REPORT

Opuha Water Ltd

Opuha Dam
Annual Safety Inspection 2014

Report prepared for:

Opuha Water Ltd

Report prepared by:

Tonkin & Taylor Ltd

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Executive summary

The annual safety inspection of Opuha Dam for 2014 was undertaken on 1 April 2014. This report incorporates the inspection on that day and a review of the dam's performance for the period between 1 April 2013 and 31 March 2014. The review is undertaken in accordance with the recommendations of NZSOLD Dam Safety Guidelines (2000).

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

A Type-B Deformation Survey was conducted in May 2013. Aside from some vertical deformation near the middle of the embankment crest, Opus concluded that the deformation survey did not indicate clear evidence of vertical or horizontal movement.

A conduit inspection took place during the beginning of June 2013 and concluded that the conduit appeared to be generally in good order. Some areas of paint degradation were identified and repaired under the direction of TrustPower Ltd during the inspection. A dive inspection of the conduit intake, intake tower, and bulkhead was also carried out in conjunction with the conduit inspection. The report remains outstanding. During the period of these inspections, the 450mm bypass conduit was operated satisfactorily. Excavation and backfilling was carried out on a sinkhole on the upstream face of the downstream weir overflow embankment (DWOE) on 12 and 13 December 2013.

There were no other significant operational incidents during the period.

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 2013 provided 13 recommendations. The current status of these is reported in Section 11.

The dam safety related recommendations that have been made as a consequence of the 2014 annual inspection are as follows:

- Weed spray the downstream weir closure embankment and areas adjacent to the existing radial gate;
- Complete maintenance on the crest of the main dam embankment including repair of the timber wave barrier structure;
- Carry out a level survey on the crest of the main dam embankment coincident with the next deformation survey. This survey should provide a good definition of the topography in the vicinity of the crest and include readings adjacent to each post at ground level and along the top of the wave barrier. The survey will clarify specific as-built crest levels and identify any unevenness along the crest;
- Ensure that TrustPower reinstate real time alert levels (ex surveillance manual) to their system and monitor telemeter data in real time for potential drains alerts and instigate procedures to promptly notify T&T and OWL in the event that a drain alert level is exceeded.
- Complete an annual de-airing of the hydraulic piezometer and undertake other works (e.g. replace certain gauges) as reported separately

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;
- Tonkin and Taylor to review dive inspection report once it is available.

1 Introduction

The 2014 Annual Safety Inspection of the Opuha Dam was undertaken on 1 April 2014, by Tim Morris and Chloe Sutherland 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 still and overcast becoming fine. The reservoir level was at 387.0 m RL.

The inspection took approximately 4 hours and progressed along the following route:

- Service spillway approach channel and Obermeyer gate structure;
- Dam crest and exposed area of the embankment upstream face;
- Auxiliary spillway and true left abutment including abutment benches to the extent visible from the spillway channel;
- Areas of the embankment downstream face H flume drains;
- True right abutment and Service Spillway;
- Powerhouse
- Downstream Weir.

This report incorporates the inspection on that day and reviews the performance of the dam in the period from 1 April 2013 to 31 March 2014 in accordance with the recommendations of the New Zealand Dam Safety Guidelines NZSOLD (2000). 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;
- Conduit;
- The reservoir, including the intake tower;
- The service and auxiliary spillways;
- The power station and tailrace;
- The downstream weir;
- Access roads;
- Surveillance and monitoring during the period including consideration of any operation incidents of note that have occurred during this time.

Various parties are involved in operation and maintenance of the Opuha Dam. These parties include: Opuha Water Ltd (OWL), TrustPower (TP, Dam Operator), Environmental Consultancy Services Ltd (ECS, data service provider), and Tonkin and Taylor, (Dam Safety Consultant).

2 Compliance

NZSOLD's Dam Safety Guidelines recommend that the Annual Inspection (referred to in the Guidelines as Intermediate Inspection) involves:

"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 is undertaken in accordance with the recommendations of NZSOLD Dam Safety Guidelines (2000).

3 Dam Instrumentation

3.1 Overview

This section reviews the data for the dam instrumentation for the period 1 April 2013 to 31 March 2014. The layout of the dam instrumentation is presented in Figure 1 below. The locations of the hydraulic piezometers located within the embankment on the instruments lines 1, 2 and 3 shown in the figure below can be found in Section 3.3.1. In general, the dam and spillway instrumentation continues to operate satisfactorily.

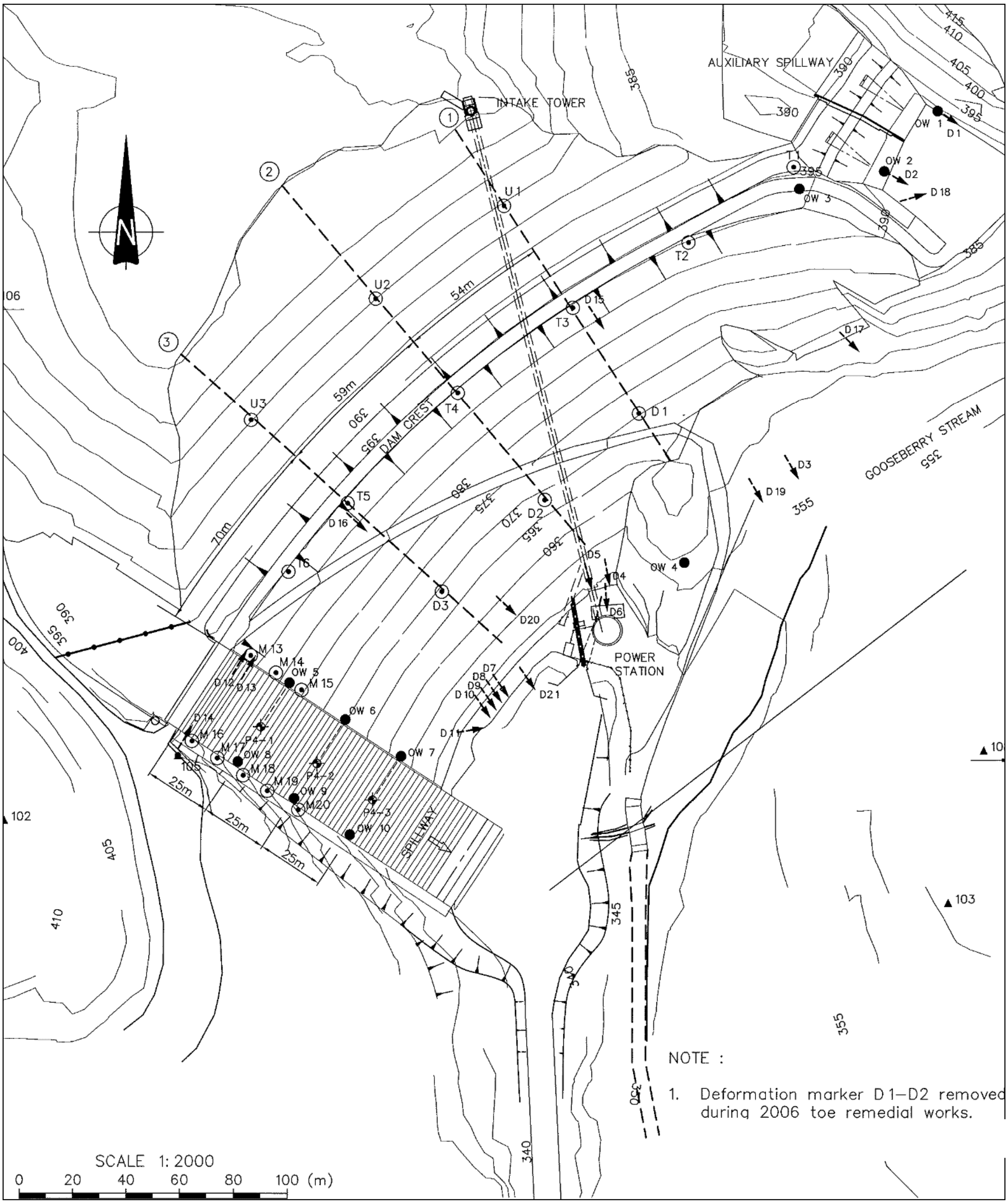

Figure 1 Instrument Layout

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 drain D7 for turbidity monitoring;
- Hydraulic piezometers with gauges in the power house;
- Pneumatic piezometers located under the Service Spillway and read when the Service Spillway operates;
- Standpipes;
- Rain gauge;
- Survey monuments to indicate embankment deformation.

