

Paradise Dam Improvement Project

Overview Report

Ensuring the safety of communities downstream of our dams, including Paradise Dam, is Sunwater's primary concern.

Sunwater conducts weekly dam inspections, five yearly Comprehensive Risk Assessments and 20-year detailed Safety Reviews as part of its overall risk management practices for managing its dams.

This report and its attachments are being released by Sunwater as they informed Sunwater's decision to undertake the essential works to ensure that Paradise Dam is safe under all conditions, including significant flood events. Sunwater's priorities in relation to Paradise Dam safety are the protection of lives and livelihoods with our primary concern being the safety of people who live downstream of the dam.

After the 2013 flood event and associated repairs were undertaken, Paradise Dam's 20-year Safety Review was brought forward, which highlighted a number of potential risks. Additional studies to determine the appropriate program of works to address these risks formed part of Sunwater's overall Dam Improvement Program and the establishment of the Paradise Dam Improvement Project.

As part of the Paradise Dam Improvement Project, Sunwater conducted further technical investigations that identified and revised risks to Paradise Dam. This included more recently assessed risks relating to a structural problem with the concrete in the dam wall, and a potential safety issue in the unlikely event that a flood like the 2013 flood of record occurs.

Although the stability of Paradise Dam is considered adequate when the dam is full, during certain flood events (like the 2013 flood event), there is an unacceptable risk of dam failure.

As a result of these recent additional issues identified in addition to the risks previously identified as part of the Dam Safety Review and Critical Risk Assessments, the independent Technical Review Panel endorsed that Sunwater needed to accelerate essential works. The Queensland Government and Sunwater promptly announced that the storage level in Paradise Dam would be lowered ahead of the 2019/20 wet season to enable these immediate essential works which would lower the dam wall by 5m to commence in early 2020. This has the added benefit of providing better community safety should a flood of record reoccur.

The following actions have been undertaken by Sunwater:

- The storage level of the dam was reduced to 42% capacity of the full supply volume.
- Emergency management procedures were reviewed with Councils and agencies, including updating warnings and triggers in Sunwater's Emergency Action Plan.
- Planning and design commenced for essential works (to lower the primary spillway) to allow construction to commence following the upcoming wet season.
- A dedicated Paradise Dam Community Reference Group was established to facilitate effective two-way communication between Sunwater and communities.
- Additional peer technical review commissioned by Tatro Hinds.
- Rolling program of community engagement initiated to keep you informed and answer your questions.
- A Burnett and Kolan Regional Blueprint process commenced to identify development opportunities for the future.

Further improvement works will still be required to follow the essential works phase, which will form part of the Building Queensland led Detailed Business Case for the Paradise Dam Improvement Project (PDIP) being undertaken in parallel with the essential works. The PDIP includes potential strengthening and anchoring works across the left abutment, primary spillway and secondary spillway, and downstream protection works. These works are significant in scope, and were previously planned for completion by the end of 2025 with the essential works now comprising early stage risk reduction measures. The PDIP will also consider alternative options for any reduced water supply options.

In addition to the broader PDIP, Building Queensland is currently undertaking an options assessment process, to review and recommend by early 2020 the preferred scope of works for the full PDIP to be undertaken, which includes the following options:

- Full Supply Level – returning the primary spillway (post essential works) back to the current level and full storage capacity (with associated improvement works), or
- Permanent Lower Supply Level – the spillway to be permanently lowered beneath the existing crest level (with corresponding improvement works, as well as considering alternative options for any reduced water supply options):
 - 5m
 - 10m, or
 - an optimised level in between
- Decommissioning.

In accordance with Sunwater's commitment to provide more transparency to the community in relation to the overall risks at Paradise Dam and the requirement for essential works to be undertaken in early 2020, this overview with attached technical reports (two reports by Sunwater's design consultant GHD; a report issued by the Technical Review Panel (expert reviewers); and a review report by specialist consultants Tatro Hinds) is being made publicly available. These reports primarily focus on the more recently identified and elevated risk in relation to the shear strength of the roller compacted concrete, which is the primary material forming the construction of the dam. While this is considered the highest risk to the dam, there are other risks that have been assessed and considered as part of design and planning for the project.

Background

Paradise Dam is located approximately 20km north-west of Biggenden and 80 km south-west of Bundaberg on the Burnett River. The dam creates a 45km long narrow reservoir, with a surface area of 3,000ha and a storage volume of 300,000ML.

The dam was constructed by the Burnett Dam Alliance. One of the participants in the Alliance was Burnett Water Pty Ltd, the owner of the dam. At the time of construction of the dam, the shares in Burnett Water Pty Ltd were held by the State of Queensland.

Paradise Dam is a concrete gravity structure and the primary construction material is roller compacted concrete (RCC).

The maximum height of the dam is 53m. The primary spillway is 315m long and up to 38m high, the secondary spillway (right abutment) is 485m long and up to 48 m high, and the left abutment is 120m long and up to 53 metres high. These sections are divided into RCC monoliths, with three across the left abutment (monoliths A, B and C), seven across the primary spillway each being 45m wide (D,E,F,G,H,I and K), and twelve across the secondary spillway (L to W).

