Otago Regional Council

TECHNICAL COMMITTEE AGENDA

WEDNESDAY 31 JANUARY 2018

10:30 am, Cargill Room, Scenic Hotel Southern Cross, Princes Street, Dunedin

Membership

Cr Andrew Noone	*(Chairperson)*
Cr Ella Lawton	*(Deputy Chairperson)*
Cr Graeme Bell	
Cr Doug Brown	
Cr Michael Deaker	
Cr Carmen Hope	
Cr Trevor Kempton	
Cr Michael Laws	
Cr Sam Neill	
Cr Gretchen Robertson	
Cr Bryan Scott	
Cr Stephen Woodhead	

Disclaimer

Please note that there is an embargo on agenda items until 8:30am on Monday 29 January 2018. Reports and recommendations contained in this agenda are not to be considered as Council policy until adopted.

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1. APOLOGIES

2. LEAVE OF ABSENCE

3. ATTENDANCE

4. CONFIRMATION OF AGENDA

Note: Any additions must be approved by resolution with an explanation as to why they cannot be delayed until a future meeting.

5. CONFLICT OF INTEREST

Members are reminded of the need to stand aside from decision-making when a conflict arises between their role as an elected representative and any private or other external interest they might have.

6. CONFIRMATION OF MINUTES

Recommendation

That the minutes of the meeting held on 29 November 2017 be received and confirmed as a true and accurate record.

Attachments

1. Minutes Technical Committee - 29 November 2017 **[6.1.1]**

7. PUBLIC FORUM

8. PRESENTATIONS

9. ACTIONS

Status report on the resolutions of the Technical Committee.

Report	Meeting Date	Action	Status
2017 Air Quality Results	29/11/17	That a report back be provided on the reduction of the use of coal achieved in other areas of New Zealand	CLOSED ITEM 11.3 OF AGENDA

Attachments

1. Actions from Technical Committee 29 Nov 2017 **[9.1.1]**

10. MATTERS FOR COUNCIL DECISION

11. MATTERS FOR NOTING

11.1. Director's Report on Progress

Prepared for:	Technical Committee
Activity:	Governance Report
Prepared by:	Dr Jean-Luc Payan, Manager Natural Hazards Dr Dean Olsen, Manager Resource Science Chris Valentine, Manager Engineering Dr Gavin Palmer, Director Engineering, Hazards and Science
Date:	25 January 2018

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1. Précis

This report presents an update on the following matters:

1. Climate, river flow and groundwater situation
2. Lake snow investigations
3. Lake Trophic Status
4. Lake Hayes remediation options
5. Clutha River bioenergetics
6. Hawea Aquifers monitoring
7. July 2017 Coastal Otago Flood Event
8. Henley flooding
9. NZ SeaRise Programme
10. Collaboration with territorial authorities on district plan natural hazards
11. Mt Alpha (Wanaka) fire
12. Geomorphic Change Detection
13. Lower Waitaki River Scheme
14. Clutha River/Mata-au (Mata-au Mouth) Offsetting
15. Central Otago Stock Truck Effluent Disposal (STEDs)
16. Leith Flood Protection Scheme

2. Climate, River Flow and Groundwater Situation

In general, higher than normal sea level pressures prevailed over New Zealand and its surrounding areas during December, which caused generally settled and warm weather over most of Otago. This resulted in December rainfall was below the long-term average for much of Otago (Figure 1, 2). Over the last 2 months, conditions have been moderately to severely dry over much of Otago (Figure 2).

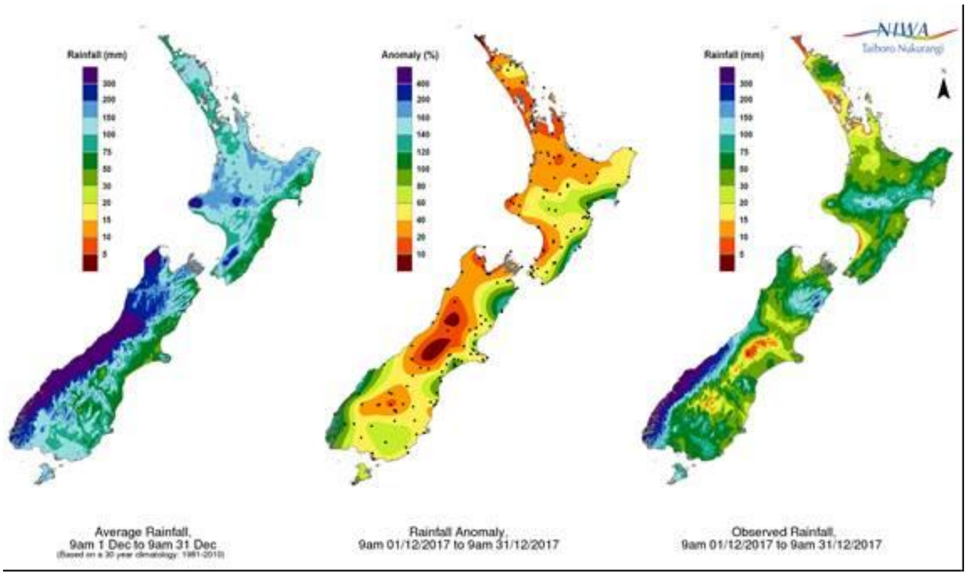

Figure 1: **Comparison of long-term average December rainfall (left map), observed rainfall for December 2017 (right map) and the rainfall anomaly (deviation from the long-term average) for December 2017, (NIWA).**

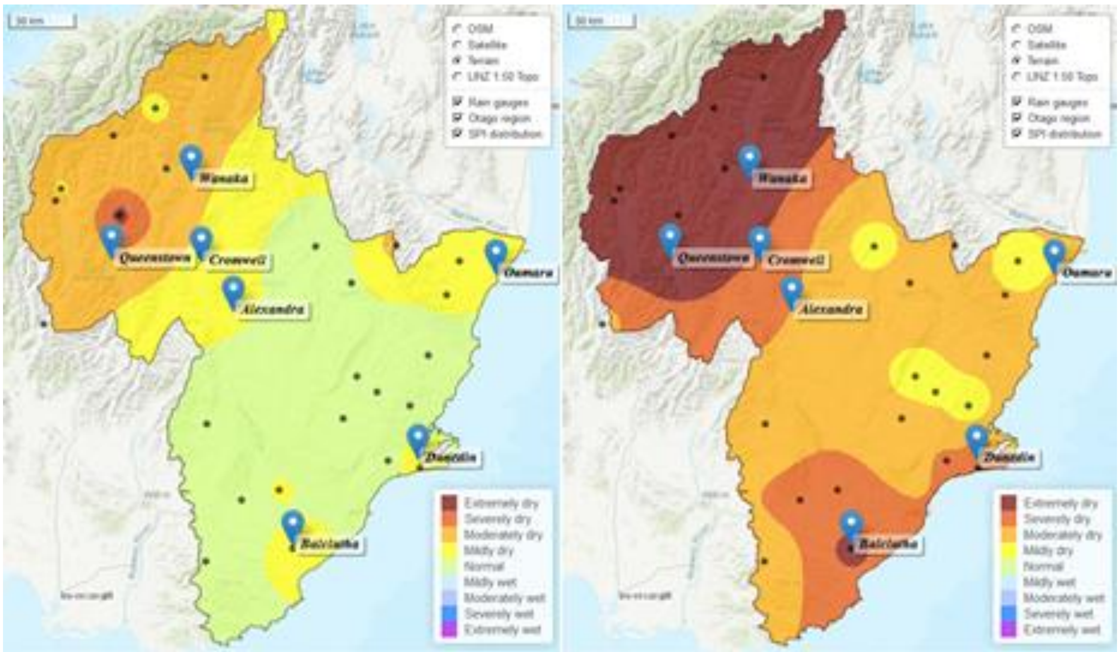

Figure 2: **Maps of 30- and 60-day Standardised Precipitation Index (SPI[1]) for Otago**

Summary of NIWA Seasonal Outlook for Otago – January to March 2018

At the start of each month, NIWA produces a seasonal outlook for the upcoming 3 months. The following are the predictions for the period January-March:

Eastern Otago: Rainfall totals are about equally likely to be in the near (35%) to above normal (40%) range. Soil moisture levels and river flows are expected to be normal (40%) to below normal (40% chance for soil moisture, 45% for river flows).

[1] SPI is a standardised index commonly used to indicate the dry/wet weather conditions based on observed rainfalls. Observed rainfalls in 49 rainfall sites around Otago have been utilised to produce the SPI maps shown.

Western Otago: Rainfall totals are about equally likely to be in the near (40%) to above normal (35%) range. Soil moisture levels and river flows are expected to be normal (45%) to below normal (40% chance).

The full seasonal outlook can be viewed at: https://www.niwa.co.nz/climate/seasonal-climate-outlook/seasonal-climate-outlook-january-march-2018

River flows - December

The December 7-day low flows (7dLF) were generally much lower compared to the long-term December averages for almost all flow sites (the only exception is Waikouaiti at 200m d/s DCC intake), particularly for those flow recorders along the Taieri, Manuherikia, and Kakanui Rivers. The December 7dLFs recorded for the Taieri at Canadian Flat, Outram, and for Kye Burn at Scott's Lane this year were the lowest on record (Table 1).

Table 1 December flow statistics for sites in the Taieri, Kakanui, North Otago, Manuherikia and South Otago catchments. All flows are expressed as 7-day December average low flows, i.e. the lowest flows averaged over a 7-day period within December.

Site	Minimum flow (m^3/s)	Length of record (year)	Long-term December average (m^3/s)	Long-term December minimum (m^3/s)	Year of the long-term December minimum	Previous Decembers with significant 7dLF (m^3/s)				December 2017 (m^3/s)
						1999	2003	2014	2015	
Taieri at Canadian Flat	-	35.1	1.714	0.830	2017	1.405	0.878	1.052	1.346	0.830
Taieri at Waipiata	1.000	25.4	2.604	0.919	2009	1.567	0.971	1.072	0.943	0.950
Taieri at Tiroiti	1.100	35.7	3.502	1.085	1989	NA	1.396	1.495	1.337	1.212
Taieri at Sutton	1.250	57.4	4.937	1.338	2009	4.979	1.414	1.704	1.389	1.422
Taieri at Outram	2.500	49.7	9.134	1.398	2017	7.350	2.412	3.451	3.356	1.398
Kye Burn at Water Take d/s 300m	-	5.2	0.380	0.242	2017	NA	NA	0.390	0.360	0.242
Deep Stream at SH87	-	25.7	1.002	0.386	2003	NA	0.386	0.567	0.701	0.420
Kakanui at Clifton Falls Bridge	-	36.7	1.102	0.399	2003	1.287	0.399	0.592	0.544	0.470
Kakanui at Mill Dam	250	28	1.229	0.352	2003	1.331	0.352	0.528	0.453	0.454
Kakanui at McCones	250	15	1.075	0.277	2003	NA	0.277	0.452	0.361	0.377
Waianakarua at Browns	200	12.7	0.519	0.170	2014	NA	NA	0.170	0.307	0.269
Shag at Craig Road	150	24.3	0.333	0.076	2003	0.341	0.076	0.132	0.116	0.174
Waikouaiti at 200m d/s DCC intake	-	3.3	0.342	0.137	2015	NA	NA	0.159	0.137	0.494
Dunstan Creek at Beattie Road	-	15.1	1.002	0.075	2003	NA	0.075	0.212	0.570	0.274
Manuherikia at Ophir	0.820	46.9	5.605	1.761	1988	7.170	2.442	2.155	2.036	2.089
Manuherikia at Campground	-	9.2	1.384	0.763	2015	NA	NA	0.938	0.763	0.941
Waitahuna at Tweeds Bridge	0.450	25.5	1.163	0.615	2003	0.938	0.615	1.089	0.830	0.783
Pomahaka at Burkes Ford	3.600	56.4	9.058	2.877	1963	8.736	4.264	6.103	8.168	4.406

Groundwater levels at restriction level bores

Schedule 4B of the Regional Plan: Water for Otago (RPW) identifies water levels at which the taking of groundwater will be restricted, and identifies the nature of the restriction, in terms of a reduction in the take of water authorised by water permits. The aquifer maximum height refers to the historic record of the water level or pressure head after the recharge season. Note that the areas over which the restrictions apply are shown on Maps D1-D4 in the RPW.

There are currently 5 restriction level bores listed in the RPW. The detail of the aquifers concerned, the names of the reference bores and the respective restriction levels assigned to each bore as shown in Schedule 4B are presented below in Table 2. Groundwater levels at the nominated restriction level bores are starting to drop after a generally high seasonal recharge. The groundwater levels are still well above the restrictions levels (between 1.13 and 3.99m above); with the exception of the West Lower Taieri Momona Monitoring Bore for which the levels are only 0.21 m above the 25% restriction threshold. Historically, Momona Bore has reached this first restriction level on 10 occasions during 21 years of monitoring).

Table 2 Ground water levels in restriction level bores (from Schedule 4B of the RPW) in Otago aquifers

Aquifer	Aquifer reference Bore	Aquifer maximum height (m above datum)	Restriction levels (m above datum)			Current groundwater level (m above datum)	Difference between current level and 25% restriction level (m)
			25% restriction *	50% restriction	100% restriction		
North Otago Volcanic	Websters Well	130.8	126	125.5	125	129.99 (31/12/17)	3.99
Lower Taieri – West	Momona Bore	101.24	100	99.5	99	100.21 (27/12/17)	0.21
Lower Taieri – East	Harleys Well, Piezo. 2	112.5	110.5	110	109.5	113.93 (28/12/17)	3.43
Ettrick Basin	Cemetery Bore	172.29	170.29	169.79	169.29	171.42 (31/12/17)	1.13
Roxburgh Basin, (Coal Creek Terrace)	White-Hall Bore	189.5	188	187.8	187.5	189.48 (31/12/17)	1.48

Harleys Well - Piezo 2 replaced by Caledonia Drive Bore - Piezo 2

* When the aquifer reaches this level, there shall be either a 25% restriction or a water allocation committee, appointed by the Otago Regional Council, will implement a protocol to take all practical steps to curb the decline in the aquifer level so as to avoid a 50% restriction. If there is no water allocation committee or the water allocation committee does not use a protocol approved by the Council, the 25% water restriction will apply.

Conclusion

Weak La Niña conditons are predicted to continue for the next three months, with more east- and northeasterly winds suggest that there is the potential for the current dry conditions to persist over summer. Low flows have resulted in restrictions in the Taieri catchment, with flows dropping to the minimum flows at all minimum flow sites in the catchment while flows dropped below supplementary minimum flows in the Kakanui, Waianakarua, Shag and Pomahaka catchments.

3. Lake Snow Investigations

Contracts are being finalised for the three lake snow research tasks being sponsored by ORC over the 2017/18 financial year. These work components were identified as priority work areas by the Lake Snow Expert Workshop

(Appendix A).

These work components include:

- Studying literature on causes of algae shifts to *Lindavia*-like diatoms in big deep lakes from around the world and studying world-wide literature on causes of polysaccharide production by the algae (Item 2B(i), Table A1, Appendix A);
- Checking all NZ diatom lists and historical collections for reference to lake snow to assess the historical presence/absence of *Lindavia intermedia* (Item 1(ii), Table A1, Appendix A);
- Coring and dating the sediments of lake snow infected lakes in the region to accurately ascertain lake snow incursion dates in Otago (Item 1(iii), Table A1, Appendix A)[2].

Discussions are underway with Environment Canterbury about including a number of their lakes in the coring study. The dating of cores takes approximately six months. The cores will be collected and processed by the end of the 2017/18 financial year, with the final analysis and report write-up being delivered by December 2018.

ORC are also actively supporting the Landcare Research Endeavour Smart Ideas project that commenced in October 2017. The title of the project is *"Lake snow detection and quantification: novel methods for an emerging environmental problem".* This is a three year, up to 1 million dollar program.

4. Lake Trophic Status

Trophic status is a common method for describing the health of lakes and an indicator of how much growth or productivity occurs in the lake, productivity being directly related to the availability of nutrients. Lakes in pristine condition typically have very low nutrient and algal biomass levels. As lakes become more enriched due to changes in land-use and land management practices, lake nutrient levels and algal productivity increases. The overall TLI score is categorised into seven trophic states (Appendix B) indicating progressively more nutrient enrichment, more algal productivity and reduced water clarity[3].

The trophic lake sampling programme that is currently underway on lakes Wanaka, Hawea, Wakatipu, Hayes and Onslow will provide an accurate estimate of the current TLI of these lakes. The interim results (along with past results) are presented in Appendix B and show that Lakes Wanaka, Hawea and Wakatipu are Microtrophic, Lake Onslow is Mesotrophic and Lake Hayes is Eutrophic.

A comparison of TLI nationally (Appendix B) shows that Lakes Wanaka, Hawea and Wakatipu have the lowest TLI (ranked highest) in New Zealand.

The full sampling programme and analysis will be reported in 2019.

5. Lake Hayes Remediation Options

[2] Lake snow technical workshop proceedings and research priorities – recommendations and programme cost estimates, Report to Technical Committee, 15 March 2017, report No. 2017/0705.
[3] Hamill, K. (2006). Snapshot of Lake Water Quality in New Zealand. Prepared for the Ministry for the Environment by Opus International Consultants. MfE. 59p.