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.

3.2 Drains

3.2.1 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 via the scheme SCADA system operated by TrustPower. An hourly average level is produced, hence an inferred average hourly flow rate is produced. Drain flows are also manually read monthly 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 2013 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 2007 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).

OWL have 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.

3.2.2 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. Drain flows were last tested in March 2013 and ongoing annual quantitative testing of drain discharges to check for the presence of suspended sediment is warranted and endorsed.

Total Suspended Solids (TSS) measurements as at March 2013 and 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/*l*) and have been so since 2012.

The D9 TSS measured on 15 April 2014 was 7 mg/*l* and is similar to the 5 mg/*l* measurement recorded in 2012 and 2013. Flows in D9 therefore seem to have slightly higher TSS results than adjacent drains 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 was found to have 4 mg/*l* 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 ongoing.

3.2.3 Drain flow turbidity meter

Based on recommendation in the 2013 Annual Safety Inspection Report, OWL has been cleaning the lens of the electronic turbidity meter in the D7 H-flume on a regular basis.

In November 2013, Trust Power started supplying the turbidity data to T&T weekly with the electronic drain flow data, for analysis as part of the monthly monitoring reports. This data has yet to establish a baseline trend.

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 turbidity readings appear to be relatively stable and are reviewed by T&T as part of the ongoing dam surveillance and monitoring requirements.

3.2.4 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.

BCM2013-03 (Installation of an automated turbidity monitoring system) is yet to be actioned. This recommendation should be reviewed in light of the data recorded by the automated D7 (base drain outlet) turbidity data. That is, the D7 turbidity meter gives variable results (refer steps in recorded data) and it is yet to be established if such steps would result in unnecessary alerts/a meaningful automatic alarm system.

Figure 2 Chimney drains D8-10, and D7

3.2.5 Drain Flows

Out 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 in Sections 3.2.5.1, 3.2.5.2 and 3.2.5.3 below where flows have exceeded Alert Levels in D9, D18 and D21. No other drains exceeded their Alert Levels during the period.

All drain flows were consistent with historical data both in terms of flow levels and responsiveness to reservoir level. Specific comments made in the 2013 Annual Safety Inspection report remain unchanged. General comments relating to the drains 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 during the summer months;
- Water level recorded flow 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 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 has historically been very responsive to reservoir level. This trend has not been so apparent since January 2011. D7 flows produced during the period are

in trend with flows produced for respective reservoir levels since January 2011. In August and December during this monitoring period, flows increased with a decrease in reservoir level which is still consistent with historical data;

- Drain D8 flows remained fairly constant throughout the monitoring period. This drain is not responsive to small changes in reservoir level; however, it recorded a decrease in flows during April and May when reservoir levels are low;
- Drain D9 produced a low constant flow during the monitoring period. It is not very reactive to reservoir levels but recorded a small decrease in April and May when reservoir levels were low. There was an uncharacteristic apparent increase in reading for 15-18 February as a result of a foreign object entering the flume. Once the foreign object was identified and removed the readings decreased to historically normal levels. The higher flows inferred at this time are not representative of actual flows. This was an anomaly and has not affected the long term flow from this drain. This caused the drain to exceed its lower bound alerts from 15-18 February but was not noticed until analysis after the fact when data was available. See section 5.2.5.3 for discussion on the importance of automatic alert levels;
- Drain D10 produced flows that were very responsive to reservoir levels which is in accordance with historical trends. The flows sometimes seem to lag behind the changes in reservoir level by a month. There has been no observed change in the base trend;
- Flows produced by drain D17 were lower in April and May during a time with lower reservoir levels and higher from October to January as the lake was kept at a relatively high level. The decrease in flows during August and March indicate that this drain is quick to respond to reservoir level changes. These trends are fitting with historical flows produced at similar reservoir levels;
- Flows in drain D18 were observed and measured on a monthly basis between 27 June 2013 and 30 January 2014 except for 29 August 2013 when there was no flow. Flows appeared during June when the reservoir level rose and disappeared in August in keeping with a small decrease in reservoir level. When the reservoir level rose again in September the flows reappeared. It rose to a maximum in October when the reservoir level was also at a high for the monitoring period. This drain is very responsive to reservoir level. The Alert Level was exceeded on 26 September 2013 and 24 October 2013. For more information on investigation into the Alert Levels produced by this drain see Section 3.2.5.2;
- 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;
- D21 flow rates have exceeded the lower bound Alert Level on several occasions throughout the period. D21 is very responsive to lake level, and the exceedance usually occurred in times of heavy rainfall when the lake is high and the drain was collecting surface water runoff from the toe of the dam. The recorded flow from D21 exceeded the Alert Level criteria continuously for a period of more than 24 hours between 17-22 June 2013, 3-4 July 2013 and 16-17 October 2013. The Alert Level criteria was also exceeded for very short periods on 3 June 2013, 22 June 2013, 1 July 2013, 4 July 2013 and 31 December 2013. It should be noted that the Alert Level varies depending on reservoir level. Periods where the flow exceeded the Alert Level were appropriately investigated. At all times flows were well below the upper bound D21 Trigger Level criteria of 500 l/s for all reservoir levels. For more information on the revising of D21 Alert Levels see Section 3.2.5.1.

The 2013 Annual Safety Inspection report have noted that D21 flows rise when the reservoir level rises above approximately 390.8 mRL.

Refer to Appendix A for the data that this discussion is based on.

3.2.5.1 D21 Alert Level

D21 flow rates have exceeded the lower bound Alert Level on several occasions since the Alert criteria was last revised in July 2010, and revision of the Alert Level is a recommendation of the 2013 Annual Safety Inspection (RCM2013-04). The July 2010 Alert Level was based on a limited amount of data, during a time in which the reservoir level was typically kept well below the spillway crest level of 391.2 m RL. Since July 2010, there is now approximately twice the number of data points for flows produced at D21. Operation of the reservoir over the last two to three years has kept the reservoir level high relative to previous years. There is also significantly more flow data available at higher reservoir levels than was available previous to July 2010.

Given the increase in the amount of data and the reservoir level in which the flow data is produced, it is appropriate that the lower bound Alert Level be revised to reflect the flows produced over the operational range of the reservoir. It is important to have a lower bound Alert Level that accurately reflects the range of flows produced at D21. Persistent alerts produced at D21 has removed the significance from lower bound alerts. Updating the alert level will allow for future alerts to be treated with the importance that is required.

