PARADISE DAM COMMISSION OF INQUIRY

Commissions of Inquiry Act 1950

STATEMENT OF CHRISTOPHER DANN

Name of Witness:	**CHRISTOPHER PETER DANN**
Date of birth:	[redacted]
Current address:	**C/- AECOM Australia Pty Ltd** **Level 8 540 Wickham Street** **Fortitude Valley QLD 4006**
Occupation:	**Civil Engineer**
Contact details (phone/email):	[redacted] **christopher.dann@aecom.com**
Statement taken by:	**Jonathan Horton QC, Senior Counsel Assisting** **Alexander McKinnon, Counsel Assisting**

I, **Christopher Peter Dann,** Industry Director Dam Engineering at AECOM, make oath and state as follows:

Background and qualifications

1. I am an Industry Director – Dam Engineering at AECOM Australia Pty Ltd and have been employed by AECOM or its legacy companies (including URS Australia Pty Ltd) since 14th February 1994.

2. I hold a Bachelor of Engineering (Civil) from the University of Queensland.

3. In my career, I have been responsible for the design management of a range of heavy civil engineering projects including:

a. dam safety upgrade projects for major water supply dams. I am currently the Project Director and RPEQ for the Detailed Design of the $100M Lake Macdonald (Six Mile Creek) Dam Safety Upgrade in Queensland. I was also the Project Director and RPEQ for a range of studies at Somerset Dam in Queensland including the 20 Year Dam Safety Review, the *Somerset Dam Geotechnical Investigations and Concept Design* and the *Somerset Dam Supplemental Geotechnical Investigations, Physical Hydraulic Model, Concept Assessment and Selection*. I was also the Design Manager and RPEQ for the $350 million Hinze Dam Stage 3 project;

b. the design of a range of new water storage dams from small hazardous water storages to major new water supply dams. I have been involved in many types of design studies from pre-feasibility level assessments, Tender design, detailed design and design reviews. I oversaw the design of two new saddle dams for the Hinze Dam Stage 3 project and managed the preliminary design of the Emu Swamp Dam in Queensland.

c. Dam safety assessments including Portfolio Risk Assessments. I was the 'Principal In Charge' for the Portfolio Risk Assessment for 26 referable dams and Mt Crosby Weir for Seqwater.

4. I lead the AECOM Australia dams practice participating in project technical reviews as well as sourcing resources across the region. I was awarded the Engineers Australia Sir John Holland Civil Engineer of the Year Award in 2009.

5. A copy of my curriculum vitae is attached to this statement and marked "**CPD-1**".

Involvement with Burnett River/Paradise Dam

6. URS' involvement with Paradise Dam, formerly known as the Burnett River Dam (the **Dam**) is, in summary, as follows.

7. In 2003 URS teamed with Thiess and Maunsell (the **Team**) to participate in a Competitive Alliance Process to deliver the Dam Project. URS was primarily responsible for the design of the dam structure. I was the Design Manager and was responsible for leading the Tender design for the dam structure, which was to a Preliminary Design level of detail. By that, I mean the design was not complete and further detailed design activities would be required to complete the design. Section 1.4 of the Design Report that was produced by URS in 2003 stated '*The alliance has been carried out design activities over the twelve week Stage 2 period and has developed a preliminary design that is of the order of 40% complete'.* The design report is **DNR.007.1087**.

8. In October 2004 I attended a visit to the Dam site during construction as part of an ANCOLD event. At the time of the site visit the dam foundation was being prepared, including treatment of defects observed in the foundation, and initial trial placements of RCC were underway. The end sill structure for the dissipator was also under construction.

9. In December 2006 I undertook a one day site visit to view the fishway at the Dam as background for the design of a fishway for the Hinze Dam Stage 3 project. During this site visit I viewed the completed Dam's structure. To my knowledge the Dam had not spilled to this date.

10. Over the period 2013 to 2014, URS was engaged by Carter Newell Lawyers on behalf of Sunwater's insurers to undertake an Independent Technical Review (**ITR**) of damage caused to the Paradise Dam Spillway during the January 2013 spillway discharge event (the **2013 Event**). I visited the Dam site on 24 October 2013 at which point remedial works were being undertaken to address damage caused during the 2013 Event. The report of the ITR is **SWA.512.001.0578** (the **ITR Report**).

11. I was the leader for the preparation of the ITR including managing the inputs of a number of technical specialists. I also coordinated internal review of the ITR Report.

Tender Process

12. The Team submitted a Registration of Interest to participate in the delivery of the Dam Project on 14 February 2003.

13. The Team were selected as one of two teams to participate in a Competitive Alliance Process receiving the 'Stage 2 – Request for Proposals' (**Stage 2 RFP**) from Burnett Water dated 12 May 2003.

14. The requested 'Stage 2 Deliverables' included:

    a. the Tender design including a Design Report and a statement of compliance with the Functional Specification and Drawings. This covered:
        (i) Design and construction methodology and planning;
        (ii) Design and construction program;
        (iii) Project resources including plant, equipment, labour and sub contractors;
        (iv) Target Cost;
        (v) Risk/Reward framework;
        (vi) Non Cost Performance Payment Proposal;
        (vii) Management Plans including Project Management Plan, Cost Management and Reporting, Risk Management Plan, Environmental Management Plan, Quality Management Plan, Health and Safety Management Plan, Stakeholder Management Plan, Human Resources Plan, Site Management Plan and Procurement Plan;
        (viii) Whole of life cost estimates.

b. URS was responsible for the following key deliverables:

   (i) The Design Report that described the basis of the Tender design (dated 1 August 2003). The design was at a preliminary stage to support the Tender submission (of the order of 40% complete). (The report is **DNR.007.1087**.)

   (ii) The permanent works design which were defined by 79 Drawings covering site investigations, foundations, main dam, outlet works, secondary spillway, fishway, instrumentation and electrical works.

