REPORT

Opuha Dam

Annual Safety Inspection 2015

Prepared for:

Opuha Water Ltd

May 2015

Job No: 51137.028

Tonkin & Taylor

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Executive summary

The annual safety inspection of Opuha Dam for 2015 was undertaken on Friday 27 February 2015. This report incorporates the inspection on that day and a review of the dam's performance for the period between 1 April 2014 and 31 March 2015. The review is undertaken in accordance with the requirements of resource consent CRC950567.1, and the recommendations of the NZSOLD Dam Safety Guidelines (2000).

At the time of inspection, the reservoir was drawn down to its lowest water level since first fill (at ~371 m RL), due to sustained low river inflows coincident with early and high irrigation demand, noting that a state of drought was declared some weeks prior to the inspection. The dam was releasing flow only for residual river flows with full restrictions on irrigation flows being in place (i.e. irrigation shutdown). This is a highly unusual event for the Opuha Dam, and the significantly lowered water level presented an opportunity to inspect a substantial area of the upstream face of the dam.

The inspection and monitoring data for the period suggest that the dam is operating in a satisfactory manner.

The Comprehensive Safety Review completed in 2012 provided a number of recommendations in addition to the recommendations provided as a consequence of previous Annual Safety Inspections. Recommendations have either been actioned, are in the process of being actioned, or being considered by OWL. The Annual Safety Inspection report for 2014 provided 5 recommendations. The current status of these is reported in Section 10.

The dam safety related recommendations that have been made as a consequence of the 2015 annual inspection are as follows:

- Clear blocked drain D16 outlet
- Update the drain flow alert criteria for D4, D7, D8, D9, D10 & D21 based on the recorded flows for reservoir levels down to 370 m RL.
- Survey upstream bench at around 374 m RL and include exposed upstream face deformation markers in scheduled 2015 deformation survey.
- OWL to monitor exposed upstream bench at around 374 m RL and exposed upstream face around the reservoir level and report to Dam Safety Consultant if ongoing erosion to the armour layer is observed.
- Refasten hanging gantry crane power cable to monorail beam
- Investigate options and undertake repair to damaged draft tube outlet concrete.
- Spray weeds on downstream weir closure embankment.

Some general suggestions regarding the monitoring and maintenance of the dam have also been provided as summarised below:

- Monitoring areas of interest noted on the upstream face of the main embankment.
- Shotcrete repair near the service spillway.
- Monitoring stilling basin and tailrace for damage from rocks.
- Routine monitoring of D18 and visual evaluation of the surrounding area.

1 Introduction

1.1 Overview

This report incorporates the 2015 annual dam safety inspection for the Opuha Dam and reviews the performance of the dam in the period from 1 April 2014 to 31 March 2015 in accordance with the Opuha Dam Surveillance and Monitoring Plan (2014) and the recommendations of the NZSOLD New Zealand Dam Safety Guidelines (2000).

At the time of inspection, the reservoir was drawn down to its lowest water level since first fill, due to sustained low river inflows coincident with early and high irrigation demand, noting that a state of drought was declared some weeks prior to the inspection. The dam was releasing flow only for residual river flows with full restrictions on irrigation flows being in place (i.e. irrigation shutdown).

This is a highly unusual event for the Opuha Dam, and the significantly lowered water level presented an opportunity to inspect a substantial area of the upstream face of the dam. The unusual lower reservoir level also resulted in drain flow readings beyond the alert level trends set for higher and more common reservoir levels (refer Section 2.2 for details).

Throughout the report recommendations are made *in italics.* In addition, general comments relating to routine maintenance works have also been made. All recommendations are summarised in Section 11.

This report covers the following:

- The Dam, comprising the embankment crest and slopes.
- Dam instrumentation.
- The reservoir, including the intake tower.
- The service and auxiliary spillways.
- The power station and tailrace.
- Conduit.
- The downstream weir.
- Access roads.
- Surveillance and monitoring during the period including consideration of operation incidents of note that have occurred during this time.

The key parties involved in operation and maintenance of the Opuha Dam are:

- The Owner, Opuha Water Ltd (OWL).
- The Operator, TrustPower (TP).
- Dam Safety Consultant, Tonkin and Taylor (T&T).
- Data provider, Environmental Consultancy Services Ltd (ECS).

1.2 Route march

The 2015 Annual Safety Inspection of the Opuha Dam was undertaken on Friday 27 February 2015, by Tim Morris and Dominic Fletcher of Tonkin and Taylor (T&T), together with Tony McCormick (CEO of Opuha Water Limited, OWL) and the Operation and Asset Manager Steve Pagan (OWL). The weather for the inspection was warm and fine with no cloud cover. The reservoir level was at approximately 371.0 m RL.

The inspection took approximately 3.5 hours and progressed along the following route:

- Service spillway approach channel.
- Dam embankment upstream face along exposed ~4m wide bench at 375 m RL.
- Auxiliary spillway and true left abutment including abutment benches to the extent visible from the spillway channel and lowest bench.
- Dam crest along road (including inspection of splashboards and barrier).
- Embankment downstream face via access road and down face at true left abutment interface.
- Powerhouse.
- Downstream toe (including inspection of H flume drains, spillway and powerhouse tailbay as visible from toe).
- Up the walkway beside the service spillway to crest road bridge (to inspect true right abutment, service spillway and Obermeyer gate structure).
- Downstream Weir (via true left access road).

1.3 Compliance

Resource consent CRC 950567.1 includes a number of conditions related to dam surveillance and monitoring, including the requirements for a dam surveillance and monitoring plan, an annual dam safety surveillance report and annual inspections in accordance with the NZSOLD Dam Safety Guidelines. The annual inspection report covers the period 1 April to 31 March each year.

The Opuha Dam surveillance and monitoring plan (2014) outlines that "*(annual) inspections shall be undertaken by the Dam Safety Consultant's representative, who shall be a suitable qualified and experienced dam safety engineer under the supervision and sign off by a Category A Recognised Engineer. Inspections shall follow a set route to ensure a consistent approach to the inspections as outlined in the NZSOLD Guidelines*".

NZSOLD's Dam Safety Guidelines (2000) recommend that intermediate inspections (such as annual and two yearly inspections) involve "*The confirmation of satisfactory behaviour or identification of deficiencies by visual examination of the dam and review of surveillance data against prevailing knowledge*". This annual inspection was undertaken in accordance with the recommendations of NZSOLD Dam Safety Guidelines (2000).

2 Dam Instrumentation

2.1 Overview

This section reviews the data for the dam instrumentation for the period 1 April 2014 to 31 March 2015. In general, the dam and spillway instrumentation continues to operate satisfactorily. A programme is in place to remedy a series of issues with the hydraulic piezometers that have been problematic in recent times.

The instrumentation consists of a series of:

- Drains, including H Flumes with water level recorders for flow measurements from selected drains.
- Turbidity meter located within the H flume outlet for turbidity monitoring.
- Hydraulic piezometers with bourdon gauges in the powerhouse.
- Pneumatic piezometers located under the Service Spillway and read when the Service Spillway operates.
- Standpipe piezometers (i.e. observation wells).
- Rain gauge (monitored by ECS).
- 3x reservoir water level recorders (1x telemetered to TrustPower, and the other monitored by ECS).
- Survey markers to indicate embankment deformation (deformation survey not undertaken within this reporting period but pending).

The layout of the dam instrumentation is presented in Figure 2.1 below. The locations of the hydraulic piezometers located within the embankment on the instrument lines 1, 2 and 3 shown in the figure below can be found in Section 2.3.1.

The alarm criteria have been separated into two cumulative level criteria, initial Alert Levels and secondary Trigger Levels, each requiring specific response actions. The intent of each of these criteria is as follows:

- Alert level – Where recorded data exceeds the normal operating levels requiring further review of observed dam performance.
- Trigger Level – Where recorded data significantly exceeds normal operating and/or design performance levels such that urgent action is required.