The ORC is continuing to investigate options for the long-term improvement of water quality in Lake Hayes. A lake water quality specialist from NIWA has been engaged to assess potential intervention options, specifically detailing what infrastructure would be required, anticipated costs, operational considerations and amenity effects on the Lake Hayes area. This study will be followed by modelling work, accompanied by a cost/benefit analysis of the various options[4]. Water quality monitoring of Lake Hayes and Mill Creek continues on a monthly basis.

Figure 3. Northern end of Lake Hayes at the mouth of Mill Creek.

6. Clutha River Bioenergetics

The Cawthron Institute continue to undertake bioenergetics modelling for the upper Clutha that will inform minimum flow setting in the upper Clutha River. The bioenergetics model sits on top of a more traditional instream habitat model being developed for the upper Clutha by NIWA and, ultimately, will be used to predict the number of trout that the upper Clutha River can support at different flows. Instream habitat modelling will be used to understand the effects of different flows in upper Clutha on instream values including habitat for fish, invertebrates, periphyton as well as riverine birds and recreation (e.g. jet boating, kayaking).

A draft report presenting the results of the bioenergetics modelling for the upper Clutha was delivered in December, with a view to the final report being ready to bring to Technical Committee in March.

7. Hawea Aquifers Monitoring

In 2011/12 a technical review of the current status of groundwater availability and quality in the Hawea Basin was carried out[5]. A groundwater flow model was developed to set an appropriate allocation regimen. At the time, sufficient data to calibrate and run a

[4] The three options being investigated are: 1) flow augmentation with water from the Arrow Irrigation Scheme, 2) de-stratification of the lake waters by aeration or mechanical mixing, and 3) capping of phosphorous-rich sediment on the lake bed.

[5] Hawea Basin Groundwater Review, Report to Natural Resources Committee, Report no. 2012/0789, 18 May 2012.

robust transient flow model was not available and so a steady-state model was developed and used as a tool to set allocation limits. The steady-state model does not allow for seasonal changes, variation in pumping, rainfall, lake level etc. Therefore, the allocation limits that were suggested may be too conservative or not conservative enough. The Annual Plan provides for the development of a transient model and the information needed to construct the model is presently being collected (Figure 4).

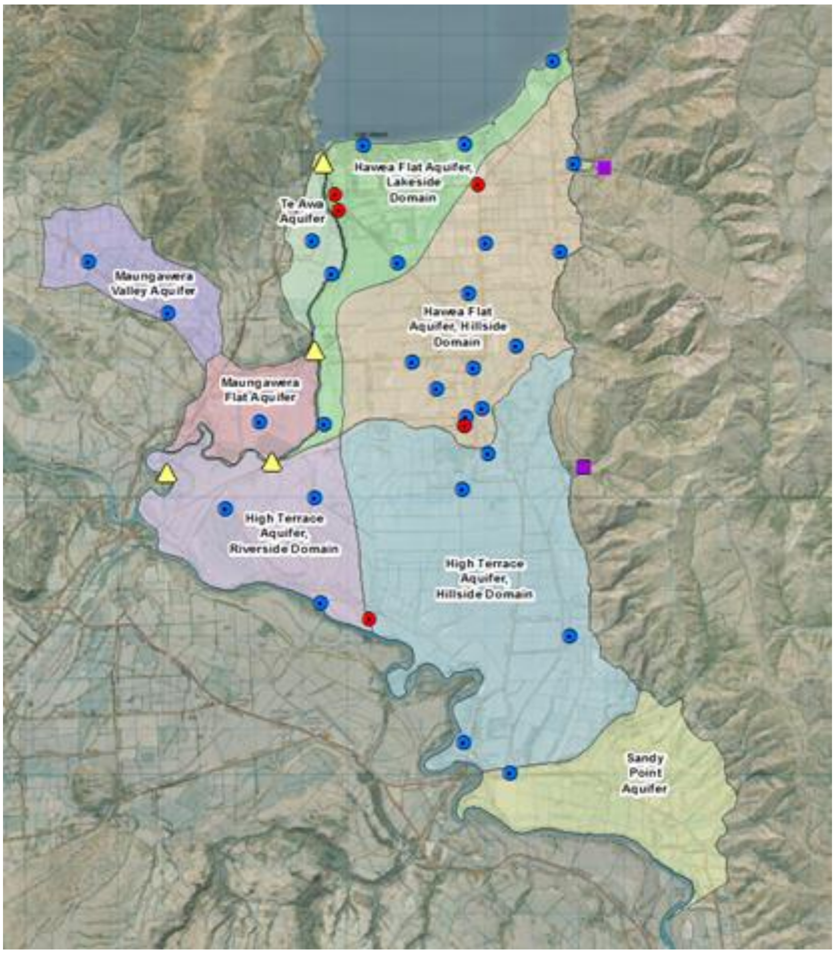

Figure 4. Location of monitoring sites for the 2017/18 Hawea aquifers study

ORC has installed two additional groundwater bores with telemetry equipment to continuously monitoring groundwater levels (for 3 total) and two flow sites on the foothill streams to quantify the recharge to the aquifer. These sites will be monitored for a full year. One of 4 gaugings at four locations along the Hawea river to characterise the groundwater – surface water interaction of the Hawea River and one of two groundwater quality and level surveys to bench mark the state of the groundwater quality compared to 2011/12 has been carried out to date. Upon completion of the data collection in mid-2018, the transient model will be calibrated to run allocation scenarios. An updated report will be published setting out the methodology around the model calibration and recommendations on suitable allocation volumes in 2018/19 with a plan change that will set out allocation limits in Schedule 4A and aquifer restriction levels in Schedule 4B of the Regional Plan Water for Otago to follow.

8. July 2017 Coastal Otago Flood Event

The analysis and reporting on the severity of the July 2017 heavy rainfall event and its impact on streams and rivers (flows, erosion, river form) is progressing. The focus is now on assessing the effects of high flows on bank erosion for the Taieri River and Silver Stream. A comprehensive report on the July 2017 heavy rainfall event will be presented to committee this year.

Investigations of the flood hazard associated with the Owhiro Stream (tributary of the Taieri River south of Mosgiel) is progressing. Large sections of the stream and tributaries are part of the East Taieri Drainage Scheme and provide land drainage to a rural standard (Figure 5). Intensification of urban development along some sections of the stream and its tributaries could affect the capacity and efficiency of the drainage scheme in this area. The main purpose of the study is to investigate the hydrology and flood hazard associated with the Owhiro Stream and main tributaries. This will inform a better understanding of the Scheme drainage network capacity and limitations in order to guide decision-making associated with future developments in the area.

Observations and data (e.g. debris marks) collected during the July 2017 heavy rainfall event have been very useful to calibrate the model used in this investigation (Figure 5). Once calibrated, the model will be used to map the flood hazard associated with the Owhiro Stream and to assess the effects of urbanisation on the drainage network capacity. The study will be completed early this year.

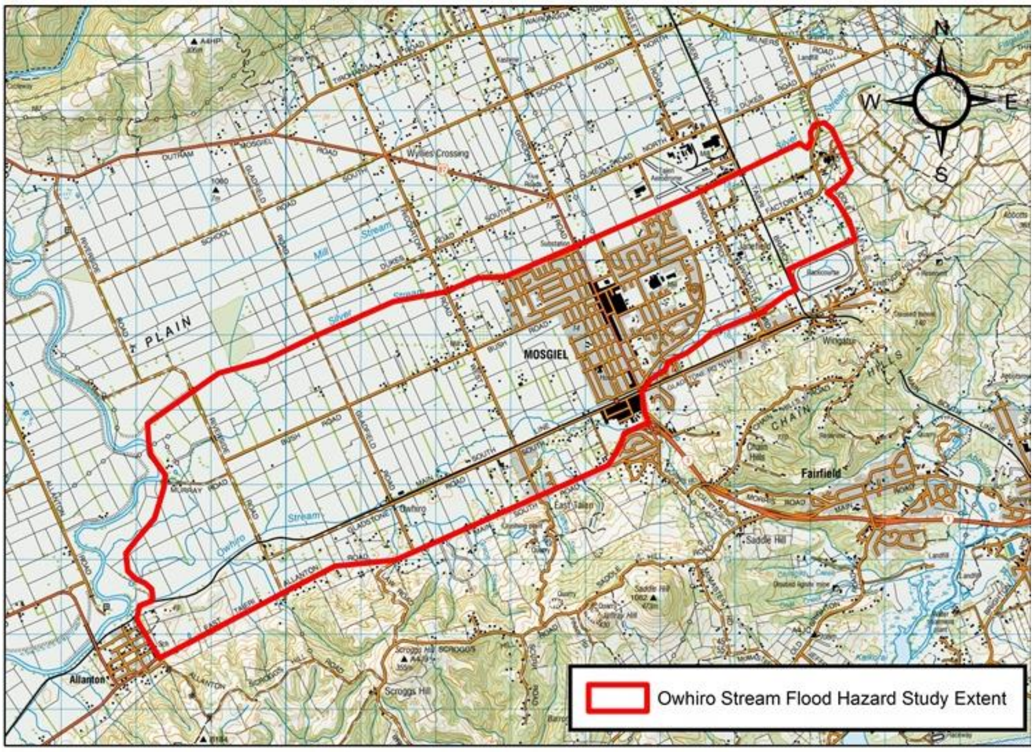

Figure 5: Study area for the Owhiro Stream flood hazard investigation.

9. Henley Flooding

Staff met on site with several residents of Henley on 18 December to discuss flooding and land drainage. The residents explained some works that could improve the standard of drainage and mitigate the effects of flooding from the local catchment (Figure 6). Staff undertook to respond to the residents' suggestions by 2 February.

Figure 6. Flooding at Henley on the morning of 22 July 2017 (ORC staff photos) - Top photo is looking downstream at the northern end of the Township – Bottom photo is looking upstream at the southern end of the Township. The flow in the Taieri River peaked approximately 5 to 6 hours later.

The height, profile and condition of the floodbank has been assessed as part of ORC's programmed floodbank condition assessment work (Figure 7). Works to address improvements to the profile of the floodbank are being scoped for inclusion in the 2018-28 Draft Long Term Plan.

Figure 7. The ORC floodbank at Henley (right of the image, July 2010, ORC staff photo)

The Henley settlement is within the Lower Taieri Flood Protection Scheme but outside the West Taieri Drainage Scheme. There is therefore a formal mechanism for dealing with the maintenance of ORC's floodbank at Henley, but not one for addressing land drainage. The residents noted that they are willing to undertake flood and drainage improvement works themselves using their own resources. Staff are considering how ORC could enable this.

10. NZ SeaRise Programme

On 21 December staff hosted a commencement meeting for work that forms part of the NZ SeaRise programme[6]. Representatives of GNS Science, Victoria University of Wellington and the University of Otago attended the meeting. It was agreed that a technical planning session will be held early this year to develop details around the geo-hydrologic data that will be collected in South Dunedin to inform the work. ORC's contribution to the programme will be the construction of an improved groundwater model and improvements to the groundwater monitoring network. The model will utilise the region-specific estimates of relative sea level rise that will be developed by the programme. The estimates will be available in 2020 and existing estimates and guidance will be used in the meantime.

11. Collaboration with Territorial Authorities on District Plan Natural Hazards

Staff are continuing to work with the Dunedin City Council (DCC) on addressing and advising on the technical aspects related to the natural hazards provisions of the second generation District Plan (2GP). The Hearing Panel is deliberating.

The Waitaki District Council (WDC) is also reviewing their district plan and ORC staff are advising on technical aspects related to the natural hazards provisions. The focus is currently on coastal hazards such as erosion and inundation; and the reassessment of projected sea-level rise rates for the Waitaki District. In November 2017 NIWA was engaged by ORC to undertake a coastal hazards study that will inform part of the District Plan review. In early December, ORC, WDC and NIWA staff visited some sections of the Waitaki coast experiencing substantial coastal erosion (Figure 8). Observations made during the site visit will be used to inform and ground truth the outputs of the coastal hazards study. The study will give consideration to the recently released (December 2017) Ministry for the Environment guidance on coastal hazards and climate change[7].

Advice on other natural hazards such as flooding and land instability are also being provided to WDC.

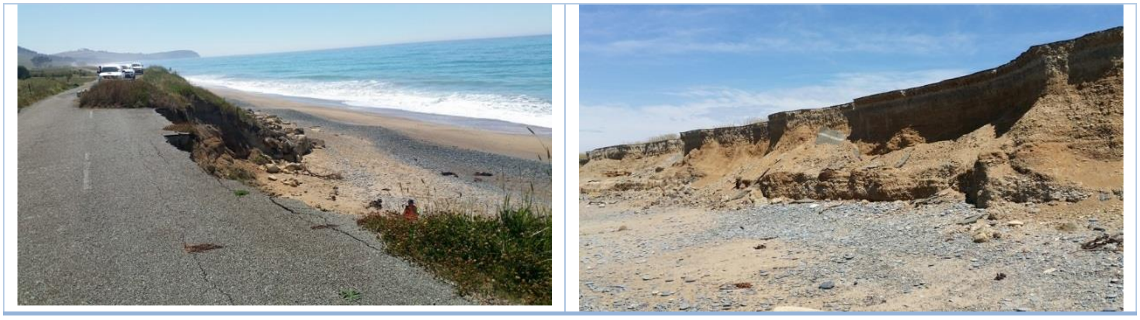

Figure 8. Example of effects of coastal erosion on the Waitaki District coast (Beach Road, December 2017)

[6] http://www.mbie.govt.nz/info-services/science-innovation/investment-funding/current-funding/2017-endeavour-round/successful-proposals

[7] Climate Change Adaptation, Report to Technical Committee, Otago Regional Council, 31 January 2018.

12. Mt Alpha (Wanaka) fire

In early January 2018 a fire burnt approximately 200 hectares of rural land on slopes near Roys Peak and Mt Alpha south of Wanaka (Figure 9).

Council staff plan to assess the effects of the fire in relation to pre-existing natural hazards. The area takes in parts of the Stoney Creek and Waterfall Creek catchments and the un-named catchments between them[8,9].

Commonly wildfires in steep terrain can increase the local debris flow hazard by destabilising hillslope sediment previously anchored by vegetation and increasing water run-off by inhibiting the infiltration of rainfall into the ground.

Figure 9. Mt Alpha fire – 4 January 2018 morning (Photo: Emergency Management Otago).

[8] Grindley, J.; Cox, S.C.; Turnbull, I.M. 2009: Otago Alluvial Fans Project. Opus International Consultants Limited, Report no. 1205 – Version 2, Reference 6CWM03.58, prepared for Otago Regional Council. 64 pages, 2 appendices

[9] Otago Regional Council 2011: Otago Alluvial Fans: High Hazard Fan Investigation. Otago Regional Council ISBN: 978-0-478-37649-4. 96 pages, 1 appendix

13. Geomorphic Change Detection

As previously advised to committee, ORC is a supporting partner in a project to develop GeoTERM – a geospatial toolkit for enhancing river management. The project, started in June 2017, is being led by Professor James Brasington from the University of Waikato (and previously when the project started Queen Mary, University of London), and includes collaborators from institutes in the United Kingdom and the USA, and NIWA.

The project is primarily funded by the United Kingdom's Natural Environment Research Council. It involves developing software to quantify geomorphic change and sediment flux ("geomorphic change detection") in gravel bedded rivers and streams with multi-temporal elevation data, such as LiDAR[10] (Figure 10).

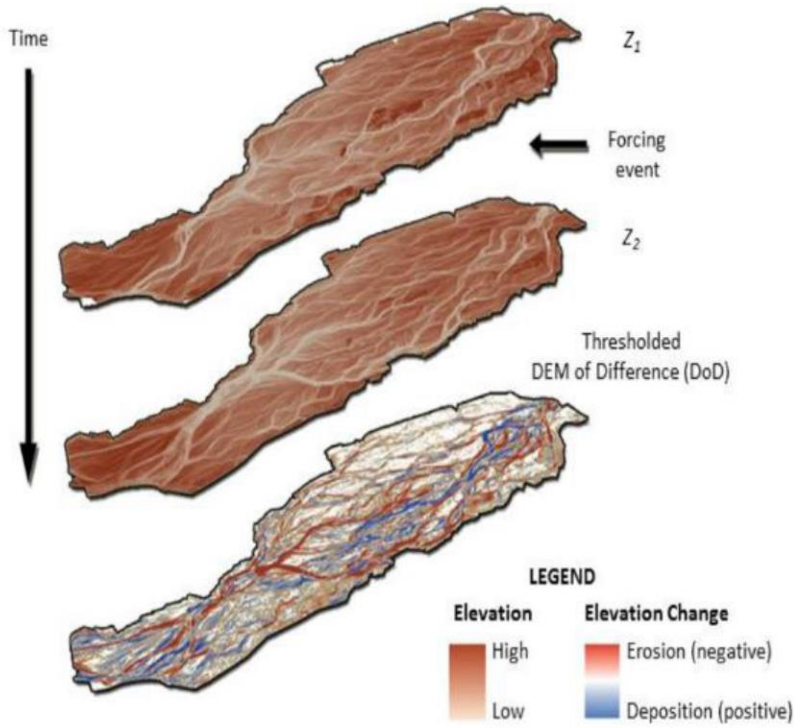

Figure 10. An example of differencing elevation models to assess river change (Rees River, Otago)

Otago's Shotover River is being used to trial the technique, along with other gravel bedded rivers in Canterbury, Hawkes Bay, and Scotland. The method has the potential to improve the way river morphology is managed, with practical implications for the management of erosion and flood hazard, river habitat and gravel extraction. It is expected the project will be completed in June 2018.

