Bulk Water **Alliance**

Memorandum

18TH MAY 2012

SUBJECT	ECD – Thermal Analysis – Cracked Section
TO	[redacted] - Owner's Chief Engineer
FROM	[redacted]

Introduction

RCC placement was put on hold at ECD on 27th February following the overtopping of the partially completed dam due to flooding, estimated to be in the order of 1 in 100 AEP. The flood waters overtopped the partially constructed dam (which was at RL511.3m at the time) by approximately 2m at the peak of the flood. The dam continued to be overtopped for eleven days. Following the recession of the flood, clean up works and preparation for the recommencement of placement was undertaken. Placement of RCC was recommenced on 5 May 2012, resulting in a total delay of 68 days.

Prior to Easter (6th to 9th of April) an upstream-downstream crack adjacent to the left abutment was identified and was being monitored. Over the Easter long weekend a cross valley crack developed in the then left abutment monolith (Monolith D) extending from the induced monolith joint to the upstream-downstream crack (this crack was observed by the TRP during the meeting of 23 April). The BWA consider the cause of this crack to be thermal shock as the ambient temperature fell to near or possibly below 0℃ on the morning of 10 April 2012.

As the surface clean up continued for the recommencement of placing RCC, additional cracks were identified across adjacent monoliths. The last of these was identified on 3 May where it appears to have terminated about midway through the monolith containing the intake tower. The timing of when these cracks occurred is not known but is suspected that they formed over the Easter weekend or some time thereafter as generally cooler ambient conditions were experienced. The cracks are located at approximately 20 to 25m downstream of the upstream face, or 15 to 20m from the downstream face, (at RL511.3m). The locations of the crack are shown in Appendix A.

It is conceivable that the monoliths to the right of this last observed cracked monolith may also contain cracks, however one layer of RCC was placed in this area on 20th April to bring a low area up to the general level of 511.3 m AHD. The area was thoroughly inspected before the RCC was placed and no cracks were found. The right abutment sees the most sun of any part of the dam, which would have limited the extent to which this part of the dam cooled. The heat generated by hydration of the small amount of RCC would also have assisted to protect the surface.

The crack adjacent to the left abutment was investigated by drilling to about a depth of 450 mm. The crack was visible in the base of this hole. Cores over the cracks were difficult to retrieve with the simplistic single tube coring rig used. A more extensive coring campaign to ascertain the depth of the cracks was therefore not undertaken.

All cracks remained relatively tight with the maximum measured surface width being 0.9mm wide.

Assessment for Crack to Propagate

Downward Propagation

The extent to which the cracks have propagated below the 511.3 surface is unknown as there was no opportunity to undertake any investigative drilling. This was due to the lack of a suitable drilling rig and the urgency to recommence

RCC placement (both as a means of applying thermal protection to the surface and to limit the commercial impacts of the delay). However it has been assumed that the crack will eventually propagate to the foundation. This assumption is supported by the original thermal stress analysis which indicated that areas of tension in the upstream / downstream direction will develop at the base of the dam as the RCC cools. It is hypothesised that given the dam is cracked, the estimated tensions will be sufficient to promote the propagation of the crack to the foundation.

Upward Propagation

Crack treatment has been put in place to prevent the propagation of the cracks upwards. This is discussed in principal in the BWA memo "ECD - Cross Valley Crack in Monolith D" dated 30 April and subsequently modified by Site Instruction issued 5 May 2012 (attached in Appendix B).

Additional thermal modelling has been undertaken to investigate the likelihood of the cracks propagating through to the downstream face and to assess the stability of the dam assuming it has cracked through to the foundation. The analysis is discussed in greater detail below.

Thermal Analysis of Cracked Section

Description of the Model

To assess the adequacy of the defensive measures constructed at the top of the cracks at RL 511.3 the BWA has undertaken additional finite element thermal analyses of the dam, including the modelling of the cross valley crack. At this stage only the maximum section has been considered. The crack has been modelled to extend from the foundation to 510.8 m AHD (the model assumes 1200 mm lifts to simplify the analysis and this is the nearest left surface to the actual 511.3 m AHD. This discrepancy is not considered to be significant). The crack has been modelled with elements that can transfer shear and compressions across the crack. This assumes that the crack does not open up to the point that shear can no longer be transferred.

The material parameters adopted are unchanged from the analysis discussed in BWA, 2011.

Modelling undertaken in January 2012 (BWA,2012) attempted to calibrate the FE model with the recorded temperatures within the partially constructed dam. This required the rate of convection to be adjusted down in the model to achieve a similar rate of temperature rise as that experienced by the dam. This rate of convection has been used in the models.

The construction program has been modified to reflect the actual construction rate up to RL 511.3 m AHD and the programmed rate above this level.

No attempt has been made to model the actual ambient conditions. The long term average temperatures have been used. This was not considered critical, in that although the cold nights are considered to be the cause of the cracking, the model assumes the dam has cracked and therefore no initiating event is required.

The model has assumed the same internal pore pressure distribution as the original uncracked model, ie reservoir head on the upstream face linearly reducing to atmospheric pressure at the downstream face. This should now be remodelled as the crack will act as a drain and therefore there will be no pore pressure downstream of the crack. For expediency, this was not updated for the current analysis.

The maximum section has modelled the large step in the RCC to accommodate the aerator. This previously has not been modelled, however as can be seen in Appendix A, the nominal position of the top of the crack is within about 10 m of the aerator step. There was a concern that the large step may cause increased stresses locally and promote the propagation of the thermal crack to this part of the downstream face.

Modelling Results
The following sections provide contour plots of the and upstream downstream stress from the model at various ages.

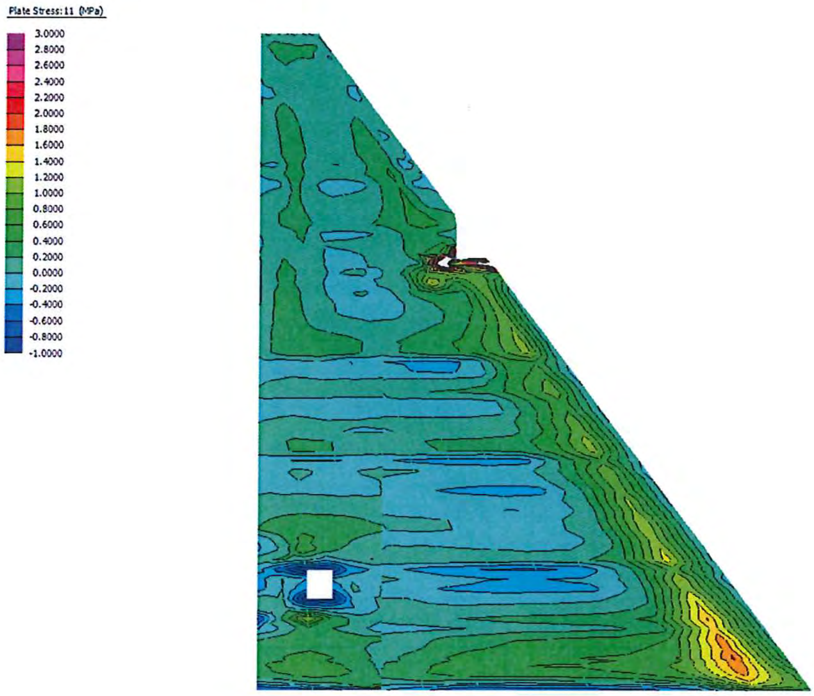


Figure 1 Maximum Principal Stresses at Summer 2012/3 (End of Construction)

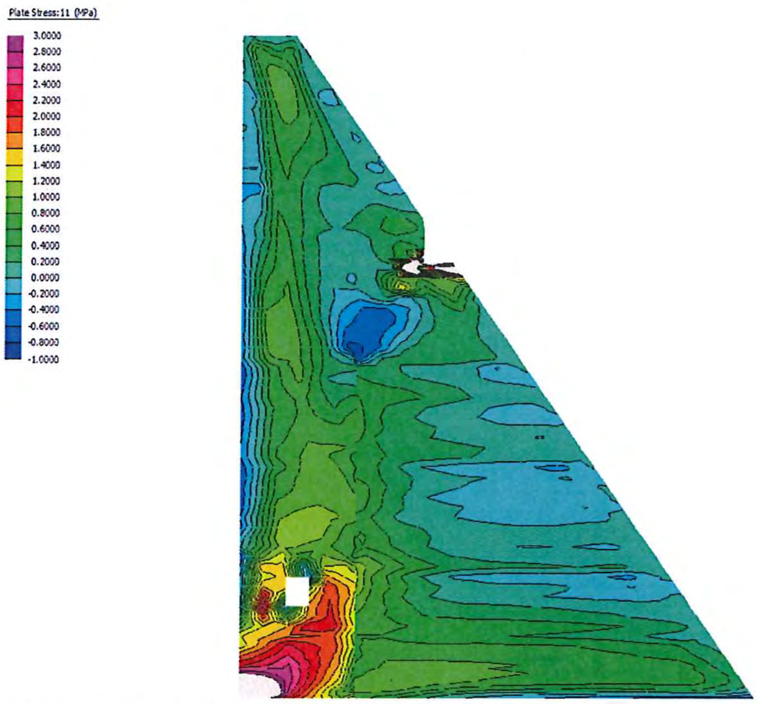


Figure 2 – Maximum Principal Stresses at Summer 2013/14 (first filling)

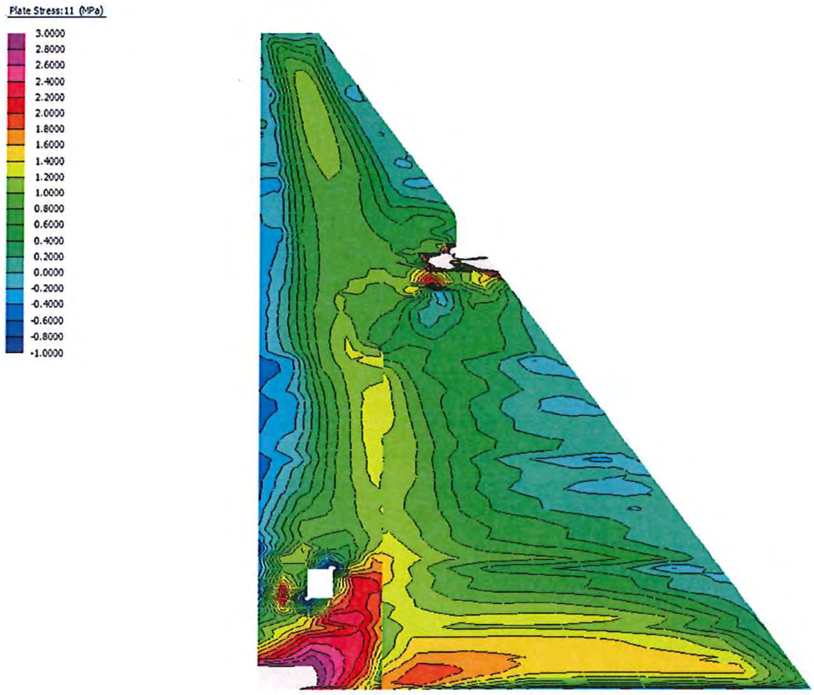


Figure 3 Maximum Principal Stresses at Summer 2030/1

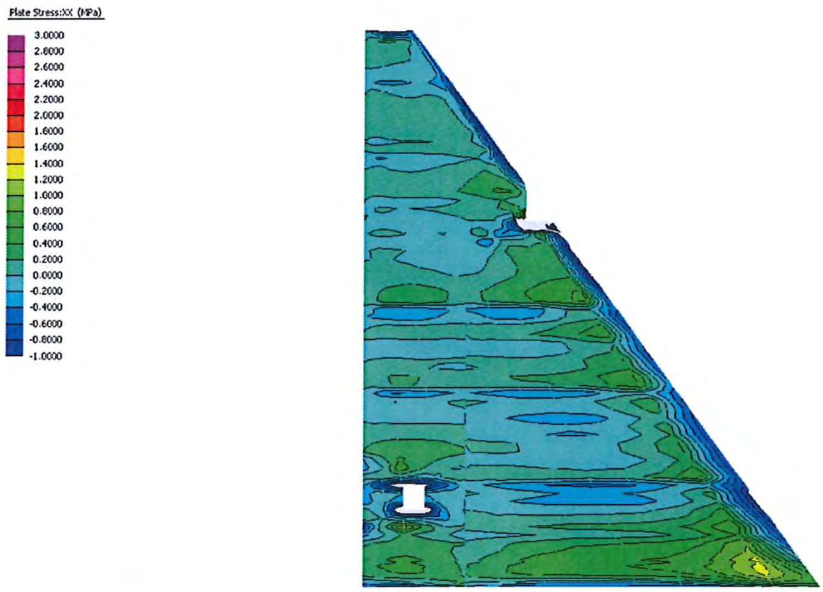


Figure 4 - Upstream – Downstream Stresses Sxx at Summer 2012/3 (End of Construction)

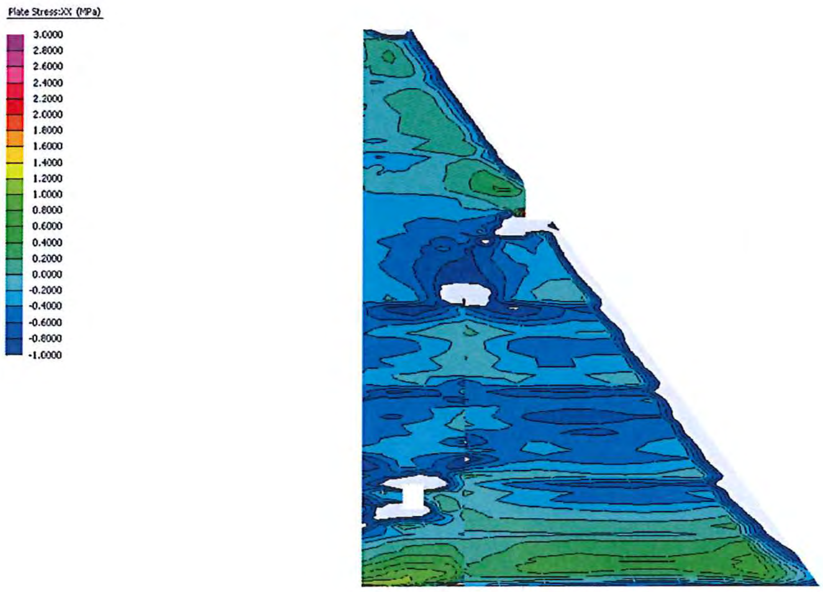


Figure 5 – Upstream – Downstream Stresses Sxx at Summer 2013/14 (first filling)

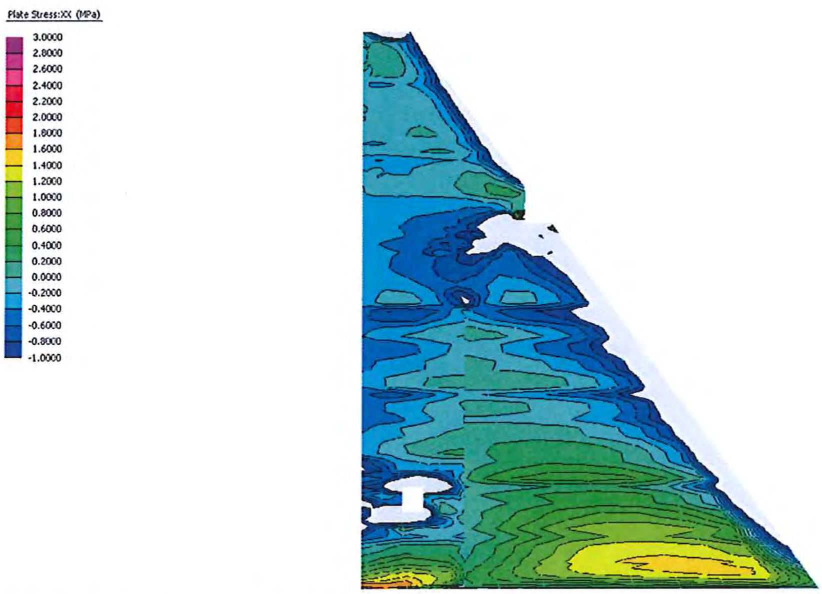


Figure 6 - Upstream – Downstream Stresses Sxx at Summer 2030/1

Discussion

As can be seen in the above plots, significant tensile stresses will not be developed above the crack. The maximum principal tensile stress occurs in the summer of 2031/2, with a magnitude of approximately 1 MPa, (within the capacity of the concrete). Stress concentrations may develop at the tip of the crack, however the sand "crack stopper" will reduce the risk of it propagating and the reinforcement will provide additional tensile strength in this vulnerable area.

Furthermore it would appear that the aerator step does not cause stress concentrations and therefore this should not promote the extension of the existing crack.