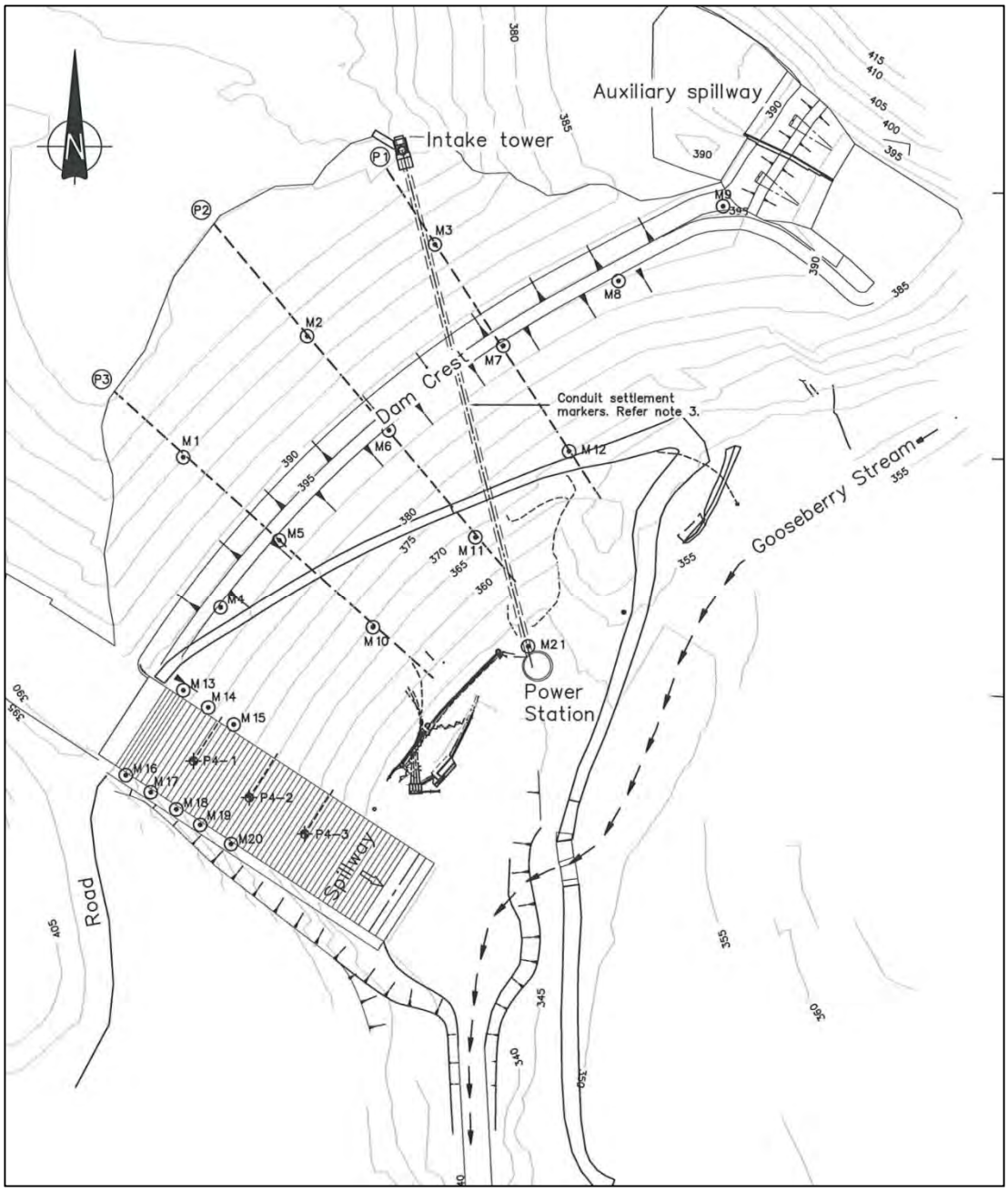

Figure 2.1 Instrumentation Layout

2.2 Drains

2.2.1 General

There is a continuous flow monitoring system for the seepage flow from drains D7, D8, D9, D10 and D21. Water levels in these five drains are recorded electronically (adjacent to the H flumes) and telemetered via a SCADA system to the TrustPower control centre. An hourly average level is produced, hence an inferred average hourly flow rate is produced. Drain flows are also manually read monthly by OWL staff by recording the time taken to fill a container of a known volume.

Measured drain flows have provided generally consistent and satisfactory results over the 12 month monitoring period, responding to fluctuations in reservoir level. Of the 21 drainage outflow measuring points, 9 have had measurable flows since the 2014 annual inspection report:

- The 350 m RL conduit drain (D4).
- The seepage drain near the power station (D6).
- The base drainage outlet (D7).
- The outlet from the second diversion channel (D17).
- The three chimney drain sumps (D8, D9, D10).
- The right hand side Auxiliary Spillway fuse plug base (D18).
- The seepage cut off wall drain (D21).

Graphs of flow readings since March 2010 are provided in Appendix A, for:

- Drains D7, D8, D9, D10 and D21 on Sheet A1/1 (manual data).
- The sum of D7-D10 on Sheet A1/2.
- D4, D17, and D18 on Sheet A1/3.
- Drains D7, D8, D9, D10 and D21 on Sheet A1/4 (water level recorder data).

In 2013, OWL redirected the flow from D4, D5 and D6 to the sump adjacent to the switch yard. This is order to keep the site tidy and limit effects that this water may have on potential ground movement in the area. Some minor weed and moss growth was noted in the sump and the safety non slip mat (refer Photo 2-1 below), but otherwise this area appeared in good condition and is easily accessible.

Photo 2-1 D4, D5 & D6 drain outlets

Debris was observed to be blocking the drain D16 outlet (refer Photo 2-2 below) (located beside the access road). It is recommended that this debris be cleared to enable monitoring from this drain (usually dry), and ongoing routine maintenance to all drains continue to ensure drains a kept clear.

Photo 2-2 Blocked D16 outlet

RCM2015-01 Clear blocked drain D16 outlet

2.2.2 Drain flow turbidity and total suspended solids

The flows conveyed by drains D7-10 and D21 have been sampled to analyse for turbidity and total suspended solids (TSS). Drain flows were last tested for TSS in April 2014 and ongoing annual quantitative testing of drain discharges to check for the presence of suspended sediment is warranted and endorsed.

Total suspended solids results over the review period (15 April 2014) are generally consistent with historical data. The TSS in drains D7, D8, D10 and D21 are below the lower bound detection limit of the test (limit 3 mg//) and have been so since 2012.

The D9 TSS measured on 15 April 2014 was 7 mg// and is similar to the 5 mg// measurement recorded in 2012 and 2013. Flows in D9 therefore seem to have slightly higher TSS results than adjacent drains on the particular day that the sample was collected albeit that the result is low and near the lower bound limit of the test. The D9 flow is also very low relative to adjacent drains.

For comparative purposes a sample taken from the reservoir water in the penstock in 2014 was found to have 4 mg// TSS and this result is in excess of the TSS results recently recorded in drains D7, D8, D10 and D21 at the same time on 15 April 2014. However there were no

past values to compare this with. Qualitative turbidity (NTU parameter) was not measured concurrently with this sampling.

The difficulties involved in monitoring the turbidity of the chimney drain flow was discussed in the 2013 Annual Safety Inspection report and comments were made in the 2013 Annual Safety Inspection Report regarding Total Suspended Solids. A recommendation was made to investigate using an alternative method for measuring potential sediment flux from particular drain discharges. This action is unresolved.

2.2.3 Drain flow turbidity meter

Based on recommendation in the 2013 Annual Safety Inspection Report, OWL has been cleaning the lens of the H flume electronic turbidity meter on a regular basis. In November 2013, TrustPower started supplying the turbidity data to T&T weekly with the electronic drain flow data, for analysis as part of the monthly monitoring reports.

The turbidity meter was initially installed in the D7 H flume, however following a period of initial monitoring which produced unreliable readings, the meter was relocated to the H flume collection sump for D7 – D10 in mid June 2014 in conjunction with the D7 H flume anti fouling painting. This relocation enables surveillance of the combined H flume flow turbidity.

This turbidity meter data has yet to establish a baseline trend, and appears to be significantly influenced by algae growth with an upward trend followed by notable drops in the recorded NTU's following cleaning. The electronic turbidity readings since February 2015 appear to be significantly influenced by rainfall, with turbidity spikes occurring immediately following a rainfall event. The magnitude of the electronic turbidity readings remains small however. Ongoing monitoring is endorsed.

OWL continues to measure and report the turbidity of drainage flows monthly by way of manual turbidity measurements taken at the time of the manual flow rate recordings. Reported manual turbidity readings appear to be relatively stable and are reviewed by T&T as part of the ongoing dam surveillance and monitoring requirements.

2.2.4 Chimney drains

Flow through the chimney drain is collected by D8, D9 and D10, with water being conveyed from the left chimney sump, central chimney sump and right chimney sump via the respective drains. The outlet for these flows is located at the base of the dam, adjacent to the spillway stilling basin. The outlet for flows conveyed from the base drain, D7, is also at this location.

2.2.5 Drain Flows

Of the nine drains that produced measurable flows throughout the period, all were within the expected range for the majority of the monitoring period. Specific details and explanations are provided below where flows have exceeded Alert Levels in D7, D10, D18 and D21. No other drains exceeded their Alert Levels during the period.

The recorded drain flows were generally consistent with historical data at the more common reservoir levels (both in terms of flow levels and responsiveness to reservoir level), noting that the drain flows reduced below the previously recorded minimum flows due to the current very low reservoir level. The recorded drain flows for the period are presented in Appendix A.

Specific comments made in the 2013 & 2014 Annual Safety Inspection reports remain unchanged. General comments relating to the drains from this annual review period are as follows.