   (iii) The temporary works design which were defined by 48 Drawings covering diversion works, dam access roads, various dam temporary works, erosion and sediment control works.

   (iv) Preliminary Technical Specifications.

15. The Team had approximately 12 weeks from the date of notification that the Team was selected to proceed to the Stage 2 RFP until finalisation of the Tender response. During this period the Team had to undertake the following:

    a. Mobilise key personnel to Brisbane. A number of the URS team were sourced from international offices including from the United States and New Zealand;

    b. Set up a project office and temporarily relocate personnel to this office to work as an integrated team;

    c. Review the information provided by Burnett Water as part of the Stage 2 RFP;

    d. Participate in hydraulic model studies. Note that Burnett Water had commissioned a 3D physical hydraulic model (1:100 scale), a 2D flume model of the primary spillway (1:75 scale) and an outlet works and fishway model (1:30 scale) for use by the Competitive Alliance Participants;

e. Develop the geological model for the site, including providing input to some limited additional investigations that were carried out during the Stage 2 RFP period;

f. Develop the design for the components of the dam including the foundations, main dam, outlet works, secondary spillway, fishway, instrumentation and electrical works.

16. URS engaged a number of technical experts to provide input to the development of the design including Malcolm Dunstan (RCC specialist), Brent Mefford (fishway specialist), George Annandale (erosion specialist), and Richard Davidson (URS Internal Peer Review).

17. URS formed an expert review panel (**ERP**) comprising Eric Kollgard (dam structures – US based), John Cassidy (hydraulic structure design – US based), Professor Robin Fell (foundation and dam design) and Brian Cooper (structural design). The ERP covered the following topics:

a. Hydrology/hydraulics (including a visit to the physical hydraulic model);

b. Stability;

c. Foundation;

d. Gallery;

e. RCC Joints;

f. Outlet Works.

18. The ERP convened in Brisbane the week of 24 June 2003 and provided a written report with key feedback to the design team on 27 June 2003. It is **DNR.003.8615.**

19. This occurred some six weeks after receiving notification from Burnett Water that the Team was selected to proceed to Stage 2 RFP. This was a critical meeting as the Thiess estimating team requested a 'design freeze' so that they had certainty in the scope of the project for pricing purposes. This timeframe was further compressed by Thiess' corporate approval process that required a review of the Tender commercial conditions including the Tender price by senior management. A period in the order of two weeks was required for this review.

20. While the Stage 2 RFP phase was about 12 weeks, allowing for time to mobilise the design team into the project office and meet the requirements for a design freeze, the majority of the key design decisions had to occur within a six to eight week period. The remaining four to six weeks of the Stage 2 RFP phase had the URS design team focussed on documenting the design including preparation of the Design Report, Technical Specifications and Drawings. This timing was very tight.

URS 2003 spillway design

21. The design criteria for the Dam was to safely pass the Probable Maximum Precipitation Design Flood (**PMPDF**). Hydrological studies adopted for the Tender design of the Dam estimated the PMPDF as approximately 90,000m^3/sec, which is large in comparison to international precedent for design flood capacity of major dams in large catchments.

22. In developing the conceptual design for the dam to safely pass the PMPDF, it was recognised that in a PMPDF flood event extensive backwater inundation would provide tailwater inundation against the dam along most of the

alignment. A secondary spillway was provided to allow the overall width of spillway flow to match the width of the tailwater inundation.

23. The URS Tender design for the spillway was in broad terms similar in concept to that ultimately constructed by the Alliance (the Alliance's preliminary design is **DNR.007.0477**). However, there are some important differences:

    a. the URS Tender design provided a primary spillway length (ie the distance across the overflow section) of 265m aligned to the high flow channel of the Burnett River. URS' design rotated the spillway alignment from the Sunwater Reference Design (the Report on Burnett River Dam Preliminary Design (Vol 1), dated February 2003, is **DNR.003.7930**) by 3.3 degrees to better align the spillway discharges with the river channel. This moved the left abutment approximately 30m downstream of the Reference Design location. The realignment of the primary spillway, with the reduced width and secondary spillway was developed to reduce the potential for large flow circulations on the right bank around the Paradise Creek junction that were observed in the three dimensional hydraulic model of Sunwater's Reference Design. The Alliance constructed a 315m long primary spillway;

    b. the URS primary spillway dissipator comprised a reinforced concrete apron 600mm thick anchored into the rock foundation with a ramped end sill 1.8m high. The reinforced concrete apron was placed over an RCC 'levelling layer' and comprised two layers of reinforcing. The ramped end sill was selected to lift high velocity flow from the apron above the bed of the river to protect the downstream bed from erosion. The dissipator was 20m wide (extending downstream from the toe of the primary spillway monoliths). The Alliance dissipator comprised an RCC apron 620mm thick anchored into the rock foundation with a vertical end sill 1m high. As described in the URS Independent Technical Review report of 2014, solid vertical faced end sills can have the tendency to create a ground roller on the downstream end that can pull gravels and rocks into the dissipator basin resulting in erosion of the end sill and dissipator slab (p. 0619 of **SWA.512.001.0578**). The Alliance apron slab was also 20m wide and comprised a single layer of reinforcing in the upper RCC layer;

c. the URS primary spillway monoliths included a sloped profile of 0.7H:1V with a stepped face (600mm high steps), whereas the Alliance constructed the primary spillway monoliths with a steeper 0.64H:1V face (also with a stepped face – 620mm high).

