1 Resource Consent Application

This application is made under Section 88 of the Resource Management Act 1991.

(For Office Use Only)
Deposit Paid: $

Charges / Deposits

A deposit **must** accompany the application (see page **8** for amounts). The applicant will be invoiced for all costs incurred in processing this application that exceed the deposit.

Council can accept electronic lodgement of applications if sent to public.enquiries@orc.govt.nz. Include "consent application" in the subject line.

Please complete the application in pen. For questions marked with an * you will find notes on page 4

1.* Applicant(s) Details

Applicant(s) name(s) in full: Pioneer Energy Ltd

OR Company Name (in full) ____

OR Names of Trustees (in full) if Applicant is a Trust ____

or Name of Incorporation ____

Postal Address: PO Box 275, Alexandra, 9340

Post Code ____

Street Address (not a P O box number) ____

Post Code ____

Phone Number: Business ____ Private ____

Mobile ____ Fax ____

Email Address ____

2.* Consultant/Contact Details (if not applicant)

Name of Consultant/ Contact Person: Hilary Lennox, Landpro Ltd

Postal Address: 13 Pinot Noir Drive, Cromwell

Post Code ____

Phone Number: Business ____ Private ____

Mobile 021300554 Fax ____

Email Address hilary@landpro.co.nz

3. On Site Supervisor/Manager Contact Details (if applicable)

Name of On Site Supervisor/Manager Person:

Postal Address ______________________________

____

______________________________ Post Code ______________

Phone Number Business ______________________ Private ______________

Mobile ______________________ Fax ______________

Email Address ______________________________

4.* a) Are there any current or expired resource consents relating to this proposal?

☐ Yes ☐ No

If yes, give Consent Number(s) and Description: 2001.475, 2001.476.V1

____

____

b) Has there been a previous application for this activity that was returned as incomplete?

☐ Yes ☒ No

If yes, give Consent Number(s) and Description: ______________________________

____

____

c) Have you a pre-application lodged with Council for this activity?

☐ Yes ☒ No

If yes, give pre-application Number(s) and Description: ______________________________

____

____

d) Have you spoken to a Council staff member about this application prior to lodging this application?

☐ Yes ☒ No If yes, please state name of staff member ______________________________

5. **The applicant is (tick one):** ☒ owner ☐ leasee ☐ prospective purchaser **of the land on which the activity occurs.**

6*. **Who is the owner of the land on which the activity occurs/is to occur? (only complete if applicant is not the landowner)**

Name of landowner: ______________________________

Postal Address ______________________________

____

______________________________ Post Code ______________

Phone Number Business ______________________ Private ______________

Mobile ______________________ Fax ______________

Email Address ____________________

7*. Who is the occupier of the land on which the activity occurs/is to occur? (only complete if the applicant is not the land occupier)

Name of land occupier ____________________

Postal Address ____________________

____

____________________ Post Code __________

Phone Number Business __________ Private __________

Mobile __________ Fax __________

Email Address ____________________

8*. Who leases the land on which the activity occurs/is to occur? (only complete if land is leased and it is not leased to the applicant)

Name of land leasee ____________________

Postal Address ____________________

____

____________________ Post Code __________

Phone Number Business __________ Private __________

Mobile __________ Fax __________

Email Address ____________________

9. Tick the consents required in relation to this proposal:

Water

[X] Take Surface Water - VARIATION

[ ] Divert

[ ] Take Groundwater

[X] Dam - VARIATION

Discharge onto or into:

[ ] Land

[ ] Water

[ ] Air

Land Use:

[ ] Bore construction

[ ] Bore alteration

[ ] Activities in or on beds of lakes or rivers or floodbanks

[ ] Disturbance of contaminated land

Coastal: [ ] Activities in the coastal marine area (i.e., below mean high water spring tide)?

Where you have indicated the type of consent that is required, you must complete the appropriate Application Form before your application can be processed. Application Forms can be found on the Council's website: www.orc.govt.nz.

10. What is the maximum term of consent you are seeking? ____N/A____ years

11.Territorial Local Authority in which activity is situated?

- [ ] Dunedin City Council
- [ ] Queenstown Lakes District Council
- [ ] Clutha District Council
- [ ] Waitaki District Council
- [X] Central Otago District Council

12*. Do you require any other resource consent from any local authority for this activity?

[ ] Yes [X] No

If Yes, please list: ______________________________

Have these consents been applied for/issued? [ ] Yes [ ] No If Yes

If Yes, please give the date applied for or issued: ______________________________

Notes on Application Form Details

1. **Applicant(s) Details**

A resource consent can only be held by a legal organisation or fully named individual(s). A legal organisation includes a limited company, incorporated group or registered trust. If the application is for a trust the full names of all trustees are required. If the application is not for a limited company, incorporated group or trust, then you must use fully named individual(s).

2. **Consultant/Contact Details**

If you are using a consultant/agent for this application put their details here. If you are not, leave question 2 blank.

4 Previous Consent

Do you currently have a resource consent to do the activity that you are applying to renew with this application? If so, please enter the permit number if known and a brief description including the date of issue and the expiry date.

6-8 **Landowner, occupier and leasee**

If you are not the landowner, land occupier or leasee of the land where the activity will be undertaken, you may be required to obtain their unconditional written approval to your application. On pg 6 there is a form that can be used.

12. **Additional Consents**

If you are carrying out earthworks or building work you may need other consents from either the ORC or your Territorial Local Authority.

Declaration

Before signing the declaration below, in order to provide a complete application have you remembered to:

Fully completed this Form 1 and the necessary Application Forms [X]

Attached the required deposit.(or pay on line) (see pg 8 for deposit that is payable) [ ] ONLINE PAYMENT
Cheques payable to Otago Regional Council

Please note: your deposit may not cover the entire cost of processing your application. At the end of the application process you will be invoiced for any costs that exceed the deposit. Interim invoices may be sent out for applications, where appropriate.

If the required deposit does not accompany your application, staff will contact you on the phone number provided on this form to request payment, and after 3 working days your application will returned if no payment is made for the required deposit.

I/we hereby certify that to the best of my/our knowledge and belief, the information given in this application is true and correct.

I/we undertake to pay all actual and reasonable application processing costs incurred by the Otago Regional Council.

Name/s H A LENNOX
(BLOCK CAPITALS)

Signature/s
(or person authorised to sign on behalf of applicant)

Designation CONSULTANT Date 9/1/2018
(e.g., owner, manager, consultant)

Otago Regional Council Postal Address: 70 Stafford St, Private Bag 1954, Dunedin 9054

Consultation

– (consultation is not compulsory, but it can make a process easier and reduce costs).

Under Section 95E of the Resource Management Act 1991 (the Act) the Council will identify affected parties to an application and if the application is to be processed on a non-notified basis the unconditional written approval of affected parties will be required. Consultation with potentially affected parties and interested parties can be commenced prior to lodging the application.

Consultation may be required with the appropriate Tangata Whenua for the area. The address of the local Iwi office is: Aukaha, 258 Stuart Street, P O Box 446, Dunedin, Fax (03)477-0072, Phone (03) 477-0071, email: info@aukaha.co.nz. If you require further advice please contact the Otago Regional Council.

Good consultation practices include:
- Giving people sufficient information to understand your proposal and the likely effects it may have on them
- Allowing sufficient time for them to assess and respond to the information
- Considering and taking into account their responses

Written approval forms are appended to this form on Page 9.

Information Requirements

In order for any consent application to be processed efficiently in the minimum time and at minimum cost, it is critical that as much relevant information as possible is included with the application**. Where an application is significantly incomplete, the Consent Authority may decide not to accept the application for processing.**

Resource Management Act 1991
FOURTH SCHEDULE—ASSESSMENT OF EFFECTS ON THE ENVIRONMENT

(Below are the provisions of the 4th schedule of the Act, which describes what must be in an application for resource consent, as amended in 2015.)

1 Information must be specified in sufficient detail
Any information required by this schedule, including an assessment under clause 2(1)(f) or (g), must be specified in sufficient detail to satisfy the purpose for which it is required.

2 Information required in all applications
(1) An application for a resource consent for an activity (the **activity**) must include the following:
(a) a description of the activity:
(b) a description of the site at which the activity is to occur:
(c) the full name and address of each owner or occupier of the site:

(d) a description of any other activities that are part of the proposal to which the application relates:
(e) a description of any other resource consents required for the proposal to which the application relates:
(f) an assessment of the activity against the matters set out in Part 2:
(g) an assessment of the activity against any relevant provisions of a document referred to in section 104(1)(b). *("document" includes regional & district plans, regulations*, *national policy statements, iwi plans*)

(2) The assessment under subclause (1)(g) must include an assessment of the activity against—
(a) any relevant objectives, policies, or rules in a document; and
(b) any relevant requirements, conditions, or permissions in any rules in a document; and
(c) any other relevant requirements in a document (for example, in a national environmental standard or other regulations).

(3) An application must also include an assessment of the activity's effects on the environment that—
(a) includes the information required by clause 6; and
(b) addresses the matters specified in clause 7; and
(c) includes such detail as corresponds with the scale and significance of the effects that the activity may have on the environment.

3 Additional information required in some applications

An application must also include any of the following that apply:
(a) if any permitted activity is part of the proposal to which the application relates, a description of the permitted activity that demonstrates that it complies with the requirements, conditions, and permissions for the permitted activity (so that a resource consent is not required for that activity under section 87A(1)):
(b) if the application is affected by section 124 or 165ZH(1)(c) (which relate to existing resource consents), an assessment of the value of the investment of the existing consent holder (for the purposes of section 104(2A)):"(c) if the activity is to occur in an area within the scope of a planning document prepared by a customary marine title group under section 85 of the Marine and Coastal Area (Takutai Moana) Act 2011, an assessment of the activity against any resource management matters set out in that planning document (for the purposes of section 104(2B)

4 (relates to subdivisions- *not included here as subdivisions not ORC jurisdiction.)*

5 Additional information required in application for reclamation

An application for a resource consent for reclamation must also include information to show the area to be reclaimed, including the following:
(a) the location of the area:
(b) if practicable, the position of all new boundaries:
(c) any part of the area to be set aside as an esplanade reserve or esplanade strip.

Assessment of environmental effects

6 Information required in assessment of environmental effects

(1) An assessment of the activity's effects on the environment must include the following information:
(a) if it is likely that the activity will result in any significant adverse effect on the environment, a description of any possible alternative locations or methods for undertaking the activity:
(b) an assessment of the actual or potential effect on the environment of the activity:
(c) if the activity includes the use of hazardous substances and installations, an assessment of any risks to the environment that are likely to arise from such use:
(d) if the activity includes the discharge of any contaminant, a description of—
(i) the nature of the discharge and the sensitivity of the receiving environment to adverse effects; and
(ii) any possible alternative methods of discharge, including discharge into any other receiving environment:
(e) a description of the mitigation measures (including safeguards and contingency plans where relevant) to be undertaken to help prevent or reduce the actual or potential effect:
(f) identification of the persons affected by the activity, any consultation undertaken, and any response to the views of any person consulted:
(g) if the scale and significance of the activity's effects are such that monitoring is required, a description of how and by whom the effects will be monitored if the activity is approved:
(h) if the activity will, or is likely to, have adverse effects that are more than minor on the exercise of a protected customary right, a description of possible alternative locations or methods for the exercise of the activity (unless written approval for the activity is given by the protected customary rights group).