A 20-metre-long spillway apron extends along the base of the primary spillway, originally intended to protect the toe of the primary spillway from impact of the plunging flood flows and to allow energy dissipation of the spillway discharge, after which outflow from the dam discharges onto exposed rock and the river bed.

Construction of the dam was completed in December 2005.

Following this, the shares in Burnett Water Pty Ltd were transferred by the State to Sunwater. From this time, Sunwater became responsible for the management of the dam.

Given the prevailing drought conditions, Paradise Dam did not fill for the first time until March 2010, at which time wet commissioning occurred.

A major flood event occurred at Paradise Dam in late 2010. The peak of the flood was almost 6 m over the spillway at 73.56 m AHD. Only limited damage was caused to the dam and plans for repair works were made.

In late January 2013, heavy rainfall associated with ex-Tropical Cyclone Oswald produced a significant flood event (the flood of record) that overtopped the spillway by 8.65m at its peak. The peak outflow was estimated to be a 0.5% AEP event (or a 1 in 200 AEP flood event).

Substantial damage occurred during this event, primarily to the spillway apron and downstream scouring. Given the dam was designed to safely pass substantially larger floods, the extent of damage during a flood of 2013 magnitude was not expected.

Paradise Dam was designed to safely pass up to a 1 in 30,000 Annual Exceedance Probability (AEP) flood event (a 0.0033% likelihood of a flood event being exceeded in any one year), though anticipating rectification works would be required to repair damage caused by significant flood events. The design basis was for a Probable Maximum Precipitation design flood with a peak discharge of 93,000 m³/s (8 million ML per day) with a corresponding peak storage (flood) level of 20.1 metres height above the primary spillway crest (which is the full supply level). Flow passes over the primary spillway first, before the secondary spillway overtops, which was designed to commence at a 1 in 1,000 AEP flood event, with the left abutment overtopping at a 1 in 10,000 AEP flood event.

In total, there is 144,000ML yield allocations from the dam made up of 124,000ML of Medium Priority water allocations, of which only approximately 24,000ML is currently committed to customers, and 20,000ML of High Priority water allocations with 2,850ML sold to date.

Dam safety reviews and comprehensive risk assessments

Sunwater responded to the 2013 flood event by:

- a) undertaking urgent flood repairs, which were completed by December 2013, and
- b) undertaking a dam safety review and comprehensive risk assessment. These reviews, which were supported by third party experts and investigations, were directed at comprehensively assessing the risks associated with the dam considering its performance during the 2013 event.

During these studies, Sunwater determined that further work was required to strengthen the Dam to reduce the risks that had been identified. The primary dam safety risks initially identified related to:

- a) limited or inadequate downstream protection, below the primary and secondary spillway, and
- b) increased risks related to geological defects and weaknesses through the foundation and rock below and downstream of the dam (particularly considering the relatively limited geological

modelling and geotechnical testing and data available from the original design and construction).

In order to undertake this work, Sunwater commenced the Paradise Dam Improvement Project (DIP) in 2015. The DIP involved, amongst other things:

- a) review and implementation of non-structural measures for improved emergency response and planning (for both the Paradise Dam catchment, and portfolio wide initiatives across all Sunwater dams) – including enhanced early warning systems and modelling, improved planning and partnering with disaster management agencies, more effective messaging, communication and education. [Stage 1 project]
- b) works to strengthen the base of the primary spillway at monoliths D and K (at each end of the spillway), such work being completed by August 2017, at a cost of approximately \$30 million [Stage 2 project], and
- c) further longer term works on the secondary spillway and primary spillway, to be implemented over the period from 2020 to 2026 for an initial total estimated value of at least \$300 million to \$420 million [originally planned as separate Stage 3 and 4 projects, but then consolidated into one project in 2017].

Based on the risks, as assessed from the 2016 CRA and Dam Safety Review, the relevant Dam Safety Guidelines, these works were prioritised across Sunwater's portfolio for all dam improvement works and planned to be completed by the end of 2025 (subject to wet weather and approvals), in accordance with Sunwater's Dam Safety Policy by undertaking required works as soon as reasonably practicable. In order to achieve this deadline, the first two project stages were commenced in 2015 and completed in 2017, with the final two stages commencing in 2017.

Current Dam Improvement Project

The current PDIP, being the consolidation of the previously planned stage 3 and 4 projects, commenced in 2017 with concept design, options assessment, and development of the Preliminary Business Case. This was to implement the final improvement works necessary to reduce dam risks to an acceptable level, in accordance with ANCOLD (Australian National Committee on Large Dams) and dam safety guidelines and standards.

Following completion of the Preliminary Business Case in 2018, two options were shortlisted. This included progressing with design for necessary improvements works to retain the dam at its current level and storage capacity (Option 2), and an option with a reduced primary spillway level (being 10m lower than the existing level) and reduced storage capacity with corresponding reduced improvement works considering the lower flood loading for this option (Option 3).