[10] Light Detection and Ranging.

14. Lower Waitaki River Scheme

Cr Brown and I attended the Lower Waitaki River Liaison Group meeting on 15 December. The works programme and financial estimates prepared by Environment Canterbury (ECan) for the period 2018 to 2028 were presented and discussed. The programme is consistent with the river management strategy developed jointly by ECan and ORC in 2015[11]. The estimates balance the need to undertake river management works whilst also restoring a satisfactory reserve balance over time. The estimates are being incorporated into ORC's 2018-28 Draft Long Term Plan.

Figure 11. Lower Waitaki River (looking upstream) on 12 October 2017. The flow at Kurow was approximately 305 m^3/s. (photograph courtesy of Environment Canterbury).

[11] Lower Waitaki River Management Strategy, Report to Technical Committee, 9 April 2015, report No. 2015/0863.

15. Clutha River/Mata-au (Matau Mouth) Offsetting

Staff are monitoring the changes taking place in the position of the mouth of the Matau Branch of the Clutha River/Mata-au. The mouth has developed an "offset" from the rest of the river channel and the offset is increasing in size. This has the potential to elevate flood levels some distance inland as it increases the length of the river. It also has the potential to damage rock armouring and floodbanks in that locality that are part of ORC's Lower Clutha Flood Protection and Drainage Scheme.

Staff are seeking expert opinion on the immediate risks and are formulating a plan for a comprehensive assessment of the situation, including potential intervention options. The longer term implications of future sea level rise will also be considered.

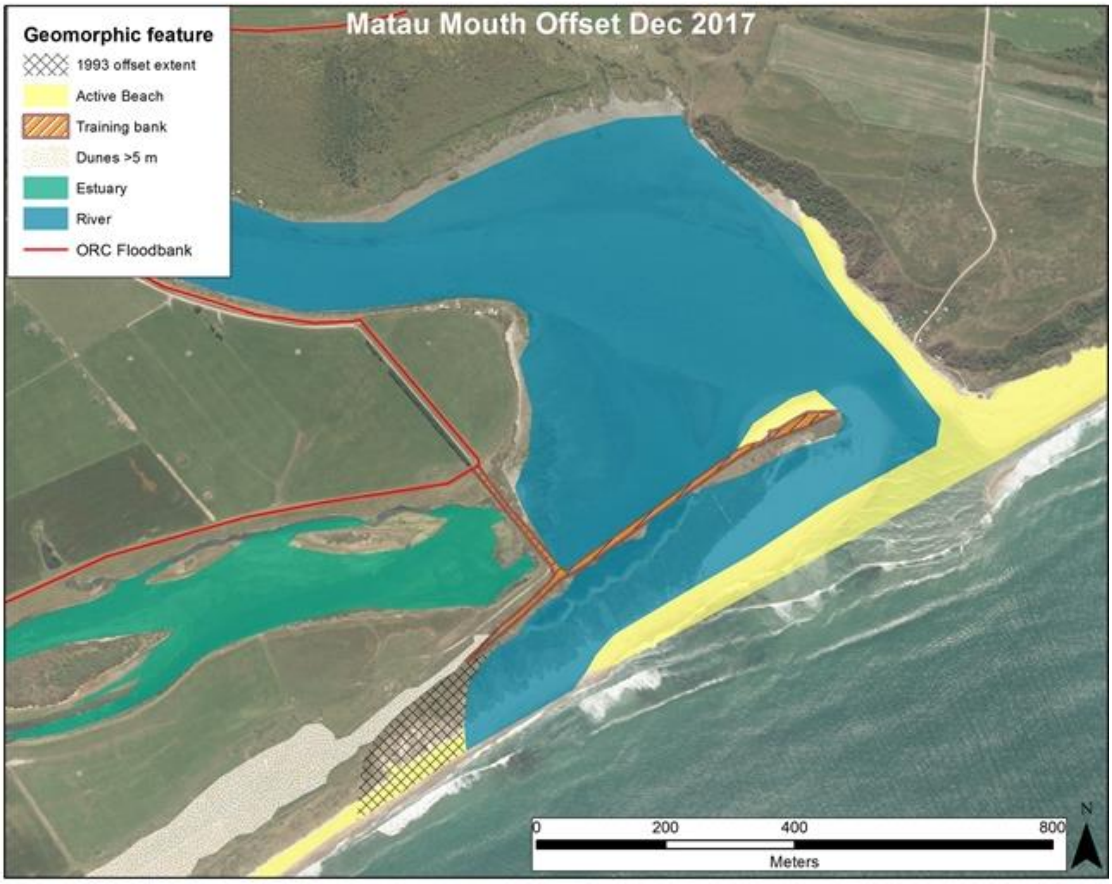

Figure 12: The changes in relative positions or "offset" of the Clutha River/Mata-au (Matau Branch) mouth and the main channel. The shaded blue area is the current mouth position. Background 2013 aerial imagery shows the location of the mouth prior to the offsetting.

16. Central Otago Stock Truck Effluent Disposal (STEDs)

The detailed design of the two new Stock Truck Effluent Disposal facilities for Central Otago is well underway. The preliminary design was supported by New Zealand Transport Agency (NZTA) subject to some changes with respect to safety considerations. The final designs will shortly be submitted to NZTA. Construction tenders will be invited in late February.

17. Leith Flood Protection Scheme

Engineering works on the Union to Leith Footbridge stage of the Scheme are progressing (Figure 13). Parts of the site are being handed back to the university and scaffolding and site fencing removed as packages of work are completed. The contractor (Downer New Zealand Ltd) advises that all works will be completed in May 2018.

Figure 13: Leith Flood Protection Scheme works between Union Street and Leith Footbridge on 25 January 2018. The photographs are looking downstream. The Information Technology Services (ITS) Building is in the background.

Physical hydraulic model investigations of the hydraulics of the Water of Leith at the Dundas Street Bridge are continuing (Figure 14). The model has been calibrated in

December 2017 and run with design flows using the existing geometry of the waterway and bridge structure. The physical model has then been modified to include the proposed culvert at 4m in width and 4.2m height. The model is presently being run under this configuration. It is expected that all modelling will be complete and a final report received by the end of February 2018. Detailed design will recommence once the results of the physical hydraulic model study are available.

Figure 14. Physical model of Water of Leith near Dundas Street Bridge (looking downstream at top and upstream at bottom) at full-scale equivalent flow of 171 m^3/s (the Scheme design flow). The wooden objects in the upper photograph are buildings at model-scale (1:25).

As previously advised to committee, a working group will develop options for improvements of amenity and ecology downstream of Forth Street. The working group has been fully established with Aukaha representing local iwi. The working group met twice in late 2017 for introductions and to be briefed on the project. Public consultation has also progressed with an online survey to begin the community engagement aspect of the project starting later this month. Further detail is provided in the Director's Report to Communications Committee.

18. Recommendation

a) This report is received and noted.

Endorsed by: Gavin Palmer
Director Engineering, Hazards & Science

Attachments

Nil

APPENDIX A

Table A1. **Research priority work streams, priority ranking, associated costs and justification.** ***The table below complements the summary table provided in the proceedings of the 20 December 2016 experts' workshop.***

Priority Ranking	Code
High - Immediate	**High - Immediate**
High - Medium term	**High - Medium term**
Medium - Medium term	**Medium - Medium term**

Work stream	Sub-program	Priority Ranking	Associated costs	Justification	Lead agency
1) Is *Lindavia intermedia* a native or non-native species? ***Top priority area. Will influence the direction of other work streams***	i) Investigation of cell genetics (microsatellite analysis) of NZ and overseas *L. intermedia* populations	**High - Immediate**	***Funded by ORC. Completed.***	This work will indicate if *L. intermedia* has recently arrived in NZ and should be considered an invasive species.	**ORC**
	ii) Comprehensive examination of NZ diatom samples, collections, reports	**High - Immediate**	**$11K** for detailed assessment of 3 separate catalogued collections Delivery 3 to 6 months.	To determine if previous '*Cyclotella*' identifications are in fact *Lindavia*. To help isolate the length of time the diatom has been present in NZ.	**ORC**
	iii) Historical dynamics of *L. intermedia* in NZ lakes from which it has been reported using paleolimnological diatom analysis of dated sediment cores.	**High - Immediate**	4 priority lakes in Otago **$56K.** ($14K per lake). Delivery 6 to 9 months for Otago's 4 priority lakes. Estimated 10 lakes needed to be cored across Otago,	This work will allow a precise estimate of the time that *L. intermedia* has been present in NZ and will complement the microsatellite work currently being undertaken in (i) above.	**ORC**

			Southland, Canterbury and Hawke's Bay		
2) What are the drivers of: **(A) *L. intermedia* dominance in lakes and**	2A i) Literature review of shifts in lake phytoplankton to increased dominance by (*Lindavia*-like) centric diatoms (e.g., climate connection)	**High - Immediate**	$3K – if aligned with 2B i).	This would increase our understanding of shifts and drivers of phytoplankton community structure to one dominated by centric diatoms and provide extremely valuable information to the NZ context.	**ORC**
	2A ii) Are historical *L. intermedia* dynamics correlated to environmental drivers in our lakes?	**Medium - Medium term**	$219K Delivery 3 years [Note: This work is covered in the University of Otago MBIE bid.]	As with 2B ii) this work-stream is extensive and likely best delivered through a University and a number of postgraduate and post-doctoral research programs.	**Catchments Otago / Uni. Of Otago / CRIs / support from RC's**
	2A iii) Are proliferations of *Didymo* and *L. intermedia* in South Island waters related to a common driver or species incursion?	**Medium - Medium term**	$19K minimum Delivery difficult to estimate	If the timing and spread of these two incursions are coherent, then that would provide evidence of a common incursion (both place and time) and support management of future incursions and responses.	**Catchments Otago / Uni. Of Otago / CRIs / support from RC's**
2) What are the drivers of:	2B i) Comprehensive literature review	**High - Immediate**	$10K	Seen as a top priority and would increase	**ORC**

(B) polysaccharide overproduction by *L. intermedia*?	on diatom polysaccharide overproduction from similar situations overseas		Delivery 3 to 6 months	our current understanding of TEP production and the lake snow phenomenon. A straightforward exercise that hasn't been undertaken to date.	
	2c) Study of the relationships between diatom polysaccharide overproduction and (1) nutrient availability, (2) climate warming, and (3) grazing pressure.	**High - Medium term**	Year 1: $204K Year 2: $211K Year 3: $198K Delivery 3 years [Note: This work is covered in the University of Otago MBIE bid.]	As with 2A ii) this work-stream is extensive and likely best delivered through a University and a number of postgraduate and post-doctoral research programs.	**Catchments Otago / Uni. Of Otago / CRIs / support from RC's**
3) Can we develop technologies for effective sampling and monitoring of *L. intermedia* and lake snow?	i) The development of new sensor technology to monitor in situ polysaccharide concentrations in lakes.	**High - Medium term**	$300K per year for three years - Part of an MBIE Smart Ideas bid – decision on success due Sept 2017.	Capacity to monitor the abundance and spatial variability of lake snow is critical to understanding the environmental drivers that lead to lake snow production. At present these techniques do not exist.	**Landcare Research / Uni. Of Otago / Support from ORC**
	ii) The development of cost-effective and efficient methods for quantitatively sampling lake snow in lakes (at different depths).	**High - Medium term**			**Landcare Research / Uni. Of Otago / Support from ORC**

	iii) Can DNA methods be developed for the sensitive detection of *L. intermedia* in lakes?	**Medium - Medium term**			**Landcare Research / Cawthron / support from RC's**
4) How might the spread of *L. intermedia* between lakes be stopped or slowed?	i) Are the BNZ Didymo sanitation methods adequate for the disinfection of *L. intermedia*?	**High - Immediate**	Currently contracted by MPI who have engaged NIWA to review the effectiveness of Check – Clean – Dry on *Lindavia*	MPI are reviewing their Check/Clean/Dry campaign and how effective it is for other pest species.	**MPI / NIWA**
5) Supporting citizen science		**High - Medium term**	$10K	Links to 3.	**ORC**

APPENDIX B

Table B1 Summary of water quality concentrations and Secchi disk depths corresponding to different lake trophic levels.

Lake Type	Trophic Lake Index (TLI)	Chla (ug/L)	TP (mg/L)	TN (mg/L)	Secchi depth (m)*
Ultra-microtrophic	0.0 - 1.0	0.13 - 0.33	0.0008 - 0.0018	0.016 - 0.034	33 - 25
Microtrophic	1.0 - 2.0	0.33 - 0.82	0.0018 - 0.0041	0.034 - 0.073	25 - 15
Oligotrophic	2.0 - 3.0	0.82 - 2.0	0.0041 - 0.009	0.073 - 0.157	15 - 7
Mesotrophic	3.0 - 4.0	2.0 - 5.0	0.009 - 0.020	0.157 - 0.337	7 - 2.8
Eutrophic	4.0 - 5.0	5.0 - 12	0.020 - 0.043	0.337 - 0.725	2.8 - 1.1
Supertrophic	5.0 - 6.0	12 - 31	0.043 - 0.096	0.725 - 1.558	1.1 - 0.4
Hypertrophic	6.0 - 7.0	> 31	> 0.096	> 1.558	< 0.4

Table B2 Comparison of TLI_3 – past / present

Lake (TLI3)	2004 – 2006 (censored data?)	2007 -2009 (censored data?)	2016/17 (12 months)	Trophic state
Wanaka	1.9	2.1	**1.41**	Microtrophic
Hawea	1.7	1.6	**1.17**	Microtrophic
Wakatipu	2.3	1.9	**1.34**	Microtrophic
Hayes	4.0	4.9	**4.25**	Eutrophic
Onslow	NA	3.9	**3.63**	Mesotrophic

Table B3 Comparison of TLI nationally (*Source: Analysis of water quality in New Zealand Lakes and Rivers. 2015. NIWA report on behalf MfE)*

Region (*Otago 2016/17*)	Lake	MfE / Stats NZ 2015 Otago 2016/17 (1 yr)	Trophic state
Otago	**Hawea**	**1.17**	**Microtrophic**
Otago	**Wakatipu**	**1.34**	**Microtrophic**
Otago	**Wanaka**	**1.41**	**Microtrophic**
Canterbury	Coleridge	1.60	Microtrophic
Canterbury	Pukaki	1.66	Microtrophic
Canterbury	Tekapo	1.71	Microtrophic
Canterbury	Ohau	1.75	Microtrophic
Canterbury	Benmore	1.78	Microtrophic
Canterbury	Aviemore	2.12	Oligotrophic
Bay of Plenty	Rotoma	2.33	Oligotrophic
Canterbury	Lyndon	2.84	Oligotrophic

Canterbury	Heron	2.85	Oligotrophic
Bay of Plenty	Tarawera	2.85	Oligotrophic
Canterbury	Alexandrina	2.96	Oligotrophic
Otago	**Onslow**	**3.63**	**Mesotrophic**
Bay of Plenty	Rotomahana	4.02	Eutrophic
Bay of Plenty	Rotoehu	4.08	Eutrophic
Otago	**Hayes**	**4.25**	**Eutrophic**
Bay of Plenty	Rotorua	4.26	Eutrophic
Canterbury	Wainono	6.04	Supertrophic
Canterbury	Waihora	6.31	Supertrophic

11.2. Climate Change Adaptation

Prepared for:	Technical Committee
Activity:	Governance Report
Prepared by:	Dr Gavin Palmer, Director Engineering, Hazards & Science
Date:	25 January 2018

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1. Précis

The government has recently released two reports to do with climate change adaptation. One of these presents a stocktake of how New Zealand is adapting to climate change[1]. The other provides guidance for local government on coastal hazards and climate change[2]. Both reports are attached.

The purpose of this committee report is to note the release of these reports as they are relevant to the functions and activities of Council. It is recommended that the findings of the adaptation stocktake and the coastal hazards guidance are noted.

2. Introduction

Addressing climate change was one of the priorities for national direction of the previous government[3]. The government initiated programmes of work to address both mitigation and adaptation[4].

Climate change resilience is one of three priority issues that Ministry for the Environment (MfE) officials recommended the incoming Ministers for the Environment and for Climate Change Issues take action on (the other two being freshwater management and improving the liveability of New Zealand's cities)[5].

In respect of climate change, officials considered the following to be the key priorities[6]:

1. New Zealand's transition to a low emissions economy;
2. Implementing improvements to the NZ Emissions Trading Scheme;
3. Clarifying the role of agriculture in the transition to lower emissions;
4. Increased focus and action on climate change adaptation;
5. Long-term governance and accountability for climate policy.