24. Primary spillway energy dissipation was assessed by URS as follows:

a. The spillway steps provide high energy dissipation (greater than 80%) for small floods up to 5,300m^3/sec. As flood flows increase, the energy dissipation on the spillway steps gradually decreases. The steps provide approximately 50% energy dissipation in 1:100 AEP flood and approximately 5% energy dissipation in the 1:1000 AEP flood.

b. In large floods the high downstream tailwater level provides a deep pool for energy dissipation of the primary spillway flow. Minimal energy dissipation works were considered necessary at the time. The ramped end sill was included in the design to ensure that the drowned hydraulic jump occurred immediately downstream of the spillway and to lift the flow jet above the river bed to minimise potential downstream erosion.

c. Appendix 3D of the URS Design Report (from p. 1516 of **DNR.007.1087**) presents a discussion of the physical hydraulic model studies and information to support the design of the spillway structure. It should be noted that URS used the 2D flume model (1:75 scale) for the design of the spillway overflow section and dissipator. In terms of the downstream apron and end sill:

(i) '*Model tests were initially undertaken without an end sill on the downstream apron. Visual observations of the flow patterns were used to determine the optimal location of the end sill to ensure that the drowned hydraulic jump (backroller) would be contained within the spillway apron and to ensure that high flow velocities over the downstream bed could be avoided. These tests showed that a 1.8m high ramped end sill, located 20m downstream of the spillway toe, would be appropriate*'. (p. 1527)

(ii) Velocity measurements were taken at various locations for a range of spillway unit discharge (m^3/sec/m) including midway along the apron, at the end sill and 15m downstream of the end sill. Velocities midway along the apron were typically in the range of 10 to 20m/sec for spillway unit flows in the range of 20 to 180m^3/sec/m. Velocities at the end sill were typically in the range of 10 to 15m/sec for spillway unit flows in the range of 20 to 180m^3/sec/m. Velocities 15m downstream of the end sill were typically less than 5m/sec for spillway unit flows in the range of 20 to 180m^3/sec/m.

(iii) By way of comparison, for the estimated 17,000m^3/sec flow over the spillway during 2013, this equates to a unit discharge of approximately 64m^3/sec/m for the URS 265m wide spillway and the results of the physical hydraulic model study showed a velocity of the order of 3m/sec at the river bed 15m downstream of the end sill.

(iv) By way of further comparison, the results of CFD modelling undertaken by URS in 2014 for the Alliance spillway design showed a ground roller circulating immediately downstream of the end sill with velocities of the order of 3.5 to 5.7m/sec for the 2013 event (with the 1m vertical end sill). (p. 0711 of **SWA.512.001.0578**)

25. Both Competitive Alliance Participants concluded from the available geotechnical information that the spillway structure would be founded on slightly weathered Goodnight Beds that was of at least high strength and resistant to erosion.

URS' ERP during tender process

26. As the Design Manager for the Tender design of the dam structure, I recognised that the team had to make some very important decisions in a very short timeframe.

27. I was also aware that for dam projects where I had previously managed design activities, it was industry practice for an owner to engage an expert review panel to provide input to the design development process.

28. In my experience, an expert review panel provides comment to the owner and design team relating to a number of aspects that can impact the design including:

    a. selecting appropriate design and performance criteria;

    b. collecting appropriate inputs to the design, in particular data related to the foundation conditions, available construction materials, the outcomes of physical hydraulic model studies etc;

    c. the selection of engineering parameters as inputs to engineering analysis;

    d. the selection of appropriate analyses methods and discussion of analysis results; and

e. the development of the design concepts and subsequent design details.

29. Engaging with an expert review panel early in the development of a design is important to ensure that there is 'buy in' to the design concepts and the activities required to ultimately complete the design.

30. Given that Burnett Water did not have an expert review panel to review the tenders, I undertook to engage our own one during the Tender period so that our team had confidence in the preliminary design concepts developed and to manage the risks that subsequent design activities could introduce major design changes which could have a range of commercial consequences for the project.

31. The members of the ERP selected are identified earlier in this statement along with the issues they considered. The ERP members were selected in consultation with other members of the design team and based on their key engineering discipline and dam engineering experience.

32. I still retain a copy of the URS Design Report (**DNR.007.1087**) prepared to describe the basis of the Tender design which includes the ERP report (the **ERP Report**) and minutes of an ERP meeting held on 26 June 2003, to which I made reference above (**DNR.003.8615**).

33. Section 2 of the ERP Report was titled 'Major Issues' (p. 8618 of **DNR.003.8615**) and selected sections from the ERP Report are summarised as follows:

    a. Design flood – The ERP makes comment on the magnitude of the design flood and states '*The very large head on the spillway and the very high unit discharge over the main spillway are to the Review Team's knowledge, unprecedented. In addition, the design to overtop* *the dam by significant depths also requires more than normal design considerations.'* (p. 8618)

b. Hydraulics – Design of the Stilling Basin (from p. 8621):

'The unit discharge into the basin is extremely high at 218 cumecs/meter which would require a very large and deep stilling basin if it were not for the fact that the tail-water elevation increases rapidly with increases in flood flow. During passage of the PMF the differential head across the dam is only 7.1m. Thus energy dissipation requirements at the foot of the dam are minimal'.

'Currently the sill of the stilling basin is being designed as a dentated sill. Observations of the flow in the physical model made during our site visit to the hydraulic laboratory on Thursday indicate that a solid sill is satisfactory. The sill as modelled causes a back roller downstream from the sill. The back roller will tend to eliminate any tendency for erosion downstream from the sill.'