(2) A requirement to include information in the assessment of environmental effects is subject to the provisions of any policy statement or plan.

(3) To avoid doubt, subclause (1)(f) obliges an applicant to report as to the persons identified as being affected by the proposal, but does not—

(a) oblige the applicant to consult any person; or

(b) create any ground for expecting that the applicant will consult any person.

7 Matters that must be addressed by assessment of environmental effects

(1) An assessment of the activity's effects on the environment must address the following matters:

(a) any effect on those in the neighbourhood and, where relevant, the wider community, including any social, economic, or cultural effects:

(b) any physical effect on the locality, including any landscape and visual effects:

(c) any effect on ecosystems, including effects on plants or animals and any physical disturbance of habitats in the vicinity:

(d) any effect on natural and physical resources having aesthetic, recreational, scientific, historical, spiritual, or cultural value, or other special value, for present or future generations:

(e) any discharge of contaminants into the environment, including any unreasonable emission of noise, and options for the treatment and disposal of contaminants:

(f) any risk to the neighbourhood, the wider community, or the environment through natural hazards or the use of hazardous substances or hazardous installations.

(2) The requirement to address a matter in the assessment of environmental effects is subject to the provisions of any policy statement or plan.

Set out below are details of the amounts payable for those activities to be funded by fees and charges, as authorised by s36(1) of the Resource Management Act 1991.

Resource Consent Application Fees (from 1 July 2017)

Note that the fees shown below are a **deposit** to be paid on lodgement of a consent application and applications for exemptions in respect of water metering devices. This deposit will not usually cover the full cost of processing the application, and further costs are incurred at the rate shown in the scale of charges. GST is included in all fees and charges.

If you wish to make a payment via internet banking, or on line, the details are below. Please note the applicants name and "consent application" should be used as reference when paying the deposit -

BNZ George Street, Dunedin - 02 0900 0532547 00. For on line go to ORC.govt. nz and follow prompts

Publicly Notified Applications: [3]	**$**
First application	5,000.00
Concurrent applications	225.00

Non Notified Applications and Limited Notified Applications: [3]	**$**
First application (except those below)	1,000.00
Concurrent applications [1]	50.00
Administrative variation	500.00
Exemptions from water measuring Regulations	200.00
Bores	500.00
Gravel	500.00

Hearings	Per Note 2 below

Transfers and Certificates Deposits:	**$**
Transfer of Mining Privilege	100.00
Transfer – other	100.00
Priority Table	100.00
Section 417 Certificate	200.00
Certificate of Compliance	200.00
Section 125 – Extension of lapse date	100.00
All Other Costs	As per Scale of Charges

Scale of Charges:		**From 1 July 2017** **$**
Staff time per hour:		
* Executive staff		235.00
* Senior Technical/Scientist		180.00
* Technical/Scientist		120.00
* Field Staff		100.00
* Administration		92.00
Disbursements		Actual
Additional site notice		Actual
Advertisements		Actual
Vehicle use per kilometre		0.70
Travel and accommodation		Actual
Testing charges		Actual
Consultants		Actual
Commissioners		Actual
Photocopying and printing		Actual
Councillor hearing fees per hour		
	*Chairperson	100
	*Member	80
	*Expenses	Actual

Notes

1. For additional permits in respect of the same site, activity, applicant, time of application, and closely related effect as the first application.

2. The deposit payable shall be 90% of the cost of a hearing as calculated by Council in accordance with information contained in the application file and using the scale of charges. The amount payable will be due at least 10 working days before the commencement of the hearing. If the amount is not paid by the due date, then the Otago Regional Council reserves the right under S36 (7) of the Resource Management Act to stop processing the application. This may include cancellation of the hearing.

   Should a hearing be cancelled or postponed due to the non payment of the charge, the applicant will be invoiced for any costs that arise from that cancellation or postponement.

   Following completion of the hearing process, any shortfall in the recovery of hearing costs will be invoiced, or any over recovery will be refunded to the applicant.

Under Section 100A of the RMA, one or more submitters may make a request to have a resource consent application heard by one or more hearing commissioners who are not members of Council. In this case the applicant will pay the amount that Council estimates it would cost for the application to be heard had the request not been made, and the submitter(s) who made the request will pay, in equal shares, the cost of the application being heard that exceeds that amount payable by the applicant.

Further, the applicant may request to have a resource consent application heard by one or more hearing commissioners who are not members of Council. In this case, the applicant will pay the full costs.

3. Where actual and reasonable costs are less than the deposit paid, a refund will be given.

Review of Consent Conditions
Following the granting of a consent, a subsequent review of consent conditions may be carried out at either request of the consent holder, or, as authorised under Section 128, as a requirement of Council. Costs incurred in undertaking such reviews will be payable by the consent holder at the rates shown in the Scale of Charges above.

Compliance Monitoring Charges (from 1 July 2017)

1. Performance Monitoring
The following charges will apply to the review of performance monitoring reports for all consent holders, except those listed in section 1.6 below. The charges shown are annual fixed fees per performance monitoring report or plan, and are inclusive of GST.

			From 1 July 2017
1.1	***Discharge to Air Consent***		***$***
Measurement of contaminants from a Stack report			86.00
Ambient air quality measurement of contaminants report			100.00
Management plans and maintenance records			33.50
Annual Assessment report			66.50
1.2	***Discharge to Water, Land and Coast***		***$***
•	Effluent Systems	Environmental Quality report	46.50
		Installation producer statements	60.00
		Return of flow/discharge records	60.00
•	Active Landfills	Environmental Quality report	58.00
		Management Plans	130.00
•	Industrial Discharges	Effluent quality report	42.00
		Environmental report	92.50
		Return of flow/discharge records	60.00
	Annual Assessment report		50.00
	Management Plans – minor environmental effects		130.00
	Management Plans – major environmental effects		260.00
	Maintenance records		30.00
1.3	***Water Takes***		
Verification reports			60.00
Annual assessment report			50.00
Manual return of data per take			80.00
Datalogger return of data per take sent to the ORC			50.00
Telemetry data per consent			35.00
Administration fee – water regulations			100.00
Low flow monitoring charge*			
- Kakanui at McCones			327.00
- Unnamed Stream at Gemmels			1,431.00

*Charge for monitoring sites established by the ORC specifically to monitor consented activities in relation to river flows.

1.4	***Structures***	
Inspection reports for small dams		130.00
Inspection reports for large dams		260.00
Structure integrity reports		80.00
1.5	***Photographs***	
Provision of photos		60.00

1.6 Set Fees for Specific Consent Holders

Performance monitoring fees will be charges as 75% of actual costs for the following consent holders

Dunedin City Council
Central Otago District Council
Clutha District Council
Queenstown Lakes District Council
Waitaki District Council
Ravensdown
Contact Energy
Trustpower
Pioneer Generation

Additional charges may be incurred for new consents granted during the year.

2. Audit

Audit work will be charged at half of the actual cost incurred, with the actual costs being calculated using the Scale of Charges.

3. Non-Compliance, Incidents and Complaints

Enforcement work on consent conditions, and remedying negative effects from permitted activities – Scale of Charges.

Gravel Inspection and Management

Gravel extraction fee – $0.66 per cubic metre (incl. GST). Where more than 10,000 cubic metres of gravel is extracted within a prior notified continuous two month period, the actual inspection and management costs will be charged, as approved by the Director Corporate Services.

Written Approvals of Persons Likely to be Adversely Affected

I/We (Please print full name/s)______________________ ____

of (Address) ____

I /we have read the full application for the proposal by (Applicant)

____

for a Resource Consent (Number) ________________________________ to ___________________________

____
and give my/our written approval to the proposed activity/activities.

In signing this written approval I/we understand that:

- The consent authority must decide that I/we am/are no longer an affected person, and disregard adverse effects on me/us
- That /we I may withdraw my/our written approval in writing before the hearing, or if no hearing before a decision is made on the application.

Signature/s____ Date _________________________
(or person authorised to sign on behalf of affected party/parties)

Phone _____________ Fax ____________ Email ____

Please note: If this application is subsequently notified the above approval does not constitute a submission as required under Section 96 of the Resource Management Act 1991.

Written Approvals of Persons Likely to be Adversely Affected

I/We (Please print full name/s)______________________ ____

of (Address) ____

I /we have read the full application for the proposal by (Applicant)

____

for a Resource Consent (Number) ________________________________ to ___________________________

____
and give my/our written approval to the proposed activity/activities.

In signing this written approval I/we understand that:

- The consent authority must decide that I/we am/are no longer an affected person, and disregard adverse effects on me/us
- That /we I may withdraw my/our written approval in writing before the hearing, or if no hearing before a decision is made on the application.

Signature/s____ Date _________________________
(or person authorised to sign on behalf of affected party/parties)

Phone _____________ Fax ____________ Email ____

Please note: If this application is subsequently notified the above approval does not constitute a submission as required under Section 96 of the Resource Management Act 1991.

Pioneer Energy Ltd

Resource Consent Application to
Otago Regional Council to
Amend Water Permit (Dam) 2001.475 and
Water Permit 2001.476.V1

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Make the most of your land

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www.landpro.co.nz

Prepared For

Pioneer Energy Ltd

Prepared By

Landpro Ltd
13 Pinot Noir Drive
Cromwell

9 January 2018

QUALITY INFORMATION

Reference: L:\17367 - Amend Water Permit & Dam Permit - Pioneer Energy Ltd\Docs\20171109 17367 Pioneer Lake Onslow variation AEE FINAL.docx

Date: 9 January 18

Prepared by: Hilary Lennox

Reviewed by: Grace Baldwin

Client Review: Tony Jack

Version Number: FINAL

TABLE OF CONTENTS

1. INTRODUCTION ... 1
1.1 Overview of Proposal ... 1
1.2 The Applicant ... 1
1.3 Purpose of Documentation ... 1
2. DETAILS OF PROPOSAL ... 2
3. DESCRIPTION OF EXISTING ENVIRONMENT ... 2
4. ACTIVITY CLASSIFICATION ... 3
5. NON-NOTIFICATION & CONSULTATION ... 3
6. ASSESSMENT OF ENVIRONMENTAL EFFECTS ... 4
7. STATUTORY CONSIDERATIONS ... 5
7.1 Part 2 of the RMA ... 6
7.2 Section 104(1)(b) of the RMA ... 6
8. CONCLUSION ... 7

Appendix A – Lake Onslow Lake Bed Profile and Invertebrate Survey

1. INTRODUCTION

1.1 Overview of Proposal

Pioneer Energy Ltd (the applicant) hold a number resource consents relating to the operation of the Lake Onslow hydroelectricity power generation scheme, which is on the Teviot River. Two of these consents are the subject of this application:

- Water Permit 2001.475 to dam the Teviot River with a 17 m high dam for the purpose of creating Lake Onslow for hydroelectricity power generation and irrigation; and
- Water Permit 2001.476.V1 to take and use water non-consumptively from Lake Onslow at a maximum rate of 6 m^3/s for the purpose of hydroelectricity power generation

Hydroelectricity generation requires water to be released from the dam and both of these permits restrict the rate at which the water level in the lake can be drawn down (Condition 2 of Water Permit 2001.475 and Condition 3 of Water Permit 2001.476.V1):

The rate at which the lake shall be drawn down shall not exceed 0.2 m over any period of seven days

This application seeks to amend this condition to increase the authorised rate of drawn down to 0.5 m over seven days. No amendments to the rate of take, the minimum operating level of the lake or the residual flows are proposed.