Further Analysis

The above analysis has been undertaken as a check that the defensive measures employed to prevent the crack from propagating upwards are adequate and not as an overall assessment of the impact of the crack on the stability of the dam under a range of loads. To assess the long term impact of the cracking and if any additional strengthening or stabilising works are required, the following analysis will be done:-

- Abutment section thermal analysis
- Maximum section stability analysis – flood loading
- Maximum section stability analysis – flood loading – crack subject to full hydrostatic pressure
- Maximum section MDE seismic loading

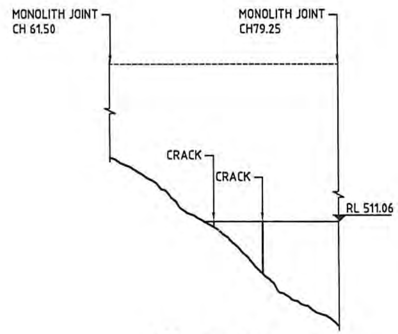
The stability analysis of the cracked model, completed as part of the original thermal analysis (BWA, 2011), considered full supply level loading only. The results of this analysis however indicated that the stresses in the cracked model with FSL loading is well within the capacity of the dam and the dam therefore behaves as a monolith, as intended in the original design. For FSL loading the cracks were therefore found not to affect the dams safety. A similar outcome is anticipated for the stability analysis of the extreme flood load case.

Because of the dynamic loading and the difficulty to model the true behaviour of the dam during a seismic event, it is difficult to predict how the dam will behave as a cracked section. However, following a review of the previous seismic analysis and the behaviour of the dam in the vicinity of the crack in the thermal analysis, it is expected that the dam will behave monolithically or close to monolithically during a seismic event, and therefore no additional strengthening works will be required. However this can not be confirmed until the seismic analysis has been completed.

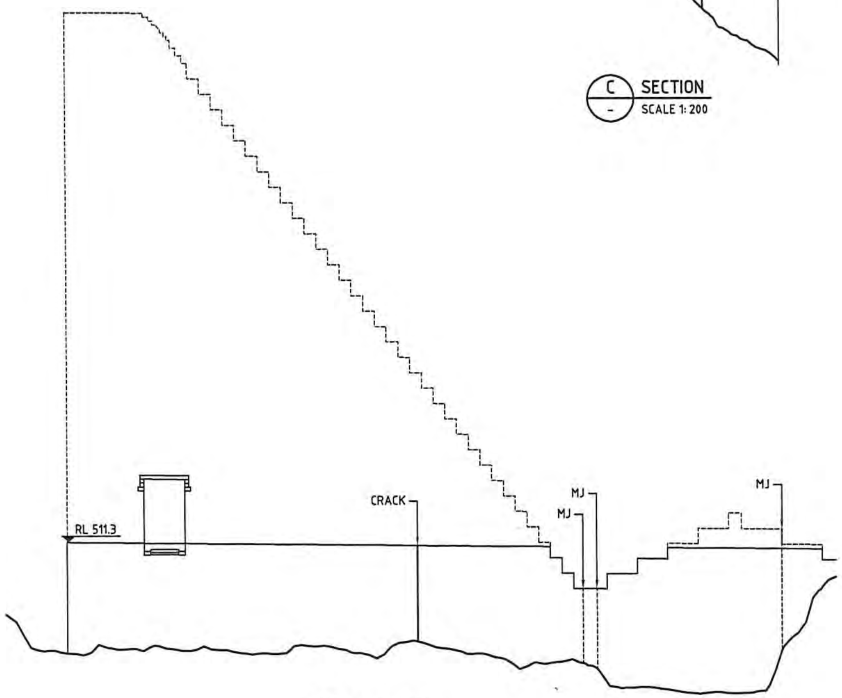
It is anticipated that the outstanding analysis will be completed by the end of August 2012.

Appendix A

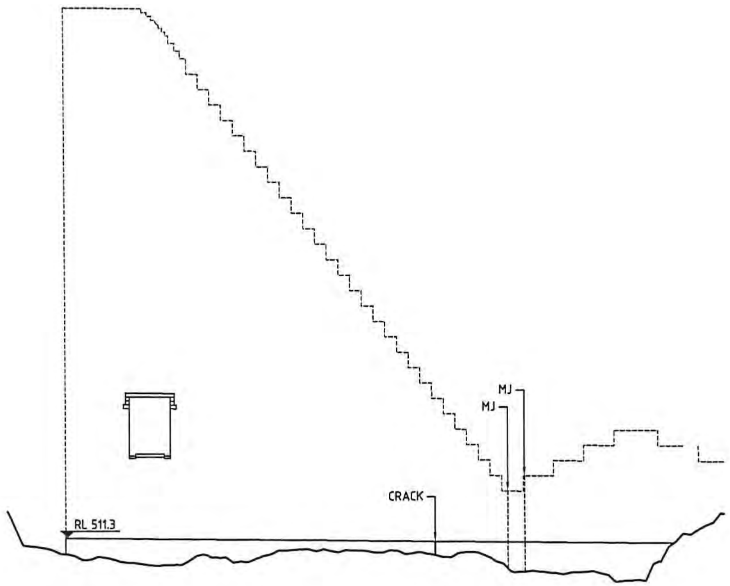
Cracks - Plan and Sections



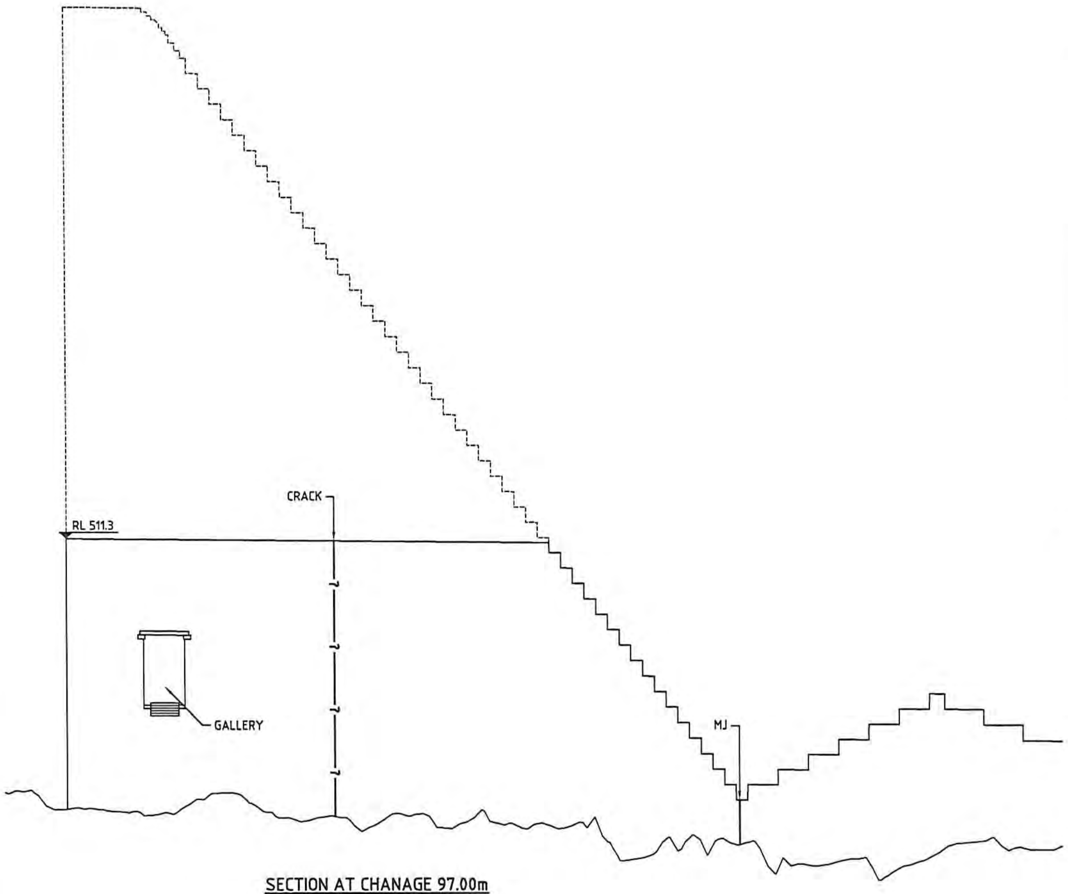
C SECTION
SCALE 1: 200



A SECTION
SCALE 1: 200



B SECTION
SCALE 1: 200



SECTION AT CHANAGE 97.00m

E SECTION
SCALE 1: 200

SECTION AT CHANAGE 107.5312m

F SECTION
SCALE 1: 200

0 2 4 6 8 10m
SCALE 1:200 AT ORIGINAL SIZE

MJ
MJ
CRACK (APPROX)
GALLERY
RL 511.3
SECTION AT CHANAGE 124.00m
G
SECTION
SCALE 1:200
0 2 4 6 8 10m
SCALE 1:200 AT ORIGINAL SIZE

1

Interim Incident Report – Cotter Dam flooding during construction – 1 March – 5 March 2012

Purpose:

Extreme rainfall in the Canberra region and Cotter River catchment in particular over the week of 26 February to 4 March 2012, resulted in the Cotter Dam (under construction) being overtopped by up to 2 m of water.

ActewAGL and ACTEW classified this incident as a *'Level C – White Alert – Unusual Indent'* under the Dam Safety Emergency Plan – Cotter River Dams Addendum 2 v 3 (Dec 2011) – Table 4 item 2 – on the basis of the 'rate of rise of water against the dam' exceeding 500 mm per hour and on water level being within 3 m of the current level of the structure.

This incident report provides the Technical Regulator covers the incident for the period from 1 March to 5 March 2012. A final report will be issued once water stops overflowing the dam, detailed inspections undertaken and damage assessment has been completed. A final report is not expected to be issued until mid April 2012.

Background

The Enlarged Cotter Dam (ECD) project consists of the design and construction of a new dam immediately downstream of the existing Cotter Dam that will increase the storage capacity of the existing reservoir. In addition, two saddle dams are required on the ridge forming the right abutment of the main dam. The new dam, once completed, will have a full supply level of RL 550.8 mAHD compared to the full supply level of RL 500.7 m AHD of the old dam.

At the time of this incident report the new dam has been constructed to a level of RL 511.3 mAHD, 10.5 m above the crest level of the old dam.

The new dam is being constructed of roller compacted concrete (RCC). It has a 3 m diameter diversion conduit constructed through the base of the left abutment which has a design flow capacity of 25 m^3/s (2,150 ML/d).

Prior to the rainfall event the water level was below the spillway crest level of the old dam at approximately RL 499.7 mAHD and water was being released and bypassing the new dam via the 3 m diameter diversion pipeline at a flow rate of approximately 300-400 ML/d. Approximately 11 GL of air space existed in the reservoir prior to the event.

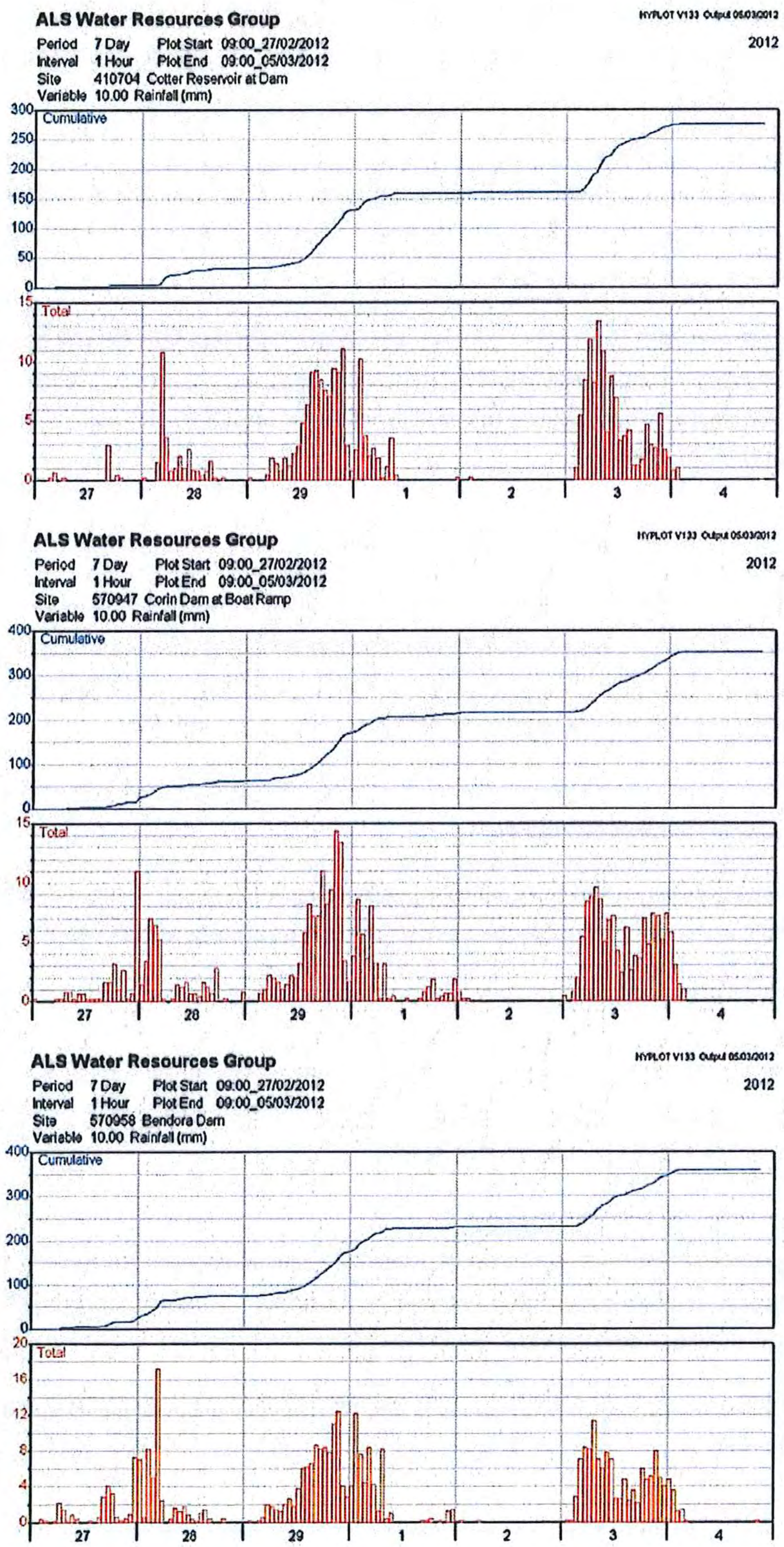
Rainfall over the Incident Period

Over the 7 day period 27 February to 4 March a total of approximately 270 mm of rain was recorded to at the Cotter Dam. Rainfall at upstream dam sites (Corin and Bendora) on the Cotter River exceeded 350 mm over the same period. See Figure 1.

The Bureau of Meteorology (BOM) has reported that this event was the largest 7 day rainfall for Canberra since 1950.

Interim Incident Report – Cotter Dam flooding during construction – 1 March – 5 March 2012

Figure 1 - Rainfall plots for Cotter, Corin and Bendora Dam sites



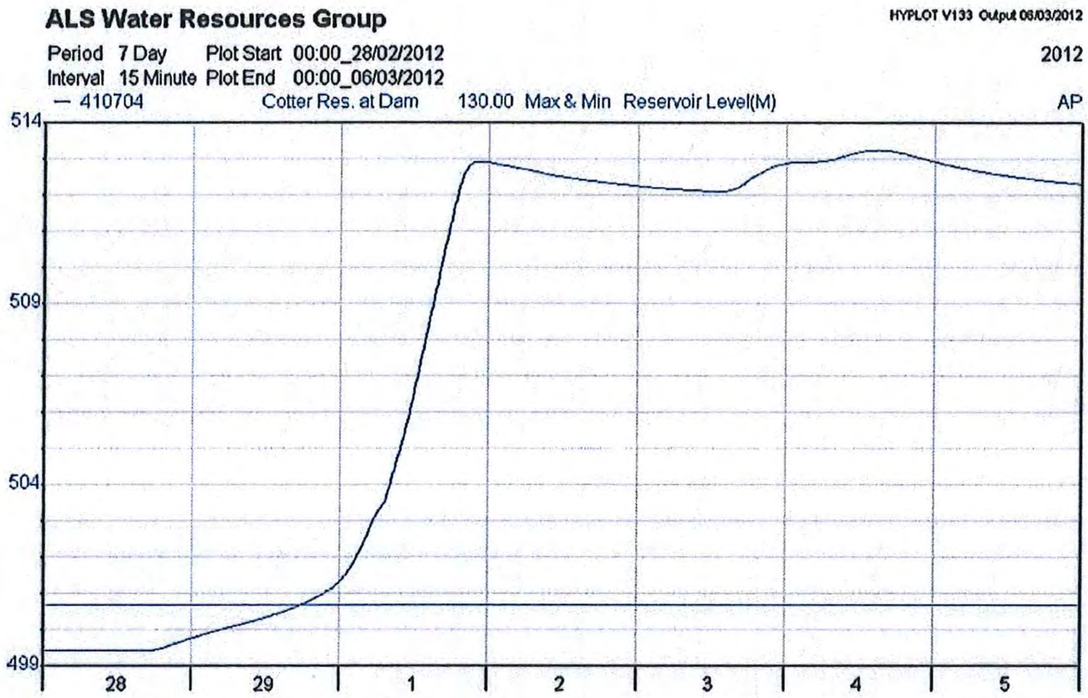
Interim Incident Report – Cotter Dam flooding during construction – 1 March – 5 March 2012

Cotter Reservoir Level over the period

At the commencement of the rainfall event the Cotter Reservoir was at a level of approximately RL 499.7 mAHD.

The reservoir level commenced to rise with the rainfall over the 27-28 February and then rapidly rose on 1 March to an initial peak of RL 512.91. From this point the level fell and reached a low of approximately RL 512.1, then rose again with rainfall on 3 March to a new high of RL 513.24. See Figure 2.