'The Alliance Design Team is considering the possibility of sloping the basin upward on its left side in order to reduce excavation costs. There is no obvious technical reason why this cannot be done but the final design should be developed using a three dimensional physical model….. Inflow from the left side of the basin will cause flow to pile up on the right had side of the stilling basis which could increase erosive velocities along the right bank of the river downstream of the stilling basin…..If the decision is made to build the left side of the stilling basin at a higher elevation than the right hand side, the three dimensional physical model should be used to determine if special measures are needed to prevent rocks from being carried into the basin from downstream.'

c. I note that at a meeting of the ERP on 26 June 2003, recorded at p. 8635 of **DNR.003.8615**, the need for this three dimensional physical modelling was noted. The ERP added, "*The current hydraulic model includes two different apron slab levels and this model shows no problematic flow patterns. However it is noted that the scale of this model is relatively small.*"

d. Foundation Excavation – Excavation Depth Assumptions (from p. 8630):

> *'We agree in general with the selection of slightly weathered rock as the foundation level on which to found the main portion of the dam. We would not reduce this requirement on the left abutment at least until the foundation level is above full supply level in the reservoir.'*
>
> *On the right side, the secondary spillway can be founded on poorer quality rock classified as moderately weathered. Depending however, on the assessment of likely seepage through any suspect zones, other foundation provisions may be necessary. One possible such added feature would be an upstream cutoff trench backfilled with concrete which can also improve the shear resistance if stability is an issue.'*

ITR Report dated October 2014

34. URS undertook a review a various background documents provided by Sunwater, through Carter Newell Lawyers, in particular selected sections of the Alliance's Detailed Design Report and various dam safety inspection reports that had been prepared since the Dam was constructed. I was an author of the ITR Report, along with Mike Phillips and Steve O'Brien. As part of the ITR, Dr George Annandale of Golder Associates undertook an assessment of the scour

that occurred at the Dam during the floods of 2010 and 2013 (his report is Appendix D to the ITR Report; from p. 0780 of **SWA.512.001.0578**). All the opinions expressed in the ITR Report are ones that I hold.

35. URS staff (including me) also visited the Dam in October 2013 to view the condition of the Dam and the extent of remedial works being undertaken.

36. Key technical reviews undertaken as part of the ITR include:

    a. Computational Fluid Dynamic (CFD) modelling to assess the hydraulic performance of the spillway, hydraulic loads on the dissipator structure, in particular the end sill, and the foundation downstream of the dam;

    b. Geotechnical and erosion assessment using the results of the hydraulic model study and mapping of the foundation that was undertaken during construction.

    c. Structural assessment of the primary spillway dissipator apron and end sill structure to assess the ability of the designed structure to resist the modelled hydraulic forces.

37. Key conclusions from the ITR Report are summarised as follows:

    a. the hydraulic design of the dissipator structure is not well documented in the Alliance's Detailed Design Report and there is no evidence of independent technical reviews being carried out on either the spillway design or the physical model study. This is a concern given the large PMPDF spillway discharges for the Dam;

    b. the reported damage to the primary spillway following the 2010 and 2013 spillway discharge events would not be expected for a structure designed and constructed to modern design standards;

c. there is no Australian Standard for the hydraulic design of energy dissipation structures. However the Queensland Dam Safety Management Guidelines (NRW 2002) provide a list of industry recognised international design guidelines for spillway dissipators, including the Design of Small Dams (USBR 1987) (**BOR.001.0001**). Based on the functional requirements documented in the Detailed Design Report and the shape of the dissipator basin, the primary spillway dissipator most closely resembles a hydraulic jump Type II basin from the U.S. Bureau of Reclamation (**USBR**). Our independent assessment shows that the design of the dissipator would not meet the USBR guidelines for the hydraulic design of a Type II dissipator structure, in particular:

(i) The length of the dissipator apron is relatively short compared to the length required by the USBR guidelines. While engineering judgement is required to select a suitable dissipator length given the expected foundation conditions downstream of the dam, precedent on other projects suggests that as a minimum the dissipator should be designed to contain the hydraulic jump from a 1 in 100 year AEP event, which would require a dissipator length of the order of 50m. Given that the constructed length of the dissipator apron was 20m and that the hydraulic jump would extend beyond the dissipator structure, there is a high level of reliance in the design that the foundation downstream of the dissipator is able to withstand the hydraulic forces of the hydraulic jump downstream of the dissipator structure.

(ii) Engineering judgement is required to select a suitable end sill height. However the 1m high end sill provided is less than recommended by the USBR guidelines, by at least 50% depending upon the event selected for design.

(iii) The USBR guidelines also recommend a dentated end sill with alternating sloped and vertical upstream faces to direct flow up above the river bed and reduce the potential for rocks to be drawn back into the dissipator basin, whereas the end sill structure provided had a solid vertical upstream face.

d. CFD modelling shows that the dissipator structure does not wholly contain the hydraulic jump formed in the 2010 spillway discharge (1 in 40 AEP event) (the **2010 Event**), the 2013 spillway discharge (1 in 170 AEP event) (the **2013 Event**) or the 1 in 1,000 year AEP event. This means that the foundation downstream of the dissipator is subjected to increased hydraulic energy from the hydraulic jump and that the design of the dissipator basin is reliant on having a high strength, erosion resistant foundation downstream of the dissipator provided.

e. CFD modelling shows that, without the end sill structure in place, the incoming high energy jet follows the river bed profile and the downstream river bed is subjected to increased hydraulic energy across a broader area of the foundation.

f. In my opinion the damage to the end sill and dissipator slabs during the 2010 Event was caused by gravel and rock materials being drawn into the dissipator due to the hydraulic performance of the dissipator structure, in particular the 'ground roller' that is shown in the 2D CFD model and the recirculation flows at the abutments as shown in the 3D CFD model. The sloped floor of the dissipator apron produced complex three dimensional hydraulics that appear to have not been well understood or documented in the design of the dissipator.

g. The hydraulic forces on the end sill structure and potential erosion damage to the apron structure would increase as a function of the increasing head passing over the spillway. Additional erosion damage to the apron slab would likely have occurred during the 2013 Event . The extent of this erosion damage is not known but it is expected that gravel and rock fragments observed at the site following the 2013 Event, in particular those deposited in the outlet channel, would have caused more extensive damage than that observed following the 2010 Event.

h. At some point during the 2013 Event structural failure of the end sill would have occurred as the hydraulic forces on the end sill due to the spillway discharges exceeded the strength of the structure.