Table 3.1 below and Figure 3 below outlines the July 2010 and April 2014 revised Alert Levels. Many of the exceedances above the proposed alert level are associated with heavy rainfall and/or the Canterbury earthquakes.

Table 3.1 D21 Lower Bound Alert Levels

Reservoir level (m RL)	D21 Alert levels – D21 drain flows (l/sec)	
	July 2010	Revised April 2014
372	0.5	0.5
373	0.5	0.5
374	0.5	0.5
375	0.5	0.5
376	0.5	0.5
377	0.5	0.5
377.5	0.5	0.5
378	0.5	0.5
379	0.5	0.5
380	0.5	0.5
381	0.5	0.5
382	0.5	0.5
383	0.5	0.5
384	1.5	1.5
385	2.5	2.5
386	3.5	3.5
387	4.5	4.5
388	5.5	6.1
389	6.5	7.7
390	7.5	9.3
391	8.5	10.9
392	9.5	12.5
393	10.5	14.1

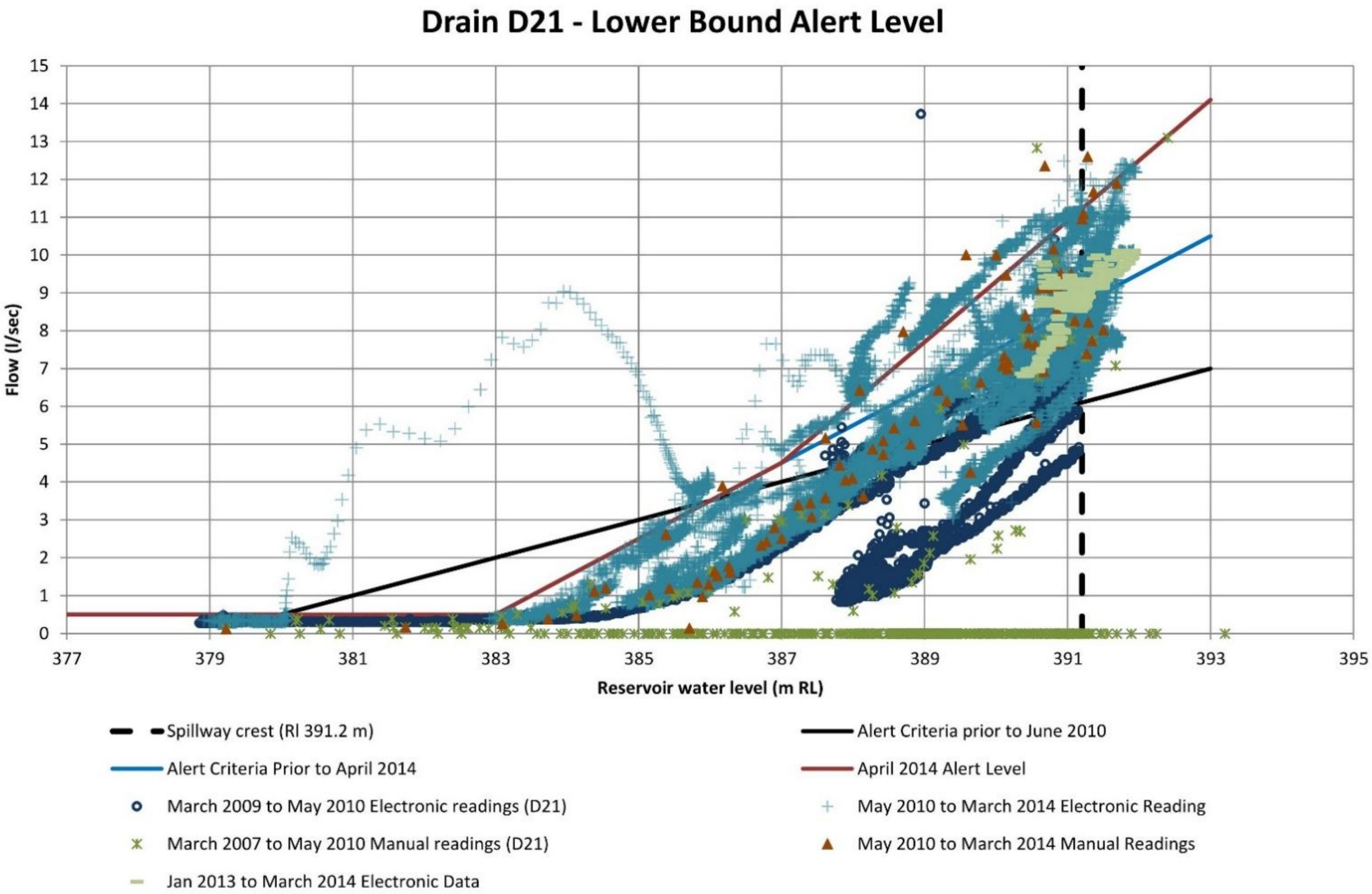

Figure 3 *Drain D21 Alert Levels*

With the currently revised Alert Level, the majority of the flows produced since July 2010 are deemed acceptable given the circumstances in which these flows were produced. Flows produced since July 2010 have outlined how D21 responds to higher reservoir levels and high rainfall. Algae build up also influences water level from time to time and this in turn influences inferred flow rates. Instances in which these have had an effect on D21 flow are now considered to be 'normal' and are not considered to be of any concern. Flows produced during the period of September 2010 to March 2012 have remained above the revised Alert Level. This is due to the effect that the earthquakes had on flow during the period, and it not being considered a normal circumstance.

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

3.2.5.2 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 on a monthly basis between 27 June 2013 and 30 January 2014 except for 29 August 2013. The Alert Level was exceeded on 26 September 2013 and 24 October 2013.

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 4 which shows the flows produced pre-grouting, post-grouting and current flows from the drain.

It has been speculated that the flow may originate from seepage through a small concave area on the upstream face of the embankment and connect through to the upstream end of the D18 drain that runs along the right hand side training wall of the auxiliary spillway. On 13 June 2013, water was pumped into this area until it was full. No response was noted in D18 (refer Section 7.3 following).

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.