Figure 2 - Upstream water level at Cotter Dam

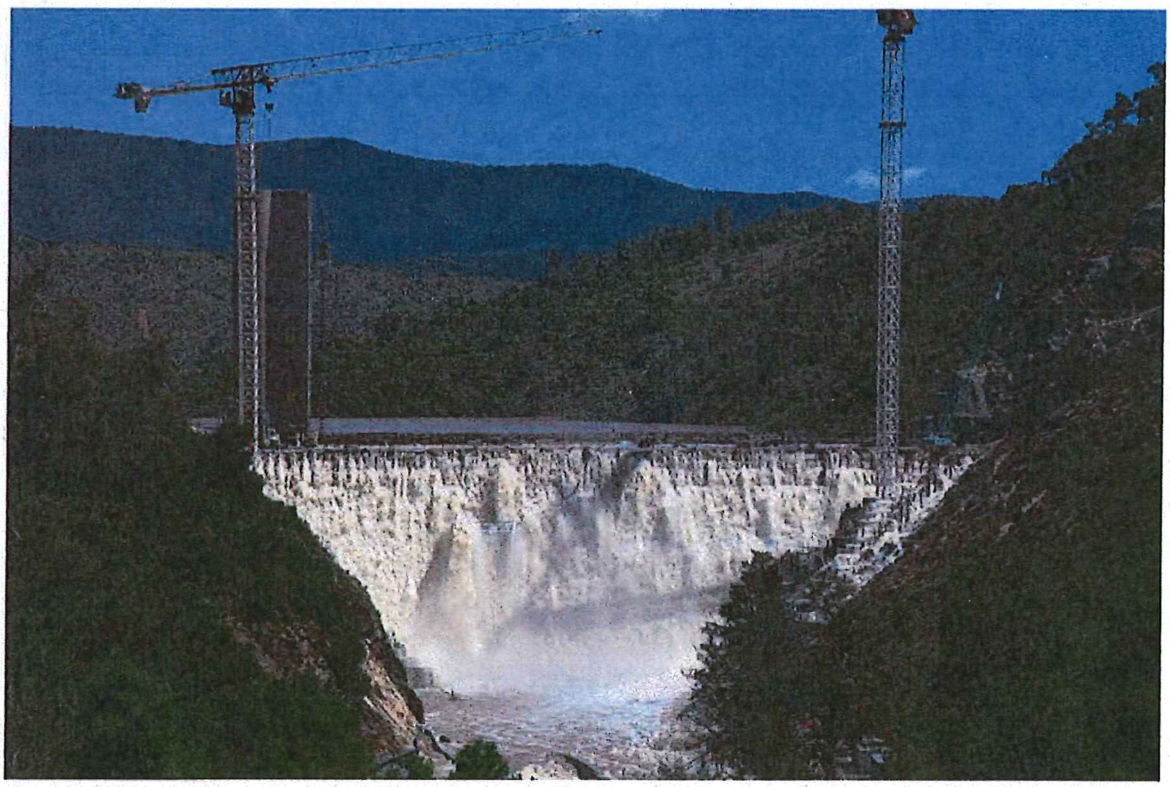


The photographs below - Figure 3 and Figure 4 show the dam site at peak flow on Sunday 4 March and Monday 5 March.

Interim Incident Report – Cotter Dam flooding during construction – 1 March – 5 March 2012

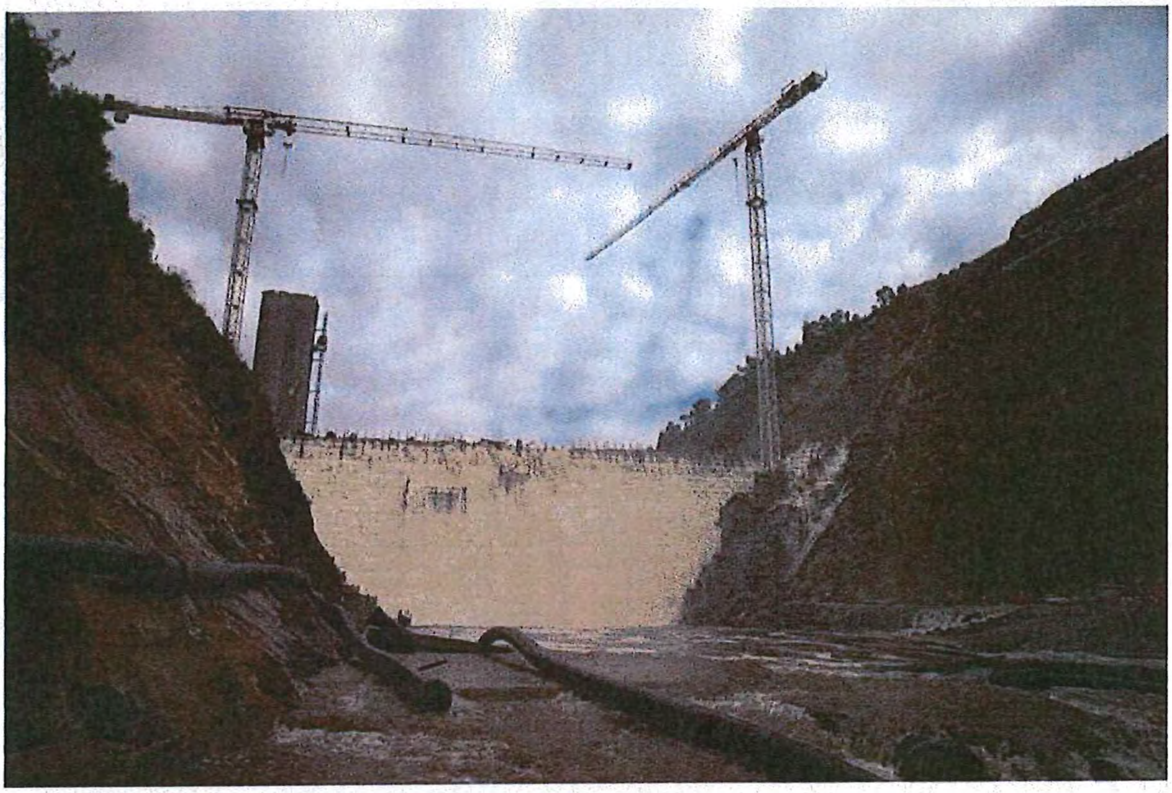
Figure 3 – Cotter Dam overflow at approximately peak flow – afternoon of 4 March 2012

Figure 4 – Cotter Dam looking upstream - 5 March 2012



Interim Incident Report – Cotter Dam flooding during construction – 1 March – 5 March 2012

Figure 5 - View of Dam from downstream - 6 March 2102



Flow Discharge passing the Dam

Flow monitoring for flows passing the Cotter Dam are monitored at the Cotter Kiosk Gauging station located approximately 1 km downstream of the dam.

Approximate peak 15 minute outflows during this event where in the order of 23,500 ML/d (272 m^3/s) on 1 March and 31,700 ML/d (367 m^3/s) on 4 March. See Figure 6.

The annual return interval (ARI) of this event is still under assessment; however, it will be classified as a significant event. (The Cotter Dam 1:100 ARI inflow is 340 m^3/s.)

The calculated volume of water discharged over the dam for the period 1 March until 5 March is in the order of 74 GL. See Table 1 below for daily outflow information.

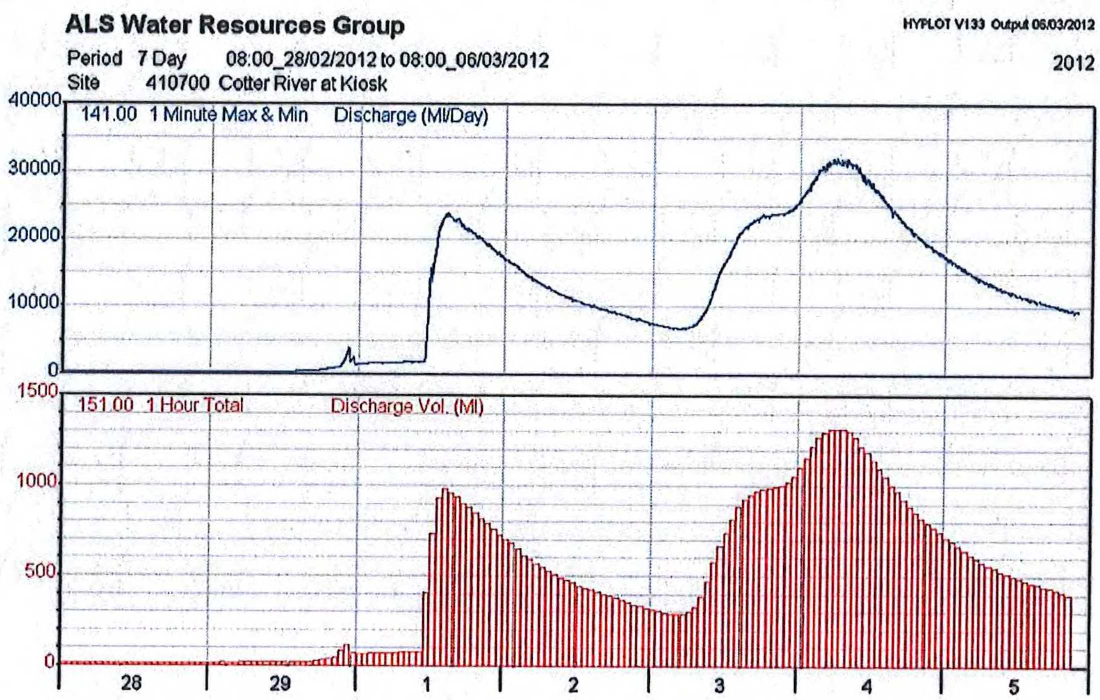
Table 1 - Estimated volumes of water discharged over Cotter Dam

Date	Volume Discharged, ML
1/03/2012	5,220
2/03/2012	15,125
3/03/2012	10,745
4/03/2012	27,189
5/03/2012	15,777
Total	**74,057**

Interim Incident Report – Cotter Dam flooding during construction – 1 March – 5 March 2012

Note: *This gauging station has maximum gauged height of 1.74m (approximately 15,000 ML/d) and this was significantly exceeded during this event, indicating the accuracy of the reported peak flow rates and volumes is likely to be* *approximate* *only.*

Figure 6 - Downstream flow data – Cotter Kiosk Gauging Station



Dam Safety Monitoring during and subsequent to overtopping

ACTEW, via the Bulk Water Alliance, is continuing to monitor the dam during this event.

A range of the planned daily safety inspections have not been possible to be undertaken due to inundation of the dam and will not be undertaken until water ceases to overflow the dam; however daily visual inspections are being performed.

Once water stops overflowing and when it is safe to access the dam, a detailed physical inspection will be undertaken and documented, and will form part of the dam's safety inspection record.

Daily visual inspections have not identified any matters of concern.

During the event the Cotter Road was closed due to localised flooding at the bridge and also to ensure public safety in the event of rapid failure of upstream formwork causing a flood wave on top of the elevated water level.

Interim Incident Report – Cotter Dam flooding during construction – 1 March – 5 March 2012

Next Actions

This report will be added to and updated once water stops overflowing the dam and a detailed physical inspection will be undertaken. In the interim visual daily monitoring of the dam will continue.

Contact Officer

Should you wish to discuss the content of this report please contact me on numbers below or by email.

[redacted]
Owner's Chief Engineer,
Water Security Major Projects
[redacted]

2

Incident Report Update to Technical Regulator

Enlarged Cotter Dam – Flood Recovery

Week Commencing 19 March 2012

Background

Following a significant flood event through the Enlarged Cotter Dam site over the week of 26 February to 4 March 2012, ACTEW Corporation provided an Interim Incident Report to the Technical Regulator via email on Tuesday 6 March 2012. The purpose of this report is to provide an update to the previously supplied report.

A final report will be issued once detailed inspections of the dam can safely be undertaken.

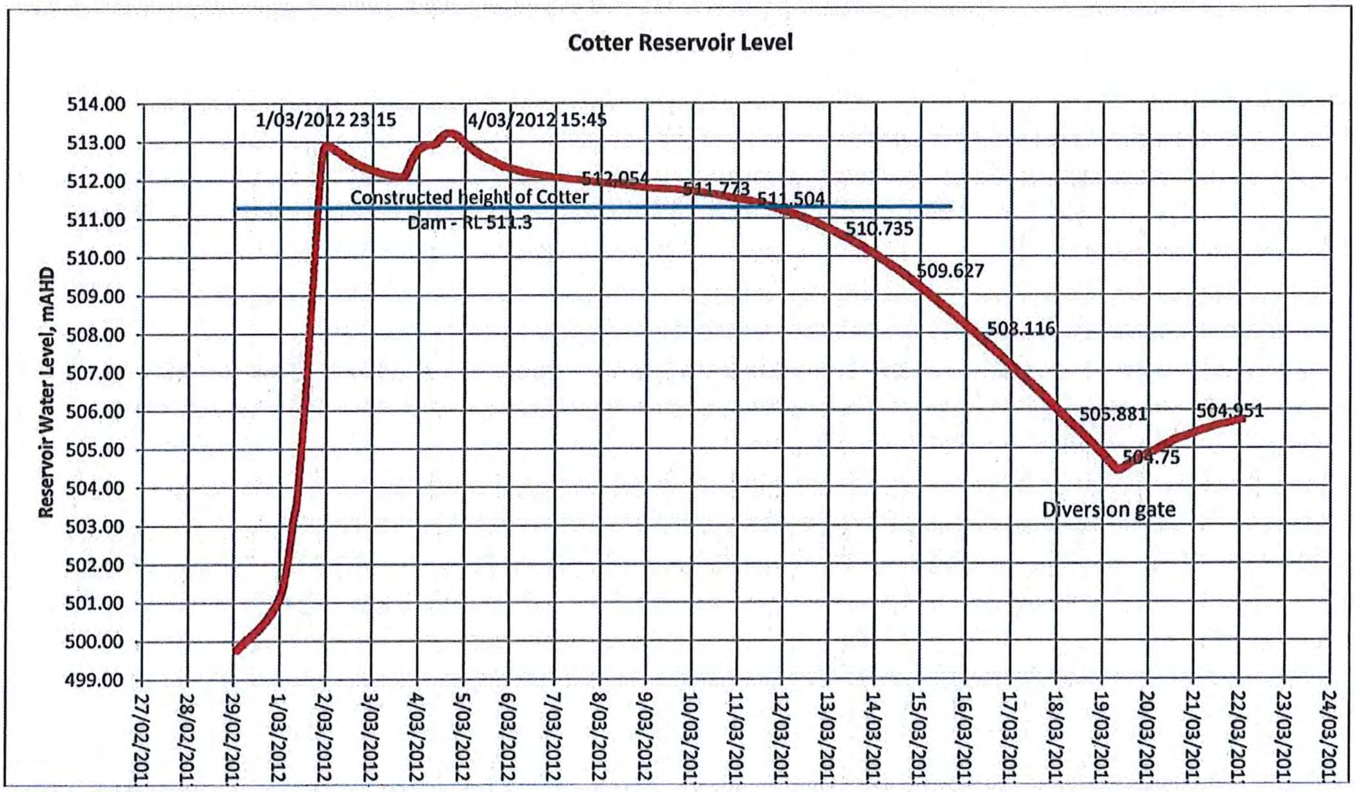
Executive Summary

- Access to the crest of the dam was regained by BWA personnel on Tuesday 13 March.
- Current reservoir level is as of 19 March at 6:50am is 6.9m below the crest of the dam.
- Preliminary assessments of flood damage to construction infrastructure, plant and equipment are currently in progress. Where possible, some rectification and clean up works have commenced.

Safety

- Safe access back on to the crest of the Enlarged Cotter Dam was gained on Tuesday 13 March.
- Current focus has been on determining safe access requirements to facilitate preliminary assessments of flood damaged areas wherever accessible. To this end engineering assessment of the valley abutment and removal of loose debris has commenced.
- Preliminary inspections and assessment of plant, equipment and tools stranded atop of the dam during the flood event has commenced. A summary of findings to date has been summarised below.
- Additionally identified key issues under active management include the need to assess the extent of damage to tower crane power supply and satellite electrical distribution boards. Previously reported issues which remain active are:
    - Risk of further flooding;
    - Floating timber removal from Cotter Reservoir;
    - Reinstatement of scaffolding and general access; and
    - Assessment of general bank stability across the ECD site.

State of River and Catchment



- As at 22 March, the Cotter Reservoir level is at RL505.75m, approximately 5.5m below crest level.
- The Cotter River diversion gate has now been closed to ensure it remains static no lower than RL504m. This is required to facilitate barge access across the top of the old Cotter Dam in order to remove accumulated timber. This work is currently in progress.
- A scour valve off the Bendora Dam pipeline, which bypasses the Cotter catchment and releases water directly into the Murrumbidgee River, has also been operated. The purpose of which is to marginally accelerate the drawdown of Bendora Dam.
- Following completion of these works, the diversion gate will be opened to regain the maximum extent of drawdown possible.