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[1] Adapting to Climate Change in New Zealand, Stocktake (Interim) Report from the Climate Change Adaptation Technical Working Group. December 2017, Published by the Climate Change Adaptation Technical Working Group.
[2] Preparing for Coastal Change, A Summary of Coastal Hazards and Climate Change Guidance for Local Government, Ministry for the Environment, December 2017.
[3] http://www.mfe.govt.nz/rma/rma-legislative-tools/priorities-national-direction
[4] The Intergovernmental Panel on Climate Change (IPCC) define *adaptation* to be the process of adjustment to actual or expected climate and its effects. In human systems, adaptation seeks to moderate or avoid harm or exploit beneficial opportunities. In some natural systems, human intervention may facilitate adjustment to expected climate and its effects. They define *mitigation* to be human intervention to reduce the sources or enhance the sinks of greenhouse gases.
[5] Briefing to the Incoming Ministers – Environment and Climate, 2017. Ministry for the Environment, 16p.
[6] Ministry for the Environment, Briefing to the Incoming Minister for Climate Change, Climate Change Portfolio, 2017, 18p.

The new government has put in place a programme to help reduce emissions and ensure a climate resilient future[7]. It has recently released two reports to do with climate change adaptation in New Zealand[8]. One of these presents a stocktake of how New Zealand is adapting to climate change. The other provides guidance for local government on coastal hazards and climate change. These reports as summarised as follows.

3. Climate Change Adaptation Stocktake

Under the Paris Agreement New Zealand is required to plan for and to take action on adapting to the impacts of climate change.

In November 2016 the Minister for Climate Change Issues established the Climate Change Adaptation Technical Working Group[9]. The purpose of the Group is to provide advice to the government on adapting to the impacts of climate change. The writer is a member of the Group. It is important to note that the work of the Group is not limited to climate change in the context of natural hazards risks.

In 2017 the Group undertook a stocktake of existing work on adaptation by both central and local government. The Group chose to extend the stocktake to consider what other sectors of society are doing on adaptation. This recognised that New Zealand will not successfully adapt through central and local government alone. It also acknowledged that there are some sectors that span both the public and private sectors.

The Minister has released the Group's Stocktake (Interim) Report[10]. The report is summarised in Appendix A.

Of particular note is the situation with respect to local government (pp 53-62) of the report.

The report is being used by the Group as the basis for a second report on options for how New Zealand can address the challenges identified and build resilience to the effects of climate change while growing the economy sustainably. The Group's terms of reference require that the final report be provided to the Minister by March 2018.

4. Coastal Hazards and Climate Change Guidance for Local Government

On 15 December 2017 MfE published the Coastal Hazards and Climate Change Guidance for Local Government 2017.

The guidance summarises the current scientific understanding and legal framework around coastal hazards and climate change. It provides information on hazard, risk and vulnerability assessments, and collaborative approaches to engaging with communities. Importantly, it provides a framework to communicate coastal hazard risks and to engage with communities.

The guidance presents sea level rise scenarios and promotes an adaptive pathway approach to managing climate change risks over time. The guidance makes it clear that sea level rise is almost certain out to mid century and provides a way of calculating the levels for that period. It presents an approach for dealing with the latter part of the century.

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[7] http://www.mfe.govt.nz/climate-change/what-government-doing.
[8] See footnotes 1 and 2 above.
[9]http://www.mfe.govt.nz/climate-change/what-government-doing/adapting-climate-change/climate-change-adaptation-technical
[10] See footnote 1 above.

Although the guidance is non-statutory it represents current best practice for New Zealand and draws on international practice. It can be considered complementary to NZS9401:2008, a guiding document used by ORC to manage natural hazards risks for a number of communities[11].

As previously reported to committee, ORC is working with Waitaki District Council (WDC) on the natural hazards component of the review of the Waitaki District Plan. Coastal hazards are of particular significance within Waitaki District. Because of this and for the reasons given above it will be used along with NZS9401:2008 to guide the technical work ORC is undertaking with WDC on the hazards provisions of the District Plan.

5. Recommendations

a) This report is received;

b) The findings of the climate change adaptation stocktake undertaken by the Climate Change Adaptation Technical Working Group are noted;

c) The coastal hazards and climate change guidance for local government is noted.

Endorsed by: Gavin Palmer
Director Engineering, Hazards & Science

Attachments

1. Adapting to climate change in New Zealand stocktake report **[11.2.1]**
2. Preparing for coastal change **[11.2.2]**
3. Appendix A _ Climate Change report _ 31 Jan 2018 **[11.2.3]**

[11] New Zealand Standard 9401:2008 *Managing Flood Risk - A Process Standard* is outlined in *Rangitaiki River Scheme Review - April 2017 Flood Event*, Report to Technical Committee, 6 October 2017.

11.3. Managing the use of coal for domestic heating in Otago and New Zealand

Prepared for:	Technical Committee
Activity:	Environmental - Air Management Planning
Prepared by:	Deborah Mills, Environmental Scientist
Date:	5 December 2017

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1. Précis

During winter months many Otago towns do not meet outdoor air quality standards set by the National Environmental Standards for Air Quality (NESAQ). The pollutant of concern is PM_{10}, very small particles (particulates) with a diameter of less than 10 microns. The major source of particulate pollution is emissions from the use of solid-fuel burners (wood and coal) used by householders for domestic heating. National and regional rules designed to lower emissions, and improve air quality, take an effects-based approach and do not address specific fuel types.

At the Technical Committee meeting held on 29 November 2017, the committee requested a paper on coal. The purpose of the paper is to inform the committee's discussion on the context and issues surrounding the use of coal as a fuel for domestic heating as it relates to air quality.

This paper describes spatial and temporal trends in coal usage across Otago and New Zealand (Section 2), the nature of coal emissions (Section 3), and the current national and regional regulatory framework that affects coal use for domestic heating (Section 4). Section 5 discusses the effects of eliminating coal use on air quality.

2. Coal use in Otago

2.1 Spatial trends in coal use

Coal is used as fuel for domestic heating in every region of the country[1]. New Zealand-wide, coal is used in approximately 4% of all households, from a low of 1% of households in Nelson to a high of 56% of households in the West Coast region. In Otago, approximately 14% of all householders report using coal as the main fuel for heating.

Figure 1 depicts regional use of coal as compared to the national average.

[1] Statistics New Zealand (2015). *2013 Census meshblock dataset: Fuel types used to heat dwellings (total responses), for occupied private dwellings*

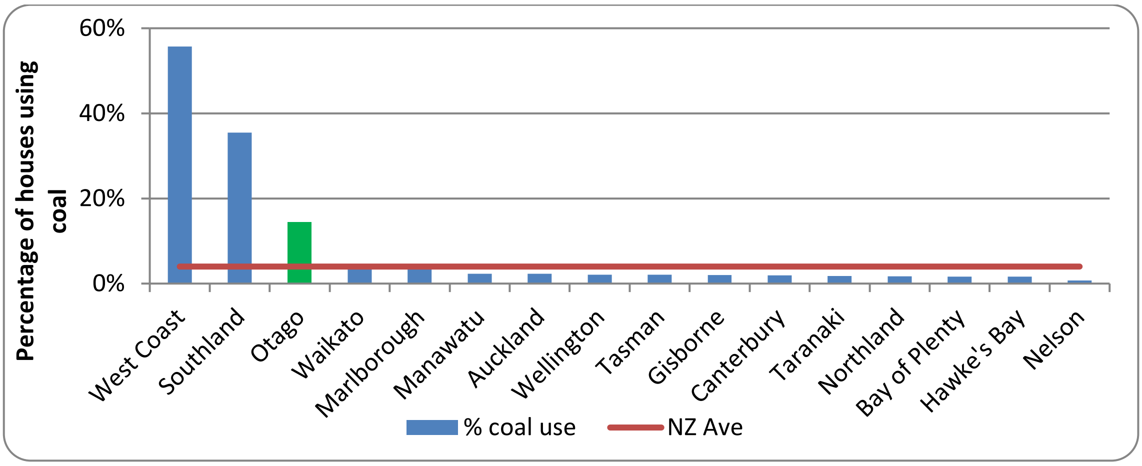

Figure 1 Variation in coal use for domestic heating across New Zealand, by region. The national average is shown by the red line.

Proximity to coal sources, relatively low cost of coal as a fuel, and the relatively high calorific value[2] of coal mean that coal has historically had high usage in southern South Island and the West Coast. Along with the Waikato, the West Coast, Southland and Otago regions operate the major coal mines in New Zealand[3].

The three major grades of coal – bituminous, sub-bituminous, and lignite – are all mined in the Southland/Otago area. Fuel specifications[4] for coal and wood are given in Table 1.

Table 1 Fuel specifications of various coal grades and wood

Fuel	Moisture content (percentage by weight)	Calorific value (Megajoules/kg)	Sulphur content (percentage by weight)
Dry wood	20%	14.6	<0.05%
Wet wood	30%	12.5	<0.05%
Sub-bituminous (Ohai)	17.24%	20.12	0.22%
Lignite (New Vale)	39.6%	15.0	0.41%
Bituminous (Kai Point)	30.4%	29.67	1.52%

Coal use also varies across Otago, with residents of the Clutha District reporting the highest usage for domestic heating, according to the 2013 Census (Figure 2).

[2] Amount of energy available for heat measured using a standard weight of fuel.
[3] New Zealand Petroleum & Minerals, Operating coal mine production figures for 2016, www.nzpam.govt.nz
[4] Data taken from Ministry for Economic Development, *New Zealand Energy Data File, Issue 12*, 2012. Values may vary slightly from mine testing results.

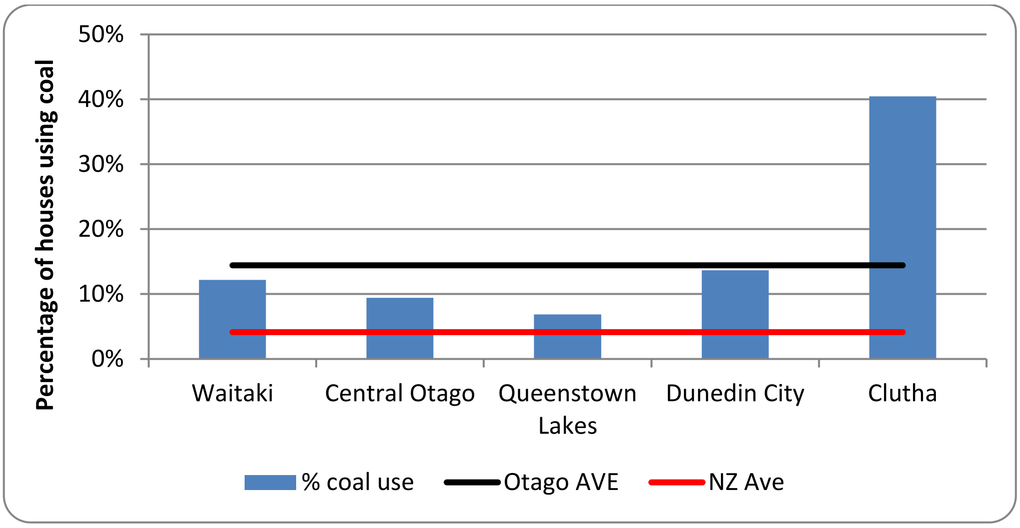

Figure 2 **Variation in coal use for domestic heating across Otago, by district. The national average is shown by the red line and the Otago regional average is shown by the black line.**

According to the 2013 Census, approximately 27% of Milton households and 39% of Balclutha households report using coal. In rural Clutha, 46% of households report using coal.

The 2016 emissions inventory[5] reported a 12% use of coal in Milton. Given the margin of errors of both the Census and the Emissions Inventory, along with change in fuel use during the three-year period (2013-2016), it is reasonable to assume that domestic coal use in Milton is approximately 20%, or one out of every five houses in town.

2.2 Non-domestic coal use

Coal is used throughout Otago in commercial, industrial, and public sector settings such as rest homes, government buildings, and schools.

In Otago, coal boiler plants with a heat generation capacity greater than 1MW trigger the discharge-to-air consenting process. Over the past 10 years, several existing consents throughout Otago have been renewed. During the renewal process, emission limits were imposed resulting in significant industry investment in plant conversions, upgrades, and/or the addition of secondary emission controls which limit particulate emissions. In addition, consent conditions are included that limit the sulphur content to less than 0.5%. These efforts have resulted in improved air quality in Central Dunedin, which has met the NESAQ for the past six consecutive years.

There are numerous smaller coal boilers that meet the permitted activity rules and, therefore, do not currently require discharge-to-air consents. One common activity in this category is the use of coal boilers in schools. According to a 2016 survey of schools[6], there are still numerous schools throughout the region using coal boilers (Table 2). The majority of these do not currently require consents due to their size.

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[5] Environet Ltd., *Alexandra, Arrowtown, Mosgiel and Milton Air Emission Inventory – 2016 (2017 Amendment),* Report prepared for the Otago Regional Council, 2017

[6] Data presented by Esther Kirk of the Toimata Foundation at a meeting on 25 May 2017 on Coal burning in Otago Schools

This situation recently attracted community attention due to the use of coal in an Enviroschool. As a result, a stakeholder group, initiated by the Toimata Foundation, formed to address what can be done to facilitate change.

Table 2 Number of schools in Otago using coal for heating, by district

District	Total number of schools	Number of coal fired boilers
Waitaki	23	12
Central Otago	15	8
Queenstown-Lakes	13	2
Dunedin City	72	42
Clutha	25	12
Total	148	76

Council staff have attended stakeholder meetings which included representatives from regional Ministry of Education offices, Enviroschools, the Dunedin City Council, and the University of Otago. A project plan leading to action and positive change for school communities is currently being developed. Ultimately, the School Energy Project is seen as a long-term, multi-agency collaboration amongst national and regional partners.

Part of Council's role in this project is as the regulator of discharge-to-air emissions. The Air Plan review process will examine whether the permitted activity rules provide appropriate thresholds and conditions for coal boilers. Changes to the limits may stimulate thinking around alternative fuel sources for heating.

2.3 Temporal trends in coal use

Domestic use of coal for home heating has decreased significantly in all areas of Otago since consistent tracking in the Census began in 2001. The national regulatory framework has influenced this change; this is discussed in Section 4. Table 3 shows the downward trend for households reporting coal use in Otago districts.

Table 3 Trend in households using coal for domestic heating from 2001 to 2013, by district

District	Number of houses using coal		
	2001	2013	decrease
Waitaki	2346	1035	59%
Central Otago	1956	690	65%
Queenstown Lakes	1509	723	52%
Dunedin City	12549	6039	52%
Clutha	3588	2634	27%

The regional regulatory framework may partially explain why the Clutha District exhibits the smallest decline in coal use as compared with the rest of the region; this is also discussed in Section 4.

The decline in the use of coal for domestic heating in Otago reflects a national trend. Although the national supply of coal has remained fairly consistent over the past 16 years, residential coal use has dropped from 64,844 tonnes in 2000 to 19,003 tonnes in

2016[7]. In 2016, of all coal consumed in New Zealand (1,278,608 tonnes), approximately 1% was used for residential heating.

The next section discusses the nature of coal burner emissions.

3. Emissions from coal burners

All solid-fuel heating appliances emit a combination of solid (particulate), liquid and gaseous components. Once emitted, these elements interact with the surrounding air and often form secondary pollutants.

The two most common appliances used to burn coal are:

- multi-fuel burner, i.e. an appliance designed to burn coal and wood
- open fire

Emission rates from coal burners differ from wood burner emissions in significant ways[8]:

- Particulate emissions from coal-burning appliances are twice as high as emissions from wood-burning appliances,

- Emissions of nitrogen oxides (NOx) are several times that of wood burner emissions,

- Coal emits 40 times more sulphur dioxide (SO_2) than wood in heating appliances

High SO_2 emissions are the cause of the sharp odour associated with burning coal. In its gaseous form, sulphur dioxide irritates the nose, throat and airways, and can cause coughing and shortness of breath and tightening around the chest. It easily reacts with other compounds in the atmosphere to form particulates which are also inhalable, causing additional health problems. The people most vulnerable to adverse health outcomes are the young, the elderly, and those with existing respiratory conditions[9].

The amount of pollutants emitted by a heating appliance is defined by their emission factor (EF); an emission factor is the average emission rate of a given pollutant for a particular appliance, relative to a standard unit of fuel burnt. Emission factors used in New Zealand have been developed from a multitude of appliance tests, both in the laboratory and in the field and are referenced as grams/kilogram of fuel burnt.

Table 4 lists the accepted emission factors for commonly used domestic heating appliances, as summarised in the latest Emissions Inventory report.

Table 4 General emission factors for domestic heating methods. The post-2006 wood burners are those considered to meet the NESAQ requirement of emissions

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[7] Ministry of Business, Innovation & Employment, *Coal Data Tables,* Produced by Energy & Building Trends, MBIE, energyinfo@mbie.govt.nz

[8] Environet Ltd., *Alexandra, Arrowtown, Mosgiel and Milton Air Emission Inventory – 2016 (2017 Amendment),* Report prepared for the Otago Regional Council, 2017

[9] Environet Ltd., *Health effects of CO, NO2, SO2, ozone, benzene and benzo(a)pyrene in New Zealand*, Air Quality Technical Report No. 43, Prepared for the Ministry for the Environment, 2004

less than 1.5 g/kg with thermal efficiencies greater than 65%. All units are in grams per kilogram of fuel burnt (g/kg).