- Changes in inferred flow for all telemetered drains (D7-D10 and D21) were apparent when cleaning of the flumes to remove algae has occurred.
- Flow rates derived from water level recorder data for the chimney drains (post quarterly hour samples) have remained relatively consistent throughout the period. However, the manual readings have produced a wider range of flows over the period. A contributing factor may be challenges associated with accurate time measurements and the rating used to determine flow rate from water level.
- Flows produced by drain D4 during the period (0.1 – 0.2 *l*/s) are fitting with historical flows produced at similar reservoir levels. This drain is generally produces flows relative to the reservoir level; however, it has a very low flow and any changes are small.
- Drain D6 flows were recorded as dripping and are too small to accurately measure.
- Drain D7 flow is historically slightly responsive to reservoir level with a fairly constant base flow of 16 – 18 *l*/s at reservoir levels above 384 m RL, with notable decreases in flow as the reservoir draws down below this level. D7 flows produced during the period are in trend with historic flows, noting that flow continued to decrease as the reservoir was drawn down to around 370 m RL. An erroneous manual measurement appears to have occurred in April 2014 (resulting in an alert level exceedance) which does not correspond to the trend or electronic data and hence has been discounted.
- Drain D8 flow is historically slightly responsive to reservoir level with a fairly constant base flow of 11 – 12 *l*/s at reservoir levels above 384 m RL, with notable decreases in flow as the reservoir draws down below this level. D8 flows produced during the period are in trend with historic flows, noting that flows continued to decrease as the reservoir was drawn down to around 370 m RL.
- Drain D9 produced low flows between 0.2 and 0.7 *l*/s (0.5 *l*/s average) during the monitoring period, as consistent with historic trends. The drain flows react very slightly to reservoir levels with the lower flows corresponding to lower reservoir levels. No alerts were recorded in the period for D9, noting that the reservoir dropped below the lower alert level bound (below 372 m RL) in late Feb 2015.
- Drain D10 produced flows that were responsive to reservoir levels and in accordance with historical trends. The recorded flows exceeded the alert criteria in mid Feb 2015 until the reservoir dropped below 372 m RL (minimum current alert criteria level). The flows reduced as the reservoir was drawn down and the magnitude of D10 flows at the lower reservoir levels is minimal (1.6 *l*/s reducing to 1.0 *l*/s).

  The alert criteria were based on historic trends (i.e. used to identify when flows increased above historic trend) and with limited data around this low reservoir level, and updates to the alert criteria the lower end are warranted to better reflect the recorded flows.
- Drain D17 produced flows that were responsive to reservoir levels. These trends are fitting with historical flows produced at similar reservoir levels.
- Drain D18 produced observable flows that were measured monthly between April – May 2014 & August - September 2014 only over the review period. This drain is very responsive to reservoir level. The Alert Level was marginally exceeded on 27 May 2014 (by 0.11 *l*/s). There is a long term trend of increasing flow from this drain since

grouting was carried out on the upstream three metres of D18 in July 2000. Further discussion on the drain D18 is outlined below.

- D21 flow rates have exceeded the alert levels at the lower reservoir level end on several occasions throughout the period. D21 is very responsive to lake level, and the historic exceedances (as previously discussed in the 2014 annual inspection report) usually occurred in times of heavy rainfall and the drain was collecting surface water runoff/infiltration from the downstream shoulder and toe of the dam. However, the recorded exceedances to alert criteria over the annual review period were predominantly during the lower reservoir level period.

  The recorded flow from D21 exceeded the alert criteria (by 0.1 – 1.5 *l/s*) for approximately 7 days in late April 2014 (17 - 24 April 2014), coincident with a storm over this period. These exceedances were considered to be due to rainfall resulting in surface water influx into the drain, and not increased seepage.

  The recorded flow from D21 slightly exceeded the alert criteria (by 0.1 – 0.5 *l/s*) continuously for most of December 2014 until mid January 2015 due to the lower reservoir levels (383 - 380 m RL) and current alert criteria based on limited historic reservoir level data in this region. The drain flows reduced to 0.1 – 0.2 *l/s* once the reservoir level dropped below 380 m RL.

  Given the magnitude of the flows and exceedance, updates to the alter criteria to reflect the improved data capture in this zone are warranted. The drain flows appear to be consistent with historic performance.

- Consideration should also be given to developing a methodology to install an antifouling coating in D21.

RCM2015-02 Update the drain flow alert criteria for D4, D7, D8, D9, D10 & D21 based on the recorded flows for reservoir levels down to 370 m RL.

2.2.5.1 D18 flow

Drain D18 is located at the RHS base of the auxiliary spillway fuse plug and only flows when reservoir levels exceed about 390 m RL. This level corresponds to the base of the right hand side auxiliary spillway channel.

Flows were observed and measured monthly between April – May 2014 & August - September 2014. The Alert Level was marginally exceeded on 27 May 2014 (by 0.11 *l/s*).

There is a long term trend of increasing flow from this drain since grouting was carried out on the upstream three metres of D18 in July 2000. The results of this can be seen in Figure 2.2 below which shows the flows produced pre-grouting, post-grouting and current flows from the drain.

It is important that close attention is given this area in order to better understand long term trend associated with seepage in the vicinity of D18.

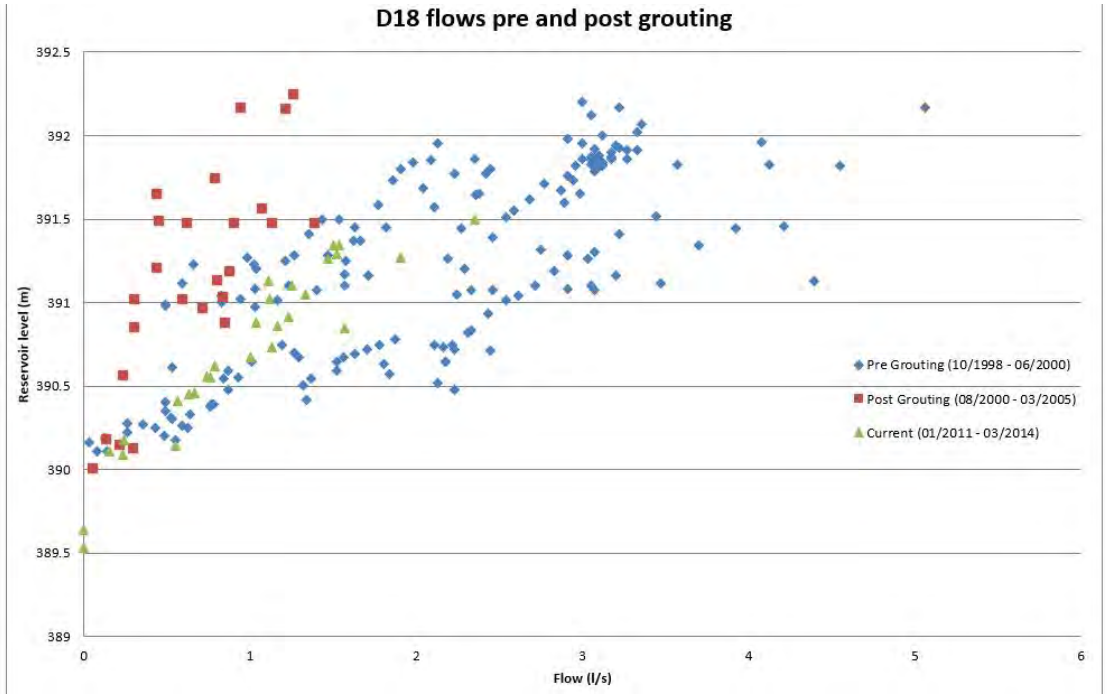

Figure 2.2 Drain D18 flows, pre and post grouting (as per 2014 annual report)

2.2.5.2 Automatic Monitoring of Alert Levels

Further to the 2014 annual inspection recommendation (*RCM2014-01*), TrustPower have yet to confirm whether they now monitor the drain flow data in real time relative to alert levels. Alerts identified from the supplied electronic flow recordings during the period suggest that this real time monitoring is not yet being undertaken to date.

Hence the recommendation that the TrustPower system is revised in order to identify any alert in real time should an alert be generated and TPL adopt procedures to communicate the alert to OWL and T&T in a timely manner remains.

2.2.6 Drain Turbidity

Drains D4, D7, D8, D9, D10, D17, D18 and D21 were manually monitored for turbidity as well as flow. In addition, drain D7 was electronically monitored for turbidity until June 2014, after which the turbidity meter was relocated to the collection sump for D7 – D10 which is now being monitoring. The turbidity data over the annual review period is plotted in Appendix A. In particular the readings from:

- D4 remained generally constant over the period at around 2 NTU and within historical values.
- D7 remained generally constant over the period at around 3 NTU and within historical values.
- D8 were lower than the longer term average NTU levels and generally constant at between 5 – 6 NTU, and within historical values.
- D9 were consistent with longer term average NTU levels and varied between 2 – 8 NTU, and within historical values.
- D10 were consistent with longer term average NTU levels and varied between 4 – 6 NTU, and within historical values.

- The D7 – D10 collection sump electronic data appears to be highly responsive to algae growth and cleaning, and no trends are apparent from the data collected to date. The magnitude of the turbidity readings remains low (< 4.5 NTU).
- D17 has generally constant NTU levels over the year (~2 – 3 NTU) with the exception of April/May 2014 which recorded slightly higher readings (~ 5 NTU) consistent with historic readings at reservoir levels above 390 m RL.
- D18 had generally consistent NTU levels when flowing (4x readings over the period) within historically recorded levels.
- D21 were consistent with longer term average NTU levels and varied between 2 – 4 NTU and within historical values.

2.3 Piezometers

2.3.1 General

Graphs of the data since 1 April 2010 are provided in Appendix A. The locations of the three lines of piezometers are shown in Figure 2.1 above and the positions of each piezometer in Figure 2.3 below.