i. In my opinion, the failure of the end sill during the 2013 Event was due to inadequate structural design of the end sill structure, in particular the connection between the apron slab and the use of RCC in the apron slab.

j. In my opinion the dissipator slab damage was caused by the poor design of the apron slab, specifically the use of RCC in lieu of conventional concrete and the amount and location of reinforcement of the apron slab. The performance of the apron slab may also have been impacted by potentially poor quality RCC and poor construction techniques. However I did not have construction records to confirm this, so I have expressed this opinion based upon an inference to that effect.

k. In my opinion, erosion to the foundation downstream of the dam was to be expected given the nature of the mapped foundation conditions under the Dam, even if the end sill structure had not failed. Failure of the end sill structure would have exacerbated the extent of erosion that occurred due to the increased hydraulic energy across the foundation.

l. In some areas of the dissipator apron the mapped foundation conditions encountered during construction showed much poorer quality rock than expected during the design. I have never seen a construction report to confirm if the dissipator design was reviewed given the change in actual foundation conditions. However given that the design of the dissipator structure was reliant on the quality of the foundation downstream of the dissipator, the dissipator design should have been reviewed and remedial works should have been implemented to protect the poor quality foundation materials downstream of the spillway.

m. The analysis in the ITR Report shows high hydraulic energy conditions within a zone at least 50m downstream of the toe of the dam (potentially up to 70m) and that erosion of weathered materials, shear zones and foundations with discontinuities within these high energy zones was to be expected, even if the end sill structure was intact.

38. In summary, based on the information made available for the ITR it was my opinion that the primary reason that damage occurred to the Dam during the 2010 Event and 2013 Event was a result of poor design. The extent of erosion damage downstream of the Dam was compounded by areas of poor quality foundation that were identified during construction. However no remedial action was taken to protect these areas of poor quality materials from erosion.

39. It should be noted that at the time of preparing the ITR Report, a number of key documents had not been made available including:

a. Construction Report;

b. colour copy of Appendix D 'Hydraulic Model Study' to the Detailed Design Report;

c. as constructed drawings;

d. The Peer Review document titled '*Erodibility of Goodnight Beds under Primary Spillway Dissipator Apron*' dated 24 November 2004.

***OATHS ACT* 1867 (DECLARATION)**

I, Christopher Peter Dann, do solemnly and sincerely declare that:

(1) This written statement by me dated 9 March 2020 is true to the best of my knowledge and belief; and

(2) I make this statement knowing that if it were admitted as evidence, I may be liable to prosecution for stating in it anything I know to be false.

And I make this solemn declaration conscientiously believing the same to be true and by virtue of the provisions of the *Oaths Act 1867*.

.... **Signature**

Taken and declared before me at Fortitude Valley...... **this** ....9th.... **day of** ....March..... **2020.**

Taken By ....

~~Justice of the Peace / Commissioner for Declarations~~ / Lawyer

AECOM Imagine it. Delivered.

CPD-1

Christopher Dann
Industry Director - Dam Engineering

Qualifications
Bachelor of Engineering (Civil)

Affiliations
Fellow, Institution of Engineers, Australia

Awards
Hinze Dam Stage 3 – Consult Australia Awards For Excellence 2012, Highly Commended
Hinze Dam Stage 3 – Engineers Australia (Queensland Division) Engineering Excellence Awards, Highly Commended Project Infrastructure over $50 million.
Sir John Holland Civil Engineer of the Year 2009
Cosseys Dam - AENZ Silver Merit Award 2006
Lake Eppalock - Engineering Excellence Award 2001
Greenvale Nickel Mine Rehabilitation – Highly Commended Engineering Excellence Awards

Career History
Chris has over thirty years civil and geotechnical engineering experience with projects spanning Australia, South East Asia and Europe. Chris has been responsible for the design management of a range of heavy civil engineering projects including:

- Dam safety upgrade projects for major water supply dams. Chris was the Design Manager of the $350 million Hinze Dam Stage 3 project.
- The design of a range of new water storage dams from small hazardous water storages to major new water supply dams.
- Dam safety assessments including Portfolio Risk Assessments.
- Hydropower and irrigation canals.
- Water supply schemes.
- Flood protection levees.
- Hazardous dams for the mining and CSG industries.
- Mine rehabilitation planning
- Geotechnical engineering including slope stability, basement and retention design, and foundation design.

Chris also leads the AECOM Australian dams practice participating in project technical reviews as well as sourcing resources across the region. In recognition of his achievements and contribution to the profession, Chris was awarded the Engineers Australia Sir John Holland Civil Engineer of the Year Award in 2009.

Detailed Experience – Water Supply Dams – Upgrade Works

Chris has been responsible for the design management of a range of large dam engineering projects including the $350 million Hinze Dam Stage 3 project.

Lake Macdonald, Queensland – Chris has been the Project Director, internal peer reviewer and RPEQ for a range of studies that have been completed at Lake Macdonald (Six Mile Creek) Dam including the Portfolio Risk Assessment (2012-2013), the AFC Review and Concept Design (2011-2012), the Flood Capacity Upgrade Option Selection and Design (2013) including investigations to the spillway slab and anchors (2013-2014), the Lake Macdonald Dam Safety Upgrade Preliminary Design (2015-2016), the Further Foundation Investigation and Optimisation Study (2017-2018) and the Lake Macdonald (Six Mile Creek) Dam Upgrade Detailed Design (2018-present).

Chris has played a key role developing the scope of the proposed dam safety upgrade works for this project in conjunction with driving the suite of site investigations that have been completed since AECOM commenced work on this project in 2010. Chris has been involved with all workshops with Seqwater's Expert Review Panel and has been instrumental in resolving a number of key project issues including developing our understanding of the geological model for the site and demonstrating that the stability of the spillway structure meets ANCOLD Guidelines. He has also led the development of methods to safely construct the upgrade works.