1.2 The Applicant

Applicant Address: Pioneer Energy Ltd
PO Box 275
Alexandra 9340

Address for Service: C/- Landpro Limited
PO Box 302
Cromwell 9342

1.3 Purpose of Documentation

Pursuant to Section 88 of the Resource Management Act 1991 (the RMA), this report provides an assessment of the activities effects on the environment as required by Schedule 4 of the RMA.

2. DETAILS OF PROPOSAL

Lake Onslow is a man-made lake formed in 1888 by damming of the Teviot River and Dismal Swamp to provide water for gold mining operations. In 1924, the dam started operating as an irrigation and power scheme. In 1982, a new dam was built, flooding the original dam and increasing the lake area from 367 ha to 830 ha. Today, water from the dam continues to be used by the applicant in a non-consumptive manner for hydroelectricity generation and is also used by the Teviot Irrigation Company to irrigate land around Roxburgh.

Hydroelectricity generation requires water to be released from the dam, which can result in drawdown of the level of the lake. The rate of drawdown is currently restricted to 0.2 m/week, which in turn restricts the amount of electricity that can be generated.

The minimum operating level of the lake is at 679.9 m above sea level, which allows for an operating range of 5 m below the crest of the dam. The lake level is usually operated within a 2.5 m range, with lows experienced about once a decade.

No change to the minimum operating level is proposed, but it is proposed that the authorised rate of drawdown be increased from 0.2 m/week to 0.5 m/week, which will allow for more electricity to be generated when required.

When the lake level is drawn down, this can lead to stranding of the invertebrates that occupy the shallower lake shoreline areas. Increasing the rate of drawdown could increase the potential for stranding, however, the rate at which these populations recover when lake levels rise again can result in higher-than-normal invertebrate numbers.

An assessment of the proposed increased drawdown rate on invertebrate populations was undertaken by Ross Dungey Consulting during 2016 and 2017 (see attached). This assessment concludes that increasing the rate of drawdown as proposed is unlikely to have a significant adverse effect on invertebrate production, especially given that the rate of draw down plays only a minor role in inveterate production. This is discussed in more detail later in this report.

3. DESCRIPTION OF EXISTING ENVIRONMENT

A description of Lake Onslow and its surrounds is provided in the Otago Regional Council report titled Otago Lakes Trophic Status, 2009, and summarised below:

- Lake Onslow is set in wide open Otago tussock 700 m above sea level.
- The catchment of Lake Onslow has an area of 126 km^2.
- Lake Onslow has a significant number of natural values, including significant trout spawning and a significant presence of trout.
- In the past five years there has been some land use modification in the catchment, with tussock being replaced by pasture. This activity and associated implications in terms of more intensive agricultural methods may have an impact on future water quality.

- Recent monitoring has shown more fluctuations in levels of phosphorus and nitrogen, which could be an indication that this changing land use is having an adverse effect on the lake's water quality.
- Although the trophic level is not changing, the lake can currently be classified as being in a eutrophic state with high total phosphorus values. The average total nitrogen and algal biomass values fall into the mesotrophic category.

Lake Onslow is listed in Schedule 1A of the Regional Plan: Water, 2004, (RPW) as having the following natural values:

- Riparian vegetation of significance to aquatic habitats.
- Significant trout spawning areas and areas for the development of juvenile trout.
- Significant presence of trout.

Lake Onslow is listed in Schedule 1D of the RPW as having the following cultural values:

- Waahi taoka – treasured resource; values, sites and resources that are valued and reinforce the special relationship Kai Tahu have with Otago's water resources.
- Mahika kai - places where food is procured or produced.

4. ACTIVITY CLASSIFICATION

Pursuant to s.127(3)(a) of the Resource Management Act, 1991 (the RMA), an application to change conditions of a consent will be treated as if the application were an application for a resource consent for a discretionary activity.

5. NON-NOTIFICATION & CONSULTATION

Pursuant to s.95E of the RMA, Council must decide that a person is affected. Clause 6(1)(f) of Schedule 4 of the RMA requires the identification of, and any consultation undertaken with, persons affected by the activity.

A consent authority has the discretion whether to publicly notify an application unless a rule or National Environmental Standard (NES) precludes public notification (in which case the consent authority must not publicly notify) or s.95A(2) applies.

The effects of the proposed changes will be less than minor, the applicants do not request public notification and there are no rules or NES' which require the public notification of the application. In addition, there are no special circumstances relating to the application. As such, notification of this application is not necessary.

Pursuant to s.127(4) of the Act, when determining who is adversely affected by a change to consent conditions, the consent authority must consider, in particular, any person who made a submission on the original application and may be affected by the change.

Water Permits 2001.475 and 2001.476.V1 were granted in 2006 as part of a suite of consents relating to the Teviot hydroelectricity and irrigation schemes. The original application was publicly notified, and twelve submissions were received, two of which were in opposition. The Teviot Angling Club Incorporated supported the application but wanted the applicant to maintain a maximum drawdown rate of 0.2 m/week between December and April. This was the drawdown rate stipulated in the application and was based on the operation of the power scheme at the time rather than being based on any science relating to protection of aquatic ecosystems. The proposed increase in drawdown rate will not result in tangible adverse effects on aquatic ecosystems compared to the current drawdown rate, and so whilst the Teviot Angling Club specified an agreeable numerical limit, there are not expected to be any adverse effects above those considered by this submitter when the consent was granted. The Teviot Angling Club are not, therefore, considered to be affected by the proposed change.

Due to the Schedule 1A and 1D values discussed above, it is likely that Fish and Game (F&G) and Aukaha would be *interested* in the proposal and so both parties have been consulted with, even though this report concludes that the effects of the proposed activity will be less than minor and no effects on these parties have been identified.

6. ASSESSMENT OF ENVIRONMENTAL EFFECTS

In addition to the application being made in the prescribed forms and manner, Section 88 of the RMA also requires that every application for consent includes an assessment of the effects of the activity on the environment as set-out in Schedule 4 of the RMA.

Lake Onslow is recognised for the instream values listed in Schedule 1A and 1D of the RPW and is a known trout fishing spot. Activities that have the potential to adversely affect invertebrate production in the lake could in turn adversely affect trout production.

Cawthron Institute undertook ecological assessments of Lake Onslow in the 1990's[1] and Dr Stark of the Cawthron Institute has previously noted that the 0.2 m drawdown rate is sufficiently slow that it should not have any adverse impacts on littoral zone macroinvertebrates or fish and that there is nothing to suggest that lake fluctuations are creating significant adverse effects on the lake ecology (see ORC recommending report 2006-202).

An assessment of the proposed increased drawdown rate on invertebrate populations was undertaken by Ross Dungey Consulting during 2016 and 2017 (see attached). This involved a bathymetric and invertebrate survey, as well as a literature search, to compare modern data with that collected in 1993 and to assess the response of invertebrate communities to various lake level alteration regimes.

For the invertebrate surveys, invertebrates were collected at three sites on two occasions. One of the sites was in the same general area as that for the 1993 sampling conducted by Cawthron Institute so that a

[1] *Freshwater Biological Assessment of Environmental Effects for the Proposed Central Electric Ltd Horseshoe Bend Hydro-electric Scheme on the Teviot River, Central Otago. Cawthron Report 389*, 1997, and *A survey of macroinvertebrate communities in seventeen South Island lakes. Cawthron Report 229*, 1993

comparison could be made after a 23-year period. The two other sites represented different habitat zones around the Lake Onslow shoreline. Table 6 of the attached report shows that sampling was undertaken when the lake was 90-95% full and when the lake was only 55% full.

The major differences between the 1993 Cawthron study and the recent surveys are invertebrate density, number of taxa, abundance of annelids, and the presence of caddis and the sphaerid bivalve. Mr Dungey concludes that this is most likely to be related to the mean lake levels. In the three years prior to 1993, mean lake level was rising steadily from approximately 9.3 m to 12.3 m, a rise of 3 m. As such, new habitat was becoming increasingly available and the invertebrate population was probably responding positively to this new habitat with significantly increased productivity. It is likely the relatively stable habitat preceding the 2016-17 samples reflects more of an equilibrium state where production is settled at lower levels.

Some of the literature discussed in the attached report suggests that the disturbance created by draw-down may actually be an advantage by "creating" new habitat with re-flooding on a rising lake, and allowing light penetration to greater depths during draw-down. In some studies, manipulation of lake level is seen as a way to increase fish and invertebrate production.

The attached report concludes that the potential adverse effects on invertebrate productivity from increasing the rate of drawdown (0.2 m/wk to 0.5 m/wk) seems likely to be largely overshadowed by:

- The effect of a dry year when the lake level reduces substantially;
- The range of variation in lake level;
- Changing production as light reaches previously deeper water;
- Annual rainfall amount and seasonal distribution; and
- Recovery as lake levels rise.

The assessment undertaken by Mr Dungey did not find any evidence to suggest that drawdown rate is likely to play a significant role in controlling invertebrate production or that the proposed increase in drawdown rate would be inherently damaging to invertebrate production. This supports the conclusion drawn by Dr Stark of the Cawthron Institute when the original consent was granted.

In 1998, an assessment by Cawthron Institute (referenced in the attached report) suggested that, based on the invertebrates present in Lake Onslow in 1993, "a suitable maximum drawdown rate should not exceed the current operating practice but that a lower rate may not appear to offer any advantages". This supports the proposition that the rate of drawdown has minimal impact on invertebrate productivity.

In conclusion, the proposed increase in drawdown rate is not expected to have any tangible adverse effects on invertebrate and trout production. Continued manipulation of the lake level may even increase invertebrate production and, therefore, increase trout production.

7. STATUTORY CONSIDERATIONS

Schedule 4 of the RMA requires that an assessment of the activity against the matters set out in Part 2 and any relevant provisions of a document referred to in Section 104 of the RMA is provided when applying for a resource consent for any activity. These matters are assessed as follows.

7.1 Part 2 of the RMA

The proposal is consistent with the purpose and principles of the RMA, as outlined in Section 5. The proposal will have less than minor effect on the lake's ability to meet the reasonably foreseeable needs of future generations, or on the life-supporting capacity of the lake and any ecosystems associated with it.

There are no matters of national importance under Section 6 of the RMA that will be affected by the proposal. The proposal is also consistent with the requirements of Section 7 of the RMA. Regarding Section 8, the proposed activity is not inconsistent with the principles of the Treaty of Waitangi.

Overall, the activity is considered to be consistent with Part 2 of the RMA, given the minor nature of the proposed amendment.

7.2 Section 104(1)(b) of the RMA

In accordance with Schedule 4 of the RMA, an assessment of the activity against the relevant provisions of a document referred to in 104(1)(b) of the RMA must be included in an application for resource consent. Documentation in this section are noted as being:

- National Policy Statement for Freshwater Management, 2014;
- Kai Taku ki Otago Limited Natural Resource Management Plan, 2005;
- Regional Policy Statement, 1998;
- Proposed Regional Policy Statement, 2016; and
- Regional Plan: Water, 2004.