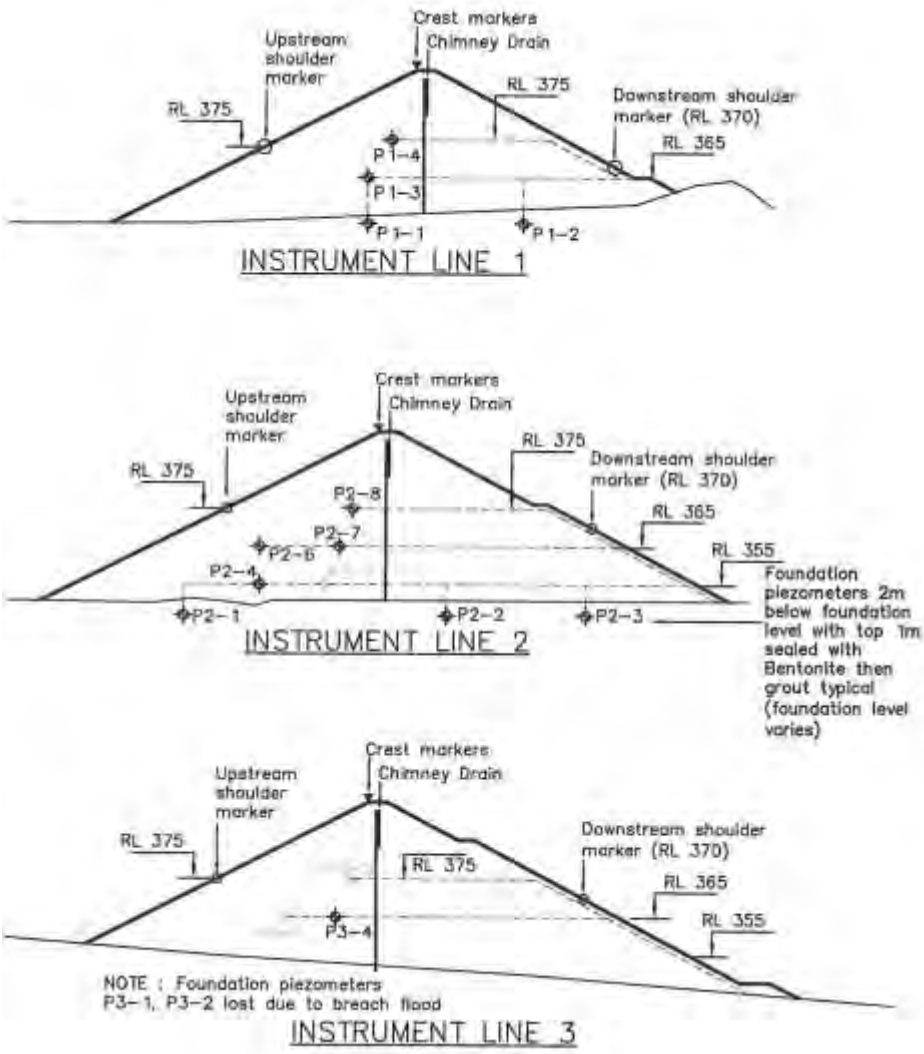

Figure 2.3 Piezometer positions

A series of matters have been ongoing for several years and have resulted in uncertainty in data collection and interpretation. Annual maintenance and testing of the hydraulic piezometers (gauge replacement and deairing) commenced in late Nov 2014. Some piezometers (i.e. P2-2) are currently being read through adjacent gauges while their gauge is repaired/replaced. Completion of deairing and installation of replacement gauges is required, and it is understood OWL will be undertaking this May/June 2015. Until this work is complete, uncertainty over the accuracy of the hydraulic piezometer readings remains.

The outcomes from this piezometer deairing will be reported in a separate deairing report following this work. The recommendations and comments from the 2013 deairing (as per April 2014 report)[1] remain current pending the 2015 deairing and maintenance work.

At least four piezometers are considered to be no longer functioning reliably and hence have been excluded from the monitoring requirements. An assessment on the piezometer reliability is reported separately in draft and is awaiting finalisation following the 2015 deairing and maintenance work discussed above. The currently discontinued piezometers are P1-4, P2-5, P3-3 & P3-5.

The following 11 hydraulic piezometers are currently monitored; piezometers P1-1, P1-2, P1-3, P2-1, P2-2, P2-3, P2-4, P1-3, P2-6, P2-7, P3-4 & P2-8. These hydraulic piezometers are currently read monthly in accordance with the Dam Surveillance and Monitoring Plan, with provision for additional readings if warranted by specific circumstances.

Current procedures provide for the pneumatic piezometers under the service spillway to be read during spillway operation. The service spillway did not operate during the period and hence the pneumatic piezometers were not read.

It is understood that the existing OWL equipment used to take the pneumatic piezometer readings is no longer functional, and that initial investigations into replacement have occurred. Given that the pneumatic piezometers are only read when the spillway is operational, provision of a pneumatic piezometer readout unit is likely only necessary during high reservoir level periods. We understand that this matter is being considered further by OWL.

2.3.2 Hydraulic Piezometer data

Piezometer gauges are located at the base of the power station and used to read the hydraulic piezometer tip pressures. Significant maintenance was undertaken to the hydraulic piezometers over the monitoring period, and reliability readings produced by piezometers are still the subject to further assessment by OWL, and will be reported separate. Specific details relating to the piezometers of relevance to this monitoring period are:

- P1-1 has produced readings that vary moderately to reservoir level. The gauge for this piezometer was removed and sent for calibration between Aug – Nov 2014, with readings taken with the adjacent P1-2 gauge (foundation piezometer) over this period recording much lower than historic values from the P1-1 gauge. The readings taken with the P1-1 gauge are consistent with historical trends. This piezometer line was noted as being the most responsive to the deairing in November 2014.
- Levels produced at P1-2 have remained at a similar level throughout the period, with little response to reservoir level. This is fitting with historical trends. The baseline reading for this piezometer has not changed.

[1] Tonkin & Taylor; Opuha Dam – Hydraulic Piezometer Maintenance, Reference 51137.020. 04 April 2014.

- As reported in the 2014 annual safety inspection report, erratic readings have been recorded from P1-3 between 2011 and 2014, with no responsive levels relative to the reservoir level or significantly lower readings for longer periods (i.e. Aug 2013 – Nov 2014). Immediately following deairing in November 2014, the readings increased by 4 m, however an incomplete response to deairing was noted. Hence, the performance of P1-3 over the monitoring period remains uncertain.
- As previously reported, a significant shift in base line for P2-1 was observed in July 2010 (approximately 18 m pressure drop), with readings following this responding to reservoir level but at a much lower pressure than historic readings prior to this. The gauge for P2-1 was removed in April 2014, recalibrated and reinstalled in October 2014, after which readings returned to previous historic pressure levels and trends, and are now generally consistent with design expectations for the piezometer location (upstream shoulder). The gauge for P2-1 was noted as responding erratically when tested as part of the deairing maintenance work in November 2014. Ongoing monitoring is warranted.
- Readings from P2-2 recommenced in August 2014 using the adjacent bourdon gauge for P2-3 (both foundation piezometers). These reading are consistent with more historic readings from P2-2 (last taken in July 2010 prior to P2-2 gauge failure). The replacement gauge for P2-2 is yet to be installed.
- P2-3 is located in the foundation under the downstream shoulder of the dam. In the last Annual Safety Inspection report it was noted that P2-3 was displaying a trend of slowly increasing readings, until de-airing in April 2013 when the readings returned to a more consistent level (See Figure A2/1 attached). This increasing trend was previously noted and attributed to de-airing in 2008 when it is believed that not all of the air was able to be purged. The piezometer readings following the November 2014 deairing did not result in a change to the trend of readings established post April 2013 (consistent levels with minimal response to reservoir level), suggesting that the volume of air in the piezometer line has remained consistent over this time.
- Historically, P2-4 levels are similar to that of the reservoir level. Levels produced over the period follow historical trends.
- P2-6 was previously noted as being responsive to reservoir level, but consistently producing pressure readings above the reservoir level and hence the trigger levels. No change to this situation occurred following either the 2013 or 2014 annual deairing work, which suggests that the P2-6 gauge calibration may need to be checked. This will be reported on more fully in the 2014/2015 piezometer maintenance and deairing report.
- Readings from P2-7 are slightly responsive to reservoir level, with response observed only with significant drops in reservoir level. One reading (24 March 2014) is significantly off trend and higher than the reservoir level at his time. The following April 2015 returned back to trend. This single reading is considered to be an error. Otherwise, this piezometer remains consistent with historical readings at similar reservoir levels.
- Readings from P2-8 have been trending with a much lower base line since deairing in mid 2013 (See Figure A2/3 attached), and appear only mildly responsive to reservoir level changes. The February – March 2015 readings all exceeded the alert criteria and the reservoir level, which given the very low reservoir levels at the time (i.e. around 370 – 372 m RL) and the piezometer level at 375 m RL suggests that these readings are not representative of piezometric conditions within the dam. Further consideration to the reliability of P2-8 will be given in the 2014/2015 piezometer maintenance and deairing report.

- Following the 2013 deairing, the base level of the readings from P3-4 increased from historic trends, such that the lower bound alert criteria were being consistently exceeded. From January 2014, readings from piezometer P3-4 were taken via the adjacent P2-4, P2-6, or P2-7 gauges (with the exception of Feb & Mar 2014 which were through P3-4) until the P3-4 gauge was reinstalled (but not recalibrated before this) in November 2014. Following the reinstallation, readings from P3-4 remained above the historic levels, and continue to provide alerts and readings above the reservoir level in some instances.