Preliminary Damage Assessment

- Preliminary assessment of the impact of the flood on plant and infrastructure in areas either safely accessible or which have become visible can be summarised as follows:
  - ***Dam Structure***
    There are no visual signs of damage to either the structural integrity or facing on the main dam wall. However access to the internal gallery is currently not possible.
  - ***Heavy Plant on top of dam wall***
    Plant found to be in working order has included; mobile crane, both dump trucks ("moxies"), one of two bull dozers, grout truck, paving machine, 5t & 8t excavators. There also appears to be no apparent damage to RCC hopper structure. Plant identified as irreparable and

requiring replacement include; two small rollers, two large rollers, Elevated Work Platform, and bedding tipper. Plant identified as repairable on the crest of the dam wall include; broom tractor, 12t excavator and second dozer. All plant can be lifted of the dam wall using Tower Crane; however the two large rollers may need to be dismantled first.

- ***Small Plant and Tools***
  Assessment as to whether power tools, compressors, blowers etc remain in working order is currently in progress. However a significant proportion of this equipment is expected to need replacement.

- ***RCC Formwork***
  The bulk of all structural elements of formwork appear to be in good condition with the exception of a few members impacted by logs. However, all plywood has either been stripped or damaged beyond reuse.

- ***Downstream Access***
  All downstream face access is damaged and will require replacement and/or rebuilding.

- ***Tower Cranes 1 (left) and 2 (middle)***
  Assessment of tower cranes has not been able to be undertaken due to damaged downstream face access. However visual inspections suggest the accumulation of debris within the tower shafts as well as missing bottom sections of access stair cases will require attention. Damage to the power supply cable to Tower Crane 2 as well as power distribution boards will also need to be addressed. Advice is currently being sought from the crane supplier as to what other technical requirements/checks are needed to bring the cranes back into safe service.

- ***Stilling basin, Gallery, Intake Tower and outlet Works***
  Access to these work areas is currently precluded due to current water levels.

- ***Diversion Pipe and Downstream Coffer Dam***
  The Diversion pipe remains operational however its discharge capacity is currently constrained due to an exposed pipe joint. Until such time as this is backfilled, the diversion gate will be used to regulate the flow in order to prevent further damage. Reinforcement of the pipe bench and reconstruction of the downstream coffer dam will also be required.

- ***Cotter Precinct Works***
  Damage has been sustained along the lower discovery trail access track including stripping of asphalt surfacing and undermining of the access track and erosion of bank protection works. A small section of the lower trail handrail has also been damaged by a fallen tree. In addition, the low level pedestrian bridge across the Cotter River has been damaged as have some large sections of pavement in Cotter Avenue. Exposure of short segments of the Murrumbidgee to Cotter Return e-flow pipeline has also been referred to ActewAGL operations.

- Key Rectification activities undertaken week commencing 19 March included:

  - Procurement of barges for removal of floating timber;
  - Clearance of logs on upstream and downstream formwork;
  - Rebuilding of access down left abutment to Tower Crane 1;
  - Checking of Tower Crane 1 electrical infrastructure;
  - Removal of debris at base of Tower Crane 1 (using rope access);
  - Recommissioning of Tower Crane 3 (right abutment);

- Reconstruction of stilling basin access road to coffer dam;
- Condition assessment of river diversion pipeline;
- Removal of damaged sections of formwork; and
- Recommissioning, repair and or removal of RCC heavy plant (affected by flood).

- The recovery program is predicated on clearing debris and removal of downstream face formwork progressively from the left to the right abutment. Once sufficient clearance has been gained against the left abutment, work will commence on regaining access down the left abutment to the base of Tower Crane 1. From this point, reconstruction of access across to Tower Crane 2 (from Tower Crane 1) will also be established. These access paths will enable work to proceed on recommissioning of the tower cranes.

- Other work fronts to occur concurrently in this period will include; removal of logs and timber in the reservoir up against the formwork, repair to plant and machinery as well as reinstatement of the haul road into the stilling basin.

- Opportunities to bring forward works in other areas of the ECD site are also being considered such as construction of the permanent boat ramp within the quarry, permanent access road to the dam crest from the left abutment as well as repair work in the Cotter Precinct.

3

Environment and Sustainable Development Directorate

Enlarged Cotter Dam

Site Visit 18th April 2012

The February-March Flood

The Canberra region and Cotter River catchment in particular was subjected to heavy rainfall over the week of 26 February to 4 March 2012. The flood inflow exceeded the diversion tunnel capacity of 25 m3/sec and the partly constructed new Cotter Dam was overtopped by up to 2 m of water. At this time, the new dam had been constructed to a level of RL 511.3 mAHD, 10.5 m above the crest level of the old dam.

ActewAGL classified this incident as a '*Level C – White Alert – Unusual Indent*' under the Dam Safety Emergency Plan – Cotter River Dams Addendum 2 v 3 (Dec 2011) – Table 4 item 2 – on the basis of the 'rate of rise of water against the dam' exceeding 500 mm per hour and on water level being within 3 m of the current level of the structure.

A preliminary incident report has been prepared by Bulk Water Alliance (BWA) covering the incident for the period from 1 March to 5 March 2012. A final report is expected in late April. The flood event is estimated to have an annual exceedence probability of around 1 in 100.

Background

The BWA planning for river diversion during construction provided a diversion conduit to enable work to proceed without interruption during normal river flows and small floods. Large floods were to be allowed to overtop the dam.

This is a standard approach for roller compacted concrete (RCC) construction and takes advantage of the ability of RCC to handle extended flood overtopping without significant damage. The partly completed dam has a large width compared with its height and hence at this stage of construction has a very high margin of safety. Hence this is an economic decision which balances the clean-up and delay costs against the provision of much greater diversion capacity.

Site Inspection 18 April 2012

The dam site was inspected by [redacted] and [redacted] on 18 April 2012 in the company of [redacted]

The two metre deep flood waters caused no damage to the partly-completed dam, as would be expected. It has caused some damage to the temporary works, including formwork on both the upstream and downstream face of the dam, the scaffolding and access ladders, the two tower cranes and the downstream access road. It also damaged to the machinery that could not be removed from the top of the dam. This damage had been considered in the planning and the cleaning and repair works have delayed the resumption of RCC placement.

The delay in RCC placement combined with cold weather has allowed the top layers of the dam to cool more quickly than desirable. This caused a small crack in the RCC on the left abutment. BWA have prepared a detailed treatment for the crack that will be considered by their Technical Review Panel (TRP).

As construction of the RCC will now proceed through the coldest and wettest parts of the year there are some issues for the TRP to consider. Whilst placement at this time of the year is likely to result in lower maximum temperatures in the concrete (and hence lower risk of cracking), the effect of any delay is now likely to result in faster surface cooling and an increased risk of vertical cracking (particularly close to the abutments). The adoption of an unusually high lift height for the RCC should also be reconsidered to ensure that the layers are placed with a minimal delay between successive lifts to minimize surface cooling. There are not likely to be any safety issues arising from the lift height and any excessive cooling will merely result in inter-lift leakage.

It is disappointing that the Enlarged Cotter Dam is not included in the excellent dam safety management program operated by ACTEW (currently ActewAgl). BWA does carry out inspections and monitor the condition of the partly completed dam but a regular review by the ACTEW dam safety team would give greater assurance that the transition to operations would be smooth. The team would also be able to assist with the correct placement of instruments to ensure that the long-term periodic dam safety inspections can be well informed and begin to load the behavior of the dam during construction into the corporate data base. This is not to take anything away from the diligent inspections carried out by BWA who should be complimented for discovering the very small surface exposure of the left abutment crack.

Resumption of RCC Placement

RCC placement is planned to resume at the end of the month. Consideration will need to be given to treatment of the existing concrete surface and techniques for placement of the initial RCC layers. A meeting of the TRC review panel is programmed for Monday 23rd April to determine detailed procedures. The issues involved are no more difficult than those encountered in the initial stages of RCC placement on the rock foundation.

Conclusion

The Cotter Dam construction, comprising the existing dam and the new works, appears to have handled the recent floods in accordance with the design provisions developed by the BWA. The new dam has suffered no damage as a result of the flood overtopping. There is some inevitable delay in recommencing construction while clean-up and repair work to access and equipment is undertaken. Some detailed procedures will need to be developed for the recommencement of RCC placement but these will be no more difficult to undertake than those required at the commencement of construction.

There are no dam safety issues associated with restarting placement of the RCC. Some minor issues associated with the changed temperature distribution in the dam will be considered by the design team and reviewed by the TRP at its next meeting.

[redacted] [redacted] Digitally signed by [redacted]
Date: 2012.04.21 12:22:46 +10'00'

[redacted] [redacted]

4

Bulk Water Alliance

Agenda

SUBJECT	Technical Review Panel Meeting No 19 23rd April 2012
LOCATION	ECD Project Office
PREPARED BY	[redacted]
ATTENDEES	[redacted] Constructor Representatives, Owner Representatives, Regulator (Part of the time only)
APOLOGIES OR NOT REQUIRED	

AGENDA ITEMS **SPEAKER**

Day 1

Thursday **23 April 2012**

1 8:15AM **Arrive**

8:30AM Brief Update [redacted]

Construction progress

Flood and associated delays

9.15AM Site Inspection [redacted]

Upstream (View from Rd22)

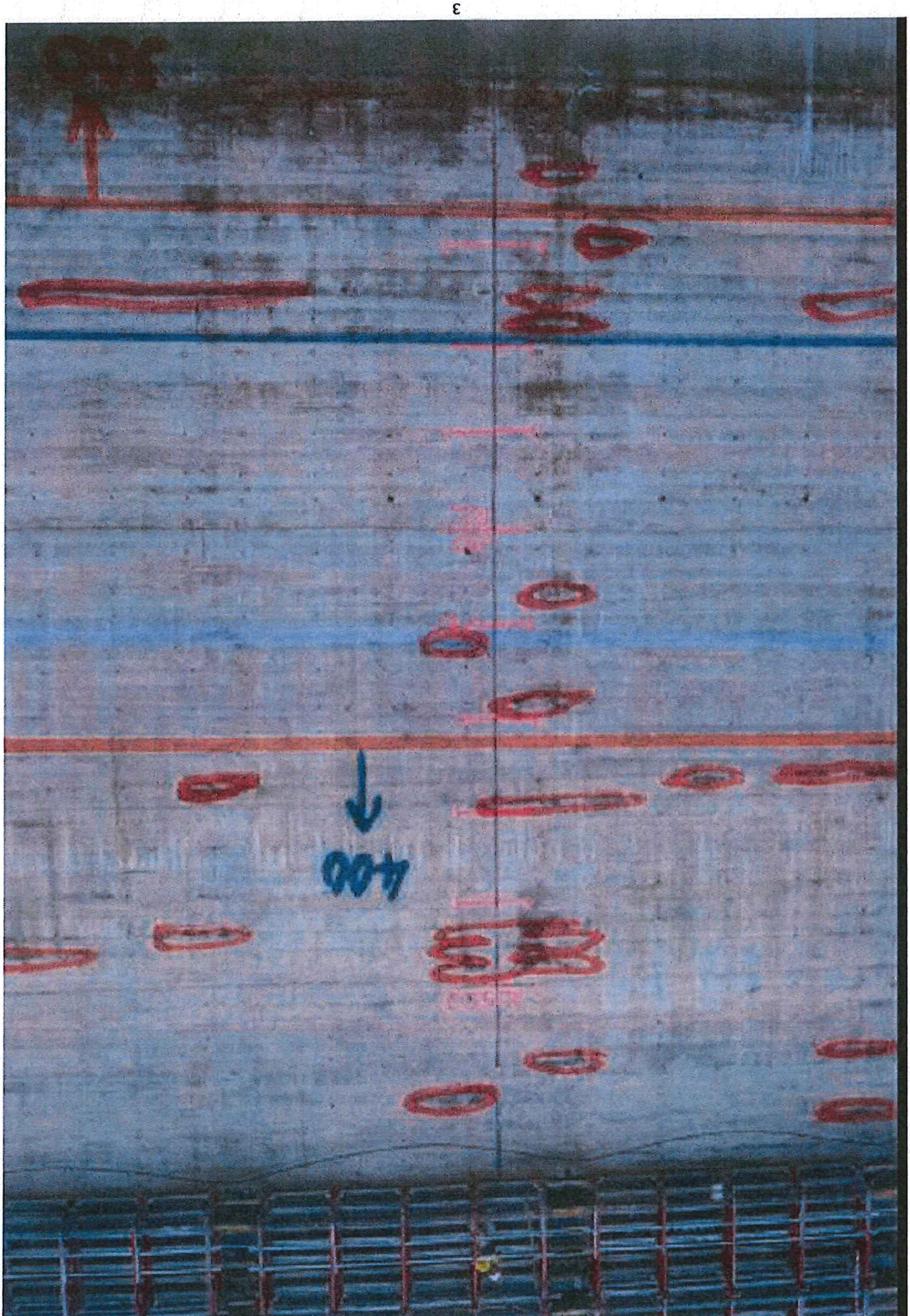
Dam crest and downstream face

11.30AM RCC and CVC results

12:15PM Laboratory – review cores

12.45PM	**Lunch**	
1.15PM	Design	[redacted]
	Remedial Measures	
	- Upstream and downstream face repairs	
	- Seeps into tower	
	- Cracks	
	- Seeps into the tower	
	Restart (thermal issues)	
	Other - Joint treatment, placement temp, winter placement	[redacted]
2.30PM	Construction	
	Shift changes, system changes (e.g. grout batching and delivery) and other	
3.00PM	TRP Review	TRP only
4:00 PM	Wrap Up	All
4:30 PM	**Finish**	


400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390

From: [redacted]
Sent: Saturday, 21 April 2012 12:32 PM
To: [redacted]
Subject: RE: Cotter dam site visit 18 April.

[redacted]

Signed copy of the Report attached

Regards

[redacted]

From: [redacted]
Sent: Friday, 20 April 2012 10:07 PM
To: [redacted]
Cc: [redacted]
Subject: Re: Cotter dam site visit 18 April.

[redacted]

Attached is a copy of the Site Visit Report for April 2012.

[redacted]

I don't recall if you sign these reports. If you do send a revised copy to [redacted]

[redacted]

6

Hartwig, Tasha

From: [redacted]
Sent: Thursday, 26 April 2012 6:36 PM
To: [redacted]
Cc:
Subject: Cotter Dam Flood Report (final)
Attachments: Cotter flood report (26 April 2012).pdf

Please find attached final Cotter Dam flood report, which also includes comments on outcomes of the last TRP meeting on restart of RCC placement and crack repair methodology/treatment.

Note the crack repair methodology/treatment document attached is still in draft form however is not likely to be modified in any significant way following presentation to the TRP last Monday.

If you have any queries please contact me and discuss.

Regards

[redacted]
Owner's Chief Engineer,
Bulk Water Alliance
Water Security Major Projects
[redacted]
Water Security Major Projects Office, Mt Stromlo Road, Mt Stromlo ACT 2611
GPO Box 366 Canberra ACT 2601
www.actew.com.au

ACTEW
CORPORATION

26 April 2012

File: H09/0213/2 Doc #617170

Director General
Environment and Sustainable Development Directorate
GPO Box 158
Canberra ACT 2601

Attention [redacted]

cc [redacted]

Incident Report – Cotter Dam flooding during construction – 1 March – 5 March 2012 (final report)

Please find attached a final report from ACTEW relating to the March 2012 Cotter Dam flooding event and damage assessment. The report also comments on the planned restart of construction in early May 2012.

Purpose:

Extreme rainfall in the Canberra region and Cotter River catchment in particular over the week of 26 February to 4 March 2012, resulted in the Cotter Dam (under construction) being overtopped by up to 2 m of water.

ActewAGL and ACTEW classified this incident as a *'Level C – White Alert – Unusual Indent'* under the Dam Safety Emergency Plan – Cotter River Dams Addendum 2 v 3 (Dec 2011) – Table 4 item 2 – on the basis of the *'rate of rise of water against the dam'* exceeding 500 mm per hour and on water level being within 3 m of the current level of the structure.

This report provides the Technical Regulator covers the incident for the period from 1 March to 5 March 2012 and the recovery actions taken up to the planned restart of placement of roller compacted concrete in early May 2012.

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Background

The Enlarged Cotter Dam (ECD) project consists of the design and construction of a new dam immediately downstream of the existing Cotter Dam that will increase the storage capacity of the existing reservoir. In addition, two saddle dams are required on the ridge forming the right abutment of the main dam. The new dam, once completed, will have a full supply level of RL 550.8 mAHD compared to the full supply level of RL 500.7 m AHD of the old dam.

At the time of this incident report the new dam has been constructed to a level of RL 511.3 mAHD, 10.5 m above the crest level of the old dam.

The new dam is being constructed of roller compacted concrete (RCC). It has a 3 m diameter diversion conduit constructed through the base of the left abutment which has a design flow capacity of 25 m^3/s (2,150 ML/d).