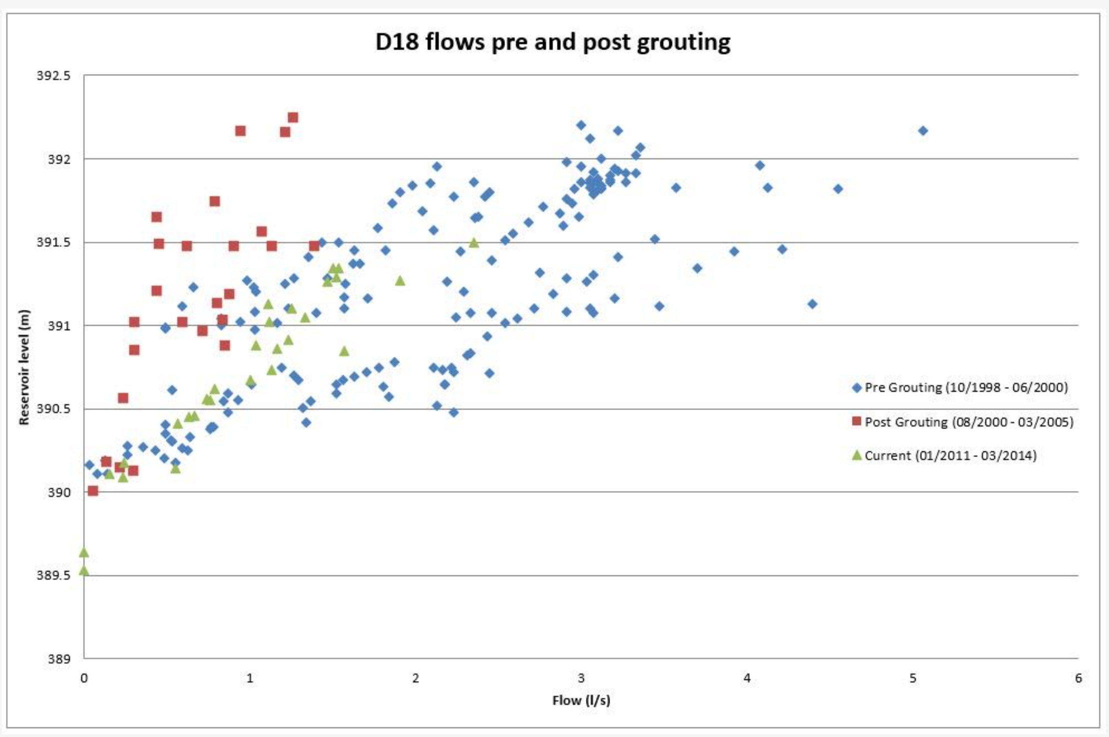

Figure 4 Drain D18 flows, pre and post grouting

3.2.5.3 Automatic Alert Levels

In February 2014 a foreign object which entered the flume artificially elevated the drain flow data in D9 for three days before the problem was identified and rectified. As a consequence of the impedance, during this time the drain flow inferred from the water level recorder data was continuously above the lower bound alert and exceeded the upper bound alert for an hour on 18 February 2014. However this apparent increase in flow this was only picked up after the fact when the electronic data was analysed and OWL staff visited site. It was subsequently identified that TrustPower do not now monitor the data in real time relative to alert levels. It is recommended 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.

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.

3.2.6 Drain Turbidity

Drains D7, D8, D9, D10, D17, D18 and D21 were monitored for NTU parameters as well as flow. In addition, drain D7 was electronically monitored for turbidity. The data is plotted in Appendix A1. In particular:

- D7 generally produces low turbidity levels, slightly higher in November to January but within historical expected levels;
- D8 was at higher than average NTU levels but still within historical expected values;
- D9 was at higher than average NTU levels for periods during the year. But still within historical expected values;

- D10 was higher for a longer period over the year (November to February) but still within historical expected values;
- D17 has had a trend on decreasing NTU levels over the year with the exception of June, September and January which corresponds with an increase in reservoir level relative to the year before;
- D18 recorded fairly expected NTU levels when flowing. It recorded high turbidity in October, while still within historically expected levels, which corresponded with the large increase in flow from the drain;
- D21 experienced a very similar increase in NTU levels to D10; this is also believed to be related to the reservoir level at the time. The levels remained within historically expected levels and clarity has since improved.

3.3 Piezometers

3.3.1 General

Graphs of the data since May 2007 are provided in Appendix A. The locations of the three lines of piezometers are shown in Figure 1 and the positions of each piezometer in Figure 5.

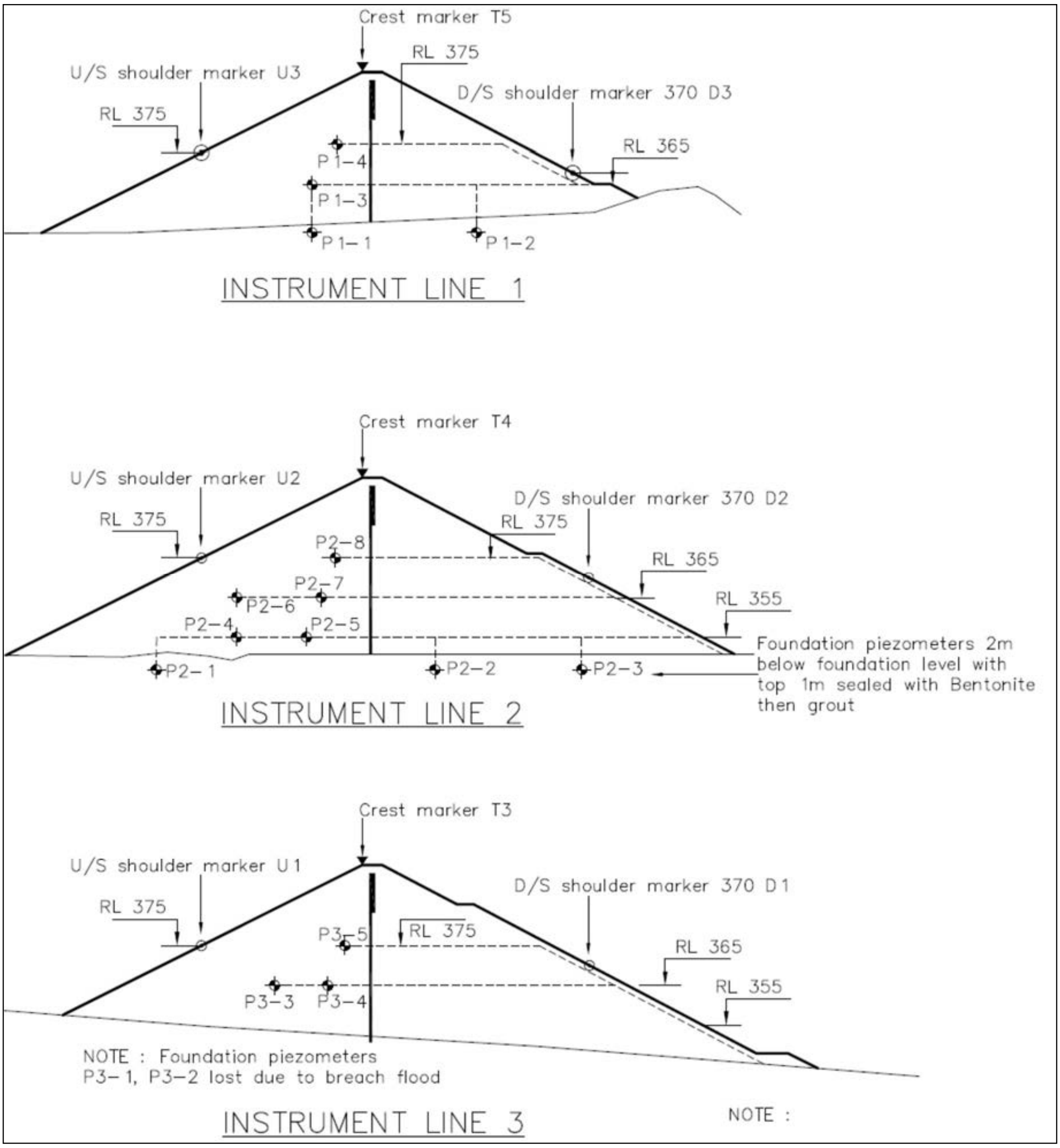

Figure 5 Piezometer positions

Hydraulic piezometer maintenance was carried out 25 – 28 March 2013. For more information read the report issues in early April[1].

Five piezometers are considered to be no longer functioning reliably and hence have been excluded from the monitoring requirements. These discontinued piezometers are P1-4, P2-2, P2-5, P3-3 & P3-5.The following 10 hydraulic piezometers are currently monitored:

- Piezometers P1-1, P1-2, P1-3, P2-1, P2-3, P2-4, P1-3, P2-6, P2-7, P3-4 & P2-8.