  Following a recommendation in December 2013, piezometer P3-4 was also read through adjacent gauges (as above) to determine whether this increase is related to an increase in piezometric pressure within the dam or an instrument error. The readings through the gauge P2-4 appear more realistic and are approximately 3 m lower than those from P3-4 and correlate better to the reservoir levels.

  This suggests that the previous alerts are as a result of an issue with the P3-4 gauge instrument. This will be reported on more fully in the 2014/2015 piezometer maintenance and deairing report, and recalibration of gauge P3-4 is recommended.

2.3.3 Pneumatic piezometers

The pneumatic piezometers are located under the service spillway and are read on the left hand side of the service spillway when the spillway operates. The service spillway did not operate during the period and no measurements were taken.

It is understood that the equipment used to take the pneumatic piezometer readings is no longer functional and options for replacement/repair are being investigated by OWL.

2.4 Observation wells

The ten observation wells are all read monthly. These are:

- Three in the left abutment area of the dam (OW1 – OW3).
- One near the downstream toe near the power station (OW4).
- Six along the sides of the main spillway (OW5 – OW10).

Graphs of these readings since 1 April 2010 are attached at Appendix A. The graphs show the two or three levels at which readings are taken in individual tubes, for the purpose of checking discrete ground water levels at a range of selected locations and elevations.

Observation well readings for the reviewed period are generally in keeping with historical readings, and continue to show no presence of significant uplift pressures underneath the service spillway. Specific details relating to the observation wells are:

- OW1 was initially responsive to reservoir level over the period and in keeping with historical data, until the reservoir level dropped to below approximately 382 m RL, after which the upper well ran dry, and the lower well (inlet at 376 .5 m RL approx.) decreased steadily giving readings higher than the reservoir from January – March 2015.
- OW2 has remained dry since October 2013, which is in keeping with historical data.
- The lower OW3 has remained dry since October 2013, and the upper well was initially slightly responsive to reservoir level over the period until it ran dry in November 2014. These readings are in keeping with historical data.
- OW4 was initially slightly responsive to reservoir level over the period and in keeping with historical data.

- OW5, OW6 & OW7 produced data that was in keeping with historic data and corroborated relative change in reservoir levels. All OW5 wells went and remained dry in October 2014, and all OW6 wells ran dry between Jan – March 2015, until 23 March 2015 when the upper and middle wells recorded a slight increase.
- However, OW7 appears to respond to the slight increase in reservoir level (~ 2 m) following 03 March 2015 which did not appear in any of the other observation wells. This is suspected to be due to rainfall over this period rather than the reservoir level increase. Further monitoring of OW7 is warranted to place this 1x set of measurements in context.
- OW8, OW9 and OW10 were response tested using a peristaltic pump on the week starting 13 January 2014. This response testing was a reaction to unexpected levels being recorded in OW8 and OW10 since October 2013. This purge was to assess the extent to which the spillway operation in October 2013 may have influenced the observation wells. The wells appear to have fully stabilised since July 2014 and readings from these wells are consistent with historic levels.
- Readings from OW8 showed a very slight response to reservoir levels, until they went dry in March 2015. These readings are in keeping with historical data.
- Readings from OW9 & 10 showed a minimal response to reservoir levels over the period, with consistent levels apart from the upper OW10 well which decreased from November 2014 onwards and ran dry in March 2015. These readings are in keeping with historical data.

As per previous recommendations, regular readings of the standpipe in the toe remediation are desirable in order to assist with establishing a base line level for this instrument. This has been undertaken approximately monthly over the period, with an effectively constant water level recorded over this period, and only minimal decrease coincident with the very low reservoir level. Monthly readings should continue where safe access permits (i.e. icy rocks during the winter months may prevent reading).

3 Dam embankment crest and slopes

3.1 Overview

Visual inspection of the embankment included:

- Areas of the upstream face to the extent permitted by the reservoir water level (~371.0 m RL at time of inspection and hence highly visible).
- Areas of the downstream face.
- Crest.

3.2 Upstream face

The upstream slope and riprap appeared to be in satisfactory condition to the extent visible above the 371.0 m RL reservoir water level.

Photo 3-1 Upstream face at 27 Feb 2015 (from true left abutment)

Substantial accumulation of debris (i.e. tree branches and timber) was visible on the face. Periodic debris removal is undertaken and this should continue.

The very low water level exposed a well defined bench on the upstream face at around 374 m RL. This level correlates well with the observed deformation marker M3 just above the bench level. The other upstream face deformation markers (M1 & M2) were not visible during the inspection.

Photo 3-2 Upstream face at elver pass outlet showing established benches

It is recommended that the elevation of this bench be confirmed, in addition to survey of the upstream survey deformation markers, as part of the scheduled 2015 deformation survey.

RCM2015-03 Survey upstream bench at around 374 m RL and include exposed upstream face deformation markers in scheduled 2015 deformation survey.

This bench is approximately 4 m wide (refer Photo 3-3 below) and occurs in the area armoured with smaller stones against wave action erosion (Zone 4B, Type 4 fill D_{50} = 100 – 150 mm, as per the Design Report[2]). It is likely that the benching was established in 2001 when the reservoir was drawn down and held at 374 m RL for 2.5 months (May – July 2001), and has not been visible since that time until now. The thickness of the armouring material at this location is shown as 1.5 m on the Drawings and hence a suitable thickness of armour material remains so long as the reservoir is not allowed to remain at this particular level for extended periods.

[2] T&T," Opuha Dam Design Report" dated May 1999. T&T Ref: 13909

Photo 3-3 Bench on upstream face around 374 m RL.

Some erosion and benching of this material was anticipated in the design and a suitably thick layer was construction to accommodate this. The risk presented by significant wave erosion at this location was considered during the design phase to be mitigated, given that the normal operating range of the reservoir is above this zone and the coincident probability of sustained high design winds with a water level in this zone is low.

It is recommended that this bench, and the exposed upstream face below this, be closely monitored while the reservoir level remains at or below 375 m RL, to check for potential erosion to the upstream shoulder fill material beneath the armour layer. Further observed erosion to the armour material should be reported to the Dam Safety Consultant in a timely manner as part of the regular inspection regime.

RCM2015-04 OWL to monitor exposed upstream bench at around 374 m RL and exposed upstream face when the reservoir level is around 375 m RL and report to Dam Safety Consultant if ongoing erosion to the armour layer is observed.

Another area of interest was noted in previous annual inspection reports on the embankment upstream face near the intake tower, where the riprap surface appeared to be slightly concave (area located in the vicinity of steel reinforcing protruding from reinforced concrete demolition material reused as riprap). However there is no other evidence of any significant movement, and this area appears stable based on observations to date (refer Photo 3-4 below).

Photo 3-4 Upstream face opposite the tower where riprap surface was previously reported as appearing concave.

3.3 Downstream face

The downstream face appears to be in good condition (refer Photo 3-5 below). Periodic spraying should continue to control weeds.

Photo 3-5 Downstream face (from true left abutment)

3.3.1 Wet patch (near D16)

Observations of the wet patch of the reporting period are consistent with the interpretation outlined in the 2014 annual safety review report.

3.4 Deformation survey

Deformation surveys are necessary to monitor potential settlement and movement of the dam structure. The most recent bi-annual Type B Deformation Survey (survey 6A) was conducted in May 2013[3] and is reported in detail in the 2014 annual safety inspection report (and hence not repeated here, please refer to the 2014 report for details).

A bi-annual Type B Deformation Survey was undertaken immediately following the reporting period, and to date the corresponding survey report is not yet available for review. The results and comment on the 2015 Type B deformation survey will be included in the 2016 annual safety inspection report.

As per the 2014 annual safety inspection report, aside from some vertical deformation near the middle of the embankment crest, Opus reported in 2013 that the deformation survey did not indicate clear evidence of vertical or horizontal movement. It was further noted that the recorded magnitude of the overall settlements are relatively modest and consistent with measured settlements from other similar dams internationally as per Hunter and Fell[4]. Nonetheless, the trend of ongoing settlement apparent some sixteen years after the base survey is of interest and it is important to continue to monitor settlement and review the results relative to expected performance.

3.5 Embankment crest

The crest roadway and fence were generally in good condition (refer Photos 3-6 & 7 below). However, as noted in the 2014 annual safety inspection, there were some instances of slight deterioration to the wave barrier and there was a small gap between the bottom board and the ground in some places. Further to RCM2014-03, we recommend that the damage to the wave barrier is repaired and any gaps between the timber and embankment surface filled. This item is being considered in more detail as part of the CSR review responses.

[3] Opus; Opuha Dam, Deformation Survey No 6A; May 2013.
[4] Hunter and Fell; Deformation and dam safety of earthfill dams; ANCOLD 2010

Photo 3-6 Upstream face of wave splash barrier

As per previous correspondence, we understand that RCM2014-04 is being actioned by OWL and that the 2015 deformation survey includes survey of levels along the embankment crest and the crest wave barrier. This information will enable a comparison of specific reduced levels and relative levels to the level crest of 395.2 m RL adopted by the recent flood hydrology study completed in 2014[5].

Photo 3-7 Observed minor deterioration of wave splash barrier

[5] Tonkin & Taylor; Opuha Water Limited, Opuha Dam: Review PMF at Opuha Dam and ability to pass the PMF, Reference 51137.017; March 2014

4 Reservoir

4.1 General

As noted above, the reservoir level was very low at around 371 m RL at the time of the inspection, and as such a significant height of the reservoir margins was visible (refer Photo 4-1 below).