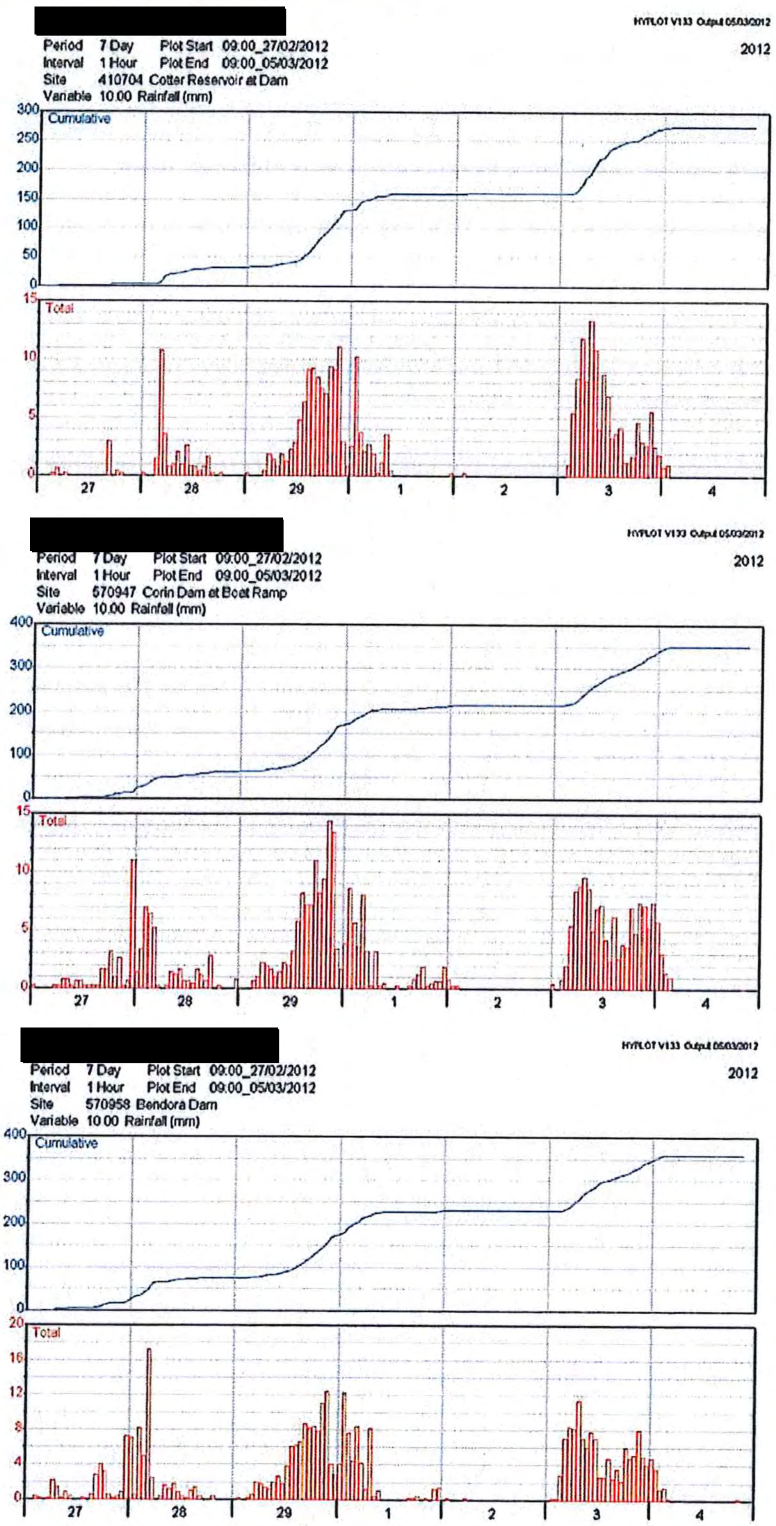
Prior to the rainfall event the water level was below the spillway crest level of the old dam at approximately RL 499.7 mAHD and water was being released and bypassing the new dam via the 3 m diameter diversion pipeline at a flow rate of approximately 300-400 ML/d. Approximately 11 GL of air space existed in the reservoir prior to the event.

Rainfall over the Incident Period

Over the 7 day period 27 February to 4 March a total of approximately 270 mm of rain was recorded to at the Cotter Dam. Rainfall at the two upstream dam sites (Corin and Bendora) on the Cotter River exceeded 350 mm over the same period. See Figure 1.

The Bureau of Meteorology (BOM) reported that this event was the largest 7 day rainfall for Canberra since 1950.

Figure 1 - Rainfall plots for Cotter, Corin and Bendora Dam sites

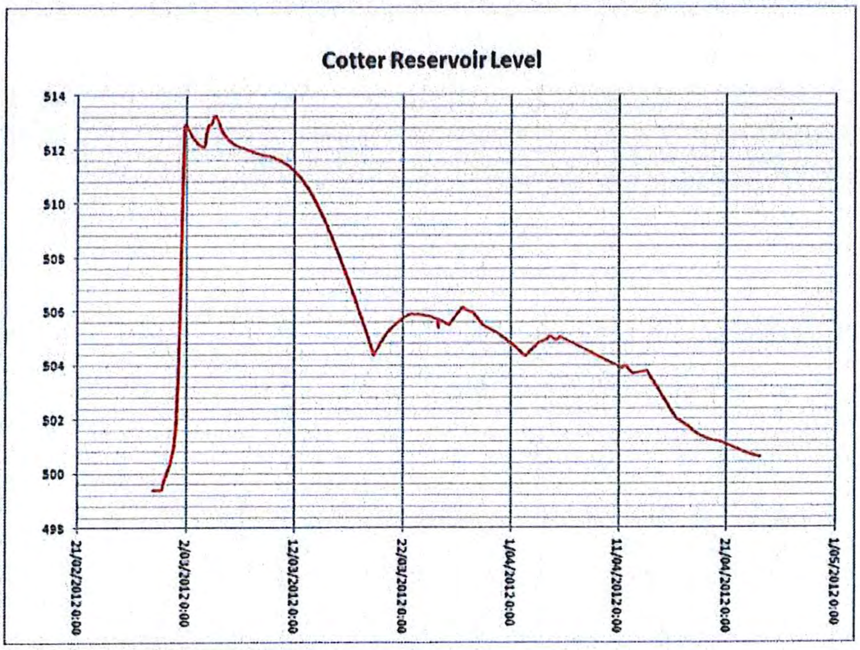


Cotter Reservoir Level over the period 28 February to 24 April 2012

At the commencement of the rainfall event the Cotter Reservoir was at a level of approximately RL 499.7 mAHD.

The reservoir level commenced to rise with the rainfall over the 27-28 February and then rapidly rose on 1 March to an initial peak of RL 512.91. From this point the level fell slightly and reached a low of approximately RL 512.1, then rose again with new rainfall on 3 March to a new high of RL 513.24 at 15:45 hr on 4 March. See Figure 2.

Figure 2 - Upstream water level at Cotter Dam



Subsequent to the flooding event the reservoir level has fallen with the rate of fall being controlled to permit removal of floating timber from between the two dams and then to ensure a slow transfer of full hydrostatic load back onto the old Cotter Dam as the water level downstream of the old dam fell back to and below the spillway crest level. At the time of preparation of this report the reservoir level was approximately 200 mm below the spillway crest of the old dam.

Flow Discharge passing the Dam

The monitoring for flows passing the Cotter Dam is undertaken at the Cotter Kiosk Gauging station located approximately 1 km downstream of the dam.

Approximate peak outflows during this event where in the order of 23,769 ML/d (275 m^3/s) on 1 March and 31,635 ML/d (366 m^3/s) on 4 March. See Figure 3.

The annual return interval (ARI) of this event is still under assessment; however, it will be classified as a significant event. (The Cotter Dam 1:100 ARI inflow is 340 m^3/s.)

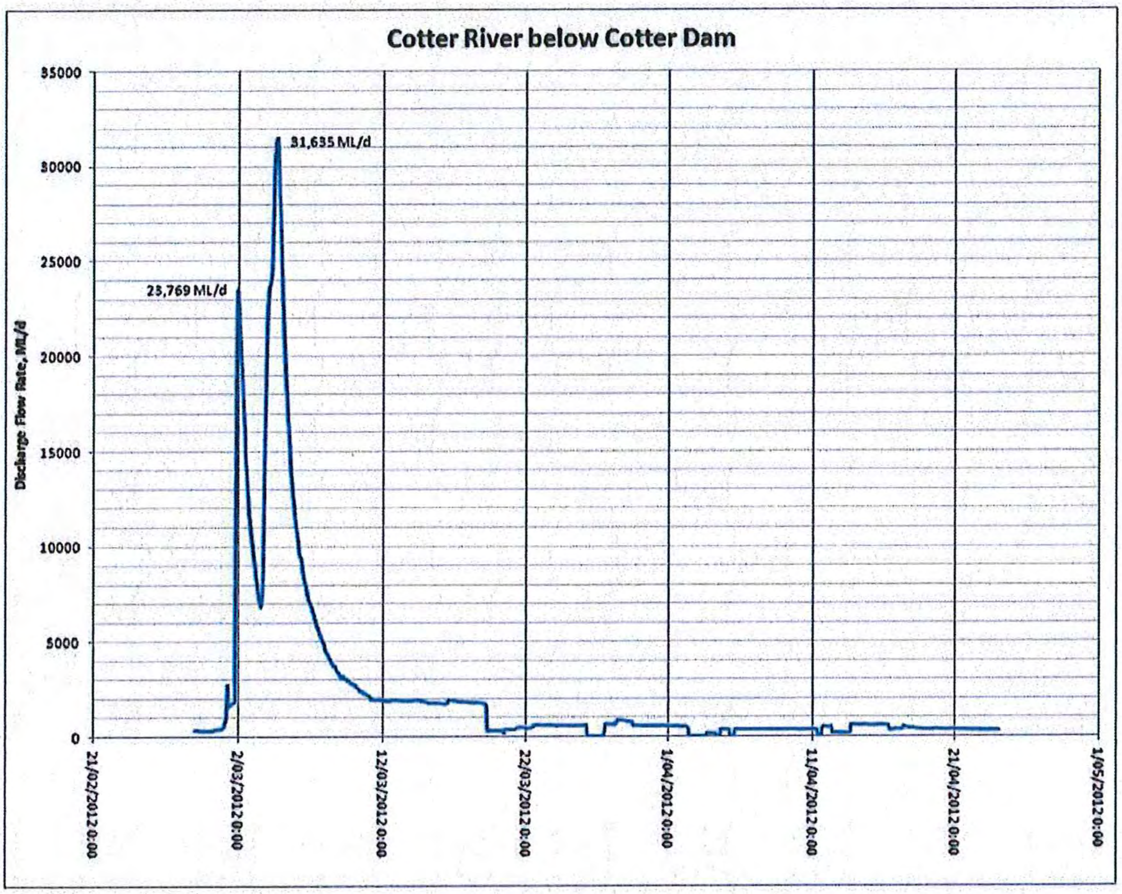
The calculated volume of water discharged over the dam for the period 1 March until 5 March is in the order of 74 GL. See Table 1 below for daily outflow information.

Table 1 - Estimated volumes of water discharged over Cotter Dam period 1 March to 5 March 2012

Date	Volume Discharged, ML
1/03/2012	5,220
2/03/2012	15,125
3/03/2012	10,745
4/03/2012	27,189
5/03/2012	15,777
Total	**74,057**

Note: *This gauging station has maximum gauged height of 1.74m (approximately 15,000 ML/d) and this was significantly exceeded during this event, indicating the accuracy of the reported peak flow rates and volumes is likely to be approximate only.*

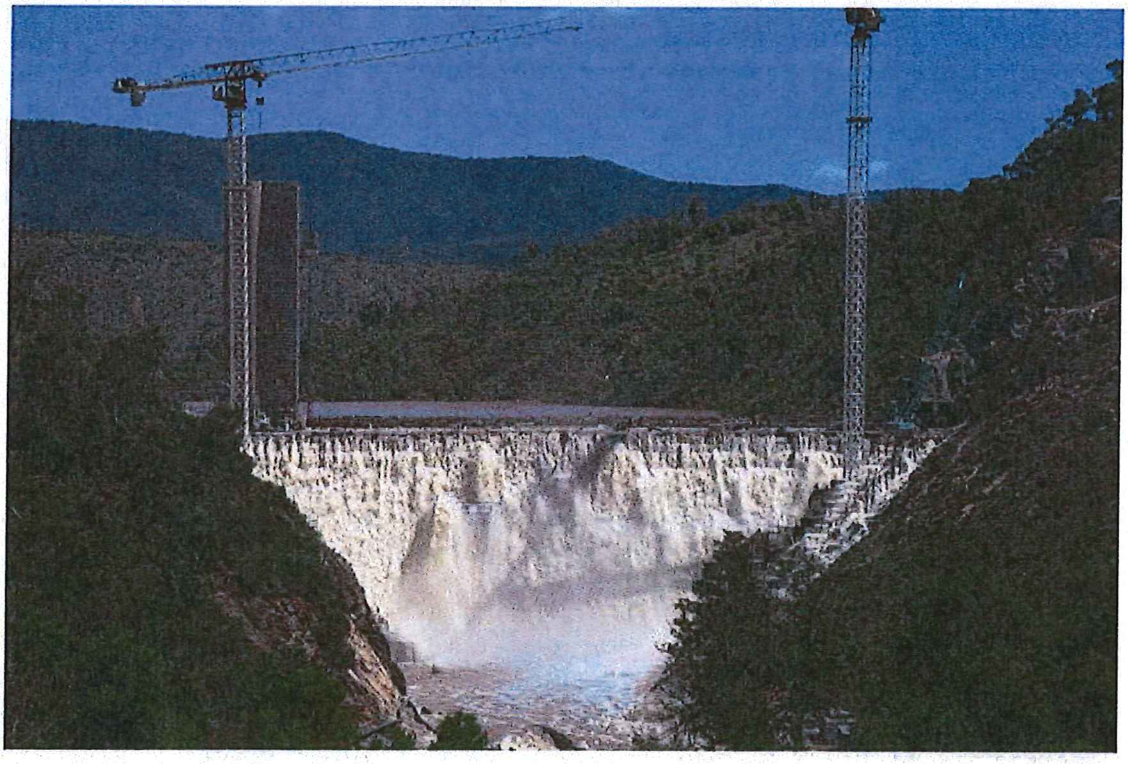
Figure 3 - Downstream flow data – Cotter Kiosk Gauging Station



The photographs below - Figure 4 and Figure 5 show the dam site at peak flow on Sunday 4 March and Monday 5 March.

Figure 4 – Cotter Dam at approximately peak overflow – afternoon of 4 March 2012

Figure 5 – Cotter Dam looking upstream - 5 March 2012



Dam Safety Monitoring during and subsequent to overtopping

ACTEW, via the Bulk Water Alliance, monitored the dam during and subsequent to the flood event.

A range of the planned daily safety inspections were not able to be undertaken during and subsequent to the flooding due to inundation of the dam, however, were recommenced on 13 March once safe access to the body of dam were possible. During this period visual inspections of the dam and associated structures were undertaken from the abutments and safe vantage points.

During the flood event the Cotter Road was closed due to localised flooding at the bridge and also to ensure public safety in the event of rapid failure of upstream formwork causing a flood wave on top of the elevated water level.

Visual inspections and detailed inspections during and subsequent to the floods have not identified any matters of concern with respect to the structural integrity or safety of the new or old dams.

Damage assessment due to flooding event

Due to the impact of flooding the Cotter Dam project was partially demobilised in the week after the flood. Full remobilisation and recommencement of work is scheduled for the first week of May 2012.

Subsequent to the cessation of flow over the dam the Bulk Water Alliance has undertaken detailed damage assessment to the dam, associated structures as well as to plant and temporary works infrastructure associated with the construction of the new dam.

While there has been significant damage to temporary works associated with the construction of the new dam, there has been no damage to the permanent works of the RCC dam from the flood. Some damage occurred to installed valves and electrical installations in the dam gallery.

Damage to temporary works associated with the construction of the new dam is extensive in the areas of:

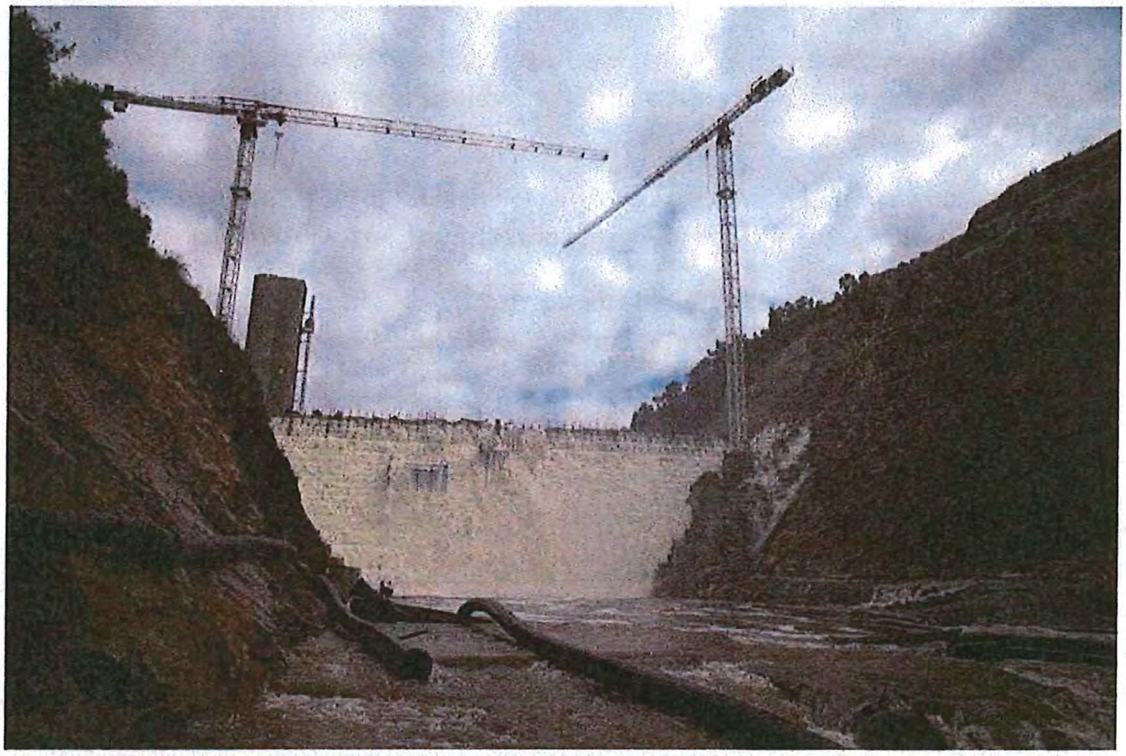
- scaffold and access systems to the dam;
- temporary access roadways downstream of the dam and into the Cotter Avenue;
- river bank erosion downstream of the dam on the left river channel, including deposition material in river channel;
- damage to plant and equipment which remained on the top of the dam during flooding, which was unable to be removed;
- damage to formwork;
- clean-up of site and tower crane access shafts, including re-establishment of power supplies, etc.