Under the RMA, regional plans need to give effect to NPSs, NESs and RPSs. For an application of this scale, an assessment of the application against the regional plans is adequate as these plans ultimately give effect to the higher order statutory instruments.

Regional Plan: Water, 2004

The following policies, which give effect to the plan's objectives, are relevant to this application for resource consent.

> *Policy 5.4.2 In the management of any activity involving surface water, groundwater or the bed or margin of any lake or river, to give priority to avoiding, in preference to remedying or mitigating:*
> *(1) Adverse effects on:*
> *(a) Natural values identified in Schedule 1A;*
> *(d) Spiritual and cultural beliefs, values and uses of significance to Kai Tahu identified in Schedule 1D;*
> *(e) The natural character of any lake or river, or its margins;*
> *(f) Amenity values supported by any water body; and*
> *(2) Causing or exacerbating flooding, erosion, land instability, sedimentation or property damage.*
>
> *Policy 5.4.4 To recognise Kai Tahu's interests in Otago's lakes and rivers by promoting opportunities for their involvement in resource consent processing.*
>
> *Policy 5.4.8 To have particular regard to the following features of lakes and rivers, and their margins, when considering adverse effects on their natural character:*

(c) The natural water level of the lake and its fluctuation;
(e) The ecology of the lake or river and its margins;

Policy 5.4.9 To have particular regard to the following qualities or characteristics of lakes and rivers, and their margins, when considering adverse effects on amenity values:
(b) Recreational opportunities provided by the lake or river, or its margins.

Due to the overwhelming impact of other factors on invertebrate production, the proposed increase in the rate of drawdown is not expected to have any tangible adverse effects on the values listed in Schedule 1A or on Mahika Kai. The lake will continue to be operated within the current operational level and no potential adverse effects on waahi taoka have been identified. Lake Onslow is a man-made lake with augmented fluctuations in lake levels and so there is little natural character that could be affected. The lake is a valued trout fishing location but as discussed earlier in this report, there is no evidence to suggest that draw-down rate is likely to play a significant role in controlling invertebrate production or, therefore, trout production.

8. CONCLUSION

In concluding, a decision to grant consent pursuant to Section 104B under delegated authority can be made on the basis that:

a) it is expected that the adverse effects on the environment will be less than minor.
b) the proposal meets the non-notification requirements of Section 95A of the RMA.
c) the proposal is consistent with the requirements of the RMA, Council policy and other relevant matters.

Granting of the consents will be consistent with the purpose of the RMA for the reasons explained within this report.

Attachment A - Lake Onslow Lake Bed Profile and Invertebrate Survey

Lake Onslow Lake Bed Profile and Invertebrate Survey

Prepared by Ross Dungey Consulting
For Pioneer Energy Ltd.
September 2017.

Index

EXECUTIVE SUMMARY. **3**

BACKGROUND **5**

SCHEME OPERATION. **6**

POTENTIAL EFFECT OF AN INCREASE IN DRAWDOWN RATE. 7

PURPOSE OF SURVEY **7**

REASON FOR SURVEY **7**

METHODS **8**

BATHYMETRY 8
HYDROLOGY 8
INVERTEBRATES 8
LITERATURE SEARCH 9
INVERTEBRATES 9

RESULTS **10**

SITE DESCRIPTIONS. 10
LAKE BED PROFILES 10
HABITAT ZONES 12
LAKE LEVELS 12
SAMPLING 15
INVERTEBRATES 17
DENSITY 18

REASONS FOR DIFFERENCE 1993-2016/7 .... **20**

PRODUCTION ZONES 22
INVERTEBRATE RESPONSES TO DRAW-DOWN 24
MIDGE LIFE CYCLE 26
TEMPERATURE RECORDS 27

DISCUSSION **29**

CONCLUSION **31**

REFERENCES **32**

APPENDIX 1. .... **34**

APPENDIX 2. .... **35**

Executive summary.

1. Approximately 80% of the lake Onslow shoreline is very shallow so a small change in depth produces a relatively large change in shoreline.
2. Hydro lake invertebrate populations are similar in density to non-hydro lakes in New Zealand.
3. Overseas studies have shown that lake levels can be manipulated to increase productivity in response to rising water level inundating previously dry lake bed.
4. The 1993 invertebrate samples revealed this response and invertebrate density and species range was much greater than in the stable sampling period 2016-2017.
5. Lake Onslow has a dry year about once each decade, recovery from which increases invertebrate and probably fish production to higher than usual levels.
6. The normal operating regime where the lake level fluctuates by approximately 2.5m results in relatively stable invertebrate productivity.
7. It seems likely that invertebrate populations in fluctuating hydro lakes have adapted to this changing environment and the resulting productivity initiated by changes in productive area makes them similar to natural lakes in terms of total invertebrate production.
8. Draw down rate seems to have relatively little effect compared to the response to rising level from a dry season.
9. Limited production in one area is generally compensated for by a corresponding increase in another as water depth changes.
10. As draw-down rate plays a minor role in invertebrate production there is minimal likelihood that an increase in draw down rate from 200mm/week to 500mm/week would have a significant adverse effect.

Figure 1, lines 1, 2, and 3 are invertebrate survey sites, others lines are water depths only, see appendix 1 for large scale map.

Background

Lake Onslow is a man-made lake originally formed in 1888 by damming the Teviot River and Dismal Swamp, figure 1. In 1982 a new dam was built flooding the first dam and increasing the lake area from 367ha to 830ha. Lake Onslow was originally to supply water for gold mining but is now used to collect water for the Teviot Irrigation Company. On its way to irrigate river terraces around Roxburgh the water is run through several small power schemes operated by Pioneer Energy Ltd.

Lake Onslow is a regionally significant trout fishery, Otago Fish and Game, (OFG) and after the construction of the new dam in 1982 produced the classic boom of trout fishing as fish responded to the increased available habitat and food production. It has since levelled off to become one of Otago's premier lake fisheries.

Recent land use changes with increasing intensity of agricultural use and subsequent loss of native vegetation pose a threat to water quality. Lake Onslow is classified as eutrophic (ORC 2009) but has unusually high levels of phosphorous which is normally a limiting factor in NZ waterways. An increase in Nitrogen (potentially from fertiliser and farming) could lead to a substantial increase in algae and plant production in the lake - not desirable given that it is already classified as eutrophic.

In 1998 an assessment by Cawthron Institute suggested that on the basis of the invertebrates present in Lake Onslow in 1993, "*a suitable maximum draw down rate should not exceed the current operating practice but that a lower rate may not appear to offer any advantages*".

Scheme Operation.

Generally the lake is operated with a view to keeping it as full as possible which clearly depends on rainfall. The lake tends to remain reasonably full (70-90%) until the end of summer when it declines to approximately -3m (below the weir crest) but refills steadily over the next few (1-3) months. Lake Onslow does not have the daily variation in level typical of larger hydro lakes. The different lake levels characterising a typical dry, medium, and wet year are shown in table 1.

Table 1, water level with reference to the weir crest for Lake Onslow for a dry , medium, and wet year as assessed from lake level records.

	Level (m)	**% full**	**Year**
Dry	-4.5	30	1990
Med	-2.0	60	2001
Wet	-.55	90	2017

An average year drops to approximately 60% of full, a dry year 30% of full, and a wet year (eg 2016-17), 90% of full - percentages are rounded.

The speed of draw down is variable and dictated by irrigation, electricity demand, and rainfall, which can be substantial in late summer (*for example Jan 2107 where an overnight rain event raised the lake level by approximately 1m and produced a flood of 0.75m over the weir crest*). Sporadic increases in draw down rate are often followed by steady periods where inflow may raise lake levels again. On occasion a rapid draw down is desired, within the allowable operating range of 0-5m, to meet electricity demand. Typically the draw down operates within 0-2.5m. The maximum rate of draw down is currently 0.2m/week, which limits capacity to meet electricity demand.

Table 2, summary of Lake statistics

Lake level	**Volume**	**% of full**	**% Area**
Crest	19000	100	100
-.5	16492	87	93
-1	14560	77	86
-1.5	12820	68	78
-2	11070	58	71
-2.5	9620	51	64
-3	8380	44	57
-3.5	7320	39	49
-4	6559	35	42
-4.5	6059	32	35
-5	4294	23	28

The proposed scheme change would allow an increased rate of draw down (from 200mm/week to 500mm/week) within the existing range. The allowable operating range is 5m but the usual operating regime is within approximately 3m.

Potential effect of an increase in drawdown rate.

If the lake could be drawn down at an accelerated rate there may be a greater potential for stranding invertebrates. However, the literature suggests that the subsequent raising of the lake level boosts production 4-6 times the base level. In addition, the species present are not particularly mobile and moving with a receding water level doesn't seem to be a strategy currently employed by the invertebrates in Lake Onslow. Life cycle characteristics, such as rapid development of various life stages therefore avoiding stranding, are characteristic of many chironomids, see discussion below. As well, higher production is at mid-depths (3m) and production improves as more light reaches the lake-bed that was previously beyond light penetration. So while dewatering of the lake-bed results in lost production from the dewatered zone there are other compensatory responses further down the lake shore profile. This would be further mitigated if the lake tends to be kept at fuller capacity, which is the current modus operandi.

Purpose Of Survey

A bathymetric and invertebrate survey was conducted to :-

1. To identify different shoreline habitat zones in Lake Onslow
2. To map the shoreline of the sampled sites and describe those shallow profiles potentially most affected by a change in draw-down rate.
3. To survey invertebrate communities within each habitat zone
4. To compare invertebrate communities from the "boat ramp" site from 1993 to those of 2016 and 2017.
5. To assess the response of invertebrate communities to differing lake level regimes over two summers (2016 & 2017)
6. To review historic lake level patterns with regard to invertebrate habitat
7. To conduct a literature search to assess the response of invertebrate communities to various lake level alteration regimes for comparison with Lake Onslow.

Reason for survey

This survey was conducted to assess the potential effects of an increased draw down rate from 200mm/week to 500mm/week.

Methods

Bathymetry

Lake bed profiles were collected to assess and describe invertebrate habitat available at different lake levels and define how lake level lowering regimes may affect habitat.

Lake Onslow Lake Bed profiles were recorded using a boat-mounted echo-sounder referenced to a base station. Levels of accuracy were in mm but influenced by wave action.

The survey was conducted 15th October 2016 with the lake level at 333mm below the weir crest. The lake could be described as full from a visual perspective. A base station, set up on LINZ survey peg #28, was used to which the echo-sounder was referenced.

Lake-bed profiles were recorded at nine preselected locations, figure 1. At stations 1, 2, & 3, (that correspond to invertebrate sampling sites), three parallel runs were made at 50m spacing. At stations 4, 5, 6, 7, 8, and 9 a single run with the echo-sounder was made.

Station 1 is adjacent to the boat ramp. The transects here went shore to shore across the channel roughly north from the boat ramp. At Stations 2 and 3 the transects extended out into the lake, perpendicular to the shore, sufficiently far to a point where the bed levelled off. Sites 4-9 are general representations of the lake bed profile, specifically in shallow areas.