AECOM is currently finalising the Tender Design for this $100M Dam Safety Upgrade project which include demolition of the existing structure, construction of a new spillway comprising an innovative secant pile cell foundation supporting a low-level ogee spillway with an upper labyrinth spillway. Embankments abut the spillway and include foundation improvement works comprising a plastic concrete cut off wall and shear walls to manage post earthquake stability. The project is currently in an Early Tender Involvement phase with Tender design to be completed in April 2020.

Somerset Dam, Queensland - Chris has been the Project Director, AECOM peer reviewer and RPEQ for a range of studies that have been completed at Somerset Dam including the Portfolio Risk Assessment (2012-2013), the 20 Year Dam Safety Review (2014), the Geotechnical Investigations and Concept Design (2016-2017) and most recently the Supplemental Geotechnical Investigations, Physical Hydraulic Model, Concept Assessment and Selection (2017-2019). These studies have been focussed on understanding the key dam safety risks for the existing structure, in particular the impact of overtopping the 'breezeway' monoliths at the abutments, the geological conditions at the site, the hydraulic performance of the spillway and dissipator basin. Chris has also directed the development of a range of dam safety upgrade options to achieve the key project objectives of meeting Acceptable Flood Capacity requirements, ANCOLD stability requirements and upgrades to the dissipator structure for the revised PMF.

Chris has been 'hands on' in directing the studies completed by AECOM in particular the studies associated with developing the geological model for the foundation of the dam and closing out a number of key issues related to the site geology, including characterising the foundation rock mass and investigating postulated landslides at the left abutment area. Chris has also directed the development of the dam safety upgrade options including the mass concrete buttress section, the dissipator upgrade works and the assessment of the sluice gate upgrades, using experience gained on similar projects including the Hume Southern Training Wall project and the Hinze Dam Stage 3 project. The upgrade works for Somerset Dam have an estimate capital cost of $350M.

Upper Yarra Dam Safety Upgrade, Victoria – Investigations at the Upper Yarra Dam comprising geotechnical investigations and a review of historic construction records showed that the cross section of the embankment did not include engineered filter zones and a review of the dam safety risk showed that the societal risk profile was at unacceptable levels based on ANCOLD Guidelines. The key dam safety risks were associated with potential failure of the embankment due to internal erosion and piping. AECOM has recently completed the detailed design of upgrade works that will require staged demolition and reconstruction of the upper portions of the embankment plus a row of secant filter piles at the right embankment to provide filter protection to those areas of the embankment considered potentially at risk of piping.

Chris is AECOM's technical reviewer for the $50M upgrade to Upper Yarra Dam. He was involved in the initial assessment of the embankment section, review of postulated piping mechanisms, development of key project design criteria and the overall scope of the proposed upgrade works. Chris was also involved with the review of the Construction Documents for the project including the Drawings, Technical Specifications and Dam

Safety Management Plan. Chris promoted the concept of a Geotechnical Baseline Report, given the inherent uncertainties associated with quantifying materials within the existing embankment that would be reused in the reconstruction works. The Geotechnical Baseline Report was developed to help provide a basis for Contractors to price the Tender and to manage changes that were expected during construction.

Lock and Weir No. 1 South Australia - Chris led an investigation into a piping incident at the left abutment of Lock and Weir No. 1. The scope of work included geotechnical investigations, piezometric monitoring and piping risk assessment to evaluate the safety risk. Chris also led studies to develop remedial works concepts and a review of stability analysis of the structure based on an improved understanding of the structure.

Greenvale Dam, Victoria - Greenvale Dam is an embankment dam with a total length of approximately 2750 m with a maximum height of approximately 51 m. The 2008 risk assessment undertaken by AECOM showed the annual probability of failure plotted above the ANCOLD defined limit of tolerability for societal risk of existing dams. The significant dam safety risk was piping through the embankment and the main contributing factor was only partial height filters for this extreme consequence storage. AECOM undertook a suite of geotechnical investigations and the detailed design of works to provide full height filter protection for the full length of embankment. Chris was one of the senior technical reviewers for the $50 million upgrade to the Greenvale Dam which comprised construction of filter buttress works to the various dam embankments to address piping risks. Key challenges during this project were managing the dam safety risks during construction while maintaining reservoir operations. Chris was also closely involved with developing remedial works for the lower right abutment area that comprised complex geological conditions that presented both piping and stability risks to dam safety. Chris also led the design of a complex vertical filter wall that was constructed to connect two chimney filter sections at adjoining embankment sections using secant filter pile techniques.

Junction and Clover Dams, Victoria - Chris was the Project Director for dam safety reviews for Junction and Clover Dams. This project commenced as a D&C Tender for a seismic upgrade of both dams with an estimated capital cost of between $40 million and $50 million. AECOM conducted preliminary seismic analysis during the Tender phase that suggested that no specific dam safety upgrade works were necessary and negotiated with the client to undertake detailed dam safety reviews before commencing any upgrade works. This included a robust process to confirm the seismic hazard for the site.

Complex structural analyses were carried out using finite element modelling and the outcomes of these analyses showed the structures were able to safely handle the design earthquake. A risk assessment was undertaken using the outcomes of the analysis and other studies into the existing condition of the dams and the outcome of the risk assessment was that there was little justification for undertaking the proposed dam safety upgrade works. This outcome delivered a substantial cost saving to the client and provided a clear pathway for ongoing dam safety management for the structures.

Dartmouth Dam Upgrade, Victoria - Chris was involved as one of the AECOM review team for the detailed design of the Stage 1 upgrade works. Chris reviewed works associated with the parapet wall and embankment reconstruction design, stabilisation of steep cuts at the right abutment, assessment of construction risk and measures to maintain dam safety during construction. Chris also attended workshops with the Owner's Independent Peer Review Panel.