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

These hydraulic piezometers are currently read monthly in accordance with the 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 operated once during the period however the pneumatic piezometers were not read because the equipment used to take readings is not functional.

3.3.2 Hydraulic Piezometer data

Piezometer gauges are located at the base of the power station to read the hydraulic piezometer tip pressures.

With the exception of P2-6 and P3-4, readings produced by piezometers over the monitoring period were generally within the acceptable range and coincide with respective reservoir levels. When piezometers are stated to be responsive to reservoir levels it is meant that they recorded a reaction to the decrease in reservoir level in April and May, the increased reservoir level towards the end of the year and the small dips in level during August and December. Specific details relating to the piezometers are:

- P1-1 has produced readings that vary moderately to reservoir level. This is consistent with historical trends;
- 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;
- The same gauge pressure was recorded at P1-3 between 14 June 2011 and 23 September 2011 (9 piezometer readings) despite changes in reservoir level. Subsequent readings have been inconsistent with prior behaviour. The readings produced August 2012 – February 2013 and September 2013 – January 2014 were particularly low relative to historical data at equivalent reservoir levels. Hence, the performance of P1-3 over the monitoring period remains uncertain;
- A shift in base line for P2-1 was observed during July 2010. Readings during the last 12 months were responsive to reservoir level and fitting with historical data since this change in trend occurred;
- P2-3 is located 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. This was attributed to de-airing in 2008 when it is believed that not all of the air was able to be removed. Since further de-airing in April 2013 this piezometer has been consistent with historical trends; however, further monitoring is required to ensure the previous upward trend does not reappear. It was noted in the monthly reports that further de-airing should be carried out coincident with the manifold rehabilitation and gauge replacement;
- Historically, P2-4 levels are similar to that of the reservoir level. Levels produced over the period follow historical trends;
- P2-6 is responsive to reservoir level but the levels were consistently above the trigger level and exceeded the reservoir level with the exception of an extra reading taken in mid-November. This piezometer responded unusually to de-airing. Readings from this instrument are considered inaccurate until further de-airing can be carried out;
- Levels at P2-7 are not particularly responsive to reservoir level. In November, it recorded a decrease in level with only a small decrease in reservoir level. In February, it recorded an increase with a decrease in reservoir level however this was

common across a few piezometers. This piezometer remains consistent with historical readings at similar reservoir levels;

- P3-4 exceeded the lower bound alert consistently from 18 July 2013 – 20 March 2014 with the exception of 30 January 2014. This piezometer requires further monitoring and being read through an adjacent gauge to determine whether this increase is related to an increase in piezometric pressure within the dam or instrument error. See section 3.3.3 for further information.

3.3.3 P3-4

As discussed above, P3-4 exceeded the lower bound alert consistently from 18 July 2013 – 20 March 2014 with the exception of 30 January 2014. It was uncertain if this was related to increases in piezometric pressure within the dam or instrument error.

A recommendation to carry out readings via another gauge was issued in December. The piezometer was read both with its own gauge and via P2-4 in January. The two readings were approximately 2.5m different (with correction factors this meant the two gauges were 3.5m different) and resulted in a reading that did not cause an alert. This suggests that the alerts are as a result of an issue with the instrument despite the piezometer report indicating that the gauge was within tolerance.

This piezometer requires further monitoring with coincident readings through an adjacent gauge regularly.

3.3.4 Hydraulic Piezometer maintenance and repair

As noted in the 2013 Annual Inspection report, piezometer maintenance was carried out in March 2013 in order to remediate and address outstanding piezometer issues outlined in previous Annual Inspection Reports. Work onsite consisted of maintenance of the de-airing board and de-airing of the manifold and piezometers. Other issues noted can be found in the report describing piezometer maintenance.

T&T recommend that[2]:

- The broken gauges on piezometers be replaced.
- The board be rehabilitated in accordance with the Piezometer Maintenance report.
- A pressure and vacuum pump be installed to assist with de-airing on site.
- That de-airing be carried out at least annually as part of the routine maintenance of the piezometers.

RCM2014-02: De-air all piezometers annually and undertake associated piezometer maintenance as is described in the Piezometer Maintenance report.

3.3.5 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 operated once during the period in October 2013. The flow produced was estimated to be <15m^3/s. No pneumatic piezometer readings were taken during spilling.

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

3.4 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 May 2007 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. Specific details relating to the observation wells are:

- OW1 reported an increase in water level relative to readings at similar levels in April and in May it reported a slight increase in water level with a decrease in reservoir level that resulted in readings that were above the reservoir level. No evidence of surface water entry was reported during these months. In June, snowfall prevented this observation well from being read. From July onwards, OW1 has been responsive to reservoir level which is in keeping with historical data;
- OW2 was not read in June due to significant snowfall at the dam. In all other months, OW2 stayed constant with changes in reservoir level which is typical of this well;
- OW3 was not read in June due to significant snowfall at the dam. In August, it produced a slightly decreased lower reading compared to previous period despite an increase in reservoir level. From September through to December the well produced slightly higher readings in keeping with the reservoir level at this point. In March it produced only a minor decrease in reading with a moderate decrease in reservoir level which resulted in an OW3 upper reading above that of the reservoir. In all other months, OW3 lower stayed constant while OW3 upper was moderately responsive to reservoir level as is consistent with historical data for this well;
- OW4 was not read in June due to significant snowfall at the dam. In all other months, OW4 remained relatively constant which is typical of this well;
- In April, July, August, October and December, OW5 produced middle readings that contradicted the relative change in level of the reservoir, i.e. the well reading recorded a decrease with an increase in reservoir level or vice versa. This is not atypical for this well. In all other months, OW5 produced data that was in keeping with historic data and corroborated relative change in reservoir levels;
- OW6 is not very responsive to reservoir level changes. OW6 upper and middle readings stayed constant through the entire monitoring period. OW6 lower produced slightly lower readings in April, May and March, and slight increase in July in September in keeping with reservoir levels at the time. At all times during the monitoring period, OW6 behaved consistent with typical data;
- In April, OW7 produced an increase in reading relative to readings at similar reservoir levels in the past. In June, OW7 lower produced a decrease in reservoir level with an increase in reservoir levels. In September a moderate increase in reservoir level resulted in no reaction from any of the OW7 readings. In March, OW7 upper again produced an increase in reading relative to readings at similar reservoir levels in the past. Overall, OW7 appears to be operating in a manner more stable than in the past.

- Over April and May, OW8 produced readings that either increased or stayed consistent with a significant decrease in reservoir level. Readings produced in OW8 from October to December were inconsistent with historical data. This well was purged in January (see below) and since then it appears to have be returning to levels slightly lower than historical data;
- OW9 readings were stable and consistent with historical data until it was purged in January (see below) when it produced a significant decrease from all readings. Since then it appears to be returning to levels slightly lower than historical data except for OW upper which is taking longer to respond;
- OW10 produced a minor increase with a decrease in reservoir level in April. From October to December, readings in OW10 increase significantly relative to historical behaviour without similar changed in the reservoir level. In December, OW10 middle also recorded a moderate decrease that is unexplained by past behaviour or reservoir level. This well was purged in January (see below) and returned to pre-purge levels immediately with the exception of OW10 middle which returned to a new lower level and stabilised.