Hydrology

Hydrologic records for Lake Onslow were investigated and analysed to be able to describe lake level patterns and potential effects/explanations for the observed invertebrate population patterns and distributions. These included lake levels, the range of annual variation, seasonal patterns, and characteristics of wet vs dry years. Water temperature seasonal patterns were assessed from Teviot River records where a permanent recorder is set up. All the hydrological information was supplied by Pioneer Energy Ltd.

Invertebrates

Invertebrates were collected at three sites on two occasions. One of the sites was in the same general area as that for the 1993 sampling conducted by Cawthron Institute so that a comparison could be made at this site after a 23 year period. The two other sites represented different habitat zones around the Lake Onslow shoreline.

Invertebrates were sampled using a 150mm diameter, 100mm deep core sampler with a 0.2mm mesh net attached. Three samples were collected at each water depth (1, 2, 3, 4, and 5m) to give 15 core samples per site. The sampler was pushed into the substrate and covered by hand before being inverted so that the sample fell back into the net. A draw string sealed the sample in the sampler. It was rinsed to allow the fine sediment to escape through the mesh and the sample was then placed in a sealed container with a label. Preservative was added shortly after.

A kick sample of approximately $1m^2$ was collected at each of the three sample sites using a net of the same mesh size, (0.2mm).

The NIWA and Landcare Invertebrate identifications web pages were used along with a 20x binocular microscope to sort, identify and count the invertebrates captured by this sampling method.

An adjustment was made to determine which depths from each sampling were comparable given the variation in lake levels between the different invertebrate sampling dates - i.e.with reference to water level at the weir the 1.364m 1993 Cawthron sample equated to the 2.224m sample from 11/5/16, and the 1.166m sample from 27/2/17. The 1993 and 2017 samples are essentially from the same levels of lake bed.

Samples were collected on two occasions (11/5//17 and 2/27/16) - the first after lake levels had been “normal” (declining in autumn) and the second sampling after an unusually wet summer that allowed lake levels to remain higher than usual over summer (this wetter summer meant draw-down had not occurred and therefore represents a longer period of potential recovery from usual draw-down scenarios).

Literature search

Information about natural vs hydro lake productivity, manipulated lake level productivity, fish and invertebrate response to draw-down, and invertebrate life cycles was sourced from New Zealand and international studies to facilitate assessment of the likely response of the aquatic fauna to draw-down scenarios for Lake Onslow.

Previous studies on Lake Onslow and the Teviot River were referenced for study design and analysis, specifically Cawthron Institute reports 229 and 389.

Invertebrates

Station 1 is similar to the earlier Cawthron sample sites and allows comparison with present and 1993 sampling, Station 2 is a shallow muddy and weed-bed location, while station 3 was chosen to represent a rocky shoreline.

At all sites mud quickly became the main characteristic of the bed. Even where gravel was present at the shoreline mud accumulated very quickly with depth so that before the bed levelled off mud dominated the samples. It was much thicker on the lake bed than the depth of the samplers (100mm).

Stark and Hayes (1998), reported on Onslow invertebrate samples collected on March 2nd 1993. We collected samples in February 2016 and May 2017.

Results

Site descriptions.

Site 1 - Boat ramp, surveyed on all occasions. This site is exposed to the north but sheltered from the south. It is initially flat then declines steeply, is very muddy at depth with abundant clumps of dead plant-root mass.

Site 2 - Muddy/macrophyte zone, it is shallow a long way out into the lake, has a very muddy lake bed, and macrophytes are abundant. The majority of the macrophytes are living. It is exposed to the north and south.

Site 3 - Rocky shoreline, has a southern aspect and is very sheltered from the north. Although the shore is gravely mud dominates very quickly, from 2m down. A few dead tussocks (mostly the root mass) remain at depth.

Lake Bed profiles

Bathymetric profiles were established at nine locations spread around the lake, figure 1 in appendix 1. They covered a range of shoreline types and gradients. Depths are colour coded along each transect (appendix 1) with for example red indicating depths of 0-3m. Individual profiles are shown in appendix 2.

The bathymetric survey allowed definition of the slope of various shorelines and an assessment of the extent to which a receding lake exposes the shoreline. The transects showed 13 shoreline profiles. By looking at the slope on the transect profiles, the distance dewatered at each shoreline for a specified drop in lake level could be determined, table 3. The distance of lakebed from the shoreline exposed by a drop from full to -3m varies from an estimated 8-540m.

Table 3, cumulative distance (m) of lakebed exposed for each 0.5m drop in lake level. L1S =Line 1 south end of transect, L8NW=line 8 northwest end of transect.

Site	0.5 drop	1m	1.5m	2m	2.5m	3m	3.5m
L1N	1	2	4	4	7	8	8.5
L1S	4	6	10	17	20	22	25
L2N	.5	5	7	10	20	40	55
L3N	2	3	4	8	10	12	15
L4N	20	50	65	70	90	140	215
L5E	20	40	50	50	75	80	130
L5W	10	15	20	20	27	30	50
L6S	25	50	325	330	340	345	350
L7S	20	125	240	500	510	530	560
L8SE	10	15	25	30	40	50	50
L8NW	1	1.5	5	10	15	20	25
L9N	1	2	5	10	15	25	30
L9S	20	115	250	350	500	540	550

Much of the southern shore, and a smaller section of the north shore, are gently sloping and therefore have significant amounts of lake bed exposed with lowering of the lake.

The slope and therefore potential exposure of lake bed as the water level drops vary at each site. The rocky shoreline is the steepest site, with the boat-ramp site intermediate and the muddy shore site the most gentle slope, table 4. These are average values and the boat ramp site is complicated by the fact that it starts off on a gentle slope but then drops off steeply at about the 4m mark. (*See also appendix 2 for individual survey site profiles).*

Table 4, slope of survey locations.

Site	Slope
Boat Ramp	0.3
Muddy	0.028
Rocky	0.2

At 3.5m below the weir crest the lake is reduced to 50% of its area and will have dewatered much of the shallow shorelines particularly on the southern shores. When the lake is half full it covers 64% of its maximum area.

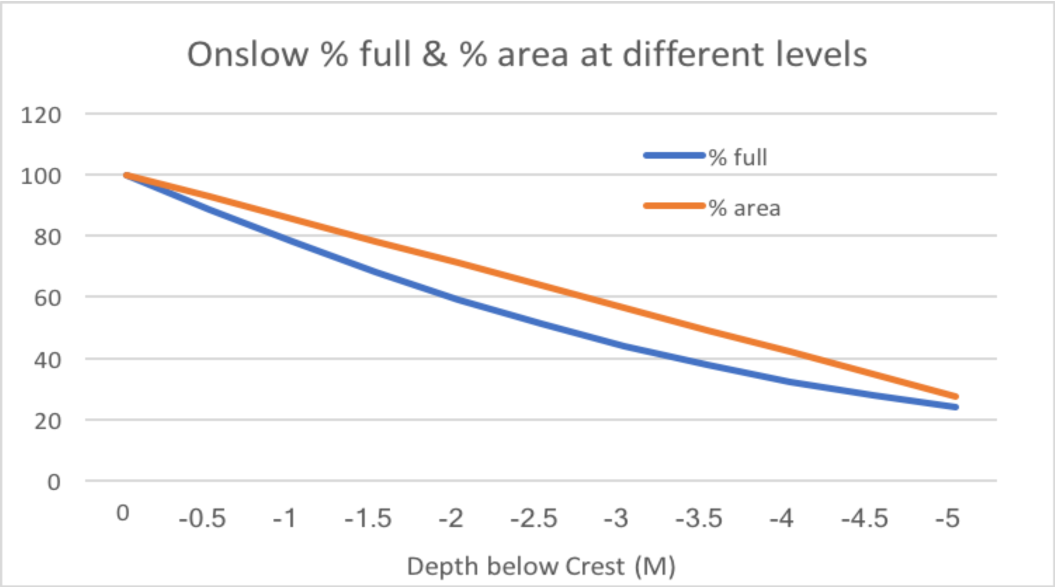

Figure 2: relationship between lake area, percent full and the water level below the weir crest. (-2 equals 2m from the weir crest down to the water level).

Table 5: Area of Lake Onslow in hectares (ha), with respect to water levels at the weir crest.

Water Level	**Area ha**
0	10940
-0.5	10150
-1	9355
-1.5	8563
-2	7770
-2.5	6978
-3	6185
-3.5	5393
-4	4600
-4.5	3808
-5	3015

Habitat Zones

Using the topographic map, the bathymetric map, and a desk-top identification of shallow vs deep, approximately 20% of the shoreline is classified as steep and 80% classified as shallow. Therefore potentially 80% of the shoreline is shows an extended dewatering effect during draw-down as a small draw-down exposures a larger area of lake bed on the shallow shoreline compared to the steep shoreline.

Lake Levels

Lake level records are available for 1974-2017 and show a general trend of relatively small variations with a dry year approximately each decade, figure 3. The lower levels up to 1982 are at the old dam level, the new scheme commenced after the construction of a new and higher dam that flooded the existing dam. The record is largely complete post 1982 but there are some gaps in the earlier record where collection of data was manual rather than automated.

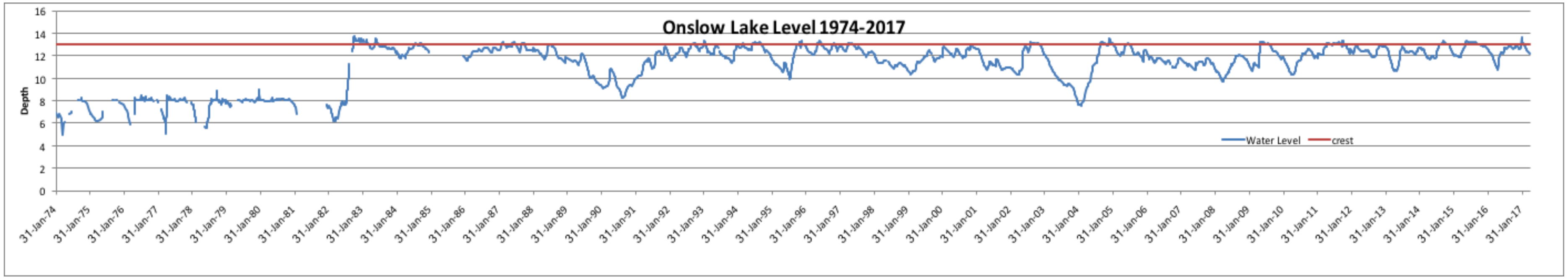

Figure 3, Onslow lake levels 1974 to 2017.

The lake levels in the months preceding each sampling can be seen in figure 4. They show conditions under which the invertebrate populations sampled existed. Mean lake levels have stabilized in recent years as Pioneer Energy Ltd. attempt to operate the scheme with lake levels as full as possible.