The project's Contract Work's insurance policy will cover a significant portion of the damage to permanent and temporary works. This insurance claim is still under preparation; however the estimated recovery from insurance is in the order of $9.1 M.

Delay costs to the project due to the flood event are borne by ACTEW and are likely to be in the order of $7.8 M.

The flood event, combined with non flood related project delays, has resulted in a revised project completion date April 2013.

Figure 6 - View of Dam from downstream - 6 March 2102



Other Impacts from Project Shutdown

Three cracks have been identified in the RCC post 10 April. Two of these cracks are in the outer shallow abutment monoliths and run 'across valley'. The third crack is a short upstream-downstream crack near the left abutment that appears to have come before the cross-valley crack in that abutment block and from which the cross-valley extends. The locations of these cracks are shown in Figure 7.

These cracks are unrelated to the flood event, but relate to the extended stoppage of RCC placement from the end of February to date. The three cracks have been caused by thermal movement in the outer shallow monoliths and most likely triggered by cold weather conditions immediately post Easter.

The three cracks are not considered to be of structural significance as of now, provided that action is taken to keep to an absolute minimum the chance that they could propagate into the new RCC that will be placed in the two abutment monoliths on the present surface at RL 511.5. Details of the proposed actions to prevent further crack propagation are provided in the attached paper (see Appendix 1).

The ECD Technical Review Panel (TRP – [redacted] inspected these cracks on 24 April and has endorsed the proposed crack treatment process.

[redacted]

Restart of construction

Restart of construction of the dam is planned for the first week of May 2012. Restart of RCC placement will occur during this week and follow the treatment of the dam RCC surface as a 'cold joint', in accordance with the established cold joint treatment procedures detailed in the specification.

The ECD Technical Review Panel (TRP – [redacted] and [redacted]) discussed the project restart with the project design and construction team on 24 April and expressed a view that the restart of RCC placement should be as soon as possible. They expressed a concern that any further delay in recommencement of RCC placement would lead to a higher risk of additional cracking of RCC monoliths as the overnight temperatures drop with the approach of winter and thermal gradients within the existing monoliths close to the present upper surface of the dam are increased by further surface cooling.

The Bulk Water Alliance design team are to undertake finite element analysis modelling of the impact of the extended shutdown on thermal stresses within the dam. The design team are of the view that the restart scenario is unlikely to be as severe as that analysed for the full height dam on the rock foundation. As the thermal stress analysis for the foundation was found to be satisfactory, the risks associated with resuming RCC placement are therefore likely to be acceptable. This will be confirmed through further thermal stress modelling. In the mean time, resuming placement as soon as possible will serve to minimise the exposure to forthcoming winter temperatures, thereby keeping risks associated with this scenario to the minimum.

The TRP fully supports that this analytical check be made, but emphasised its results should not delay a restart on RCC placement as this could increase the potential for further cracking.

A copy of the TRP report covering the April meeting will be forwarded to the Technical Regulator once received.

Contact Officer

Should you wish to discuss the content of this report please contact me on numbers below or by email.

[redacted]

Owner's Chief Engineer,
Water Security Major Projects

[redacted]

Appendix 1 - Bulk Water Alliance Memorandum relating to cracking and treatment of cracks[1].

1 The final version of this document will be forwarded once available.

Bulk Water Alliance

Memorandum

17/4/2012

SUBJECT	ECD - Cross Valley Crack in Monolith D
TO	[redacted] (Owners Engineer, BWA)
FROM	[redacted]
REVIEWER	[redacted]

Introduction

RCC placement has been on hold at ECD since 27th February, which is seven weeks ago, at the time of writing. Construction was delayed at this time due to rainfall and flooding. The flood event is estimated to be in the order of 1 in 100 AEP. The flood waters overtopped the partially constructed dam (which is at RL511.3m) by approximately 2m at the peak of the flood. The dam continued to be overtopped for eleven days. Clean-up works have been undertaken since and RCC is planned to resume on 2nd May 2012 (nine weeks after RCC was stopped).

Over the Easter long weekend (6th - 9th April) a cross valley crack developed in the current left abutment monolith (Monolith D). We were monitoring a less significant crack (which tends upstream-downstream close to the abutment) that had appeared before Easter in this area. When we returned after the Easter break, the crack had been intercepted by a cross-valley crack.

Crack Details

The cracks are situated adjacent the left abutment, approximately 10m from the downstream end of the existing placement area. Whilst the cross-valley crack has not yet been cored, it is anticipated that the crack extends to the foundation. The initial crack has been cored and the crack could clearly be seen at the base of the 450mm deep core hole.

Assuming the cross-valley crack extends to the foundation, it is approximately 8m deep at maximum and it tapers to nothing at the abutment. It is approximately 27m downstream from the upstream face, or two thirds of the way between the upstream face and the theoretical dam toe (i.e. where the projected 0.75H:1V downstream slope meets the foundation at this location). The downstream step vertically above, is approximately 11m from the top of the crack. At the surface, the cross valley crack is currently approximately 0.6mm wide.

The location and extent of the crack has been surveyed. Plans, sections and photos have been included in Appendix A.

A thorough inspection of the remainder of Monolith D has been undertaken and on the equivalent monolith on the right abutment. No other cracks were detected. An initial inspection of the remaining monoliths has been undertaken, but the surface has not yet been washed and cleaned to facilitate crack detection. A more thorough inspection will be undertaken prior to placement when the lift surface is properly cleaned.

Thermal Cracking

The thermal analysis conducted prior to construction of the dam identified the potential for thermal stress induced cross-valley cracking. As the warm concrete in the dam cools and shrinks, the foundation remains at a fairly stable temperature and therefore provides resistance to the foundation from shrinking. This restraint imparts tensile stress on the RCC, which can lead to cracking.

In a similar fashion, the exterior of the dam cools before the interior. The internal concrete therefore serves as restraint to the exterior concrete as it cools and similar stresses and crack potential arises.

During production, subsequent layers of RCC serve as insulation on previous layers. When production stops, the concrete cools and the risk of cracking increases. Thermal cracking of this sort has occurred in several dams after extended delays to RCC production.

Abutment Irregularities

The abutment contours (shown in Appendix A) show the presence of minor irregularities in the foundation profile in the vicinity of the cross valley crack. Two subtle 'spurs' are present on the excavated abutment either side of a set 2 defect which may have provided differential restraint, which could have influenced the orientation of the cracking.

With this crack formed, the width of the monolith was effectively reduced at this point, thus forming the shortest distance across the monolith for the second crack to form.

Abutment irregularities may therefore have been a contributing source of the crack.

Seepage Affected RCC

It is possible that some of the RCC may have been affected by seepage. As discussed above, the first crack was situated in the vicinity of a gully down the abutment, which coincided with a set 2 defect. The gully naturally accumulated seepage emerging from the abutment, which would emerge following rain events.

Larger seeps are generally diverted, but given that the seepage into this area was only intermittent, inflows were typically being managed during placement. In this area when seepage was a concern, the placement area was kept low. The RCC/GERCC would then be placed in the low spot in a concentrated effort once the water had been removed and inflows were being directly managed using the sucker truck. This process was however, not always followed and on multiple occasions RCC had to be removed as it had been compromised by the inflows.

It is possible that the RCC may have been compromised on other occasions without being detected and removed. Should this have occurred, the RCC strength and drying shrinkage would have been affected, which would increase its risk of cracking.

Temperatures

Within the Dam

At last reading (late February) the peak temperature in the dam was 36 degrees and about 24 degrees at the extremities (0.75m from the dam face). These are reasonably consistent with modelled results. The data loggers were destroyed in the flood and current expectations are that we will not have the replacement logger connected before the end of the month.

Ambient

Several cold days occurred during the Easter break, with temperatures falling close to zero (Celsius). See the temperature plot for the last two months attached in Appendix B.

Curing

Immediately following the floods curing of the dam could not continue as the water delivery infrastructure was destroyed and works were underway on the downstream steps reinstating power to the tower cranes. The curing system was re-initiated before the Easter Break. The water from the curing would have contributed to the cooling of the RCC, with wet bulb temperatures being considerably below dry bulb temperatures.

Preventative Measures

Although a procedure for protecting the concrete during cold weather has been established and has been used previously on the project, no such measures had been implemented at the time of the cracking. This was due to distractions of the post flood remedial measures and being caught out by the first cold nights of the 2012. Following the onset of the cool weather and detection of the crack, the abutment monoliths have been insulated using plastic and geofabric. This system was found to be suitable for the foundation concrete construction last winter. A temperature plot from one of the foundation pours, constructed of GERCC-m-25, which was insulated in this manner, is included in Appendix C.

Monitoring

There has been no discernable increase in the width of the crack since we started monitoring it after Easter. There is also no sign of it propagating beyond the monolith joint.

Potential Issues

Crack Propagation

If the cross-valley crack were to extend vertically through to the downstream face, significant pressures could generate in the crack from velocity head and associated pressure pulses which could compromise the stability of that part of the monolith downstream of the cross valley crack. If the downstream part of the monolith were to fail, the stability of the upstream part could also be compromised on account of the reduced mass and restoring moment resulting from the truncated cross section.

It is therefore important that we prevent the cross-valley crack from propagating vertically through to the downstream face.

It is also important that the cross valley crack does not propagate into the adjacent monoliths and compromise their stability. However, as the monoliths are independent, separated by a physical joint (transverse joint), it is unlikely the crack will propagate into the adjacent monolith as the transverse joint will tend to act as a "crack stopper".

Thermal analysis

The thermal analysis (BWA, February 2011) highlighted the potential for cross valley cracking in the long term. It was however concluded that if we use the indirect tensile strength of the RCC (rather than direct tensile strength) the stresses are anticipated to be within the capacity of the concrete.

Analysis of the thermal loading that arises from an extended delay to RCC production was not modelled. For this load case however, the abutment monoliths have undergone much of the cooling considerably sooner than for the long term case and the concrete is much younger and weaker. The same peak temperature may however, not have been reached (on account of the relatively minor thickness of RCC placed to date in the abutment monoliths), which would mean the temperature differential may not be quite as severe. Regardless, on account of the maturity of the concrete and the corresponding reduced tensile capacity, the risk of cracking is apparent.

Should cracks occur, if they remain within the body of the dam (i.e. do not propagate to a free surface), and the resulting stress redistribution does not exceed the capacity of the concrete, the global stability of the dam is not affected. On account of the identified crack potential, thermal modelling of a cracked model was undertaken to investigate this.

The cracked analysis demonstrated that if cracking were to occur, it would reduce the stresses in the concrete near the foundation and the vertical extent of cracking is unlikely to be the full height of the dam. For the model that assumed the full tensile capacity of the RCC (2MPa - indirect tensile capacity), the strength of the concrete itself was sufficient to keep the cracks below top of gallery level. The stress redistribution arising from the cracking did not exceed the capacity of the concrete for any of the load cases examined (including extreme flood loading) and the cracking remained within the body of the dam. The stability of the dam was therefore found not to be affected.

Notwithstanding the outcome of the analysis, having identified a crack, there is potential for it to propagate and it is prudent that it be treated. Adding to this, the load case giving rise to the cracking is however different to that analysed. Having already gained considerable strength and stiffness and having already undergone some of its cooling, the RCC already placed will serve to provide some restraint to the thermal movement of the RCC above, similar to that typically exerted by the foundation. With a predetermined plane of weakness (i.e. the crack) stresses may concentrate at this point and initiate further cracking in the RCC above. Treatment is therefore required to address this risk.

Treatment

The intended treatment of the crack is as outlined in the sketches included in Appendix C. The crack will be covered with a strip of sand and a strip drain. This is to serve as a crack stopper (i.e. to distribute any strain associated with movement of the joint below over a larger area, thereby reducing the stress in the RCC at the crack tip) and to serve as a drain should any pressures develop in the crack. A PVC pipe will connect from the sand and strip drain to the gallery to facilitate drainage and alleviate excess pressures should they exist. The crack may also be able to drain into the transverse joint, should it open.

Reinforcement will also be provided over the crack as a second line of defence should the crack continue beyond the sand layer. This will be situated at the bottom of the second and third layers of RCC after placement resumes, as outlined in the sketches.

28mm reinforcing bars will be provided at 200mm centres above the crack.

Resumption of RCC

Whilst we are unable to obtain current readings from the thermocouples, it is fair to assume that the RCC close to the surface has undergone considerable cooling. It will therefore provide restraint to the RCC above, similar to the restraint typically provided by the foundation, as per the thermal analysis. The differences are:

- The existing RCC is stiffer (currently approximately 20GPa) than the upper 5m of the foundation (assumed to be 8.5GPa in the thermal analysis), but more flexible than the foundation at depth (assumed to be 28GPa over 5m depth).
- Heat is still radiating from the body of the dam below. When subsequent layers of RCC are placed above, it will serve as insulation to the layers below. The existing surface will therefore heat up again, both from heat trapped within the RCC below and from heat generated from hydration of the new RCC above.
- The RCC surface is generally planer, compared to the foundation which is quite irregular, which can lead to differential restraint, giving rise to possible stress concentrations

Whilst the first of the points above would serve to increase the stresses encountered in the RCC above, the latter two would give rise to a reduction in the stresses. It is considered that the net effect is a stress regime that is less severe than analysed for the foundation. As the thermal analysis for the foundation was found to be satisfactory, the risks associated with resuming RCC are therefore also considered to be acceptable.

Conclusion

The crack is understood to be a thermal crack, arising as a result of extended delays to RCC production, exacerbated by the cold weather that followed Easter. There are also several other local factors that could have contributed to the initiation of the crack.

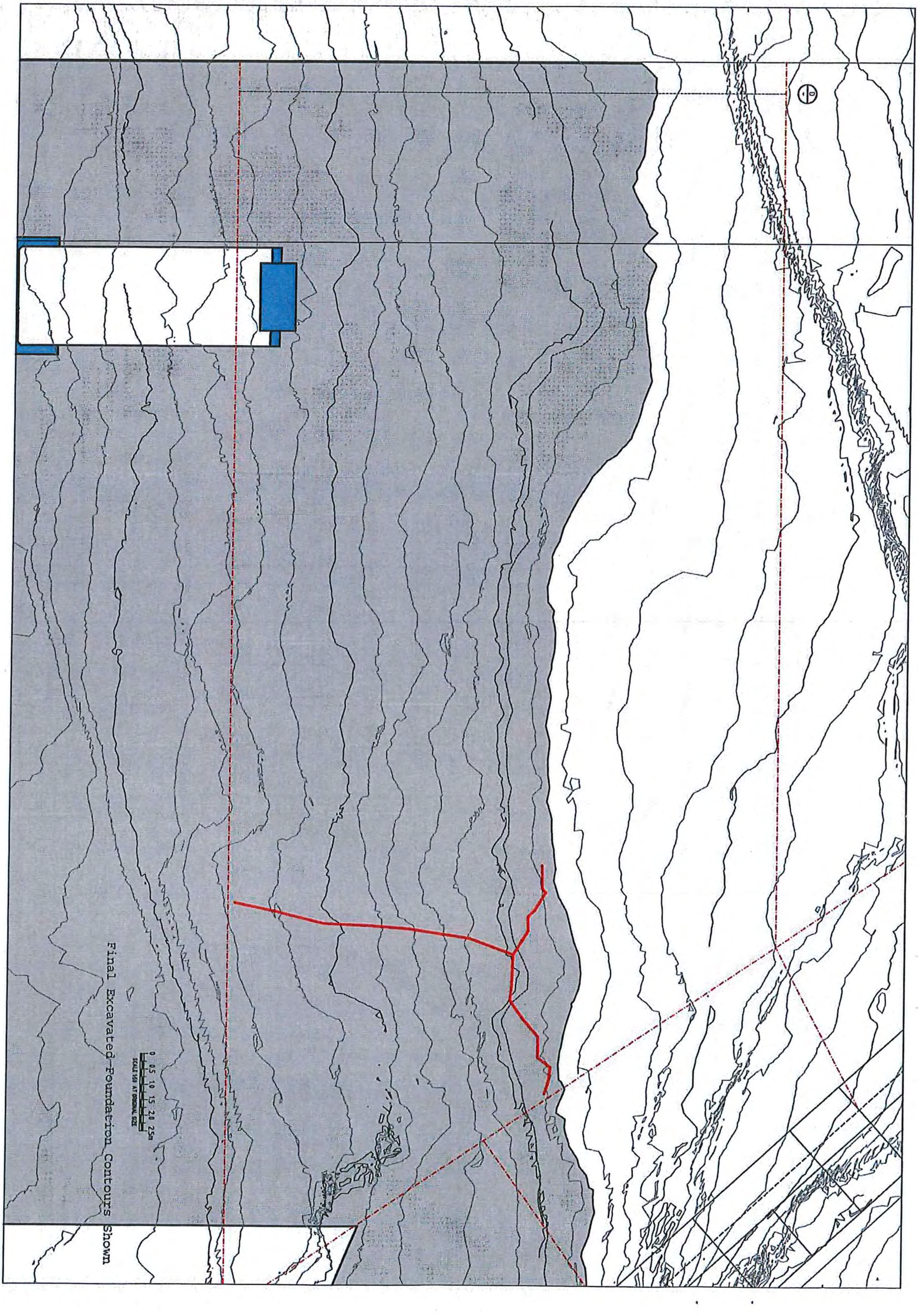
The original thermal analysis of the dam included assessment of a model with cross-valley cracks. The case examined in the model was for the long term cooling, rather than cooling as a result of a prolonged delay to RCC production mid construction. The results of that analysis however, was that the cracking remained within the body of the dam and the overall stability of the dam was therefore unaffected.