Hume Dam Upgrade, New South Wales – Hume Dam is a 51metre high, concrete gravity dam with earth embankments. AECOM carried out feasibility, concept and detailed design of an innovative mass concrete buttress for the Southern Training Wall (STW). The STW is a 42m high mass concrete gravity wall that retains the embankment dam. The wall was strengthened by constructing a mass concrete buttress to replace the function of a horizontal tie back system and to improve its capacity for earthquake loading.

AECOM was responsible for undertaking further geotechnical investigations during the early phases of construction to investigate the presence of obstructions within historic fill material and to confirm target founding levels for the buttress foundations, construction of a suite of temporary works that allowed construction of the buttress from the floor of the river bed downstream of the existing dam. These works included a temporary cofferdam within the river and construction of a working platform to construct the buttress foundations, construction of the buttress foundations using a series of secant pile cells that were constructed in stages to minimise the impacts of these works on the existing STW structure, construction of a mass concrete buttress that was structurally connected to the existing STW structure.

Chris was involved as a technical expert, bringing specialist expertise in secant pile wall design and construction as well as experience gained from similar mass concrete spillway construction from the Hinze Dam Stage 3 project. Chris was involved in the detailed design phase of the project and was also involved with the construction phase, in particular the early phases where work methods and QA/QC procedures are being established on site.

Hinze Dam Stage 3, Queensland - Chris led the design of the $350 million Hinze Dam Stage 3 project that included a 15 m embankment and spillway raise, a new saddle dam of over 700 m in length, raising two intake towers, an upgrade to the mechanical and electrical works and the development of an innovative trap and haul fish transfer system.

Chris also led the Optimisation Study that was undertaken to determine the scope of the Stage 3 project. This included a structured process facilitated by a number of critical workshops to identify and evaluate the optimal arrangement for the Project. Each step included stakeholder workshops with representatives from the alliance design, environmental, communication, and construction teams, Gold Coast City Council, Gold Coast Water Officers, members of Council's independent expert review team and the Queensland Dam Safety Regulator.

A probabilistic quantitative cost benefit analysis was developed to facilitate selection of the optimal upgrade solution, which included economic, social, and environmental considerations. In broad terms, the cost benefit analysis included capital costs for project delivery (construction and commissioning), operating costs and risk costs for project delivery.

The alliance approach to the optimisation of the Project ensured a robust, defensible upgrade solution was developed and agreed upon by the alliance team and its key stakeholders within a challenging timeframe.

Risk assessment techniques were used to evaluate a range of complex engineering challenges on this project in particular piping risks associated with the right abutment and construction risks associated with the proposed remedial works. A plastic concrete cut-off wall was selected as the best solution to reduce the risk of piping at the right abutment to acceptable levels and careful planning was required to manage a range of key risks including complex technical challenges; potential risks to dam safety, the environment and surrounding community; as well as delivering the works on a tight construction schedule to an agreed budget value. The 220 m long and up to 53 m deep cut-off wall was the largest wall of this type constructed to date in Australia. Critical to the success were the planning, integration and risk reduction measures undertaken during both design and construction.

Cosseys Dam, New Zealand – Chris was the Design Manager for the investigation and design of upgrade works to a 41 m high, zoned earth and rockfill dam with potential piping problems, and strengthening of the intake tower for increased seismic loading. Chris was responsible for developing the scope of the optimal upgrade solution, site investigation studies, geotechnical analysis and seepage assessments, design development and documentation for upgrade and temporary works and client/peer review presentations. Chris also provided support during construction, in particular review of the 'observational approach' used to monitor embankment stability during construction.

Yarrawonga Weir, Victoria - Chris was involved with the investigation and design of seismic upgrade works including stone columns to strengthen dam foundations, construction of a downstream stabilising berm, placement of engineered filter and design of erosion protection for overtopping of the weir. Chris was responsible for development of the geotechnical model, analytical and modelling works, design development and design documentation.

Detailed Experience – Water Storage Dams – New Dams

Chris has managed the design of a range of new water storage dams from small hazardous water storages to major new water supply dams. He has been involved in many types of design studies from pre-feasibility level assessments, Tender design, detailed design and design reviews. The major water dam projects require the management of muti-discipline teams to cover the broad range of technical disciplines involved in the development of a major new dam project.

Confidential project, NSW – Chris led a fast track prefeasibility level assessment of potential new dam sites for a confidential project in New South Wales. The assessment comprised a desk top study that utilised various historic studies that had been undertaken across the region in the 1960's and published regional information. The key objectives of the study were to select a site for a new dam for the purposes of developing a budget planning level cost estimate. Chris led the development of a high level dam design concept to provide the target water storage capacity and the preparation of a high level cost estimate for the selected dam site. Given the limited investigations and design work that had been possible in the time available, these estimates were considered suitable for preliminary planning purposes only. The assessment was completed within the agreed fast track timeline.

Hinze Dam Stage 3, Queensland – Chris lead the design of the $350 million Hinze Dam Stage 3 project that included two new saddle dams to safely contain the increased FSL and flood surcharging up to the PMF. The existing saddle dam at the right abutment was extended by 700m and comprised both central core earth and rockfill embankment sections and a zoned earthfill embankment to optimise the use of available materials at the site. Extensive geotechnical investigations were undertaken as part of the design to understand the complex foundation conditions. Risked based decision making was used to develop defensive foundation design measures.

Emu Swamp Dam, Queensland - Chris managed the development of a preliminary design that included geotechnical investigations for the dam foundations and construction materials, to support the Environmental Impact Statement for the project. The concept design included an RCC dam, pump station for both urban and irrigation supplies, concepts for fish transfer in conjunction with the outlet works and infrastructure upgrade associated with the new dam inundation area.