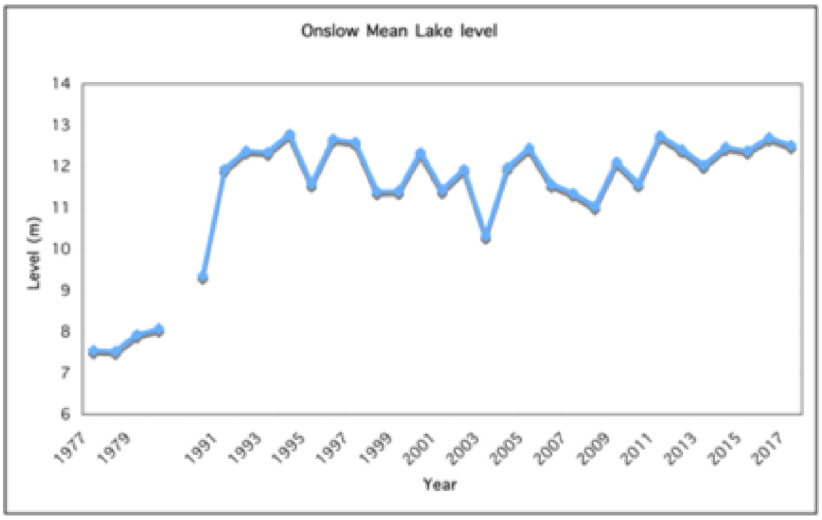

Figure 4: Lake Onslow mean lake levels, before new dam 1977-1980 and post-dam 1991-2017.

The above graph shows in particular the lake levels in the years prior to each sampling and a marked difference prior to each sample set (1991-1993 and 2013-2017). Prior to 1993 there a was a marked increase of approximately 3.75m in mean lake level from a low of 8.25m in September 1990 to a sustained high of 13m in October- November 1992, whereas prior to 2016 there were three years where the mean lake level varied less than a metre. Invertebrate populations reflect conditions present in preceding months and are a summary of all the factors that affect invertebrate populations and control production.

The normal operating range for Lake Onslow as a small hydro/irrigation scheme is from full to approximately 2.5m below full (51% full). Occasionally the lake level drops below 2m in the autumn but lower levels usually only last for a few weeks (4-8). In a very dry year, e.g. 1990, the level may drop as low as -4.5m but this is a rare event as can be seen from figure 4. The allowable operating range is 5m and normal operating range is 2m (100-60% full), pers com Tony Jack Pioneer Energy Ltd. The hydrograph below shows lake levels and patterns of change in lake level over the last 5 years 2013-2017.

Plotting the annual hydrograph (figure 5) shows that the low lake levels typically occur in the months April, May, June, ie late summer early autumn but that from July to March the lake is typically operating within a 1.5m range. Temperatures at the time of lower lake levels are cooling thus minimising potential adverse effects that high mid summer temperatures may create on freshwater habitats.

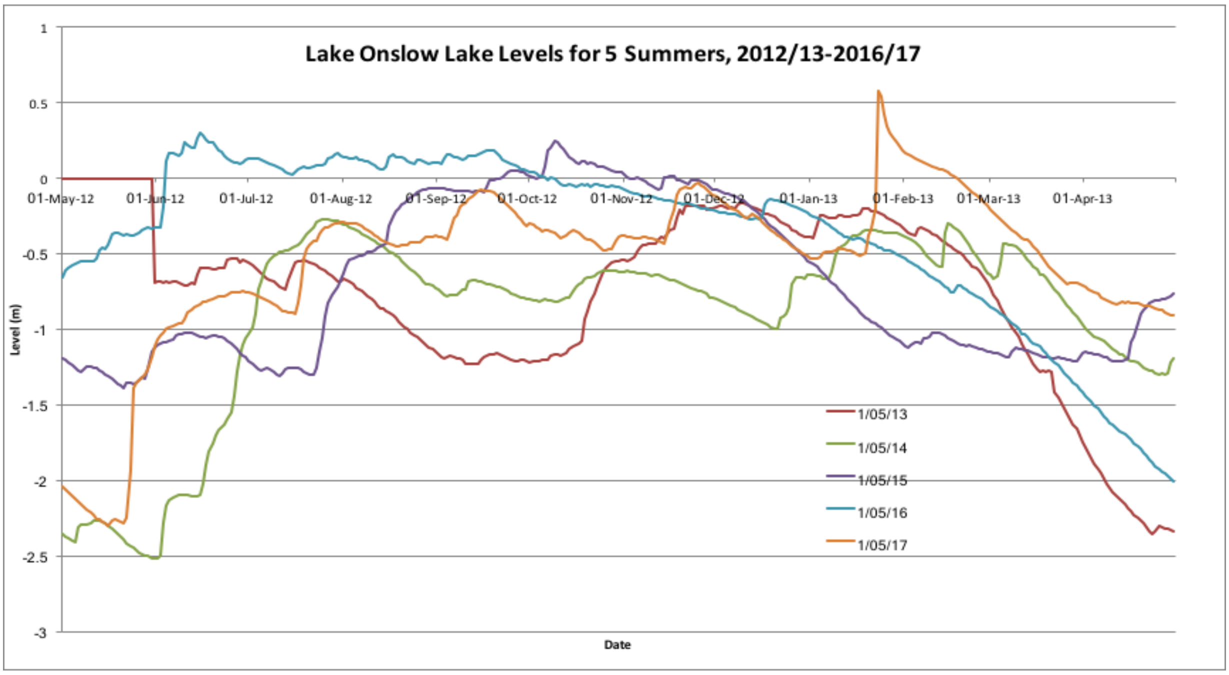

Figure 5: Hydrograph for Lake Onslow 2012-2017 that covers the lead-up and sampling period for the 2016 and 2017 samples.

Sampling

All the Cawthron sample information is taken from Cawthron Report #229. The recent samples were not collected at the same lake level so some explanation of how they relate to each other is required. The most significant aspect is that there was an extended period of relatively stable and high lake levels with little variation in lake level prior to the 2016 and 2017 samples.

Table 6: Sample designation, date, name, and lake level.

Number	Sample date	Name	Lake level (mm)	~% full
1	2/3/93	Cawthron 1993	-361	90
2	11/5/16	Pioneer 2016	-222	55
3	27/2/17	Pioneer 2017	-166	95
	15/10/16	Bathymetry	-333	~92

From the table below it is evident that samples have been collected over a depth range of 6m (relative to the weir crest) and that to compare recent data to the first Cawthron study sample a correction of 1m should be used. The Cawthron 1993 sample and the Pioneer 2017(3) samples are from approximately the same lake level.

Table 7: Relative depths of each survey with regard to weir crest at 0m.

Crest level (m)	Cawthron 1	Pioneer 2	Pioneer 3
0			
1	1.36		1.17
2	2.36	1	2.17
3	3.36	2	3.17
4	4.36	3	4.17
5	5.36	4	5.17
6		5	

Figure 6 shows the relative depths for each sampling session and that the 1993 and 2017 samples are essentially at the same depth but the 2016 samples are about 1m deeper.

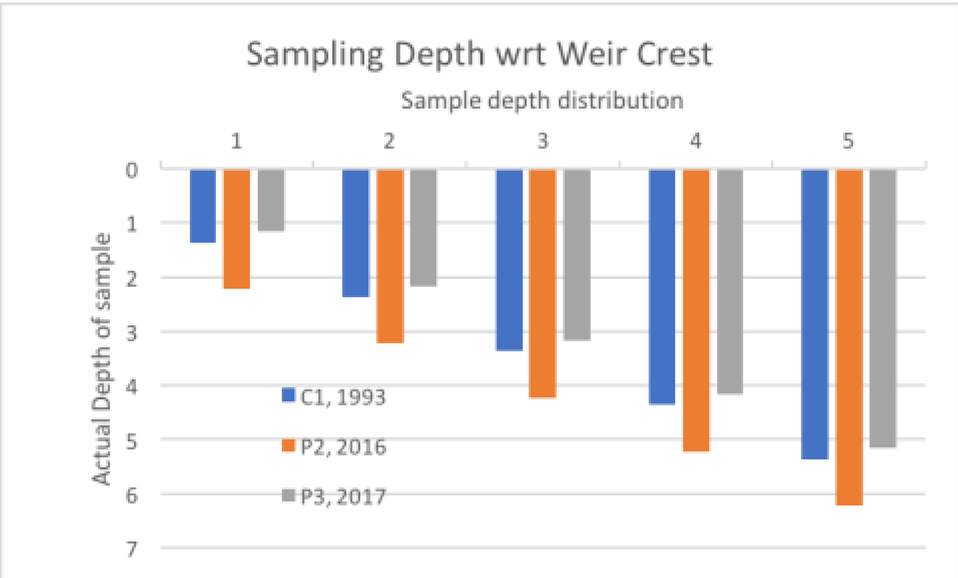

Figure 6: Depth of samples with respect to (wrt) weir crest. Weir crest taken as zero in the figure. C1 = Cawthron, P2 and P3 = Pioneer samples, for the respective years.

Invertebrates

The three sites sampled showed variation in density, number of taxa, dominant species and distribution relative to depth. Based on the samples collected distribution was often very patchy and species present could vary substantially between and within sites. The two recent samples were quite similar in most population statistics but showed differences related to habitat type. There is a marked difference from 1993 to 2016-17, particularly for density and the proportion of oligochaetes.

Shoreline kick samples collected, numerous common bullies, corixa (water boatmen), and a similar invertebrate biota to the lake bed samples. Corixa were the only species collected in the kick samples that were absent from the substrate samples.

Patchy distribution of invertebrates was a common feature for all the Onslow surveys, and is reported from other lake benthic invertebrate studies – such as L Roxburgh, Winter (1964) - and other overseas lakes described in the literature – e.g. Kolding & van Zweiten (2012).

In summary, the invertebrate sample characteristics for the Boat Ramp site are;

1. Snails increase with depth.
2. Chironomids show highest numbers in 2016 and decline with depth
3. Caddis increase in 2017 and increase with depth
4. Annelids increase with depth for 2016 but decrease for 2017, however the changes are small between these two samples compared to the differences from 1993 to 2016-17
5. The number of taxa is 3-4x higher in 1993
6. The density of invertebrates is 6-7x higher in the 1993 sample

Table 8: Mean species richness (number of taxa) by year and site

Sample	Boat Ramp	Muddy	Rocky
1, 1993	33		
2, 2016	7	8	6
3, 2017	10	7	7

Density

In summary, the density for Cawthron (1) sample varied with depth and was highest at 3m, then 2m, then 1m, whereas density for Pioneer (2) sample, was highest at 1m (corrected to ~2m), and density for Pioneer (3) sample, was highest at 2m.

Table 9: Mean density (invertebrates/m^2) by year and site.

Sample	Boat Ramp	Muddy	Rocky
1, 1993	29467	n/a	n/a
2, 2016	3137	3270	2207
3, 2017	5385	2076	1001

Table 10, compares species % composition with respect to sites and depths. There is a clear change from 1993 to the later samples which are characterised by wide variability in percent composition especially on the muddy shoreline samples where caddis, chironomids, bivalves, and snails are major groups represented in the samples.

Table 10: Mean values for percent (%) species composition, dominant taxa are highlighted. - eg Boat Ramp 1 (BR1) annelids are 49-74% over the range of depths. R = rocky shore, M = muddy shore.

	BR1	BR2	BR3	R 2	R 3	M2	M3
% Annelid	49-74	19-46	3-60	21-94	38-100	3-29	6-60
% Caddis	0.1-0.7	7-37	11-74	0-43	0-26	12-71	0-47
% Chiron	6-31	18-69	7-30	0-19	0-19	13-54	20-37
% Bivalve	0	0-2	0-10	0-16	0-18	0-11	3-22
% Snail	0	0-2	0-60	0-.7	0-4	0-2	0-33

Table 11 compares invertebrate density with depth and lists the mean density which is much greater in 1993 and consistently much lower for other years.