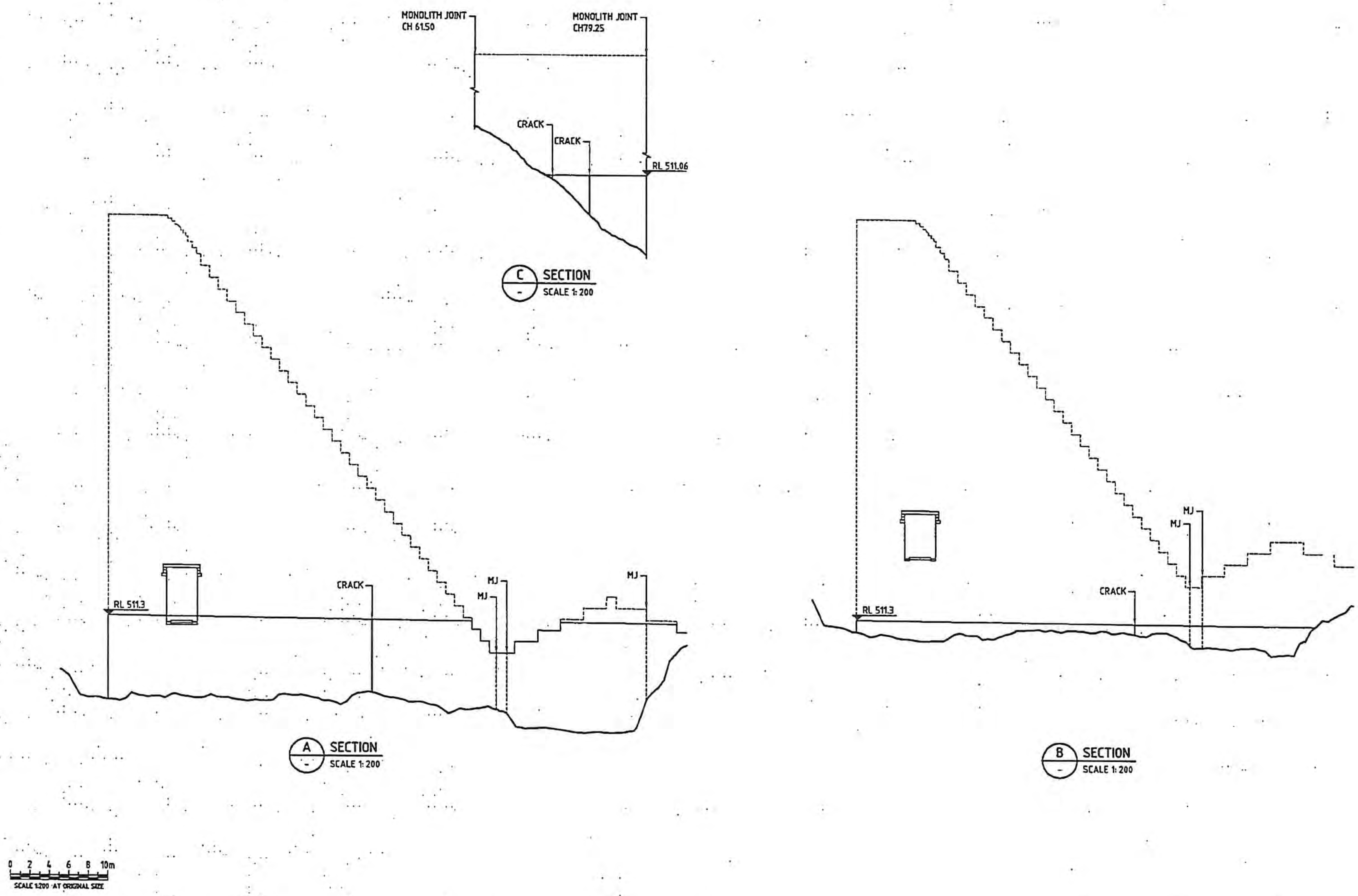
Notwithstanding the above, having a crack already present in the dam, the potential for it to propagate has been identified and treatment will be provided. Robust treatment involving both a "crack stopping" sand layer, which will also serve to alleviate excess pressures (should they exist), and reinforcement has been nominated to address the risk of crack propagation. A PVC pipe will connect from the gravel drain to the gallery to facilitate drainage and alleviate excess pressures should they exist.

More general thermal issues associated with resuming RCC placement after an extended delay has also been considered. This scenario is considered to be less severe than analysed for the full height dam on the rock foundation. As the thermal analysis for the foundation was found to be satisfactory, the risks associated with resuming RCC are therefore also considered to be acceptable.

Appendix A

Plans, Section and Photos


Final Excavated Foundation Contours Shown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CRACK
CRACK
RL 511.06
C SECTION
SCALE 1: 200
RL 511.3
CRACK
MJ
MJ
MJ
A SECTION
SCALE 1: 200
MJ
MJ
CRACK
RL 511.3
B SECTION
SCALE 1: 200
0 2 4 6 8 10m
SCALE 1:200 AT ORIGINAL SIZE

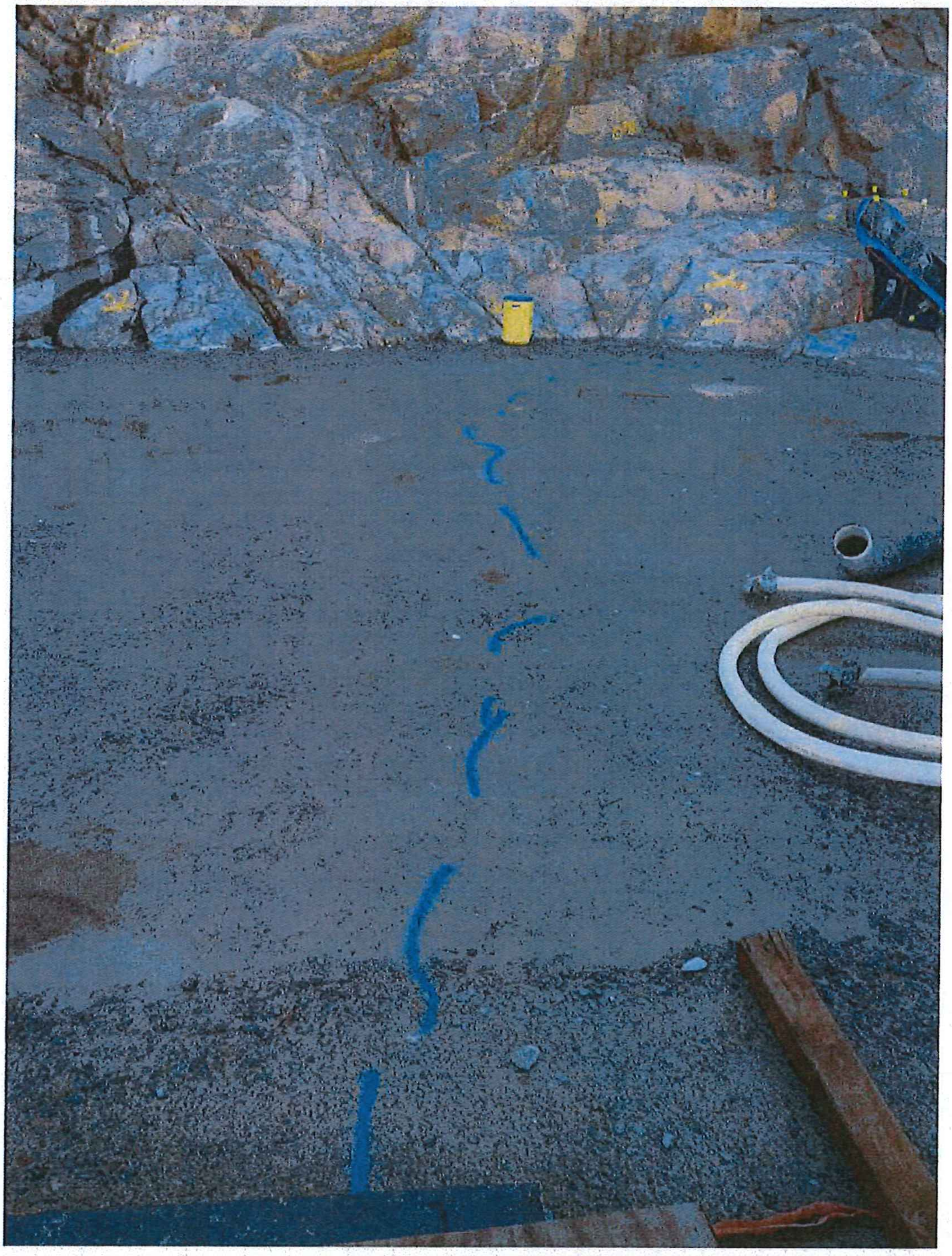
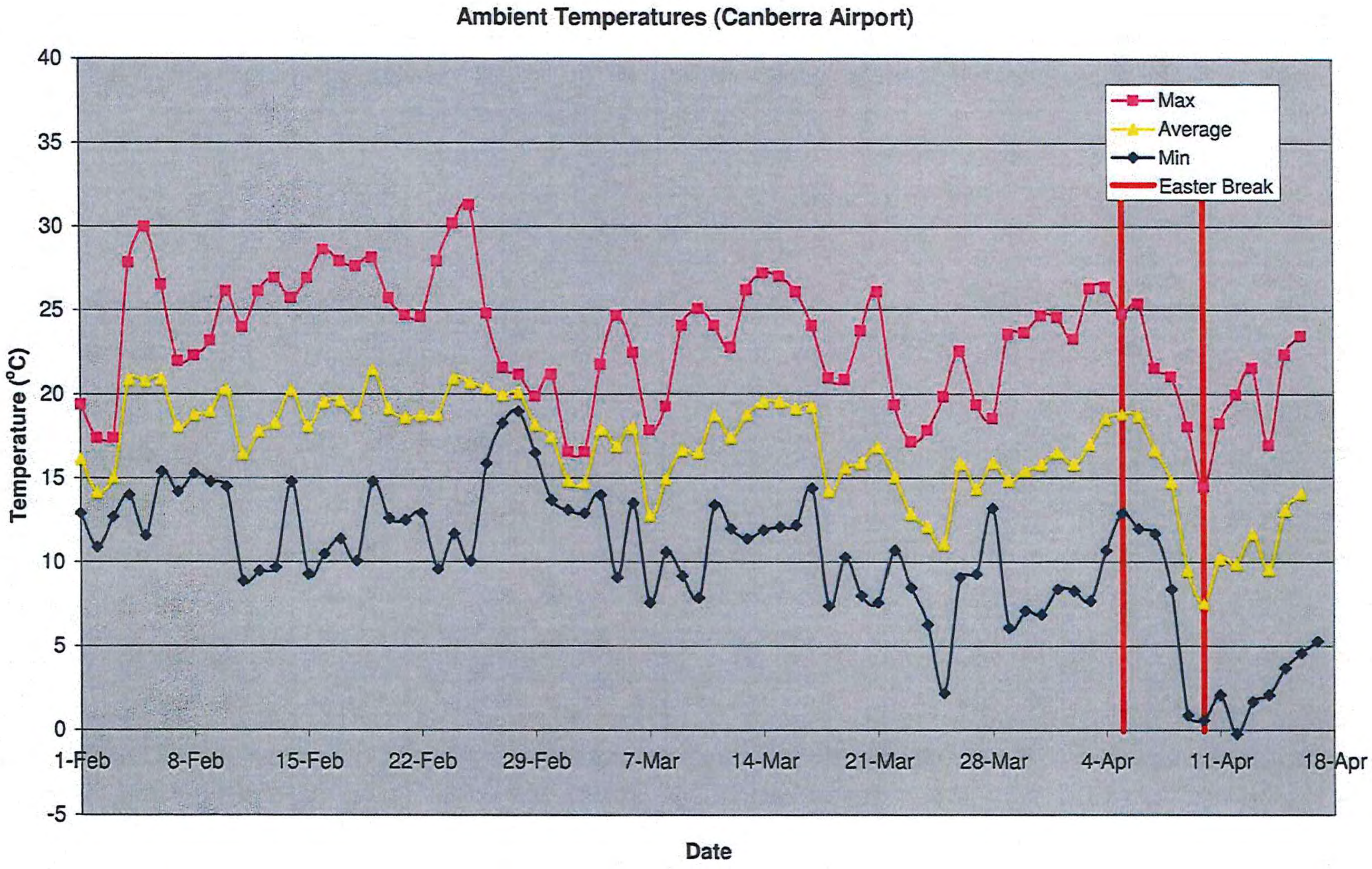


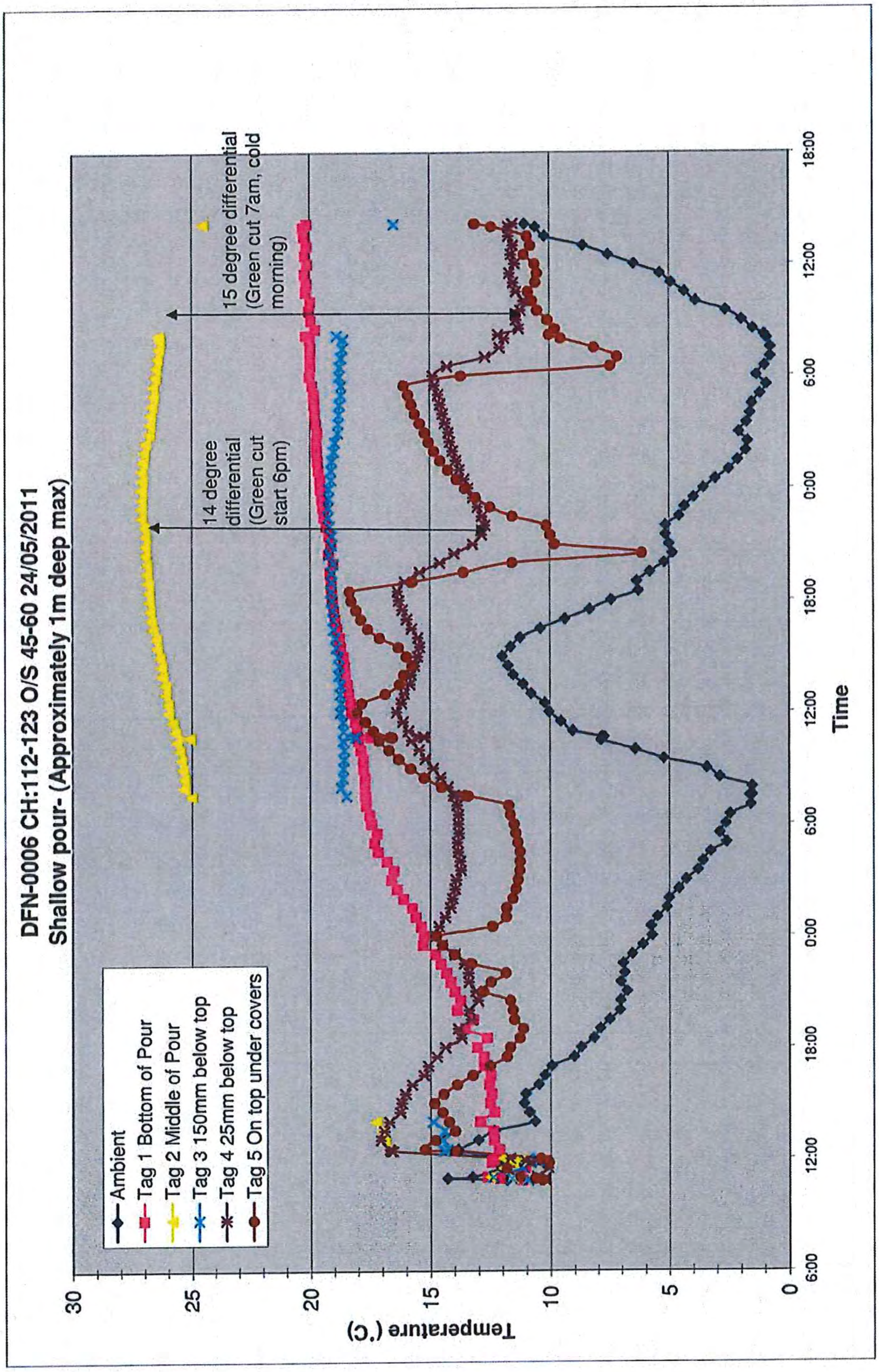
Photo 1 - Cross valley crack in Monolith D. Taken looking towards left abutment.