Confidential Client: Project Director and RPEQ for the design of over thirty water storage ponds comprising lined earthfill embankment dams with storage capacity of the order of 200 to 250ML. The design process typically included siting studies, geotechnical investigations, hydraulic assessment and design of the embankments, spillway structures and site infrastructure. Approximately half of these dams have been constructed to date with AECOM providing construction support services and 'as built' records.

North Para Dam, South Australia – Chris provided peer review and technical input to the design of an RCC flood control dam on the North Para River to provide flood mitigation to the Gawler township north of Adelaide. Chris was also involved in developing the design documentation for the project including the Detailed Design report, Technical Specifications and Construction Drawings.

Burnett River Dam, QLD - Chris was the Design Manager for the Tender design of a 41m high, ~$200 million RCC dam including foundation works, erosion protection, RCC and dam design, spillway and apron structures including a primary and secondary overtopping section, outlet works for irrigation and environmental releases and development of Queensland's potentially first fish lift structure developed based on our international experience. Chris was responsible for building a multi-disciplinary design team, developing a range of innovations and assessing performance against project objectives, managing design in compressed timeframes including temporary works, design documentation, and leading client presentation and discussion.

Detailed Experience – Water Supply Dams – Strategic Management & Dam Safety

Chris has been the Project Director and Peer Reviewer for a broad range of dam safety assessments, including the Portfolio Risk Assessment for Seqwater.

Seqwater Portfolio Risk Assessment, Queensland - Chris was the 'Principal In Charge' for the Portfolio Risk Assessment for 26 referable dams and Mt Crosby Weir for Seqwater. The objective of the PRA study was to provide Seqwater with an understanding of the major dam safety risks within the portfolio and to provide a management tool for prioritising future risk reduction works. Chris oversaw the delivery of the PRA study and was heavily involved in developing staged remedial measures that varied from operational controls, additional investigations, engineering analysis and risk reviews, as well as various capital upgrade works.

Somerset Dam, Queensland – Project Director for the 20 Year Dam Safety Review that was undertaken to meet the requirements of the Queensland Dam Safety Management Guidelines. The safety review also included analysis of two key dam safety risks identified during a recent Portfolio Risk Assessment: erosion of the abutments under dam overtopping and stability of the dam under extreme flood scenarios. The outcomes of these studies showed that the risk probabilities increased as a result of the additional analysis.

Atkinson Dam, Queensland – Project Director for the 2014 Dam Safety Review. The Seqwater Portfolio Risk Assessment identified Atkinson Dam as one of the higher risk dams in the portfolio, with an overall societal risk being up to half an order of magnitude above the ANCOLD limit of tolerability. The most significant contributor to risk was piping through the embankment, primarily as the embankment does not have a chimney filter. The Dam Safety Review included detailed geotechnical investigations to assess the conditions of the embankment and foundations, in particular the risk of liquefaction of loose sands underlying the embankment.

Cooloolabin Dam, Queensland – Project Director for the 20 year Dam Safety Review that was undertaken in 2014. Key components of the Dam Safety Review included detailed geotechnical investigations and analysis, evaluation of key dam failure modes identified in the PRA, the development of risk mitigation upgrade options, selection of a preferred risk reduction option and concept level design of preferred option.

Confidential Client: Project Director and RPEQ for the assessment of over fifty water storage ponds of varying storage capacity. The assessments included condition assessment of the existing storages, categorising the storages based on dam safety and environmental risk, identification of potential deficiencies and developing strategies to reduce the identified risks by increased surveillance, implementing remedial works and in some instances planned decommissioning of the storages.

Detailed Experience – Water Supply Schemes

Tiebaghi, New Caledonia – Chris was the Project Manager for the development of a water supply scheme to identify potential water sources in New Caledonia. Three water supply schemes were developed, including various water supply dams, groundwater sources and pipelines connecting elements of the scheme to the mine site. Designs were developed for an RCC dam, a concrete faced rockfill dam and a conventional zoned earthfill embankment. Chris was responsible for scoping various options, managing data collection and site studies, optimising the preferred option, design development and design documentation.

Detailed Experience – Canals and Levees

Central Plains Irrigation Project, New Zealand
The Central Plains irrigation scheme has the capacity to supply water for up to 60,000ha of farmland. Stage 1 of the scheme comprised an intake structure at the Rakaia River and approximately 17km of headrace canal.

Chris provided advice to the design team on the selection and design of the HDPE liner for the canal.

Tekapo Canal Remediation Project, New Zealand – Chris was the lead designer for the PVC geotextile composite liner that was selected as the primary remediation measure to the Tekapo Canal to address material incompatibility and piping risks between the canal earthfill lining and the underlying outwash gravel foundation that have plagued the canal since its construction in the 1970's. Chris worked closely with internationally recognised geomembrane specialist J P Giroud to assess the ability of the liner to span post-earthquake induced embankment cracking and to design innovative ballast measure to resist hydrodynamic forces from canal flows.

Arnold Hydropower Project, New Zealand
The Arnold hydropower project comprised re-development of an existing HEPS to a 46MW capacity scheme. The proposed scheme comprised a new intake structure, some 6km of headrace canal, a Storage pond and a Regulation pond feeding into a powerhouse with a design flow of the order of 100m³/sec. Chris lead the Reference Design during an ETI process that was undertaken to review key project risk areas to develop a target outturn cost for the project. Key technical issues included canal embankment and liner design, post-earthquake stability, leakage assessment and liner performance. Chris also lead the development of concepts for the storage pond design.

BSO Flood Levee, QLD – Chris was the project director, technical reviewer and RPEQ for the detailed design of a 6km flood protection levee for the Broadmeadow Mine, near Moranbah in QLD. URS was responsible for undertaking geotechnical investigations and the design of the levee, as well as ancillary drainage works and a 'filter buttress' to reduce the risk of piping to a seepage area at Ramp 2. URS also provided a field team during construction of the works to provide design support and QA/QC input.