Table 11: Invertebrate density /m^2, with depth, 1=1993, 2= 2016, 3= 2017.

Invertebrate density	1m	2m	3m	4m	5m	Mean
Boat Ramp 1	30790	32321	40593	14222	29407	29467
Boat Ramp 2	6396	4454	1624	1528	1681	3137
Boat Ramp 3	2281	2870	11490	6113	4171	5385
Rocky 2	662	3000	2734	2847	1794	2207
Rocky 3	283	340	509	1964	1907	1001
Muddy 2	3792	4075	2734	2564	3187	3270
Muddy 3	2134	2604	2021	2094	1528	2076

The major differences between the 1993 and 2016-17 samples are in density, (largely related to far fewer annelids) and in number of taxa (fewer in the 2016-17 samples), in particular those represented by small numbers of individuals, table 12. There are also some changes in species present with the appearance of caddis, snail, and bivalve seldom recorded in 1993 but common in the 2016 and 2017 samples.

Table 12: Number of taxa at each depth

Invertebrate species richness	**1m**	**2m**	**3m**	**4m**	**5m**
Boat Ramp 1	18	15	14	11	18
Boat Ramp 2	7	7	5	4	5
Boat Ramp 3	6	8	10	11	8
Rocky 2	3	4	4	7	6
Rocky 3	2	1	7	7	8
Muddy 2	7	8	7	6	8
Muddy 3	6	10	9	7	7

Table 6 below is copied from the James et al (1998) Lake Coleridge survey. Invertebrate abundance for the recent Lake Onslow surveys (1000-5000/m^2) is similar to most of the lakes listed in their summary table. Given the altitude of Onslow with relatively severe winter cold where the lake may freeze over it is very close to the inveretbrate density of most of the lakes listed in this table.

Table 6 Abundance and biomass of macroinvertebrates in South Island, New Zealand lakes. Samples from macrophyte beds are expressed as per m^2 of lake bed. (DW = dry weight.) (Abundance and biomass for lakes surveyed by Timms (1982) were mostly for profundal samples at depths > 5 m.)

Lake	Abundance no. m^{-2}	Biomass mg DW m^{-2}	Author
Grasmere	19150–51150		Stark (1981)
Ohau	3358		Kirk & Henriques (1982, 1986)
Alexandrina	574–3500	2100–8300	Talbot & Ward (1987)
Upper Clutha	232–4958	132–3732	Biggs & Malthus (1982)
Rotoroa		3700	Timms (1980)
Rotoiti		1600	Timms (1980)
Tekapo	1222	800	Timms (1982)
Pukaki	75	<100	Timms (1982)
Ohau	856	600	Timms (1982)
Benmore main arm	7055	500	Timms (1982)
Ahuriri arm	1600	1000	Timms (1982)
Waitaki	6616	3600	Timms (1982)
Pearson	5862	4900	Timms (1982)
Coleridge	14–34300	7–5630	present study

The Lake Onslow 1993 sample was unusual in that it reflected the increase in production associated with an increasing water level and reflooding of the lake bed. The other years (2016 & 2017) reflect stable conditions and consequently lower production.

Reasons for difference 1993-2016/17 samples

A variety of effects are likely to have contributed to the observed changes in macroinvertebrate populations from 1993 to 2017.

1. Seasonal variation in wind and consequent wave action at low level draw-down (removes fine sediment and changes habitat suitability)
2. Seasonal differences in sampling times that may have missed some lifecycle stages in one or other of the surveys
3. Less organic material input since tussock has been replaced with grassland (less food for organic sediment feeders such as oligochaetes)
4. Unidentified effects (agricultural herbicides and insecticides) on macrophyte beds and invertebrate life cycle stages
5. Minimum lake level in the years preceding sampling
6. Lake level variation in the years preceding sampling
7. Large increase in lake level 1990 to 1993, approximately 3.75m.

The effect of lake levels is really the only factor that there is substantial information for that can be investigated. The range in mean lake level in the years prior to sampling is noticeably different for the two datasets, being about 3.4m for the 1993 sample and 0.7m for the other set.

Table 13: Mean lake levels prior to sampling, referenced against the weir crest at 13.06m, for 1990 the lake level was 2.7m below the weir crest.

Cawthron 1993 sample		Pioneer 2016 & 2017 samples	
1990	9.36	2012	12.42
1991	11.93	2013	12.03
1992	12.38	2014	12.47
1993	12.35	2015	12.38
		2016	12.70

The annual range in lake level has varied from approximately 1-6m, mostly reflecting draw-down but also influenced by floods such as in January 2017 and dry periods. Annual variation and mean lake level is presented in figures 7 and 8 and show periods of varying stability. Of particular relevance are the years prior to the 1993 samples and the years prior to the 2016 and 2017 samples. The recent samples were preceded by a period of relative stability and low variation in lake level whereas the 1993 sample followed major increases in mean lake level mimicking the scenario of a new lake. If invertebrates had been sampled in 2006 similar invertebrate population characteristics to the Cawthron 1993 sample may have been expected as the lake refilled from the low of 2004/5.

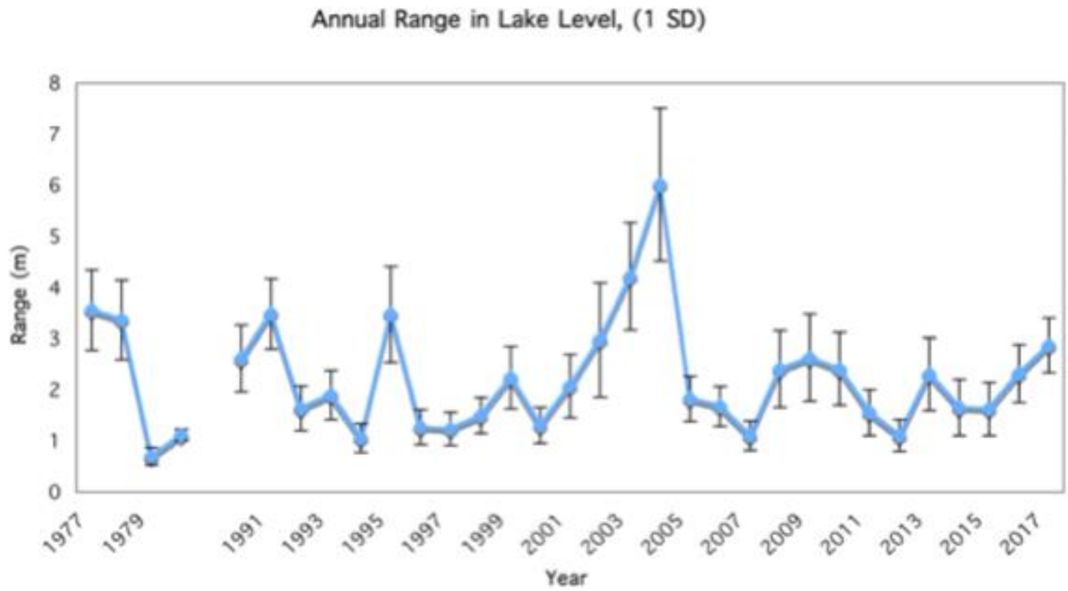

Figure 7: Annual variation range for Lake Onslow.

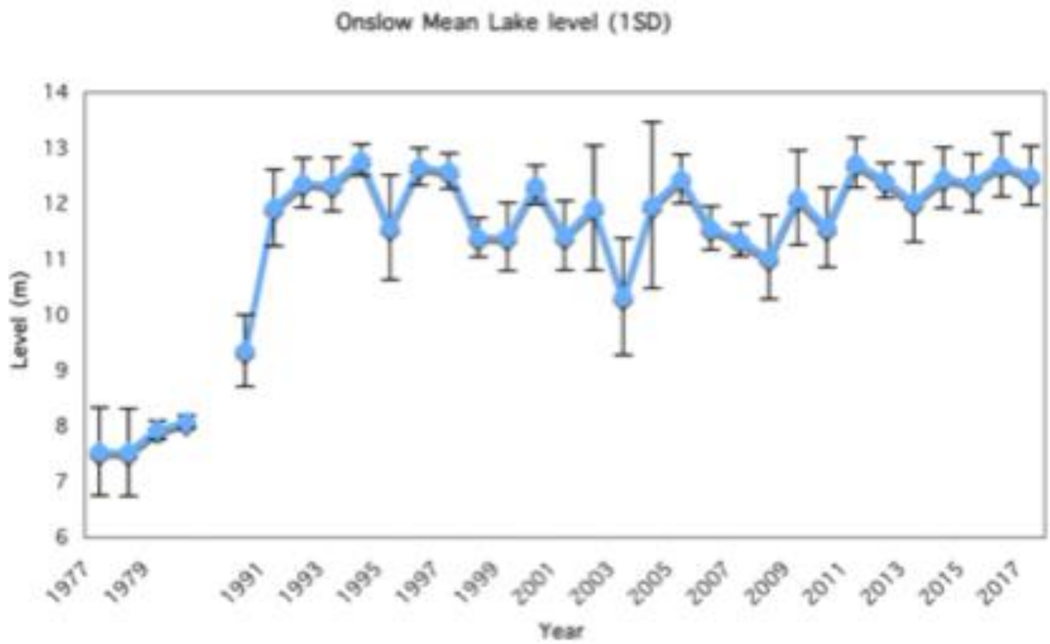

Figure 8: Mean lake level for Onslow +/- 1SD, (crest level is 13.06m).

Production Zones

The literature has an abundance of lake studies researching a wide variety of biotic and hydrographic scenarios in New Zealand and overseas.

Weatherhead & James (2001) identified four littoral zones in New Zealand lakes:

1. Wave wash zone
2. Macrophyte (limited at top by wave action and at depth by light penetration)
3. Detrital zone with organic rich sediments
4. Fine sediment zone

They hypothesised that a key habitat determinant was substrate and that the lake level history was a secondary factor, partly because of the role cobbles played in providing habitat. In particular they noted that detrital biomass had a positive relationship with oligochaetes. It is possible that recent cultivation of tussock lands around Lake Onslow and subsequent conversion to pasture has altered the detrital biomass inputs to the lake and may therefore affect oligochaete production.

James et al (1998) Lake Coleridge survey identified three communities:

1. Shallow water, wave action zone with caddis and chironomid
2. Middle macrophyte zone, high abundance and snails and oligochaetes
3. Deeper fine sediment zone with oligochaetes.

The greatest abundance of invertebrates was below the effective wave base. This corresponds to the highest production in Onslow at around the 2-3m depth, which is the effective wave base zone. There is major difference between Onslow and Coleridge and that is the substrate in Onslow is almost entirely fine and very fine sediment. Invertebrate communities represented are those with a preference for this type of habitat whereas in Coleridge, habitats are more varied and generally coarser. Lake Coleridge also has greater annual fluctuations in lake level of up to 4m.

James et al (1998) also noted “there is little evidence from New Zealand studies that taxa richness or macroinvertebrate density in hydro-electric lakes subject to lake level fluctuations differ significantly from those in natural uncontrolled lakes”.