Observation Wells 8, 9 and 10 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. Currently, the wells appear to have mostly stabilised however close attention should be paid to these wells until all three wells have fully stabilised.

In the last Annual Safety Inspection report T&T recommended that regular readings of the standpipe in the toe remediation be carried out in order to assist with establishing a base line level for this instrument. This has yet to be carried out and is still considered desirable for dam safety. This should be carried out monthly however it is not required if safety concerns, such as icy rocks during the winter months, prevent it.

4 Dam embankment crest and slopes

4.1 Overview

Visual inspection of the embankment included:

- Upstream face to the extent permitted by the reservoir water level (387.0 m RL at time of inspection);
- Areas of the downstream face;
- Crest.

4.2 Upstream face

The upstream slope and riprap appeared to be in satisfactory condition to the extent visible above the 387.0 m RL reservoir water level.

Figure 6 Upstream face

Accumulation of debris was visible on the face. Periodic debris removal is undertaken and this should continue. A deep rooted weed was removed during the visit. No other deep rooted weeds were noted. To the extent that it was visible, the riprap is mostly robust and sound.

An area of interest was noted 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. It is suggested that in addition to close visual monitoring OWL install a means to monitor this area for evidence of movement. The basis to monitor the area may include tape and string line survey from known points as well as collection of reduced levels at particular locations, at least coincident with the next few deformation surveys.

4.3 Downstream face

The downstream face appears to be in good condition. Periodic spraying needs to continue to control weeds to prevent them from penetrating into the embankment fill.

Figure 7 Downstream face

4.3.1 Wet patch (near D16)

Investigation into the historical wet patch on the upper part of the embankment dam face, on the access road and near the D16 drain outlet, found evidence that it was present before the filling of the dam and thus is unlikely to be hydraulically connected to the reservoir.

It is believed that surface water is infiltrating the embankment and exiting at this location. The level of the wet patch coincides with a change in dam fill type in the downstream shoulder from Type A (NSCZ) fill to Type B (NSCZ) fill. It is inferred that there is a horizon of lower permeability material that traps rainfall infiltration in this area. It is speculated that rainwater infiltration into the shoulder is tracking sideways when reaching this lower permeability zone and exiting on the downstream face.

Figure 8 Wet patch located on dam road near D16 during and after construction

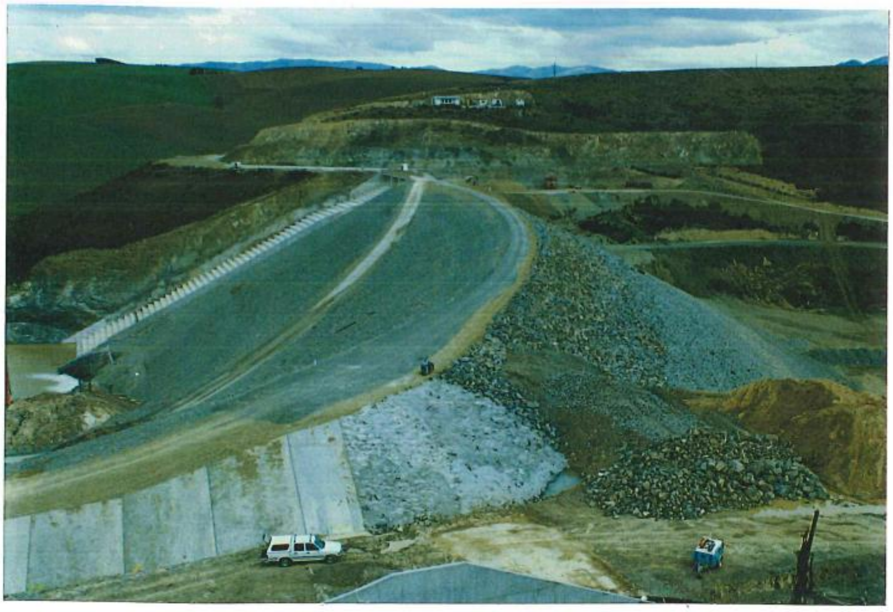

Figure 9 Picture taken on the same day during construction – reservoir was not full

4.4 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 was undertaken in accordance with the specification

[3] Opus; Opuha Dam, Deformation Survey No 6A; May 2013.

contained within the dam surveillance plan[4]. The Opus 6A deformation survey report is included as Appendix B and includes further details of the survey methodology and results.

The downstream row of survey markers, D1, D2 and D3 were replaced in June 2008 and picked up during the course of the 2011 and 2013 surveys. The 2013 survey was the first survey that included the new conduit Anchor Block 2 (AB2) marker, P1A, installed following the AB2 remediation.

Aside from some vertical deformation near the middle of the embankment crest, Opus report that the deformation survey did not indicate clear evidence of vertical or horizontal movement.

Table 4.1 below summarises vertical settlement of the embankment crest advised by Opus as well as relative settlement (refer to Figure 1 on page 3 for location plan of crest settlement markers).

Table 4.1 Crest Settlement

Crest Settlement Marker	Vertical Settlement March 1998 to May 2013 (mm)	Vertical settlement April 2011 to May 2013 9 (mm)	Relative settlement as at May 2013(%) (Note 1)
T1 (True left hand side)	7.7	0.4	-
T2	23.4	1.1	0.094
T3	38.2	2.8	0.107
T4	49.4	3.7	0.114
T5	37.3	1.7	0.094
T6 (True right hand side)	27.2	1.2	0.112

Note 1 Relative settlement is determined from the total vertical settlement divided by the estimated embankment height at a particular location.

Opus Figure 1 contained in the deformation survey report (Appendix B page 14) plots crest settlement as a function of time. Figure 10 below shows relative settlement as a function of time at locations T2 to T6 (log scale).

[4] Tonkin & Taylor; Opuha Water Limited, Opuha Dam: Dam Surveillance and Monitoring Plan, Reference 51137.008; November 2011.

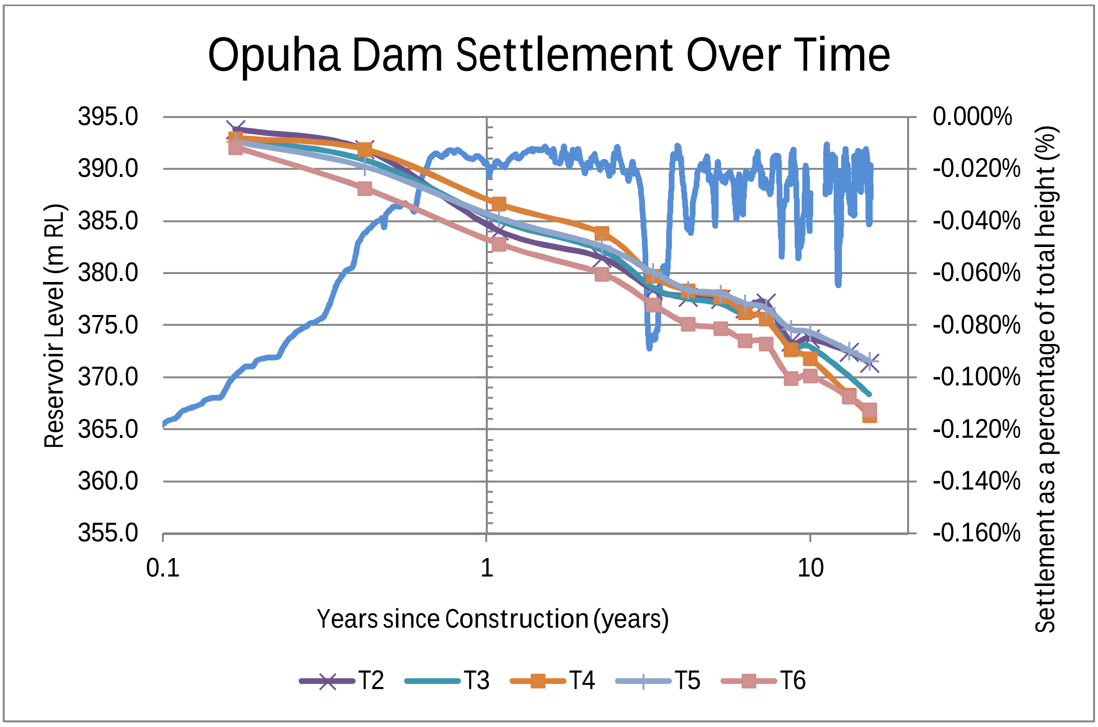

Figure 10 Settlement of Opuha Dam crest (log scale)