When planning these further longer-term works, and conducting further detailed analysis in preparation for those works, further risks to the safety of the dam were identified. These risks had not been identified earlier due to the dam being taken as designed and constructed appropriately. Given the increased dam safety risk and concerns, the only practical way to assess whether the construction of the roller compacted concrete (RCC) by the Burnett Dam Alliance was satisfactory was to carry out geotechnical investigations and testing. Sunwater engaged a geotechnical consultant to undertake testing of the RCC, as well as additional specific testing through other areas of the dam and foundation. This work was carried out from February to August 2019. RCC cores and lift joint samples were obtained from vertical and horizontal boreholes drilled from the spillway and abutment, with laboratory testing undertaken from August to September 2019. The consultant also reviewed core samples taken by Sunwater in 2015 as part of the Comprehensive Risk Assessment.

The risk found is associated with the lift joint quality of the RCC and its shear strength. RCC dams are constructed in horizontally successive continuous shallow lifts of typically 30cm. The presence of many lifts in an RCC dam such as Paradise Dam requires that every lift surface has sufficient shear capacity to sustain the applied loads on the dam, with reserve capacity sufficient to satisfy margins of safety.

The design consultant revised its stability assessment based on the latest available test results in August 2019. A Technical Review Panel workshop was held on 27 and 28 August 2019, comprising six national and international experts with significant experience and a range of expertise. A revised stability assessment report, and separate detailed report on the RCC strength, was submitted by the design consultant on 5 September 2019. A final report from the workshop was provided on 19 September 2019 by the Technical Review Panel.

For clarity it is noted that, in accordance of the requirements of the Qld Professional Engineers Act (2002), a single point RPEQ accountability (Registered Professional Engineer Queensland) for design of the improvement works associated with Paradise Dam has been assigned to GHD, as the design consultant. The project Technical Review Panel, and various peer reviewers, may offer suggestions and recommendations, but do not have RPEQ accountability for the design.

The condition of the dam is likely a result of the existing integrity of the numerous lift joints within the dam, though at this stage it is not possible to determine this with complete accuracy. The only way to ensure this with complete accuracy would be to physically inspect the wall through demolition and rebuild. The Technical Review Panel report supports Sunwater's design processes and study outcomes, in addition to the design consultant's revised stability assessment.

As a result of this work, Sunwater has determined that:

- a) the stability of the dam is considered adequate when the dam is full
- b) during certain flood events, there is an unacceptable risk of dam failure. This risk arises because of the assessed quality of the construction of the RCC joints (as the major failure mechanism).

To appropriately ensure the safety of downstream communities, immediate action was taken, including:

- a) reducing the storage level of the dam to 42%
- b) reviewing emergency management procedures with Councils and agencies, including warnings and triggers in Sunwater's Emergency Action Plan
- c) immediately commencing planning and design of essential works (lowering the primary spillway) to allow construction to commence at the end of the upcoming wet season, and
- d) engaging a RCC expert to undertake a review of the Technical Review Panel findings.

The RCC expert consultant (Tatro Hinds) has concluded that (Summary of Findings):

"After review of the GHD reports and the supplied reference information we have concluded the observed and anticipated extent of unbonded lifts in the structure is sufficient to invoke the ANCOLD requirement to assume no bonded lift joints in the structure and limit stability analyses to only residual shear strength. This determination is based on review of several core drilling programs, mixture properties, and construction records."

Timeline of Paradise Dam

The timeline of key events and Sunwater's actions are summarised on the following page:

20 September

2019

Event: Commenced lowering the dam to 42% capacity
Preparing to reduce the level of the spillway by 5m
Building Qld commenced options assessment to determine next steps
Action: Emergency Action Plan further revised, including trigger levels for warnings.
Commenced planning for early stage 'essential works' (lowering of the

January

2019

Event: Business Queensland to lead Paradise Dam Improvement Program Detailed Business Case
Action: Includes review and planning of two preferred options from the Preliminary Business Case

May 2015 to August

2017

Event: Stage 2 Dam Improvement Project works
Action: Completed (\$30.6M)

June

2016

Event: Revised Comprehensive Risk Assessment
Action: Completed

- Identified similar risks and proposed staged improvement works
- Incorporated additional studies since the 2015 Comprehensive Risk Assessment, Identified potential shear failure

April

2016

Event: Revised Dam Safety Review
Action: Completed

May

2015

Event: Stage 2 Dam Improvement Project works
Action: Commenced

October 2014– January 2015

2014

Event: Comprehensive Risk Assessment
Action: The Comprehensive Risk Assessment assessed increased dam risks and placed the dam above the Australian National Committee on Large Dams (ANCOLD) Guideline Limit of Tolerability for failure
Structural and non-structural improvements were incorporated into Sunwater's Portfolio Risk Assessment

October

2014

Event: Dam Safety Review
Action: Completed

2013

Event: Damage by Tropical Cyclone Oswald
Action: Repair work completed (\$34.2M)

December 2010–April 2011

2011

Event: Three major flood events:

- December 2010
- January 2011
- March 2011

Action: Minor structural damage. Plans for rectification works were made following inspections of the dam

November

2005

Event: Paradise Dam built