Appliance	PM_{10}	$PM_{2.5}$	Carbon monoxide	Nitrogen oxides	Sulphur dioxide	Volatile organic compounds	Carbon dioxide
Open fire: wood	7.5	7.5	105	1.2	0.2	30	1600
Open fire: coal	21	18	70	4	8	15	2600
Pre-2006 wood burners	10	10	140	0.5	0.2	33	1600
Post-2006 wood burners	4.5	4.5	63	0.5	0.2	20	1600
Pellet burners	2	2	20	0.5	0.2	20	1600
Multi-fuel: wood	10	10	140	0.5	0.2	20	1600
Multi-fuel: coal	19	17	110	1.6	8	15	2600

4. Air quality management and the regulatory framework

This section discusses national and regional rules and how they affect the use of coal; in addition, a round-up of other councils' approaches to coal use is included.

4.1 National regulations

In 2004, the Ministry for the Environment (MfE) introduced the National Environmental Standards for Air Quality to provide a minimum level of health protection for all New Zealanders[10]. In addition to establishing threshold concentrations of pollutants, MfE provided tools for councils to use in their own air quality management programmes.

Two sets of provisions for home heating were made; they include:

1. After 1 September 2005, wood burners installed on properties less than 2 hectares have to meet strict emission and thermal efficiency standards. Demonstration of compliance is done through laboratory testing using Australia and New Zealand standards[11].

2. A ban on new solid-fuel burning open fires in gazetted airsheds that breach the ambient PM_{10} standard.

The national regulations provide a baseline of emission/efficiency standards for all voluntary installations of new and replacement wood burners into the future. No

[10] Ministry for the Environment, *Resource Management (National Environmental Standards for Air Quality)Regulations 2004, Amendment Regulations 2011 (SR 2011/103)*

[11] Australian/New Zealand Standard 4012:1999, *Domestic sold fuel burning appliances – Method for determination of power output and efficiency* and 4013:1999, *Domestic solid fuel burning appliances – Method for determination of flue gas emission*

mandatory burner phase-outs were proposed at the national level. In effect, whatever the existing fleet of domestic heating appliances was at the time the regulations came into effect, they could continue to be used indefinitely until voluntary replacement. At replacement, wood burners are required to emit no more than 1.5 grams of particulate for every kilogram of dry fuel burnt (g/kg) and have a thermal efficiency of at least 65%.

Nationwide the focus is on wood burners due to their being the preferred solid-fuel burning appliance. The regulations do not apply to:

- Multi-fuel burners
- Pellet fires
- Coal burners
- Cooking stoves

Using just this tool, it was expected that emissions would reduce over time as older, less efficient burners of all types were replaced with low-emission, high-efficiency wood burners.

The NESAQ's second home heating tool, the open fire ban, was meant to eliminate the installation of new open fires in airsheds that are considered polluted[12]. This is because open fires are disproportionate polluters and a very inefficient form of heating. Taken together, these provisions are meant to assist councils with air quality management.

In December 2017, MfE provided a Briefing to the Incoming Minister (BIM) on the environment; included in the BIM is the MfE's position and recommendation on air quality. Improvement to the country's overall air quality over the past decade is noted with acknowledgement that there is more work to do to address the winter-time pollution in remaining airsheds. The Ministry recommends the amendment of the NESAQ in order to align it more closely with the latest health research, and notes opportunities for funding and facilitating further work on appliance upgrades, behaviour change programmes and warm homes initiatives.

To emphasise the collaborative nature of the work needed to improve air quality, the Ministry highlighted the following key partners; Ministries of Health, Transport, and Business, Innovation and Employment; district health boards, Energy Efficiency and Conservation Authority; and the solid-fuel industry.

Inherent in the national standards is the ability for councils to establish stricter regulations. The Otago Regional Council has done that through the Regional Plan: Air (from 1 January 2009); this is discussed in the next section.

4.2 Regional regulations

The Otago Air Plan gives consideration to the national regulations, but also includes stricter rules. The Air Plan designates three local air management areas, called air zones: Air Zone 1 is comprised of the urban areas of Alexandra, Arrowtown, Clyde, and Cromwell; Air Zone 2 contains 18 other towns and centres in Otago, and; Air Zone 3 is considered rural Otago[13]. (NB: Milton is in Air Zone 2).

[12] Currently, Otago airsheds 1 and 2 are classified as polluted. See Appendix 1 for list of airshed designation.
[13] Air Zones are used to manage local air quality. See Appendix 2 for list of Air Zone designations.

4.2.1 Air Zone 1 – Home heating

Regulation for Air Zone 1 took an *active* approach to all solid-fuel burner replacements, requiring all new appliances to have emission rates of no more than 0.7 g/kg with heating efficiencies of at least 65%. (NB: This is stricter than the NESAQ which requires emission rates of 1.5 g/kg for new wood burner installations).

Newly installed burners must be on the list of burners approved by the Ministry for the Environment. In addition to these requirements for newly-installed burners, as of 1 January 2012 the rules state that emissions from any appliance are to be less than 1.5 g/kg.

These rules promote a reduction of PM_{10} emissions in two critical ways:

1. They phased out (as of 1 January 2012) the operation of older, higher-emitting burners that do not meet the low-emission standard, and

2. The use of higher-emission coal burners is essentially eliminated because coal and multi-fuel burners do not currently meet the required emission standards.

4.2.2 Air Zone 2 – Home heating

Regulation in Air Zone 2 took a *passive* approach towards solid-fuel burners. The assumption was that PM_{10} concentrations would lower enough to meet the NESAQ through the natural attrition rate of burners as householders replaced older solid-fuel burners with either newer, lower-emitting burners or by converting to no-emission heating (e.g. heat pumps).

While all pre-existing burners are still allowed in Air Zone 2 towns, any newly-installed domestic heating appliance must meet the 1.5 g/kg emission rate standard. Because very few coal burners meet the required emission standard, the use of coal is decreasing in Air Zone 2 towns as burners are replaced.

There are two locally manufactured coal boilers (for domestic use) that have been tested by the Home Heating Association and found to meet the emission/efficiency standards for Air Zone 2 limits.

4.2.3 Regional implications for coal use

The significance of these policies in relation to coal use is that Air Zone 1 rules are a virtual elimination of domestic heating coal use through:

- strict emission limits for new appliances , and
- burner phase-outs on older appliances.

There are no coal burners that meet the requirements for the air zone. The sharp reduction in coal use is evident by the 65% downward trend in coal burning indicated for Central Otago (refer Table 1). Due to incomplete compliance with the rules, there are still coal-burning appliances in the Air Zone 1 towns. According to the 2013 Census, and corroborated by the 2016 Emissions Inventory, approximately 2-3% of households still report using coal in each of the towns (Alexandra, Arrowtown, Clyde, and Cromwell). Those households will be contributing a disproportionate amount of PM_{10} due to their relatively high emissions.

Conversely, in Clutha District (Air Zone 2) there has only been a 27% reduction in coal use as natural attrition of older burners takes place. New burners do need to meet the 1.5g/kg limit, thereby limiting the installation of coal burners, but there are no phase-out rules. On average in coastal Air Zone 2 towns, approximately 20% of householders report coal use, ranging from 9% in Oamaru North to 39% in Balclutha.

Milton was originally put into Air Zone 2 on the basis of limited air quality information; however, once continuous monitoring indicated the extent of particulate pollution over winter months it became evident that more active measures were necessary to improve air quality.

Though not in Air Zone 1, financial incentives through council's Clean Heat/Clean Air funding have been available to Milton homeowners for several years for upgrades to cleaner heating. Currently, a programme to upgrade 50 Milton households is being administered through the Otago Homes Community Trust, using council funding.

4.2.5 Approaches by other Councils to home heating emissions

Sixteen regional and district councils are responsible for managing ambient air quality. A nationwide review of home heating rules was undertaken in 2015 by MfE. Results of that review (Table 5) show the number of Councils using a variety of techniques to manage air quality emissions.

Table 5 Techniques used by councils to management air quality

Emission management rules	Number of Councils (out of 16)
Banning coal use	0
Ban use of indoor open fires	4
Apply 1.5g/kg to all appliances (not just wood burners)	5
Stricter emission limits than 1.5g/kg	3
Phase-out of older burners	5
Restrictions on types of burners allowed in new houses	4
Point-of-sale rules	3

No council in New Zealand has directly banned the use of coal. Most other councils with air quality problems have used a variety of rules to limit emissions from existing and new houses. Common techniques include phasing out older burners, limiting the types of appliances allowed in new houses or as replacements in existing houses, and setting strict limits on appliance emissions. In effect, many of these rules restrict the use of coal-burning appliances since those do not meet very low emission limits.

As mentioned previously, Otago Regional Council has used phase-out rules and required very low emission rates on all burner installations in Air Zone 1.

Environment Southland, through their plan review process, proposed the idea of prohibiting the use of 'high sulphur content' fuels for domestic heating, primarily for amenity purposes. This proposed rule received over 500 submissions, the vast majority ‘against’ the rule. The hearing panel decided not to endorse the rule[14].

5. Effect of eliminating coal use

Eliminating the use of coal for domestic heating will reduce emissions of $PM_{2.5}$, PM_{10}, and SO_2. That is true whether a household converts from a coal-burning to a no-emission appliance (e.g. heat pump) or a low-emission appliance (e.g. pellet or MfE-compliant burner).

Amounts of PM_{10}, $PM_{2.5}$ and SO_2 emitted from a single appliance over a typical winter day are given in Table 6 to illustrate the difference in emissions.

Table 6 Typical winters' day mass emissions (g/day).

	Mass Emissions (grams/day)		
Appliance	**PM_{10}**	**$PM_{2.5}$**	**SO_2**
Multi-fuel coal burner	290	260	122
Multi-fuel wood burner	243	243	5
MfE compliant wood burner	110	110	5
Pellet burner	15	15	1.5

At the town scale, the magnitude of the overall reduction in emissions depends on what the current level of contribution to air pollution is from coal burners: the larger the proportion of coal-burning appliances, the greater the reduction in emissions when they are taken out of use.

Alexandra and Milton are used as an example. Assuming that every coal burner is upgraded to a compliant wood burner, the following reductions in PM_{10} emissions are possible:

Alexandra: 2%
Milton: 10%

Neither reduction is sufficient to ensure that the NESAQ will be met. However, a 10% reduction in PM_{10} emissions would be a significant improvement in air quality, particularly coupled with such a marked decrease in SO_2 emissions.

6. Recommendation

a) That this report be received.

Endorsed by: Gavin Palmer
Director Engineering, Hazards & Science

Attachments

Nil

[14] Environment Southland, *Proposed Regional Air Plan (2014), Decision Report*, Section 2.6.10

APPENDIX 1 - Gazetted airsheds

Airshed 1

Alexandra
Arrowtown
Clyde
Cromwell
Naseby
Ranfurly
Roxburgh

Airshed 2

Palmerston
Mosgiel
South Dunedin
Green Island
Milton

Airshed 3

Balclutha
North Dunedin
Central Dunedin
Oamaru
Port Chalmers
Waikouaiti

Airshed 4
Hawea
Kingston
Queenstown
Wanaka

APPENDIX 2 - Otago Air Zones

Air Zone 1

Alexandra
Arrowtown
Clyde
Cromwell

Air Zone 2

Balclutha
North Dunedin
Central Dunedin
South Dunedin
Green Island
Hawea
Kingston
Milton
Mosgiel
Naseby
Oamaru
Palmerston
Port Chalmers
Queenstown
Ranfurly
Roxburgh
Waikouaiti
Wanaka

11.4. Review of surface water State of the Environment monitoring

Prepared for:	Technical Committee
Activity:	Environmental - Water Quality and Quantity SOE
Prepared by:	Dr Dean Olsen, Manager Resource Science
Date:	25 January 2018

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1. Précis

NIWA were engaged by ORC to review the surface water State of Environment (SoE) monitoring programme. The review covered river monitoring network design, monitoring variables, lake monitoring, linkages between river and lake monitoring (and other domains) as well as key out-of-stream pressures. This review has informed the development of the 2018-28 Draft Long Term Plan (LTP). This paper summarises the main findings of the NIWA review and presents how the recommendations of this review are proposed to be provided for in the LTP.

2. Background

Freshwater is managed in accordance with policies and objectives set out in the Resource Management Act (RMA), the National Policy Statement for Freshwater Management (2014) (NPS-FM) and the Regional Plan: Water for Otago. To determine whether the objectives are being met, ORC collect various data regarding the water quality and quantity of the different waterbodies (aquifers, lakes, rivers) throughout Otago. This monitoring is commonly referred to as “State of the Environment” (SoE) monitoring and is a requirement of s35 of the RMA.

Regular reviews of SoE monitoring are considered good practice, to ensure that the network design, monitoring methods and approach remain fit for purpose and are following best practice. The last review of the ORC surface water SoE monitoring program was conducted in 2006. Recently, the NPS-FM, and the National Objectives Framework (NOF) that sits within it, has introduced a number of compulsory attributes that are to be monitored by regional councils.

ORC recently engaged NIWA to review the surface water SoE monitoring programme. The findings are presented in the report Review of Otago Regional Council’s State of the Environment monitoring programmes, river and lake water quality and ecology, December 2017 (attached). This review has informed 2018-28 Draft Long Term Plan resourcing currently under development.

The scope of the NIWA review included:

- River monitoring network
- Monitoring variables
- Lake monitoring
- Linkages between river and lake monitoring (and other domains)
- Key out-of-stream pressures to measure.

It is important to note that the review is of the monitoring undertaken for SoE purposes. The primary objective of SoE monitoring is to allow for accurate statements about the water quality and ecological state in Otago's waterways. In order to satisfy requirements under the NPS-FM, it is necessary to be able to make these statements about all Freshwater Management Units in Otago (in Otago, this refers to the Receiving Water Groups (RWGs) in Schedule 15 of the RPW), as well as at a regional scale. A secondary objective is to collect information that allows for the development of regional-scale water quality models.

The NIWA review has been peer reviewed by Cawthron Institute and by science staff of Environment Canterbury.

3. Key findings of the NIWA review:

3.1. River monitoring network

NIWA found that the current river water quality monitoring network of 65 sites over-represents pastoral sites and under-represents natural sites, with few sites present in RWG 3. The current river water quality monitoring network has sufficient sites to detect statistically significant differences in water quality between pastoral sites and the natural state, and between RWG groups and the NOF attribute states (particularly the C-D band threshold) for most of the water quality variables assessed. However, the network has insufficient sites to detect statistically significant differences between current water quality and the Water Plan limits, and between natural and urban water quality states. Increasing the number of sites in RWG 3 and urban areas provide the greatest gains in statistical power. Conversely, it is possible to reduce the number of sites in RWG 2 or pastoral areas without reducing the power to detect significant differences.

In the course of changing the network design in light of these recommendations, some sites will be removed from the SoE network. However, staff propose some of these sites will be retained as long-term monitoring sites where they have value for another purpose (e.g. tributary to an estuary or lake, long-term dataset), however, they will not be included in SoE analysis and reporting.

3.2. Monitoring methods

The current suite of water quality monitoring variables largely aligns with those recommended for river SoE monitoring. Variables that were recommended to be added include black disc visual clarity, because of its critical importance as a measure of optical water quality. Dissolved copper and zinc (together with dissolved organic carbon and total hardness for at least one to two years) were recommended at urban SoE sites.

Overall, the existing SoE monitoring network has a strong water quality focus and would benefit from the inclusion of additional measures of ecosystem health across a greater number of (wadeable) sites, including (a) monthly assessments of periphyton cover, (b) annual monitoring of macroinvertebrates, and (c) annual assessments of stream habitat.

Additional recommendations include:

- monthly assessments of periphyton biomass and deposited sediment cover at a selection of sites, with both current and potential future land use pressures considered when identifying these sites;
- supplementing the existing annual biomonitoring programme with continuous measurements of water temperature and dissolved oxygen for periods of 1-2 weeks during the warmest months of year, prioritising monitoring at sites with poor riparian shading; and
- making estimates of flow at the time of sampling (‘flow stamping’) at all water quality sites that lack regular flow monitoring.

3.3. Lake monitoring sites

ORC currently monitors nine lakes, covering a range of depths, types, trophic state, and upstream catchment landcover. While more of the 60+ lakes in Otago could be monitored, a higher priority is to establish representative open water monitoring sites across the monitored lakes, where possible. At the minimum, based on the findings of the review, NIWA recommend:

- ongoing monitoring of open water sites on Lakes Wakatipu, Wanaka and Hawea;
- establishing an open water monitoring site on each of Lake Onslow and Lake Tuakitoto that is monitored monthly for at least two years to verify the monitoring results obtained from outlet monitoring to date; and
- reducing the return interval for monitoring open water sites on Lakes Waihola and Waipori from 10 to 5 years to improve the ability for timely detection of changes in lake condition.

While monitoring at lake shore sites in bays or outlets is not recommended as a replacement for monitoring open water sites, shore sampling is preferred to no sampling at all.