Photo 2 – Bifurcation of upstream downstream crack with cross valley crack.

Photo 3 – 150mm core through upstream-downstream crack.

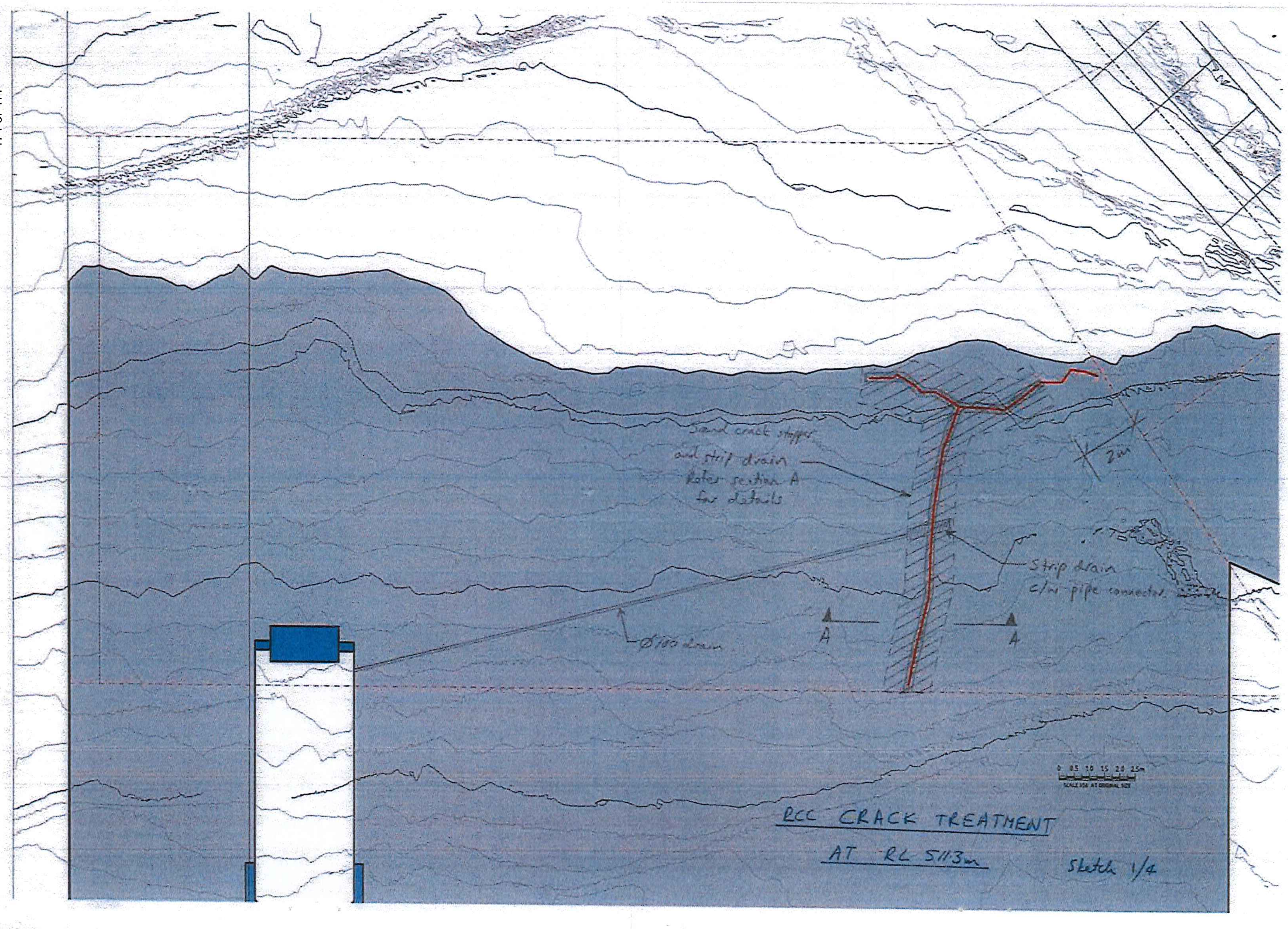

Ambient Temperatures (Canberra Airport)
Temperature (°C)
40
35
30
25
20
15
10
5
0
-5
1-Feb
8-Feb
15-Feb
22-Feb
29-Feb
7-Mar
14-Mar
21-Mar
28-Mar
4-Apr
11-Apr
18-Apr
Date
Max
Average
Min
Easter Break

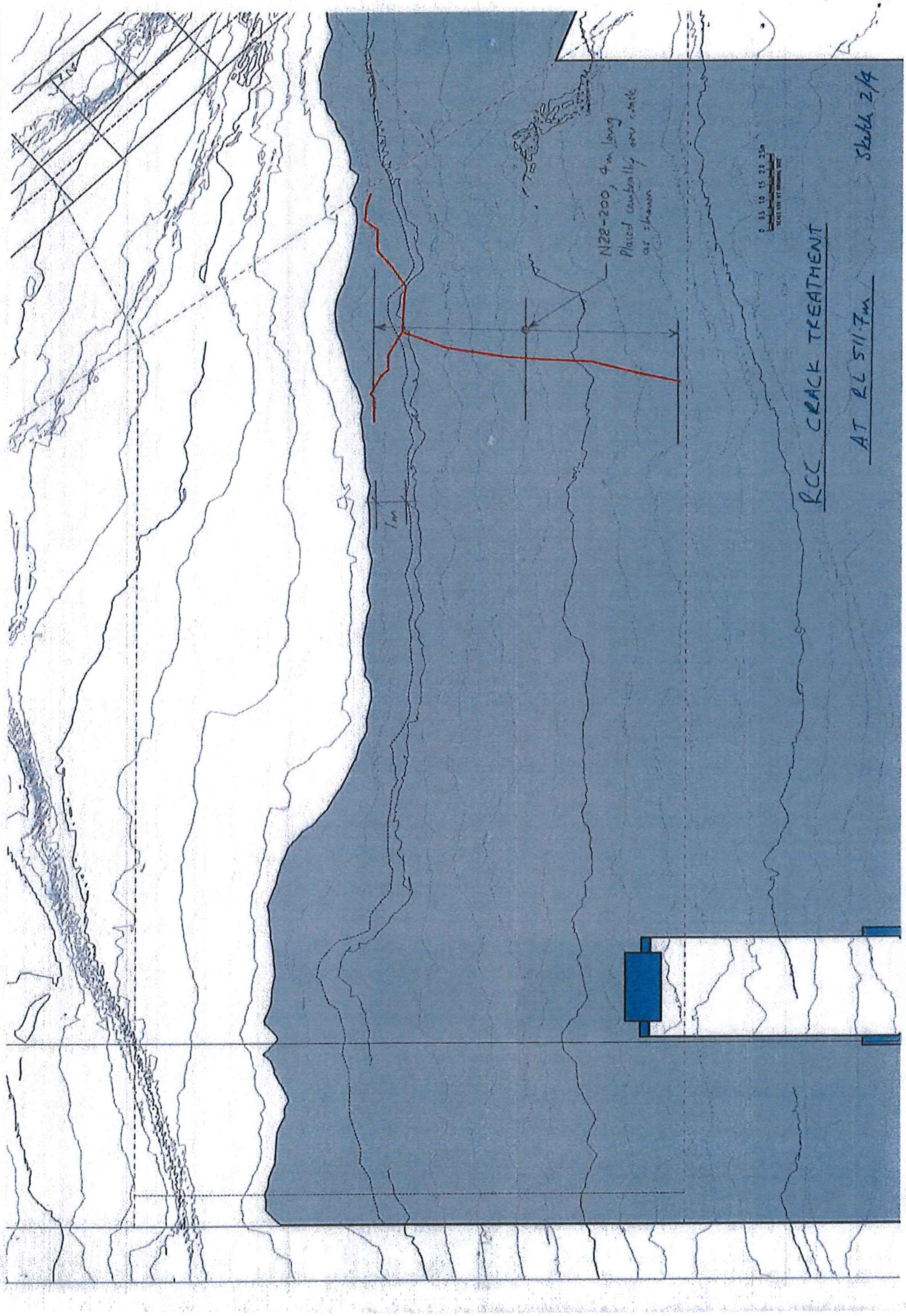
Appendix C
Thermal Monitoring of a Dam Foundation Concrete Pour

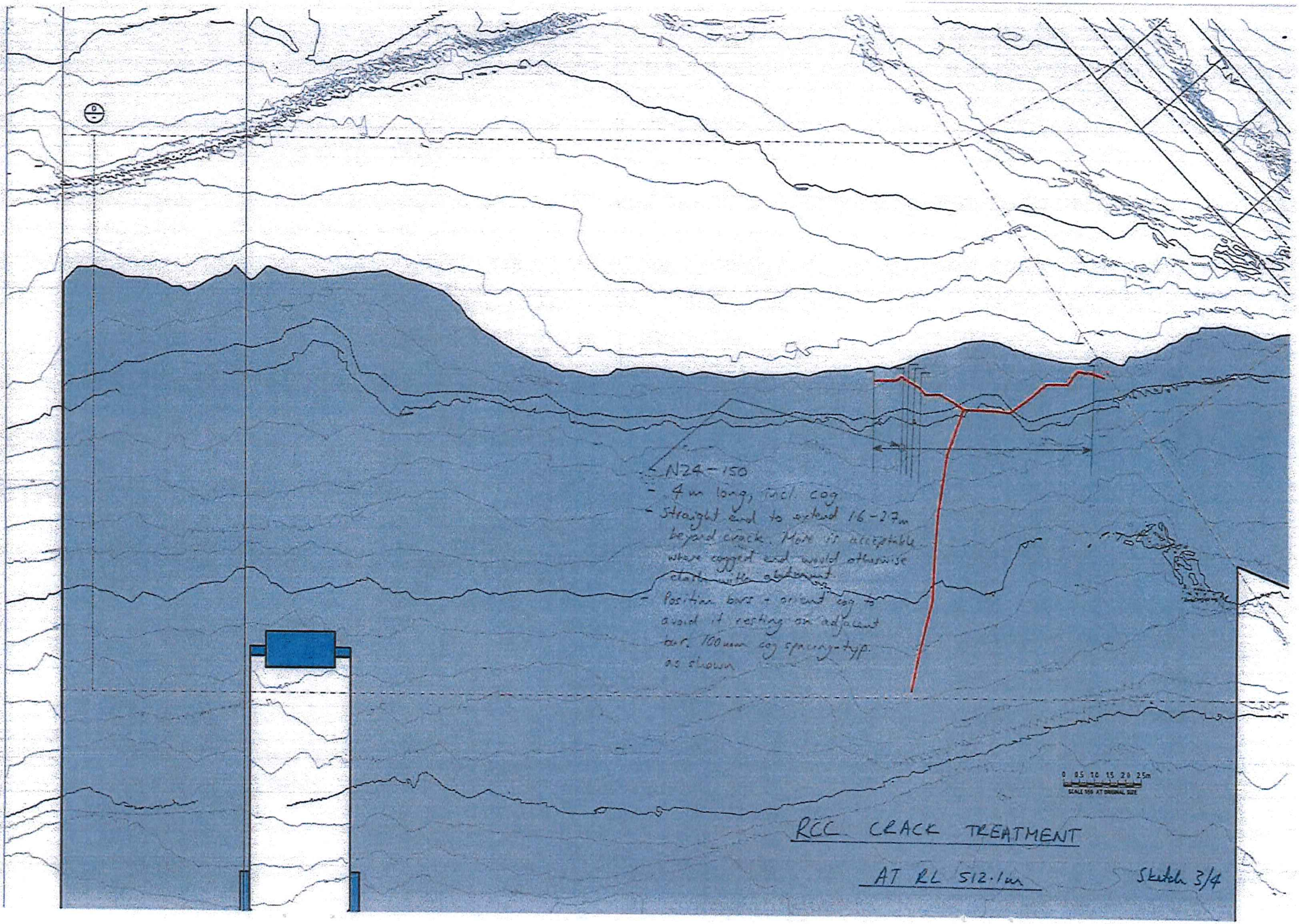


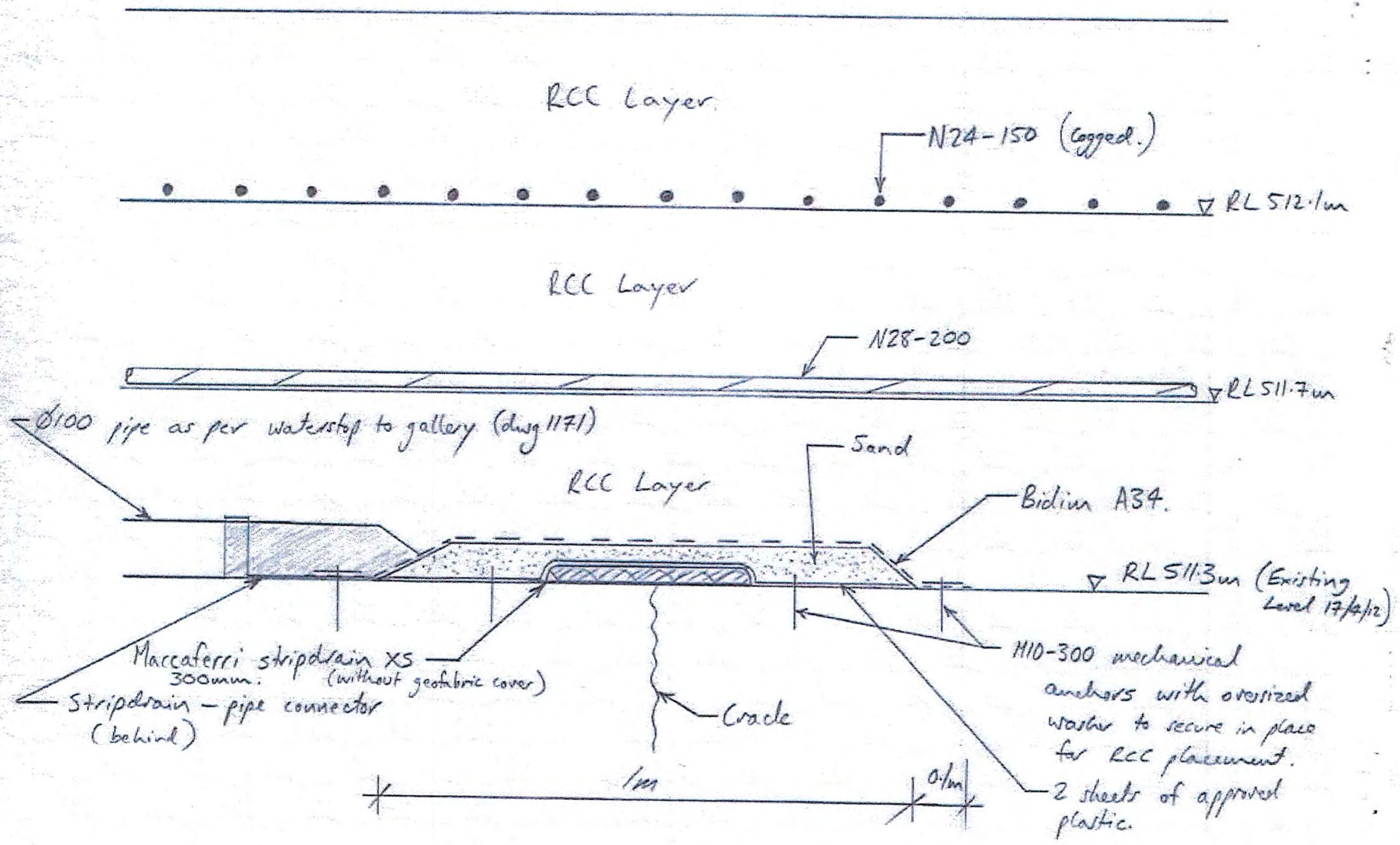
DFN-0006 CH:112-123 O/S 45-60 24/05/2011
Shallow pour- (Approximately 1m deep max)
Ambient
Tag 1 Bottom of Pour
Tag 2 Middle of Pour
Tag 3 150mm below top
Tag 4 25mm below top
Tag 5 On top under covers
14 degree differential (Green cut start 6pm)
15 degree differential (Green cut 7am, cold morning)
Temperature (°C)
30
25
20
15
10
5
0
6:00
12:00
18:00
0:00
6:00
12:00
18:00
0:00
6:00
12:00
18:00
Time

Appendix D
Draft Crack Treatment Design


Sand crack stopper
and strip drain
Rofer section A
for details
Strip drain
c/w pipe connector
Ø100 drain
A
A
2m
RCC CRACK TREATMENT
AT RL 5113m
Sketch 1/4


N28-200, 4m long
Placed centrally over crack as shown
1m
RCC CRACK TREATMENT
AT RL 511.7m
Sketch 2/4


N24-150
- 4m long, incl. cog
- Straight end to extend 1.6-2.7m beyond crack. More is acceptable where cogged and would otherwise clash with abutment
- Position bars + orient cog to avoid it resting on adjacent bar. 100mm cog spacing-typ. as shown
0 0.5 1.0 1.5 2.0 2.5m
RCC CRACK TREATMENT
AT RL 512.1m
Sketch 3/4



Section A-A

Sketch 4/4