Photo 4-1 Observed reservoir margins from the dam crest.

The reservoir margin and adjacent slopes in the immediate vicinity of the embankment was visually inspected from the dam crest, upstream face bench, both abutments and from the island in the middle of the reservoir.

The public boat ramp located near the service spillway approach channel has concrete that is being undermined. This was noted in the last Annual Safety Inspection. It was recommended that maintenance work be carried out to infill the void; however, this is not a dam safety matter.

Aside from the undermining of the boat ramp discussed above, based on the extent of visual inspection from the dam crest there is no apparent sign of slope instability at the margin of the reservoir in the vicinity of the embankment. In addition, OWL has not reported any slope instability at the reservoir margin in the period.

4.2 Intake Tower

The intake tower was mostly above water level (10 m submerged only) at the time of inspection and appeared to be in acceptable condition (refer Photo 4-2 below).

It was however observed that the gantry crane power cable was not fully attached to the monorail beam and hanging loose for a section. Reattachment of the loose section of power cable is recommended. We understand that the crane certification is current.

RCM2015-05 Refasten hanging section of gantry crane power cable to monorail beam

Photo 4-2 Intake tower from crest of the dam

A dive inspection of the intake tower was undertaken during this monitoring period (between 17 – 19 March 2015) with the very low reservoir facilitating improved access the longer safe dive times. Assessment and maintenance was undertaken on the submerged tower bolts (i.e. cleaning, retightening, and replacement as deemed necessary) and some of the braces at this time.

Following this inspection, bolt replacement work commenced and will be undertaken progressively as the water level increases allow access to higher levels of the tower. The tower was reported to be in good condition with only few small rust nodules observed where the protective coating had been chipped.

The 2015 dive inspection report is appended and includes inspection photos and description of this work.

5 Service spillway

5.1 General

The service spillway provides for the controlled release of water. The gates were not operated to enable spill during this annual review period.

5.2 Spilling Events

The service spillway did not operate during the period.

5.3 Spillway approach

The approach to the service spillway was visible at the time of the inspection due to the very low reservoir level. The approach had moderate debris present, primarily drift wood. The approach was observed to be in good condition (refer to Photos 5-1 & 2 below).

Photo 5-1 Exposed approach service spillway

The repair to the slip failure that occurred to the right hand side of the approach channel/road cutting northwest of the service spillway (between the bridge and the boat ramp) remains effective and in good condition (refer Photo 5-2 below).

Photo 5-2 True right bank of approach channel to service spillway

No sign of failure of the shotcrete coating repair over the rock on the right hand side of the spillway inlet approach was observed during the inspection.

Photo 5-3 Shotcrete repair area (TR bank of inlet)

The structural concrete spillway approach walls are in good condition with no further movement visible between the spillway left side approach wall and concrete bridge abutment (refer to the 2006, 2007, 2008 and 2009 Annual Safety Inspection for background details).

5.4 Obermeyer gates

On the day of the inspection, OWL reported that the gates were operating as required. It is noted that the Obermeyer gates were not required to operate over the period given the reservoir water levels.

We understand OWL are considering installation of an upgraded control system for the Obermeyer gates.

5.5 Stepped spillway chute

The service spillway did not operate over this annual review period.

The spillway steps appeared to be in satisfactory condition. A few medium sized rocks were noted on the spillway, but there was no visible damage of major significance at this time to the step edges (refer Photo 5-4 below).

Photo 5-4 Service spillway

5.6 Stilling Basin

Inspection of the stilling basin indicated that it is in a satisfactory condition as could be viewed from the ground surface. However, the sill along the end of the stilling basin is damaged as noted in previous annual inspections. Inspection indicated that operation of the spillway during the period does not appear to have caused noticeable additional quantities of rock to erode from the platform directly beyond the stilling basin. At some point, it will be necessary to undertake repair of eroded rock at this location.

Previous Annual Reports have recommended monitoring of this area and it is important that this continue. At some point, it will be necessary to drain the stilling basin to inspect the structure and remove accumulated rock.

Photo 5-5 Tailrace and spillway stilling basin

Photo 5-6 Damaged Sill of Stilling Basin (taken in 2014 as underwater at time of 2015 inspection)

6 Auxiliary spillway

6.1 Fuse plug and channel

The auxiliary spillway appeared to be in good condition. The riprap on the upstream face and approach channel were in good condition (refer Photo 6-1 below). Routine spraying should continue in order to prevent establishment of vegetation on the fuse plug fill, particularly in the vicinity of the triggering device outlets.

Photo 6-1 Auxiliary spillway upstream face (from true left abutment)

OWL advise that the fusing device clay pipes have recently been flushed and that they are clear of blockages and debris. Any future blockages should be removed as they arise, as per routine maintenance procedures.

6.2 Left abutment cut slope

The left abutment cut benches, above the auxiliary spillway, are in satisfactory condition. The historical wedge failure downstream of the fuse plug shows no sign of recent movement. There were no further signs of significant movement on the slope or of fuse plug erosion from concentrated stormwater runoff down the cutting.

Photo 6-2 Left abutment cut slope

A survey benchmark was exposed at the toe of the true left abutment by the auxiliary spillway cut (refer Photo 6-3 below), due the very low reservoir level.

Photo 6-3 Left abutment survey marker

6.3 Upstream face area of interest

Observations over the current review period and measurements of D18 drain flows are consistent with historic observations, noting that D18 was dry from November 2014 onwards due to the low reservoir levels.

Photo 6-4 Area of interest on the upstream face of the auxiliary spillway

7 Power station, draft tube outlet and other ancillary structures

7.1 Powerhouse

The external and internal structure appeared to be in satisfactory and tidy condition. The powerhouse was viewed from the access platform and from around the base of the generator and turbine. No seepage was observed around the penstock pipe penetration through the station wall. Also no other internal leakage into the structure was observed. The power station was operating at the time of the inspection. The FCD was not operated at the time of the inspection but is understood to be operating correctly.

An auxiliary power generator was installed adjacent to the powerhouse and commissioned in May 2013.

The seismograph that OWL currently possesses is not operational. GNS advise that the instrument is obsolete as the technology required to extract the data no longer exists. GNS also previously advised that their service contract has expired.

Resource Consent CRC950579.3 requires the consent holder to devise and carry out a monitoring programme which measurers and reports on the seismic accelerations at the dam. It is recommended that a seismograph is set up in the powerhouse to allow the accurate reading of any future seismic movement at the dam location.

Recommendation RCM2013-11 (Installation of Seismograph) remains relevant. Potential suppliers include Canterbury Seismic Instruments as well as GNS.

7.2 Draft tube outlet

The recommendation from the dive inspection carried out in 2008 (RCM2008-32) has yet to be fully resolved, but is in progress. RCM2008-32 states that the observed damage to the draft tube outlet/tailbay concrete should be investigated in greater detail to assess the effects and consequences and determine whether immediate repairs are required.

OWL engaged Trustpower to undertake an inspection of the draft tube outlet area, which occurred 26 March 2015 (following the tower dive inspection and bolt replacement). To enable a more thorough inspection of the tailbay concrete conditions, this area was isolated and dewatered.

Concrete erosion was observed on the tailbay channel invert immediately downstream of the transition for the gate/bulkhead. Two areas of damage where the reinforcement was exposed (HD16 bars at 200 mm centres as per As-built Drawings) were identified (refer Photo 7-1 below as provided by Trustpower).

It was speculated that this damage may be due to scouring from turbulent flows and rock impact in these locations, though this has not been established as the damage mechanism. It is also possible that this damage may be due to turbulent flow pressure fluctuation in this transition.

It is noted that these areas of damage may have been present for a long time (i.e. first identified in 2008), and do not appear to be rapidly progressing. Repair to the areas where the reinforcement is exposed is recommended at the next available opportunity, noting the operational constraints may mean this occurs outside of the irrigation season. Selection of the preferred repair solution and methodology given the operational constraints requires further consideration.