The magnitude of the overall settlements are relatively modest. Nonetheless, the trend of ongoing settlement illustrated in Opus Figure 1 (Appendix B page 14) some sixteen years after the base survey is of interest and warrants some comment.

It is possible to compare the relative settlement to other dams in order to gain an appreciation of significance of the observed settlement. Hunter and Fell[5] describe measured settlements of generally similar earth dams being earth dams with thick cores comprising Silty Sand or Silty Gravel.

At locations T2 to T6 where total settlement has slowly increased, as at May 2013, relative settlement as a percentage of embankment height is considered to be within the bounds of comparable settlements when compared to the data published by Hunter and Fell. However, it is important to continue to monitor settlement and review the results relative to expected performance.

At location T1, located adjacent to the right abutment, there is no evidence that vertical movement has occurred for a number of years.

4.5 Embankment crest

The crest roadway and fence were generally in good condition. However, 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. We recommend that the damage to the wave barrier is repaired and any gaps between the timber and embankment surface filled.

[5] Hunter and Fell; Deformation and dam safety of earthfill dams; ANCOLD 2010

Figure 11 Damage to wave barrier

We recommend that subject to peer review comments, the scope of the next deformation survey is expanded to collect reduced 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[6]. Sufficient density of points are necessary to clearly define the crest topography and enable a meaningful evaluation.

RCM2014-03: Carry out crest maintenance on the main embankment including repair of the timber wave barrier.

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.

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

5 Reservoir

5.1 General

The reservoir margin and adjacent slopes in the immediate vicinity of the dam was visually inspected from the dam crest and both abutments. The reservoir level was 387.0 m RL at the time of the inspection.

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 addition, OWL has not reported any slope instability at the reservoir margin in the period.

5.2 Intake Tower

Figure 12 Intake tower

A dive inspection of the intake tower has was undertaken during this monitoring period. Safety matters arising from the inspection have been reported to T&T. Nonetheless, it is suggested that the dive inspection report is forwarded to T&T for review in accordance with the Dam Surveillance Plan.

6 Service spillway

6.1 General

The service spillway provides for the controlled release of water. Following uncertain performance prior to the period considered, OWL advise that the Obermeyer flap gates that are mounted on the spillway crest are now functional. The gates were lowered to provide controlled spill on one occasion.

6.2 Spilling Events

The service spillway operated once during the period in October 2013 at <$15m^3/s$.

6.3 Spillway approach

The approach to the service spillway was visible at the time of the inspection due to the low reservoir level. The approach had some debris present, primarily drift wood. The approach was in good condition. The shotcrete coating on the rock on the right hand side of the spillway sounds hollow along the height of the northern side of the repair. This suggests a void is present behind the repair. The repair should be monitored closely to ensure that the shotcrete remains stable.

Figure 13 Shotcrete repair

The structural concrete spillway approach walls are in good condition with no movement 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).

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.

6.4 Obermeyer gates

On the day of the inspection, OWL reported that the gates were operating as required.

High reservoir levels throughout the period required operation of the Obermeyer gates once during the period to allow spilling as discussed earlier. They also operated during portions of July, October, November, December 2013 and January 2014, to retain water and provide additional storage capacity. No issues arose from operation.

6.5 Stepped spillway chute

The spillway steps appeared to be in satisfactory condition. A few medium sized rocks were noted on the spillway as well as a large branch; however, there was no visible damage of major significance at this time to the step edges due to the rocks being thrown onto the spillway.

Figure 14 Service spillway

These rocks will be washed into the spilling basin at the toe of the spillway.

6.6 Tailrace and Stilling Basin

Inspection of the tailrace and stilling basin found that they were in a satisfactory condition as could be viewed from the ground surface. However, the sill along the end of the stilling basin is damaged. 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. 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.

Figure 15 *Stilling basin*

Figure 16 *Damaged Sill of Stilling Basin*

7 Auxiliary spillway

7.1 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. Routine spraying should continue in order to prevent establishment of vegetation on the fuse plug fill, particularly in the vicinity of the drain outlets.

Figure 17 Auxiliary spillway upstream face

Figure 18 Right hand side fuse plug triggering device clay tile pipes

On 18 June 2013, OWL reported that water had been pumped through the fuse plug triggering device clay tile outlet pipes. This confirmed that the pipes are currently clear of blockages and debris. Any future blockages should be removed as they arise.

7.2 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.

Figure 19 Left abutment cut slope

7.3 Upstream face area of interest

Work was carried out on 13 June 2013 to ascertain if the area of interest identified in the 2013 Annual Safety Inspection report was connected to the increase in flow from D18. The area of interest is on the right hand side of the upstream face of the auxiliary spillway.

Water was pumped into the area of interest until it was full. The pump was left running for 3 hours and then the area was allowed to drain. The capacity of the pump was 10 l/sec and ponding took about an hour to fill and drained rapidly. This led OWL to note that the rate of drainage of the area was likely only slightly below the capacity of the pump. No visible response was noted in D18 or anywhere on the downstream face.

As noted in Section 3.2.5.2, based on this work current indications are that the concave area of interest is not directly linked to seepage flow exiting D18. Further ongoing monitoring of D18 drain flows is warranted.

Figure 20 Area of interest on the upstream face of the auxiliary spillway

8 Power station, tailrace and other ancillary structures

8.1 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 advise 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.

8.2 Switchyard

Fencing was installed around the power station and switchyard during the period. Fencing and security was in very good condition.

8.2.1 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. 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.

Figure 21 Conduit outlet drain discharge

8.3 Tailbay concrete

The recommendation from the dive inspection carried out in 2008 (RCM2008-32) has yet to be resolved. RCM0213-32 states that 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. The dive inspection of June 2013 did not note erosion at the draft tube outlet.

Figure 22 Draft tube outlet

8.4 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 a fence and lockable gate that surrounds the power station and switch yard.

The valve to the Allendale line is usually shut and it is understood that the line is not currently used.

We suggest that the status of the pipe is clarified in accordance with recommendation RCM2010-04. Subject to the review, recommended outcomes could include repair, decommissioning, or clarification of maintenance responsibility.

8.5 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.

8.6 Conduit inspection

The main conduit that runs under the dam to the power station was inspected on 5 June 2013. Please refer to appendix C for further discussion.

8.7 Elver Pass

The elver pass over the main embankment is functioning and appears in good condition. Several elver were observed in the box adjacent to the dam crest.

