plan)	A plan prepared under s49 of the *Disaster Management Act 2003* that documents planning and resource management for disaster management for the state.
Sunny Day Failure	The failure of a dam without any other general flooding or spillway discharges.[15]
Susceptible	Likely or liable to be influenced or harmed by something (Oxford Dictionary 2018).
Timely	Done or occurring at a favourable or useful time. This does not necessarily mean quickly; rather, it means something occurs or is done at the time when it will be of most use or effect.
Volunteers	People who are formally affiliated with an emergency service organisation or non-government organisation, and act under the respective organisation's direction and authority.
Vulnerability	The conditions determined by physical, social, economic and environmental factors or processes which increase the susceptibility of an individual, a community, assets or systems to the impacts of hazards. (Department of Home Affairs, 2018, *Profiling Australia's Vulnerability: the interconnected causes and cascading effects of systemic disaster risk*)

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[3] FEMA, 2013, Living with Dams know your Risks, P2
[4] Queensland Government 2019 Water Supply (Safety and Reliable) Act 2008,1 July 2019, https://www.legislation.qld.gov.au/view/html/inforce/current/act-2008-034
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