RCM2015-06 *Investigate options and undertake repair to damaged draft tube outlet concrete.*

Photo 7-1 *Tailbay dewatering and condition assessment (looking down) showing exposed rebar on invert at transition (Provided by Trustpower).*

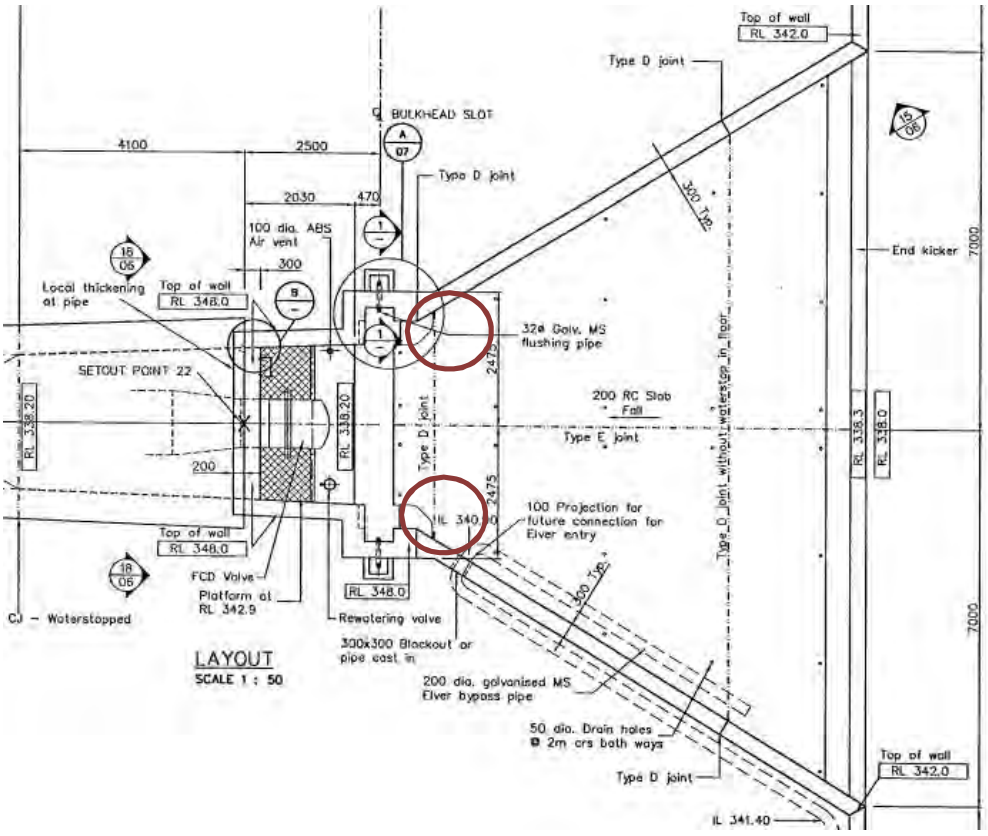

Figure 7-1 *Excerpt from As-built Drawing 13897-5-S05 showing draft tube outlet and tailbay areas of observed damage (circled in red)*

7.3 Switchyard

Security fencing was installed around the power station and switchyard during the 2013 - 2014 period. Fencing and security measures was observed to be in very good condition.

7.4 Conduit outlet drain pipes

The conduit outlet drain pipe is now feeding into a sump that also serves the subsoil drainage system in the switchyard (refer Photo 7-2 below). This additional water is creating a surcharge on the subsoil drainage system which should be monitored to ensure it does not affect the performance of the subsoil drainage system and stability of loess fill in this vicinity.

Photo 7-2 Conduit outlet drain discharge

7.5 Allandale pipeline

Two valves adjacent to the power station control small diameter pressurised pipelines that run across the dam toe. The valves are covered by timber lids that are not vandal proof. However they are now separated from the public with the security fence and lockable gate that surrounds the power station and switch yard.

The valve to the Allandale line is usually shut and it is understood that the line is not currently used. OWL have advised that recommendation RCM2010-04 regarding the condition and status of this line has been resolved.

7.6 Conduit Anchor Block AB2

The anchor block appeared in good order. A survey marker has been installed on the top of the anchor block and is incorporated as part of the deformation survey as required.

7.7 Conduit inspection

No conduit inspection was undertaken in this review period. The most recent inspection was undertaken on 5 June 2013 and is reported separately (refer 2014 annual inspection report for summary).

7.8 Elver Pass

The elver pass over the main embankment is functioning and appears in good condition. Several elver were observed in the box at the downstream weir during the inspection, suggesting suitable passage exists from the downstream weir.

The elver pass outlet pipe line was exposed on the upstream face of the dam (refer Photo 7-3 below). Some minor blockage was noted and cleaned by OWL during the inspection but otherwise the pipeline appeared to be in operable condition.

Photo 7-3 Exposed elver pass outlet pipe on upstream face of dam

7.9 Plant critical to dam safety

The following section details plant that are critical to dam safety and this section of the report quickly outlines the status of all of these components.

7.9.1 Obermeyer gates

The Obermeyer gates are advised to be currently functional and operating as expected.

7.9.2 FCD Valve and associated valving

The FCD valve and associated valving was not operated during the 2015 annual inspection, as the powerhouse was operating during the inspection to provide the residual flow requirements.

TrustPower advised that the FCD was operated on the following dates in the review period:

- 7 April 2014 (flow from 10 to 7 m^3/s)
- 21 – 23 May 2014 (4 m^3/s)
- Intermittently for a few hours on 6 June 2014 and 30 September 2014 (flow range of 6 - 10 m^3/s)
- 16 June 2014 (flow from 5 to 4 m^3/s)
- 1 and 2 October 2014 (1.8 to 16.5 m^3/s)
- Part of 12 October 2014 (1.8 to 16.5 m^3/s)
- Part of 13 November 2014 (16 m^3/s)
- Intermittently between 19 and 27 January 2015 (flow range of 1 - 7 m^3/s)

Other valving of significance was not operated over the period (i.e. the 450mm by-pass).

7.9.3 Conduit bulkhead

The conduit bulkhead and lifting arrangement was tested during the 5 June 2013 conduit inspection and worked well. No inspections of the conduit were undertaken during this review period.

7.9.4 Auxiliary power supply

An auxiliary power supply (60kVA standby diesel generator) has been installed and is now present in the power station.

8 Downstream weir

8.1 General

The Opuha Dam Downstream Weir (DSW) is approximately 1.4 km downstream of the Opuha Dam and is physically separated from the main dam. The DSW attenuates the flow released from the main dam and regulates the flow discharged to the Opuha River downstream. The key components consist of a radial gate, fixed spillway, fusible embankment and enclosure embankment. These are shown in Photo 8.1 below.

Photo 8-1 Opuha Dam Downstream Weir

The crest, part of the upstream face and downstream face of the right hand closure embankment were inspected. Monitoring instrumentation on the downstream weir and appurtenant structures include:

- Regulation pond water level recorder
- River downstream water level recorder which is used to infer flow rate discharged from the radial gate and various other parameters
- Gate position encoder.

To the extent visible, the upstream and downstream faces of the closure embankment are in a satisfactory condition.

8.2 Downstream weir overflow embankment

8.2.1 General

The Downstream Weir Overflow Embankment (DWOE) is designed to fuse during a five year or greater Average Recurrence Interval (ARI) flood. The estimated five year ARI routed dam

outflow is approximately 100 m^3/s. The present DWOE was reconstructed in 2009 after it operated during high flows in May 2009.

Photo 8-2 Downstream face of overflow embankment and spillway

8.2.2 Recent embankment reinstatement

Remedial works were undertaken on 12 and 13 December 2013 to excavate and backfill a sinkhole located on the DWOE. The identified sinkhole was the only collapse or erosion feature seen on the upstream face in the monitoring period. Some additional movement was noted in January and March 2014 during visual inspection of the area.

During the 2014 annual inspection an 8 m long crack was noted on the OE crest and assessed to be of a minor nature. This feature appeared unchanged as observed during the 2015 inspection, and noted on the monthly surveillance records from OWL. We recommend that this area continue to be monitored into the new period for further movement.

Movement of the upstream face of the overflow embankment occurs as a consequence of the upstream fine liner washing into voids within the main embankment fill. Because the structure was considered to have a short design life T&T were previously advised that the cost of a filter was not justified. It was also not a dam safety matter insofar as the stability of the bulk/gravel fill is concerned and that that seepage was of nuisance value.

It is anticipated that the life of the overflow embankment will now increase (due to proposed downstream weir enhancement works) and thus it is suggested that OWL review the strategy to manage the overflow embankment. Options range from visual surveillance and regular monitoring and review whilst accepting some minor leakage to a major rebuild featuring filters between the upstream liner and gravel bulk fill.

Photo 8-3 Crack in crest close to recent embankment repair (2015)

8.3 Enclosure embankment

The enclosure embankment appears to be generally in good condition with the exception of presence of weeds in the area immediately adjacent the radial gate structure (see Photo 8-4 below). Weed growth is this area was advised to be likely due to the new fill added in this location to top up the embankment crest level following the recent survey. Spraying of these weeds is recommended (as per ongoing maintenance requirements).

Photo 8-4 Area of weed growth on downstream weir enclosure embankment for spraying

RCM2015-07 Spray weeds on downstream weir embankment.

It was recorded in previous monthly monitoring reports that seepage and a resulting 'boggy area' were observed at a low point in the land just south of the downstream weir enclosure embankment. This seepage was noted at times when the pond water level was particularly high. The usual water table level, as measured in late 2012 when a test pit was carried out in the area, is below ground but analysis suggests that it could raise above ground if the water level in the pond was high and the seepage gradient through the dam remained constant.

This area was observed as being greener than the surrounding land during the 2015 annual inspection, and otherwise unchanged and consistent with historic observations. This seepage is not considered to be of concern at this time, as the seepage appears consistent with historical observations and inferred seepage gradients appear unchanged, however ongoing monitoring is recommended as part of the usual dam surveillance.

8.4 Weir and control structure

The weir and control structure was generally in good condition. No issues around the repair to the gabion baskets carried out in the 2010-2011 period have been reported.

The concrete weir spillway is in a satisfactory condition (refer Photo 8-5 below). Small horizontal cracks and superficial spalls noted in previous inspection reports do not appear to have significantly changed in the last year.

Photo 8-5 Service spillway

Visual inspection suggests that the downstream radial gate is in serviceable condition, but in need of routine cleaning at the next available opportunity.