3.4. Lake monitoring methods

NIWA recommends that monthly sampling on an ongoing basis should be implemented where possible and including, as a minimum, at all primary open water monitoring sites on Lakes Wakatipu, Wanaka and Hawea. If monitoring campaigns for periods of two to three years are unavoidable, the return interval should be no more than five years to improve the ability for timely detection of changes in lake condition.

NIWA accept the practical advantages of a predetermined, fixed depth for epilimnion and hypolimnion sampling. However, it is recommended for the three largest lakes that:

- the current approach of pooling four samples between 0.2 and 45 m is replaced with a single depth-integrated sample to 10 m to avoid contact with the higher nutrient metalimnion waters; and
- hypolimnion samples – currently collected at 150 m depth – are collected closer to the lake bottom to provide improved information on the accumulation of nutrients in the hypolimnion.

NIWA also recommend measuring depth profiles of water temperature and dissolved oxygen (DO) from the water's surface to near the bottom of each lake on every sampling occasion, using a CTD profiler. For Lakes Wakatipu, Wanaka and Hawea, this represents a change in monitoring practice where profiles are currently limited to 200 m due to equipment limitations. Biannual profiles of nutrients in these lakes – and Lake Hayes – would provide useful information about the effects of stratification and mixing.

3.5. High frequency lake monitoring

High frequency monitoring technology is of increasing importance in monitoring lake health. The deployment of an automated monitoring buoy in each of Otago's three largest and deepest lakes, Hawea, Wanaka and Wakatipu, would aid in understanding nutrient dynamics in these lakes which depend strongly on vertical stratification and winter mixing. In particular, the high-frequency data that buoys provide would support modelling of water movements (hydrodynamics), which control nutrient transport and cycling.

A buoy with a fixed string (rather than vertical profiler) is recommended to enable water quality measurements down to the maximum depths of these lakes. Monitoring buoys would complement but not replace ORC's existing monthly water quality monitoring.

4. Implementation of NIWA's recommendations

4.1 Network design

Based on NIWA's recommendations, three options for the river SoE network were scoped by staff:

- Option 1 - 65 SoE sites (Figure 1), 6 urban SoE sites, 13 other LT sites
- Option 2 - 73 SoE sites(Figure 2), 6 urban SoE sites, 11 other LT sites
- Option 3 - 90 SoE sites (Figure 3), 6 urban SoE sites, 10 other LT sites

The intention of Option 1 was to minimise the number of additional sites required to achieve a representative network. Option 2 represented a moderate increase in the number of sites, which would enable the retention of more of existing sites within the network, while Option 3 represents a more significant increase in the number of sites. The current financials included in the 2018-28 Draft Long Term Plan are based on Option 2. Cost estimates for the three options are presented in Table 1.

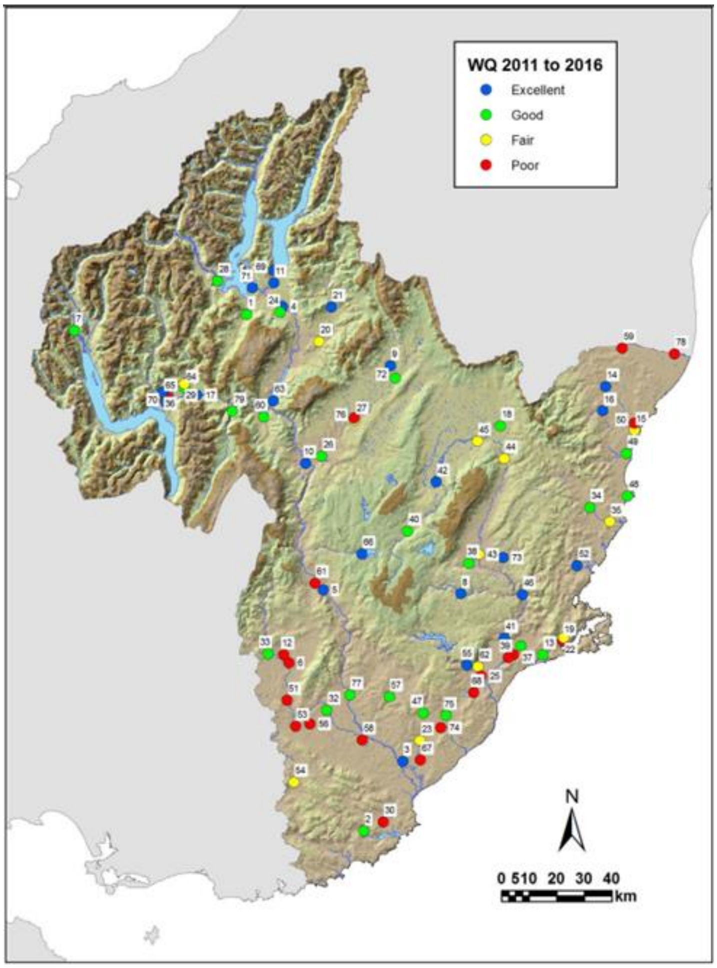

Figure 1 Map showing the locations of current SoE sites .

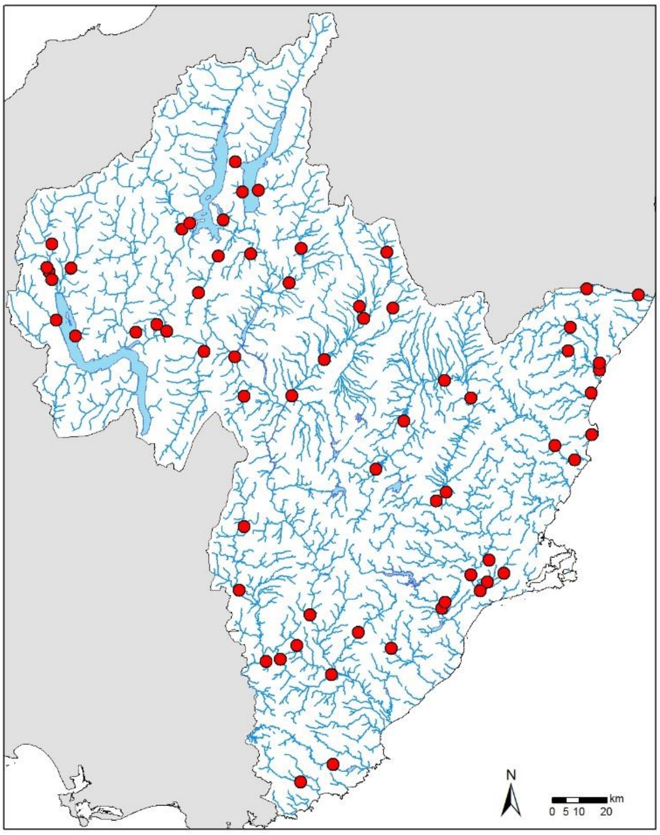

Figure 2 Map showing the indicative locations of river SoE sites under Option 1.

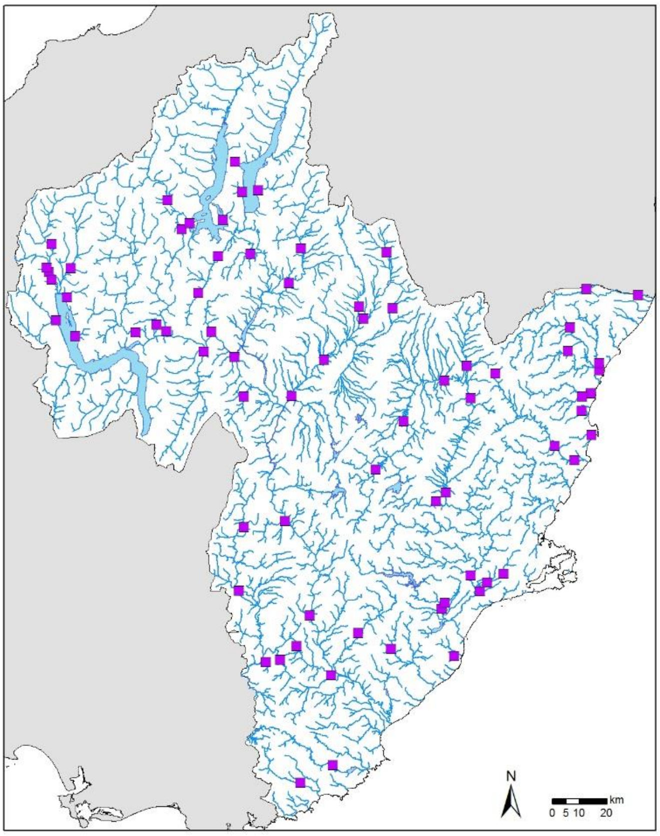

Figure 3 Map showing the indicative locations of river SoE sites under Option 2.

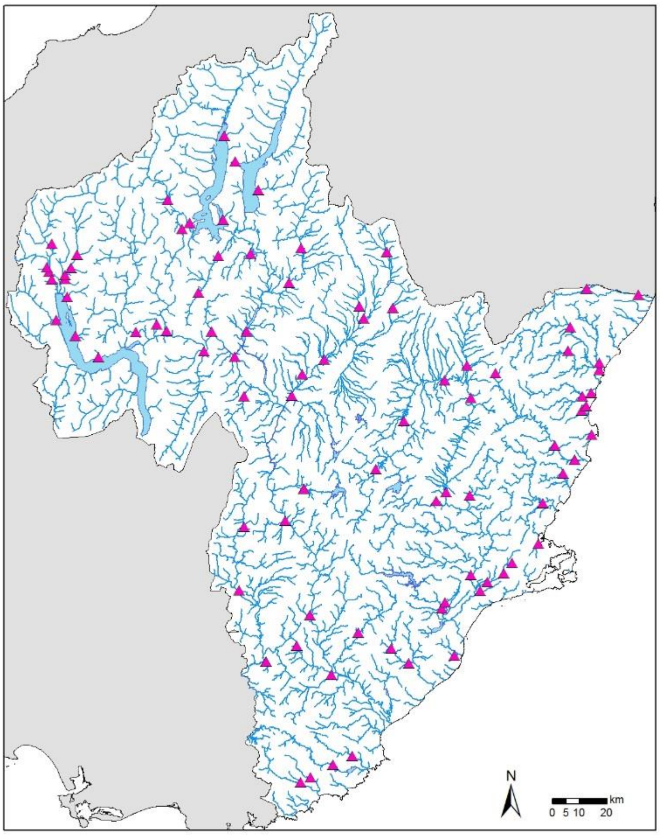

Figure 4 Map showing the indicative locations of river SoE sites under Option 3.

Table 1 Estimated annual monitoring costs associated with the three network design options over the first three years of the LTP

Option	Number of sites				Number of samples	Indicative total cost
	SoE	Urban SoE	Other long-term sites	Total		
1	65	6	13	84	1008	230,240.64
2	73	6	11	90	1080	247,046.40
3	90	6	10	106	1272	290,741.76

4.2 Monitoring methods

It is proposed that the recommended changes to monitoring variables outlined in Section 3.2 are incorporated into future SoE monitoring. Monthly periphyton monitoring is planned for up to 27 sites. Following consideration of the costs of using external providers to undertake this monitoring, a new role is proposed to be established within the Resource Science team to oversee and undertake this monitoring, starting midway through the 2018/2019 financial year.

Table 2 Estimated monitoring costs associated with biomonitoring planned for the first three years of the LTP

	Cost		
	18/19	19/20	20/21
Periphyton	129,175	88,350	88,350
Macroinvertebrates	31,975	31,975	31,975

4.3 Lake monitoring

Continued monthly, boat-based sampling in Lakes Hawea (1 site), Hayes (1 site), Wakatipu (3 sites) and Wanaka (3 sites) was planned to continue until the end of 2018/19, but it is proposed in the LTP that this monitoring continues indefinitely (Table 3).

It is proposed that continuous, quarterly sampling is undertaken in Lakes Onslow, Tuakitoto, Waihola and Waipori. Sampling would be boat-based in Lakes Waihola and Waipori, but shore-based in Onslow and Tuakitoto. The costs associated with this are outlined in Table 3.

Lake monitoring buoys are currently proposed to be installed in Lake Wanaka in 2021/22, in Lake Wakatipu in 2023/24 and Lake Hawea in 2025/26 (Table 3).

Table 3 Monitoring costs associated with lake monitoring planned for the first three years of the LTP

	Costs		
	18/19	**19/20**	**20/21**
Lakes Hawea, Hayes, Wakatipu, Wanaka	139,060	139,060	144,060
Alpine lakes reporting	-	-	46,850
Other lakes	36,160	36,160	36,160
Lake snow	102,900	102,900	102,900

5. Recommendation

a) *That this report be noted.*

b) *That the changes to State of Environment monitoring recommended in this report be endorsed for inclusion in the 2018/28 Draft Long Term Plan.*

Endorsed by: Gavin Palmer
Director Engineering, Hazards & Science

Attachments

1. OR C 17302-2017287 WN Final report **[11.4.1]**
2. CAL 1747 R Young J Clapcott review of NIWA report ORC SOE **[11.4.2]**
3. Letter to ORC Lake So E Review **[11.4.3]**

11.5. Review of groundwater information and models

Prepared for:	Technical Committee
Activity:	Environmental - Regional Plan: Water Quality Environmental - Rural Water Quality Environmental - Water Quality and Quantity SOE
Prepared by:	Dr Dean Olsen, Manager Resource Science
Date:	25 January 2018

1. Précis

Pattle Delamore Partners (PDP) were engaged to review the Otago Regional Council (ORC) groundwater information available in the region, including models as well as data collection programmes and to identify any gaps in understanding or knowledge relating to the management of the region's aquifers. This report summarises the results of this review. PDP consider that, overall, the state of knowledge available for each of Otago's aquifer is very good. They have recommended some improvements which are being incorporated into the 2018/28 Draft Long Term Plan.

2. Background

ORC engaged Pattle Delamore Partners (PDP) to review the ORC groundwater information available in the region, including models as well as data collection programmes, and to identify any gaps in understanding or knowledge relating to the management of the region's aquifers. The objectives of the review were to:

1. summarise the state of knowledge and data collection programmes for each of Otago's aquifers in terms of both water quality and water quantity;
2. assess the quality of the available data and collection programmes; and
3. comment on whether the data and methods used by ORC to inform the sustainable management of their aquifers are fit for purpose.

3. Review findings

PDP's findings are presented in the report Review of Otago Regional Council Groundwater information, August 2017 (attached). Overall, the state of knowledge available for each of Otago's aquifer is very good. The majority of aquifers have detailed reports regarding the patterns of groundwater movement within them, their sources of recharge and locations of discharge. As a result, the conceptual understanding of each of the aquifers is well documented and easily accessible. Many of the aquifers are represented by numerical groundwater models that help to validate those conceptual models.

Groundwater monitoring

Overall, monitoring in the region is appropriate and is generally consistent with the requirements under the National Policy Statement for Freshwater Management (NPS-FM) and the Regional Plan: Water for Otago, relative to the scale of groundwater use in a particular catchment. For the dedicated groundwater monitoring bores the frequency of monitoring is generally at appropriate intervals for groundwater levels and also for water quality. In addition, the parameters analysed from water quality samples are appropriate and consistent.

In some areas, additional monitoring may be required if and/or when groundwater utilisation increases in those areas. Based on the PDP review, conceptual understanding, and the extent of groundwater use in the area, high priority areas for additional monitoring include the Papakaio Aquifer and the Bendigo Tarras aquifer. In addition, the review recommends targeted monitoring of the quality of the groundwater that discharges into surface waterways.

Given the development in the Queenstown Lakes District and the sensitive nature of the lakes, advice from staff is that monitoring in the Kingston and Glenorchy Aquifers is of high priority. Currently only one State of Environment bore is located in Kingston and no monitoring is currently undertaken at Glenorchy.

Groundwater Modelling

Generally, the groundwater models used to represent groundwater in the region's aquifers focus on modelling water quantity rather than water quality. The models are generally good and considered fit for purpose, but in some cases need additional uncertainty analyses, or calibration to surface water flows to ensure that the predictions are within reasonable bounds and appropriate to the water quality and quantity objectives for the models.

Integrated modelling for some of the aquifers has also been undertaken to relate limits to surface water values where groundwater and surface water interaction is important. However, specific values, objectives and limits are not yet assigned to all the aquifers, although that is an ongoing process that is taking place in many of the aquifers, as set out in the ORC Long Term Plan 2015-2025.