8.8 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.

8.8.1 Obermeyer gates

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

8.8.2 FCD Valve and associated valving

The FCD valve and associated valving was not checked on the 1 April 2014 during the annual inspection. It operated on the following dates:

- Intermittently between 2 and 26 June 2013 (flow range 2.3 m^3/s to 16 m^3/s);
- 2 July 2013;
- 11 and 12 September 2013; and
- Between 19 and 21 November 2013.

It has been reported that it is working well. Other valving of significance was operated during the 5 June shutdown, including the 450mm by-pass.

8.8.3 Conduit bulkhead

The conduit bulkhead and lifting arrangement was tested during the 5 June 2014 conduit inspection and worked well.

8.8.4

8.8.5 Auxiliary power supply

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

9 Downstream weir

9.1 General

The Opuha Dam Downstream Weir (ODDW) is approximately 1.4 km downstream of the Opuha Dam and is physically separated from the main dam. The ODDW 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 Figure 23 below.

Figure 23 ODDW

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.

9.2 Downstream weir overflow embankment

9.2.1 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 constructed in 2009 after it operated during high flows in May 2009.

Figure 24 Downstream face of overflow embankment and spillway

9.2.2 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 annual inspection an 8 m long crack was noted on the OE crest. We recommend that this area 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 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.

Figure 25 Crack in crest close to recent embankment repair

9.3 Enclosure embankment

The enclosure embankment appears to be generally in good condition with the exception of presence of weeds.

The September and November monthly monitoring reports noted seepage and a resulting 'boggy area' at a low point in the land just south of the 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. From this assessment, T&T do not believe that this seepage is a major concern at this time as the seepage appears consistent with historical observations and inferred seepage gradients appear unchanged.

RCM2014-05: Weed spray downstream weir embankment.

9.4 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. Small horizontal cracks and superficial spalls noted in previous inspection reports do not appear to have significantly changed in the last year.

9.4.1 Downstream radial gate

Visual inspection suggests that the downstream radial gate is in good condition. The DC back up for the operation of the radial outlet gate appears to be working as required.

Figure 26 Service spillway

The concrete and stone armouring on both banks is generally in satisfactory condition. 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.

Figure 27 Undermining of chute

Cracking 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.

Figure 28 Cracking of concrete wall

The DC back up for the operation of the radial outlet gate appears to be working as required.

Figure 29 Current handrail configuration

Some of the handrails around the control structure 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.

10 Access road

10.1 Access to dam

The maintenance of the access road to the dam is the responsibility of the 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.

10.2 Dam road

The dam road was generally in good condition. The dam crest road has a safety barrier on the upstream edge. In addition, public access is restricted by a locked chain with signage.

Access to the powerhouse and downstream weir were clear at the time of inspection.

In the previous annual review 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 advise that they will continue to monitor the grading of the road and consider options to improve road drainage.

OWL also advised that the blocked drains on the bridge have been cleared so that surface runoff from this area is running directly into the spillway.

11 Recommendations

11.1 2014 Recommendations

Some general suggestions regarding the maintenance of the dam have also been provided for consideration by OWL as summarised in Table 11.1 below.

Table 11.1 Opuha Dam Annual Review recommendations

Reference	Report Section	Recommendation	Category
RCM2014-01	3.2.5.3	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
RCM2014-02	3.3.4	De-air all piezometers annually and undertake associated piezometer maintenance as is described in the Piezometer Maintenance report.	N
RCM2014-03	4.5	Carry out crest maintenance on the main embankment including repair of the timber wave barrier.	N
RCM2014-04	4.5	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
RCM2014-05	9.3	Weed spray downstream weir embankment.	N

The current statuses of all recommendations from the inspection of 2008-2011 and 2013 are presented below in Table 11.2. The recommendations are numbered and, referenced to the section in this report where they arise and are 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).

The colouring in the Table 11.2 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, is being actioned (if an ongoing recommendation) or has been resolved in a way different to the recommendation.

Table 11.2 Previous Opuha Dam Annual Review recommendations

Reference	Recommendation	Category	Status
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.
RCM2013-02	Particle size distribution analysis of D10.	N	Completed
RCM2013-03	Installation of an automatic turbidity monitoring system on the chimney drains.	N	Completed.
RCM2013-04	Revision of the Alert Level for D21.	N	Completed.
RCM2013-05	Replacement of broken piezometer gauges.	N	Outstanding.
RCM2013-06	Regular readings of the standpipe in the toe remediation.	D	Ongoing
RCM2013-07	Outstanding deformation survey to be undertaken as soon as practical.	N	Completed.
RCM2013-08	Investigation into source of wet patch on downstream face of Dam.	N	Completed.
RCM2013-09	Requirements for the outstanding dive inspection be confirmed, and the inspection undertaken as soon as practical.	N	Completed.
RCM2013-10	Investigation into D18 flow path and visual monitoring of the area of interest on upstream face of auxiliary spillway.	N	Completed.
RCM2013-11	Installation of the seismograph.	N	In Progress.
RCM2013-12	Repair the area of infiltration through the DWOE.	D	Completed.
RCM2013-13	Ongoing visual monitoring be undertaken by OWL of area of scour of downstream face of the Dam, below the road.	N	Ongoing.
RCM2011-01	Hydraulic piezometer gauge calibration factors to be checked and gauge maintenance works to be undertaken. Pneumatic piezometer leads to be repaired and rehoused.	D	Completed.
RCM2011-03	Requirements for the outstanding dive inspection be confirmed, and the inspection undertaken as soon as practical.	D	Completed.
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
RCM2010-01	Complete a comprehensive review of the hydraulic piezometer system and identify necessary upgrade and maintenance works (e.g. gauge calibration, consideration of a requirement for a control gauge, review of bladder and the like).	D	Completed

Reference	Recommendation	Category	Status
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	Outstanding
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
RCM2008-18	The guide rope between the SW tower leg and the bypass valve should be reinstated and the bypass valve then inspected. (3.2)	D	Resolved.
RCM2008-19	The location of the bulkhead valve handle should be established or a new handle obtained (3.2)	D	Resolved.
RCM2008-20	The loose steel bar/plate at the NE tower leg splice should be further investigated during the next diver inspection in 2010. (3.2)	D	Resolved.
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. (4.1)	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. (5.3)	N	Outstanding
RCM2008-37	Debris should be regularly removed to prevent it from becoming stuck in the gate. (6.3)	N	Debris removed August 2008. Monitoring ongoing

Complete a review of the assumptions incorporated in the existing PMF estimate for the catchment and, if changes in the assumptions result in a revised PMF estimate, complete a series of routing studies to determine peak reservoir levels and spillway discharges during the PMF.

11.2 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 are shown in Table 11.3 below. All other recommendations have either been completed or have been actioned. A full list of the conclusions reached during the completion of the DSR are stated in the June 2012 Opuha Dam Safety Review Report[7].

Table 11.3 Opuha Dam unactioned CSR recommendations

Recommendation	Comment	Current status
Develop a dam safety assurance programme that meets the requirements of the Building (Dam Safety) Regulations	OWL's current surveillance regime meets current NZSOLD Guideline requirements and will be expanded for new Dasm Safety Assurance Programme as prescribed by the Regulations when they become operative from march 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
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.	Not actioned
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 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).	Scope of options to be completed by T&T.

[7] Tonkin & Taylor; June 2012 Opuha Dam Safety Review Report

12 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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