At the time of inspection, the gate was held open by the hydraulic ram, noting that the backup of steel legs to prevent the gate from closing completely (to ensure residual flow requirements are met) remained. OWL advised that the gate operated unintentionally during this assessment period due to a fault with the downstream river level recorder (recorded zero resulting in full gate opening), which was picked up due to observation by TrustPower staff on site at the time.

The DC electrical power back up for the operation of the radial outlet gate was advised to be working as required.

The concrete and stone armouring on both banks is generally in satisfactory condition (refer Photo 8-6 below). It has been previously noted that the mass concrete beyond the end of the chute right hand training wall (beyond the toe of the ogee weir) is at least partially undermined. This has not changed significantly since 2010 but ongoing monitoring of this area by OWL is warranted.

Photo 8-6 True right bank of radial gate channel

Movement of the concrete wall next to the control shed previously reported has not appeared to have moved during the period when compared with photographs from last year's inspection.

Some of the handrails around the control structure (refer Photo 8-7 below) may not comply with current requirements according to Building Code Clause F/4 which requires that, in areas used exclusively for maintenance where someone can fall more than 1 m, vertical gaps between longitudinal bars must not exceed 460mm. We suggest investigating whether these handrails require upgrading.

Photo 8-7 Current handrail configuration

9 Access road

9.1 Access to dam

The maintenance of the access road to the dam is the responsibility of the Mackenzie District Council, including removal of slumps from the batters on the west side of the access road leading to the dam. Road access was clear at the time of the inspection.

9.2 Dam road

The dam road was generally in good condition. The dam crest road has a safety barrier on the upstream edge (as reported above). In addition, public access to the dam crest road is restricted by a locked chain with signage. Access to the powerhouse and downstream weir were clear at the time of inspection.

In a previous annual review (2013) it was noted that there were issues relating to scour on the downstream face below the road due to surface water runoff. This is an issue that relates to the grading of the road by the contractor (slope of the road, extent of swale and extent of longitudinal bund along the outside edge). It is important to keep the road functional and avoid drainage issues which may result in the erosion of the downstream face of the embankment. OWL advised that they will continue to monitor the grading of the road and consider options to improve road drainage.

10 Recommendations

10.1 2015 Recommendations

Dam safety recommendations arising from the 2015 inspection and review are collated below in Table 10.1. The recommendations for action on each component of the project are numbered, referenced to the section in this report where they arise and categorised as:

- N (Necessary) to be done as a priority (within 12 months) or regularly
- D (Desirable) to be done at a suitable time before the next Comprehensive Safety Review (CSR).

Some general suggestions regarding the maintenance of the dam have also been provided for consideration by OWL as summarised in Table 10.1 below.

Table 10.1 Opuha Dam 2015 Annual Review recommendations

Reference	Report Section	Recommendation	Category
RCM2015-01	S2.2.1	Clear blocked drain D16 outlet	N
RCM2015-02	S2.2.5	Update the drain flow alert criteria for D4, D7, D8, D9, D10 & D21 based on the recorded flows for reservoir levels down to 370 m RL.	N
RCM2015-03	S3.2	Survey upstream bench at around 374 m RL and include exposed upstream face deformation markers in scheduled 2015 deformation survey.	D
RCM2015-04	S3.2	OWL to monitor exposed upstream bench at around 374 m RL and exposed upstream face when the reservoir level is around 375 m RL and report to Dam Safety Consultant if ongoing erosion to the armour layer is observed.	D
RCM2015-05	S4.2	Refasten hanging gantry crane power cable to monorail beam	N
RCM2015-06	S7.2	Investigate options and undertake repair to damaged draft tube outlet concrete.	N
RCM2015-07	S8.3	Spray weeds on downstream weir closure embankment.	N

The current statuses of all recommendations from the inspections of 2008-2011, 2013 & 2014 are presented below in Table 10.2 (including categorisation as per Table 10.1 above). The colouring in the Table 10.2 refers to the status of the recommendations which are categorised as:

- White: Recommendation has not yet been actioned;
- Light Grey: Recommendation is in the process of being actioned;
- Grey: Recommendation has been actioned within this annual review period, is being actioned (if an ongoing recommendation) or has been resolved in a way different to the recommendation (refer to previous annual inspection reports for details of completed/resolved recommendations prior to this period)

Table 10.2 Previous Opuha Dam Annual Review recommendations

Reference	Recommendation	Category	Status
RCM2014-01	TrustPower to monitor all telemetered drain flow data and identify in real time alerts should these occur and implement procedures to ensure that OWL and T&T are advised of alerts in a timely manner.	N	Outstanding.
RCM2014-02	De-air all piezometers annually and undertake associated piezometer maintenance as is described in the Piezometer Maintenance report.	N	In progress.
RCM2014-03	Carry out crest maintenance on the main embankment including repair of the timber wave barrier.	N	Outstanding.
RCM2014-04	Expand the scope of the next deformation survey to clarify the embankment as-built crest and timber wave barrier levels (specific levels as well as relative difference/potential low spots) in accordance with the recommendations of the recent PMF review.	N	In progress.
RCM2014-05	Weed spray downstream weir embankment.	N	Completed. Maintenance ongoing.
RCM2013-01	Investigate an alternative method for accurately measuring sediment flux from the drains and collection of samples for particle size distribution analysis.	N	Outstanding.
RCM2013-05	Replacement of broken piezometer gauges.	N	In Progress.
RCM2013-06	Regular readings of the standpipe in the toe remediation.	D	Ongoing.
RCM2013-11	Installation of the seismograph.	N	In Progress.
RCM2013-13	Ongoing visual monitoring be undertaken by OWL of area of scour of downstream face of the Dam, below the road.	N	Ongoing.
RCM2011-06	Routine maintenance to ensure that the inlets to the fuse plug triggering device clay pipes are kept clear of debris.	N	Maintenance ongoing
RCM2011-09	Ongoing visual monitoring be undertaken by OWL of wet spot on DSWOE	N	Ongoing
RCM2010-03	Clear fuse plug triggering device clay tile outlet pipes and maintain these pipes free from blockage.	N	Completed. Maintenance ongoing.
RCM2010-04	Review status of Allendale water supply pipe line and ensure all valves in the vicinity of the power station are secured against tampering by vandals.	D	Completed

Reference	Recommendation	Category	Status
RCM2009-01	Develop and implement an investigation procedure to determine the source of seepage emerging at the embankment face near Drain D16.	N	Ongoing
RCM2009-08	Spray gorse on the Downstream weir closure embankment	N	Maintenance ongoing
RCM2008-28	The damage to the spillway basin downstream sill should be repaired with concrete. The use of mesh reinforcement or alternatively fibre reinforced concrete is recommended to reduce the chance of further damage, preceded by clearing off all loose rock and growth.	N	Ongoing monitoring occurring
RCM2008-32	The damage to the tailbay concrete should be investigated in greater detail to assess the effects and consequences and determine whether immediate repairs are required.	N	In progress
RCM2008-37	Debris should be regularly removed to prevent it from becoming stuck in the gate.	N	Debris removed August 2008. Monitoring ongoing

10.2 2012 CSR recommendations

The 2012 CSR highlighted some issues around dam safety that required action. OWL is currently following through with the recommendations. Recommendations that have not yet been actioned or are in the process of being actioned are shown in Table 10.3 below.

All other recommendations have either been completed or have been actioned and are not reproduced below. A full list of the conclusions reached during the completion of the CSR are stated in the 2012 Opuha Dam Safety Review Report[6].

Table 10.3 Opuha Dam outstanding CSR recommendations

Recommendation	Comment	Current status
Develop a dam safety assurance programme that meets the requirements of the Building (Dam Safety) Regulations 2008	OWL's current surveillance regime meets current NZSOLD Guideline requirements and will be expanded for new Dam Safety Assurance Programme as prescribed by the Regulations when they become operative from July 2015.	Not actioned
Complete a Failure Modes and Effects Analysis (FMEA) before the next CSR.	OWL previously indicated that this would be coordinated after upgrade of the DSW project.	Not actioned

[6]Pickford Consulting Ltd "*Opuha Dam Safety Review Report*" June 2012

Undertake and document regular exercises to test emergency procedures and provide emergency personnel with appropriate training.	Regular training exercises will ensure that personnel are aware of their responsibilities and are familiar with all emergency procedures.	Updating of EAP in progress
Install an intruder detection/alarm at the spillway gatehouse.	To reduce/manage the risk of intrusion and vandalism.	Not actioned
Install an intruder detection/alarm at the re-regulation gatehouse.	To reduce/manage the risk of intrusion and vandalism.	Not actioned
Install a log boom across the front of the DSW radial gate outlet structure.	To improve public safety.	Not actioned
Complete a thorough review of piezometer and observation well alert levels and piezometer trigger levels.	Alert and trigger levels should reflect current trends and expected dam performance.	De-airing ongoing.
Review the reliability of the existing piezometers and consider installing additional instrumentation to monitor seepage conditions within the seepage control zone (Zone A).	Unusual piezometric pressures have been recorded at a number of piezometers and no effective instrumentation is in place to identify a change in seepage behaviour within the seepage control zone (Zone A).	Initial assessment complete as reported separately, finalisation pending completion of piezometer deairing

11 Applicability

This report has been prepared for the benefit of Opuha Water Ltd with respect to the particular brief given to us and it may not be relied upon in other contexts or for any other purpose without our prior review and agreement.

Tonkin & Taylor Ltd

Environmental and Engineering Consultants

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