Priority of work and long-term planning
The PDP report presents a table of additional monitoring requirements with a level of priority. It is presented below in Table 1 along with actions proposed to address these recommendations:

Table 1: Additional monitoring required

Aquifer	Monitoring required	Reasoning	ORC proposed action
Papakaio Aquifer (High priority)	Groundwater level /quality monitoring	Groundwater level and quality monitoring required to determine limits particularly as groundwater allocation is approaching the allocation limit. Groundwater level monitoring is planned. Further groundwater quality information is required to determine limits.	ORC are in discussion with a land owner who is drilling a new bore in the Papakaio aquifer. If this bore yields enough water, the existing bore will be decommissioned and it may be possible to negotiate access to the decommissioned bore for monitoring purposes. If it is not a feasible option, then ORC will revert to the plan to drill and install a monitoring bore.
Bendigo Tarras Aquifer (High priority)	Groundwater Level monitoring	Bendigo Tarras aquifer maximum annual volume is based on a groundwater model which is uncertain and a drawdown limit that may not protect the values that may be assigned to surface water bodies that depend on the aquifer discharge, for example the Lindis River, and the Bendigo Wetland. Whilst the consented allocation is relatively small compared to the MAL (around 10% to 15%) the uncertainty around the limit means that additional monitoring for both water levels and water quality should be installed in the aquifer.	ORC will work on access to an existing bore for water level and water quality monitoring.
Hawea Basin Aquifer	Groundwater level / quality monitoring	Groundwater level monitoring / information required	Monitoring is currently being undertaken for the Hawea aquifer to calibrate

(Medium Priority)		regarding groundwater interaction with Campbells Wetland and effect of proposed allocation limit. Additional groundwater quality monitoring may be required to determine any effect on the wetland from surrounding landuse. We also note that not all the water quality monitoring bores in this aquifer include analyses for E. coli (although from June 2017 E. coli will be part of the standard set of parameter analysed for each bore).	a transient model and confirm sustainable allocation limits. See Director's Report to Technical Committee 31 January 2018. The existing monitoring bores will be added to the SOE network and set as restriction level bores.
Pisa – Luggate – Queensbury Groundwater Management Zone (Low priority)	Groundwater level and quality monitoring	Further investigation is taking place in this aquifer, two groundwater level and quality monitoring bores have been installed in June 2017 for the Pisa and Luggate GWMZ.	Monitoring is currently being undertaken for the Pisa/Queensbury/Luggate area to calibrate a transient model and confirm sustainable allocation limits. The existing monitoring bores will be added to the SOE network and set as restriction level bores.
Cromwell Terrace Aquifer (Low priority)	Groundwater Level monitoring	No dedicated groundwater level monitoring is available although quarterly groundwater level monitoring may be sufficient until aquifer consented allocation increases. Limits are already set for this aquifer.	Changes in aquifer consented allocation are being monitored.
Earnscleugh Terrace Aquifer (Low priority)	Groundwater level and quality monitoring	No groundwater level or current monitoring is available, however, the consented allocation is very small compared to the maximum annual volume and dedicated groundwater level monitoring may not be	Changes in aquifer consented allocation are being monitored.

		required unless groundwater allocation increases. Groundwater discharges into the Fraser River and some groundwater quality monitoring may be required in order that any effects due to groundwater seepage on that water body can be identified. We also note that not all the water quality monitoring bores in this aquifer include analyses for E. coli.	
Manuherikia Claybound Aquifer (Low priority)	Groundwater level monitoring	Groundwater allocation in the downgradient Dunstan Flats aquifer depends on throughflow from the Manuherikia Claybound aquifer. Groundwater level monitoring is required to allow some early warning if that throughflow may be declining as a result of reduced losses from irrigation races. However, representative groundwater levels may be difficult to define due to the stratified nature of the strata. Groundwater level monitoring in the Dunstan Flats aquifer may therefore be suitable as a proxy.	ORC is currently working on options for the Manuherikia claybound aquifer as part of the minimum flow and allocation setting process for the Manuherikia Catchment. Groundwater level monitoring is currently proposed for inclusion in Year 4 of the 2018-28 Draft Long Term plan.
Maniototo Tertiary Aquifer (Low priority)	Groundwater level monitoring	No groundwater level monitoring data is available although further data collection is planned and ongoing.	ORC monitors two bores in the Maniototo Basin as part of State of the Environment monitoring. Two additional bores are proposed to be installed in Year 4 of the 2018-28 Draft Long Term Plan.

Kingston and Glenorchy Aquifers	Groundwater levels and groundwater quality	No dedicated groundwater level monitoring is available for either aquifer, and only groundwater quality monitoring is available for the Kingston Aquifer. Given potential development, some monitoring would be appropriate.	Monitoring bores are planned to be installed in 2017/18 financial year.

4. Recommendations

a) This report is noted.

Endorsed by: Gavin Palmer
Director Engineering, Hazards & Science

Attachments

1. C 03577500 R 001 Groundwater Review Final v 2 29.08.2017 **[11.5.1]**

11.6. November 2017 Roxburgh Debris flow

Prepared for:	Technical Committee
Activity:	Safety & Hazards - Natural Hazards
Prepared by:	Dr Jean-Luc Payan, Manager Natural Hazards Dr Ben Mackey, Natural Hazards Analyst
Date:	25 January 2018

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1. Précis

Flooding caused by the 26 November 2017 intense thunderstorm in the Roxburgh Township area resulted in extensive sedimentation in the Township. The purpose of this report is to present the observations and preliminary assessments made after the event and associated flooding. The report also describes the alluvial fan hazards for this area.

The pre-existing debris flow hazard for Roxburgh has been known for at least four decades. Damaging debris flows and floods triggered by very intense rainfall events occurred in the past, with documented events in 1938 and 1978. One of the creeks (Black Jacks Creek) also experienced an event in 2015.

Further investigations and assessments are in-progress to understand the implications of the November 2017 event on the alluvial fan characteristics and associated hazards and to establish the need for monitoring and any further mitigation measures. Some initial findings and conclusions are presented in this report.

Staff of ORC and CODC are working together to determine the most appropriate way of updating and informing the Roxburgh community about this work.

It is recommended that this report is received and noted.

2. Event description

The area around Roxburgh Township experienced thunderstorms on the afternoon of 26 November 2017 accompanied by very intense and localised precipitation. Metservice had issued a thunderstorm watch for Central Otago earlier that afternoon predicting rainfall intensities of 25 to 40mm per hour (Figure 1).

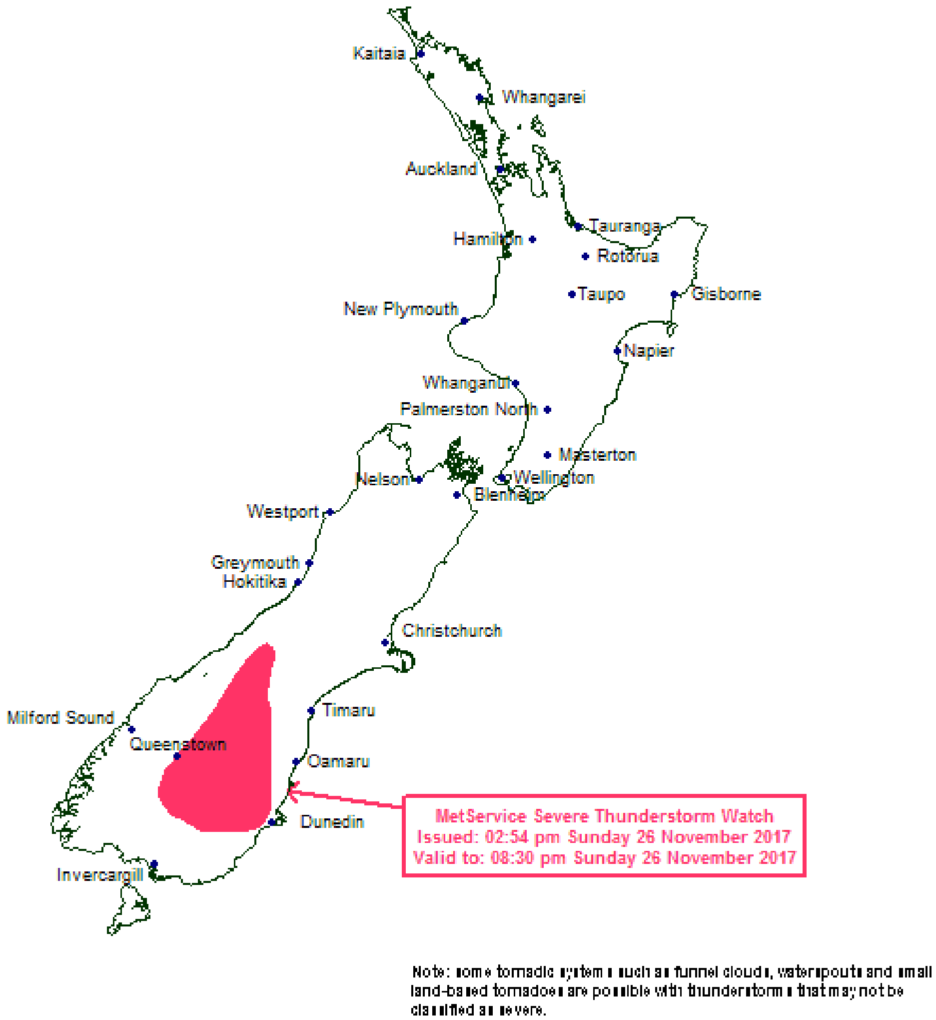

Figure 1. **Forecast thunderstorm area from the Metservice Severe Thunderstorm Watch issued at 02:56 pm Sunday 26 Nov 2017.**

A preliminary assessment of the intensity of the rain event indicates that the thunderstorms produced short duration, high intensity rainfall bursts (>40mm/h) located above the Roxburgh Township and in the Teviot/Millers Flat (Tima Burn) area.

Creeks draining the steep hillsides west of Roxburgh Township (Figure 2) mobilised substantial volumes of sediment (possibly as debris flows or hyperconcentrated flows) and deposited some of this material across alluvial fans and into the Clutha River (Figure 3). Observations made by Otago Regional Council (ORC) staff on 27 November 2017 indicate that rapid sediment aggradation filled some channels beyond capacity, causing flows to spread and avulse across the channels' alluvial fans.

The most severe out of channel sedimentation occurred on the alluvial fans of Reservoir Creek, which flows through northern Roxburgh and of Black Jacks Creek 3km south of the township. Un-named creeks near the golf course in southern Roxburgh, and just north of Roxburgh Township were also impacted (Figure 2).

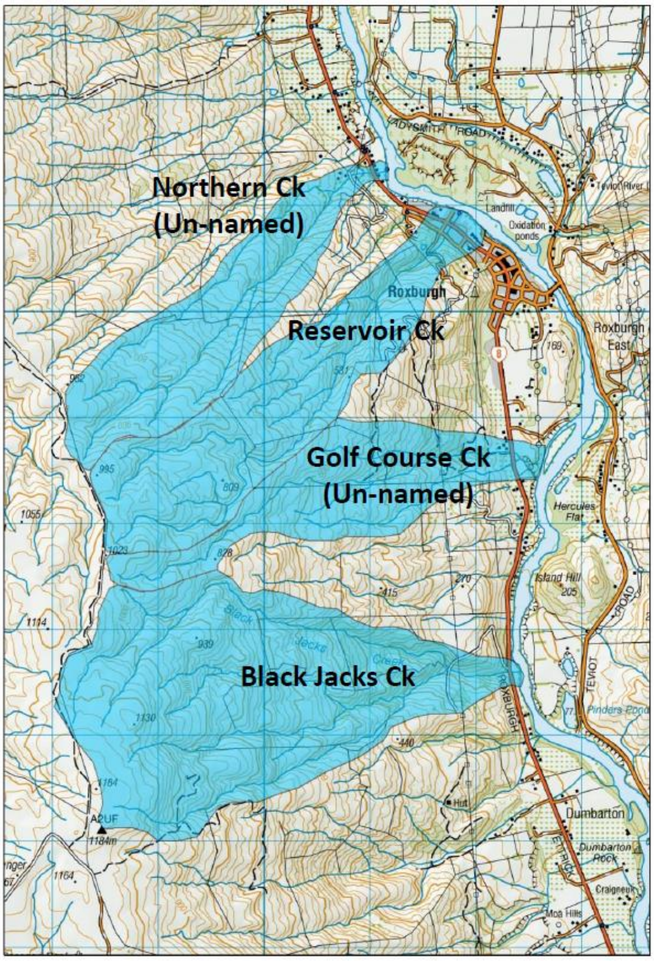

Figure 2. Location of catchments where substantial alluvial fan sedimentation occurred on 26 November 2017.

Figure 3. View up Reservoir Creek showing sediment and debris deposited at the confluence with the Clutha River – Photo taken by ORC staff on 27 November 2017. Excavator has cleared part of the channel in the middle of the view. Width of debris at river edge is approximately 70 m. The Clutha River flows from right to left.

In the upper catchments, many small landslips and bank failures were observed adjacent to the channels (Figure 4). Observations suggest that sediment laden flows travelled down the channels, stripping vegetation from the channel banks, and mobilising bed sediment. Significant quantities of sediment, ranging from silt to large boulders (over 1m diameter), were deposited across alluvial fans, including in northern Roxburgh Township (on roads, streets, properties, school grounds) (Figure 5).

The debris deposited in the Clutha River at Reservoir Creek and Black Jacks Creek have created deposition lobes which extend tens of meters into the river. These lobes potentially reduce channel capacity, and could induce bank erosion by changing river flow patterns (Figure 5).

Figure 4. **Example of small landslips and bank failures in the upper reaches of Black Jacks Creek – Photo taken by ORC staff on 27 November 2017.**

Figure 5. **Sediment deposition in Roxburgh Township and in the Clutha River from Reservoir Creek – Photo taken by ORC staff on 27 November 2017. The sediment lobe from Reservoir Creek protruding into the Clutha River is visible in top right of image. Note the finer sediment deposited on SH8 in the centre of the image.**

The event did not cause fatalities but some properties were severely affected and disruptions to some infrastructure was significant: SH8 was blocked for several days north and south of Roxburgh. Access to other streets in the township was also blocked due to debris deposition. Water and wastewater pipes were damaged during the event. The power and communication networks were also affected in the area.

A number of households were evacuated on Sunday evening until the water levels has receded. Some houses suffered partial inundations (water and fine sediment). The grounds of the Roxburgh area school were damaged by flooding resulting in the closure of the school for a few days. It was fortunate that the event happened on a day that the school was not in use.

3. Previous work on alluvial fans

The pre-existing debris flow hazard for Roxburgh has been known for at least four decades. Damaging debris flows and floods triggered by very intense rainfall events occurred in the past, with documented events in 1938 and 1978. One of the creeks (Black Jacks Creek) also experienced an event in 2015[1]. Information on these hazards is available to the public through the Otago Natural Hazards Database[2].

In 2006, the ORC initiated a general review of the hazards associated with alluvial fans in the region, which was undertaken by Opus International Consultants Limited and GNS Science. The review resulted in a report (Opus 2009) describing the nature and formation of alluvial fans, the type of hazards that they pose to land use and human activity, and how such hazards may be mitigated. More than 2000 alluvial fans, equating to 6% of the total land area of the Otago region have been mapped.

Following this regional compilation, in 2008 ORC engaged GNS Science to map and assess a selection of fans in greater detail, including fans in the Roxburgh area (GNS 2009.). A subsequent 2011 ORC report reviewed high hazard alluvial fans, including Reservoir Creek in Roxburgh (ORC 2011).

4. Alluvial fans in the Roxburgh Township area

All catchments in the Roxburgh area with alluvial fan activity on 26 November 2017 were previously identified as having active and recently active alluvial fans (e.g., Figure 6).

As noted above damaging debris flows and floods triggered by very intense rainfall events occurred in the past, with documented events in 1938, 1978 and (at Black Jacks Creek) 2015.

[1] Coastal Otago Flood Event: 3 June 2015, Otago Regional Council, October 2015, p53.

[2] https://www.orc.govt.nz/managing-our-environment/natural-hazards/otago-natural-hazards-database

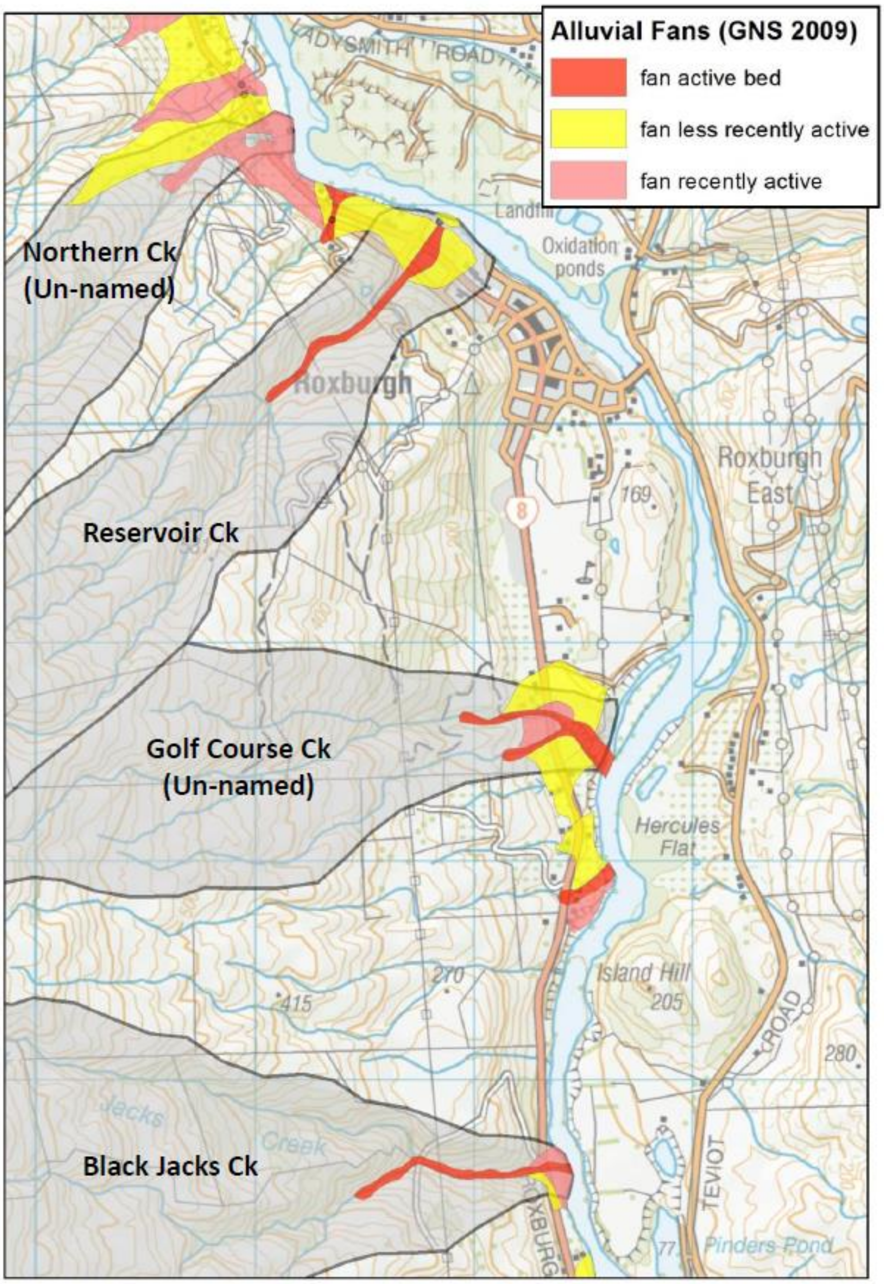

Figure 6. Mapped alluvial fan landforms near Roxburgh Township (GNS 2009).

4.1. Reservoir Creek

Reservoir Creek is a 3.5 km2 catchment which runs through northern Roxburgh. Reservoir Creek alluvial fan was specifically described in the 2011 ORC report (ORC, 2011, Appendix A). This fan has been modified extensively by urban development and is bisected by State Highway 8 (SH8) (Figure 7).

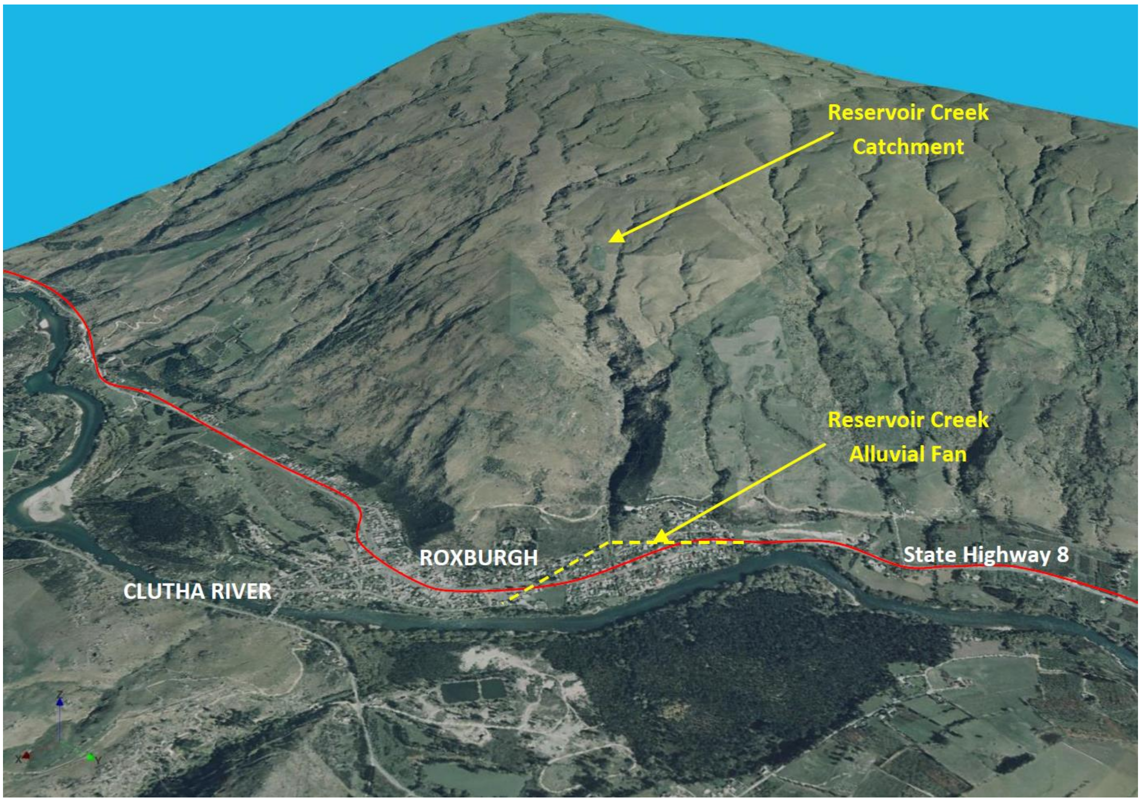

Figure 7. **Image showing the Reservoir Creek alluvial fan with respect to the surrounding environment (from ORC, 2011).**

The fan has been subject to recurrent debris flow events in the past. In October 1978, debris flows overwhelmed the channel and affected residential properties on the surface of the fan above and below SH8 (Figure 8).

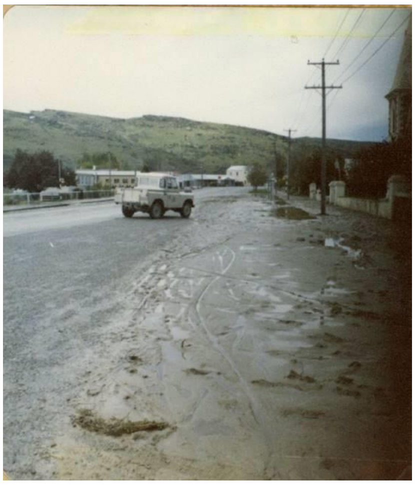

Figure 8. Sedimentation on the Reservoir Creek fan surface. Top left photo is looking downstream and top right photo is looking upstream (16 October 1978). Bottom photo is showing silt deposited on SH8 (15 October 1978) (OCB photos).

Following this 1978 event, in the early 1980's, the Otago Catchment Board (OCB) has excavated the channel and constructed a concrete lined channel in the downstream section of Reservoir Creek (from where it exits the valley). The channel structure is designed to rapidly convey floodwaters and debris across the alluvial fan and into the Clutha River (Figure 9). The concrete channel is 200 m long, 3 m wide at its base, 9 m wide at the top, and 2 m deep.

Figure 9. Concrete lined channel in the downstream section of Reservoir Creek (2009, ORC staff photo).

On 26 November 2017, out of channel sedimentation occurred across the alluvial fan of Reservoir Creek. In the early stages of the event, the concrete lined channel contained most of the debris within the channel as designed, and deposited it in the Clutha River. Eventually the concrete channel backed up with sediment, and resulted in silt and water exiting the channel. Silt-laden floodwater escaped the channel near the top of the fan, and flowed downslope into nearby properties including the Roxburgh Area School (Figure 3 and Figure 5).

The concrete channel was filled with sediment, a volume of 2400 cubic meters. At the outlet of the channel at the Clutha River, a 70 m wide and 35 m long visible lobe of sediment accumulated, with an estimated volume of a further 5000 cubic meters. An unknown volume of sediment also accumulated on the river bed, and additional sediment likely bypassed the lobe deposit and was swept downstream. Boulders up to 1 m in diameter were visible in the lobe deposit. The Reservoir Creek sediment deposited in the bed of the Clutha River created a new rapid with standing waves in excess of 1 m in amplitude.

4.2. Black Jacks Creek

The 6.5 km2 Black Jacks Creek catchment is located 3km south of the Roxburgh Township (Figure 2). This catchment is not urbanised but SH8 crosses the relatively small alluvial fan. Black Jacks Creek runs under the highway through a concrete box culvert before discharging into the Clutha River.

There are no flood mitigation structures on Black Jacks Creek and debris can readily block the culvert under SH8 sending floodwaters and debris across the highway.

Like Reservoir Creek, the fan has been subject to recurrent debris flow events in the past. In October 1978, a debris flow overwhelmed the channel and large amounts of debris were deposited on SH8 (Figure 10). An event also occurred in 2015 closing SH1 for two days (Figure 11)[3].

Figure 10. **Sedimentation on the lower reach of Black Jacks Creek – 15 October 1978. Left photo is looking upstream to the culvert under SH8 and the right photo is looking along SH8 towards Roxburgh Township (OCB photos).**

Figure 11 **Flooding at Black Jacks Creek at SH8, 3 June 2015.**

[3] op cit.

Figure 12. Sedimentation on the lower reach of Black Jacks Creek – 27 November 2017 (ORC staff photo). Width of view along the riverbank is 150 m.

A significant volume of sediment also needed to be removed from SH8 and from the fan surface (Figure 12) to re-establish the channel. The Black Jacks Creek alluvial fan is comparatively small, but the 120 m long and 50-100 m wide central area of the fan was covered by sediment averaging ~0.5 m in thickness, including a 70 m length of SH 8. The channel also required excavation to re-establish a flow path. These two components suggest approximately 6000 cubic meters of sediment was deposited in the lower channel and on the fan surface. Black Jacks Creek did not build a substantial lobe out into the Clutha River (compared to Reservoir Creek), but an unknown volume of sediment bypassed the alluvial fan and was deposited in the River. The sediment on the fan surface ranged from fine silt, through to boulders in excess of 1 m in diameter.

4.3. Other creeks

Two other catchments in the Roxburgh Township area experienced notable flooding and sedimentation during the 26 November event.

Golf Course Creek (informal name) blocked the culvert crossing SH8, and a large volume of coarse sediment (small boulders) was deposited upstream of and across the highway, inundating adjacent paddocks. Floodwaters carried fine sediment across the broader alluvial fan, with significant sediment deposited across the rugby grounds (Figure 13).

Figure 13. **Sedimentation in the lower reaches of an unnamed creek, here referred to as Golf Course Creek– 27 November 2017 (ORC staff photos). In the left image, boulders inundated a paddock upstream of the highway. The right photo shows finer sediment (silt to small gravels) deposited across the rugby field.**

An un-named creek immediately to the north of Roxburgh (Figure 2) also had debris deposited across its alluvial fan, which blocked SH8 and resulted in sediment deposited against structures (Figure 14).

Figure 14. **Sediment deposited across the alluvial fan of a creek north of Roxburgh (27 November 2017, ORC staff photo).**

In the Teviot/Millers Flat area (Tima Burn) south of the Roxburgh Township (Clutha River left/eastern bank, opposite Roxburgh), the intense rainfall generated damaging flash flooding and sediment laden water, but no debris flows were documented.

5. Investigations and assessments following the event

After the 26 November rainfall event, ORC staff undertook several site visits to document the event and assist with clean-up operations. Following the site visits more in-depth assessments and associated data collection have been commissioned.

In order to quantify the extent of sedimentation that occurred in the Clutha River, a bathymetric survey of the Clutha River in the vicinity of Roxburgh Township (5km long approximately) was undertaken in early December 2017. Post-event aerial photography was also captured in late December 2017 so it can be compared with pre-event photos to assist in estimating the volumes of sediments mobilised in affected catchments. This data set will also assist in identifying debris supply and deposition areas.

In response to the sediment deposition into the Clutha River, Damwatch Engineering was engaged by ORC to undertake a preliminary assessment of the significance of the sediment deposition lobes in the Clutha River and of the resulting potential increase of the flood and bank erosion hazards (Damwatch Engineering, 2017). Their report is attached.

The assessment involved a site visit by Damwatch Engineering and computational hydraulic modelling of river flows past the sediment deposition sites to estimate changes in water levels for flows of different magnitudes and increases in flow velocities. This assessment utilised the bathymetric survey data described above.

The main conclusions of the Damwatch Engineering assessment are:

1. "*The sediment lobes deposited by Reservoir Creek and Black Jacks Creek [...] are the only ones that have significantly affected the water level profile along the river at these locations*";
2. The existing flood hazard has "*increased slightly due to slightly elevated flood levels. The extent of these elevated flood levels will rapidly diminish within several hundred meters upstream of each sediment deposition area due to the steep slope of the Clutha River*";
3. "*There are a number of houses located along the section of Tweed Street which runs parallel with the Clutha River which will be exposed to a slightly increased flood hazard*" when flows exceed 3350m^3/s (approximate magnitude of the December 1995 flood);
4. "*The sediment deposition areas in the Clutha River at the Reservoir Creek and Black Jacks Creek confluences has also caused the existing bank erosion hazard along the opposite left bank to be increased slightly due to increased flow velocities. However, the increased flood flow velocities are not excessive and tend to approach an upper limit of 3.4-3.6m/s. The river banks are protected by willow trees at both locations*";
5. "*The lateral slope of the sediment deposits will enhance erosion of sediment material by flood flows. While the largest boulders may not be moved by flood flows, erosion of sediment material around them will tend to undermine them and cause them to roll down the slope and deposit on the river bed*";
6. "*The gradual erosion of the sediment deposits by flood flows over time will cause the slightly increased flood and bank erosion hazards to slowly trend back to the pre 26 November 2017 levels*".

Damwatch Engineering also recommended to capture more bathymetric data to confirm some assumptions made during their preliminary assessment and to assist the monitoring of the gradual attrition of the Reservoir Creek deposition area due to erosion by continual flood events. This additional work is being arranged and will allow more thorough assessment of the matters described in conclusions 2 and 3 above.

GNS Science was engaged by ORC to assess the debris supply and mobility in the upper catchments and the likelihood and consequence of localised avulsion and breakout should further flooding occur. An assessment of the potentially increased likelihood of further sediment-laden floods will also be provided. GNS Science was also asked to include recommendations on any works and monitoring that should be put in place to reduce the short-term risk of future debris flooding. These assessments by GNS Science are in-progress and conclusions and recommendations are expected by the end of January 2018.

ORC is also taking advice on the feasibility and benefits of the installation of a monitoring network on notable landslides adjacent to the creeks which have the potential to block the creek and initiate further debris flows.

In the longer term and based on the assessments described above, the natural hazards risk for the Roxburgh Township area will be re-assessed. The re-assessment will use NZS9401:2008 (Managing Flood Risk - A Process Standard), have regard to the notified Regional Policy Statement and incorporate present understanding of future climate change. This action is consistent with Council discussion in respect of the Rangitaiki River April 2017 flood event[4]. It is planned to collaborate with Central Otago District Council (CODC) during this assessment.

Part of this assessment will be the determination of target or design channel geometries (longitudinal profiles, cross-sections) for the four major creeks. This will require assessment of sediment storage and conveyance characteristics between the top of each catchment and the Clutha River and decisions on how these are best managed. This information will enable river maintenance requirements and responsibilities to be more clearly defined.

Staff of ORC and CODC are working together to determine the most appropriate way of updating and informing the Roxburgh community about this work.

6. Conclusion

The debris flows and flooding caused by the 26 November 2017 intense thunderstorm in the Roxburgh Township area resulted in extensive sedimentation across alluvial fan surfaces associated with some of the catchments draining the steep hillsides west of the Township.

Damaging debris flows and floods triggered by very intense rainfall events have occurred in the past. The alluvial fan characteristics and associated hazards were described in several reports commissioned by the ORC from 2006.

[4] Rangitaiki River Scheme Review – April 2017 Flood Event, Report to Technical Committee, 6 October 2017.

Further investigations and assessments are in-progress to understand the implications of the November 2017 event on the alluvial fan characteristics and associated hazards and to establish the need for monitoring and mitigation measures.

In the longer term and based on the assessments described above, the natural hazards risk for the Roxburgh Township area will be re-assessed.

7. Recommendation

a) *This report is received and noted.*

Endorsed by: Gavin Palmer
Director Engineering, Hazards & Science

References

Barrell D.J.A..; Cox, S.C.; Greene, S.; Townsend, D.B. 2009: Otago Alluvial Fans Project: Supplementary maps and information on fans in selected areas of Otago. *GNS Science Consultancy Report* 2009/052. Prepared for Otago Regional Council. 19 pages, 3 tables and 3 appendices

Grindley, J.; Cox, S.C.; Turnbull, I.M. 2009: Otago Alluvial Fans Project. Opus International Consultants Limited, *Report no. 1205 – Version 2*, *Reference 6CWM03.58*, prepared for Otago Regional Council. 64 pages, 2 appendices

Otago Regional Council 2011: Otago Alluvial Fans: High Hazard Fan Investigation. Otago Regional Council *ISBN: 978-0-478-37649-4*. 96 pages, 1 appendix

Webby G: Roxburgh – Preliminary Assessment of Flood and Erosion Hazards in Clutha River. *DAMWATCH Engineering Letter 22 December 2017.* 24 pages, 1 appendix

Attachments

1. Appendix A **[11.6.1]**
2. Glossary **[11.6.2]**
3. 2017-12-22 preliminary assessment of flood and erosion hazards in Clutha River at Roxburgh **[11.6.3]**

12. NOTICES OF MOTION

13. CLOSURE