All the studies described above show a change in density of invertebrates with depth, with the peak being at about 3m and tapering off each side of that. Onslow seems to follow this pattern with the upper limit set by water level and the lower by light penetration that is controlled by the dark peat stained water and perhaps wave action that suspends fine sediment and discolours the water. The depth limits of aquatic macrophytes in South Island lakes was usually explained by light penetration but may also have been influenced by grazing, (Schawrz eta l, 2000).

Winter (1964) in his study of Lake Roxburgh, noted there was high production down to a depth of 20m, far in excess of Onslow but this is likely the effect of water clarity which is substantially higher in Roxburgh.

McLachlan (2000) studied Lake Kariba, a shallow lake in the Zambesi valley and noted “major chemical and faunal changes with an advancing shoreline” and further that enhanced production of chironomids caused a considerable increase in biomass and changed the invertebrate depth distribution pattern.

The main invertebrate groups from a study of seven North Island lakes were oligochaetes, chironomids, and molluscs, (Forsyth 1978). This author observed that chironomids were of no value in determining levels of organic enrichment. Chironomid densities in Lake Onslow can be substantial but are highly variable, perhaps a consequence of rapid life cycles so that sampling may miss the high numbers if it occurs when much of the population has matured to the winged adult stages.

The 2016 Onslow sample was at lower water levels so that 1m in 2016 equates to 2m in the 2017 sample. If the samples are adjusted to equate to the same depth relative to the weir crest the 2016 sampling still shows increased production at the mid-range depths of 3 and 4m, (table 12 invertebrate numbers by site and depth). The 1993 and 2017 samples are at similar depths so production and distribution is comparable between the two surveys. Noticeable changes include the decline of annelids and appearance of caddis, snail and bivalve.

The general distribution of taxa for the different surveys is described below, table 14. In general, the “Rocky” shore has fewer annelids with depth, chironomids peak mid-range and with depth, and caddis are usually found at deeper levels.

On the “Muddy” shore annelids decline with depth, chironomids are steady or increase with depth, and caddis increase with depth.

At the “Boat Ramp”, annelids show opposite patterns - for 2016 they decline with depth but in 2017 they increase - caddis increase or are uniform throughout and chironomids slowly decline with depth. Snails are mid-range depths for 2017, shallow only for 2016 and middle and deep for 1993. In the 1993 survey annelids dominate but they and chironomids decline with depth.

Table 14: Relative abundance and distribution of main taxa. (> = most abundant, ~ = generally at all depths)

Species	**1993**	**2016**	**2017**
Annelid	mid zone	Decline with depth	Increase with depth
Chironomid	> shallow & mid	> in shallow	> @ mid depth
Caddis	Few in shallow	~ all depths	> @ mid depth
Snail	mid & deep	Shallow only	> @ mid depth
Bivalve	Very Rare	shallow	> @ mid depth

Invertebrate responses to draw-down

The literature search revealed a variety of responses to lake level draw-down and recovery processes of different species groups.

Some studies recorded a decline in various population statistics with declining water levels, others recorded increases in those same statistics. A New Zealand comparison of the productivity of hydro versus natural lakes found essentially no difference in invertebrate density between natural and hydro lakes and that two of the top five (for invertebrate density) were hydro lakes (Cawthron Report 229).

In a study on Lake Roxburgh, Winter (1964) noted that the highest density of invertebrates was at 10m depth or more and were mostly oligochaetes and sphaerid bivalves, both of which are present in Onslow. In that study, it was noted that water fluctuations sorted and compacted the fine sediment on the shoreline as the lapping water receded and advanced. This compaction made the substrate less suitable as invertebrate habitat. Stark (1993) noted a similar zone of low production in Lake Benmore where wave action was believed to be responsible for the removal of soft sediment. Winter (1964) also recorded chironomids at $329/m^2$ typical of other oligotrophic lakes (406, 484, 671, $740m^2$). Chironomid densities for Onslow ranged from $3339/m^2$ (1993), to $1789/m^2$ (2016) and $758/m^2$ (2017). As we found in the Onslow surveys, the sphaerid bivalves also had a patchy distribution in Lake Roxburgh. Daily lake level fluctuations in Roxburgh were 0.46m in summer and 0.76m in winter. The effect of such short-term changes in water level are to render the exposed shoreline non-productive as algae and invertebrates cannot be supported under this regime. In Lake Onslow, however the fluctuations are spread over days or weeks with a likely much less severe effect on invertebrate production as the production zone can to a degree “migrate” with a slowly receding/fluctuating water line.

The Cawthron study (Report 229) noted that;

1. Hydro fluctuations limited species richness and density, particularly in the 2-5m depth range
2. Invertebrate density in hydro lakes approximately doubled from 0.5-5m depth but in natural lakes density trebled
3. In the “17 lake study” (Stark 1993), Onslow was in category E, high altitude and oligotrophic. The fauna was dominated by ostracod, chironomid, oligochaete and the snail *potamopyrgus*
4. This category (E) had the lowest density of all groups
5. The number of taxa/sample ranged from 2-22
6. Organisms tended to be sediment dwellers and fed on organic matter.

In our surveys this pattern was generally followed, but dominance in the Onslow aquatic fauna was variously shared by chironomids, caddis and oligochaetes. However greatest densities were in the mid range 2-4m. This represents some significant changes from 1993 to present, notably much lower densities, far fewer oligochaetes, and the appearance of some other taxa more typical of hydro lakes. Perhaps supporting the idea of new colonizer versus stable populations associated with the relatively minor seasonal lake-level variation. The "new colonisers" are typical of the recovery from an unusually dry year.

Most of the invertebrates found in the Lake Onslow sediments have very limited individual ability to migrate and population responses to reducing lake levels appear to take more diverse approaches such as short life cycles and multiple generations per year (voltinism). Voltinism has been reported in several overseas species of chironomids and may be the same here.

Compression of life cycle stages such as hatching within a few days (4 @ 20^{o}C) enables egg-laying adults to essentially following a receding shoreline. The whole life cycle may be completed in 2-7 weeks, and this allows rapid recolonisation of new habitat as it becomes available as lake recedes or refills. Baxter (1977) noted that colonisation and survival of chironomids in reservoirs regularly drawn down, was facilitated by small body size and r-selected life history strategies, reported by (Statzner 2001).

Rose & Mathews (2013), found that fish and chironomid larvae in Beulah Reservoir declined as the reservoir reduced to 68% of full. Benthic densities of chironomids were significantly lower in substrates that were frequently dewatered compared to those that are partially dewatered or not dewatered. The annual range in Onslow varies from full to 60% (table x), so a similar pattern of decline may occur here too.

Monakov (1999) classified chironomids according to feeding behaviour - filter feeders, scrapers, predators, or mixed feeders. Tanypodinae (low numbers in our samples) are generally stated to be carnivorous. The species found in Onslow are likely to cover a range of feeding behaviours. The most common gut content for chironomids is detritus (dead organic material) suggesting scraping and filter-feeding. Most of the orthocladinae (prey species and therefore higher numbers than predator) are either algae or algae-detrital feeders - Oliver (1971) - and since most Onslow chironomids belong to the family orthocladinae, this is the most common trophic group.

In comparison Vander Zanden & Vadeoncoeur (2002), found that macroinvertebrate density and biomass in reservoirs under regular draw-down schemes can be equal to or greater than those in similar natural lakes. Also noted was that "draw-down may extend the littoral zone by allowing increased light penetration farther from the shore when the water was shallower or by altering the thermal regime." This seems to be the case in Onslow where the density tapered off with depth, probably because of diminished light penetration in the peat-coloured waters.

Kolding & van Zweiten (2011) developed a relative fluctuation index (RLLF), an empirical indicator, where mean annual or seasonal amplitude/mean depth x100 is used to predict resilience to disturbance. They noted "shallow lakes and man-made reservoirs in general have the highest level changes but also the highest fish yield .."even extreme fluctuations seem only to accelerate biological processes."

In a review of productivity controls these authors further noted that the pulse effect described to explain the observed high production of flood plains also applies to shallow lakes and reservoirs. A strong positive response to new habitat made available by flooding produces higher yields of fish that feed on invertebrates that are also responding to more and richer habitat. Although these studies considered mostly tropical lakes, the same processes seem to apply in hydro lakes including Lake Onslow where the pattern of disturbance is similar, i.e. new habitat becomes available with changes in lake levels.

Midges (chironomids) are major taxa represented in the Lake Onslow invertebrate samples and of the taxa present maybe the most readily available to trout. This group, rather than oligochaetes which are buried in the sediment, are therefore likely the mainstay of fish aquatic insect diet, although no studies have been done to describe this. Fly anglers regularly target trout using midge patterns. Lifestyle and patchy distribution may limit the availability of other invertebrate species to trout.

Midge Life Cycle

There are four stages in the life cycle:

1. Eggs are laid on the surface of the water and sink to the bottom and may take up to a week to hatch.
2. The larvae live on the lake bed and develop into “blood worms” so called because of the haemoglobin that allows them to respire in low oxygen conditions. The larval stage may last from a few days to 7 weeks.
3. Larvae to pupae occurs on the lake bed and after about 3 days the pupae swims to the surface and hatches to the adult stage.
4. Adults mate in swarms and only live 3-5 days. In summer months the entire life cycle can be completed in 2-3weeks but in winter, development is delayed until warmer temperatures arrive (Apperson et al 1999).

The significance of this short life cycle is that it may allow a style of migration with receding water levels thus allowing manipulated lakes to provide greater invertebrate production than might be expected. In the case of Onslow with extensive shallow margins there is also a broad production zone within the boundaries formed by dewatering on one side and depth (too deep and poor light penetration) on the other.

The ability to cope with draw-down regimes is dependant on organisms having survival strategies such as dispersal mechanisms, life history patterns or physiological adaptations to enable survival under ephemeral conditions, (Williams 1987 and Delettre 1989).

Lake Onslow has been operated as a reservoir for about 129 years in total but 35 years at the higher level and most of the aquatic invertebrates present are likely to have been selected by the “operating environment” because they possess these features. There has been an adaptation so that species present now are those that can cope with the lake level changes characteristic of the hydro/irrigation scheme and these communities support a regionally very significant fishery.

Lake Onslow is one of Otago’s best lake fisheries for brown trout offering excellent fishing for all skill levels and all methods, according to NZ Fishing.com. Onslow supports heavy angling pressure and consistently produces an abundance of fish. It has long had a reputation as a prime high altitude still water angling location. At the time of collecting samples in February 2017 we encountered several groups of anglers with substantial catches of large (3-4lb) trout, pers obs.

Temperature records

The Teviot River is the outflow for Lake Onslow and a permanent water level and temperature recorder is set up at the Bridge Huts bridge site. Temperature records for 1999-2017 are available from here and presented as a surrogate for Onslow temperatures. Mean daily temperature fluctuates between 8.4 and 10.6 ^{o}C, Figure 9. The minimum water temperature is always less than 2 ^{o}C and frequently less than 1 ^{o}C, figure 10. Temperatures this low will limit fish production and may have a similar effect on invertebrates. The size of the water body and range of depths available may provide some opportunity for small fish to avoid extremely low temperatures characteristic of the river but there is still likely to be a significant temperature limiting effect on productivity.

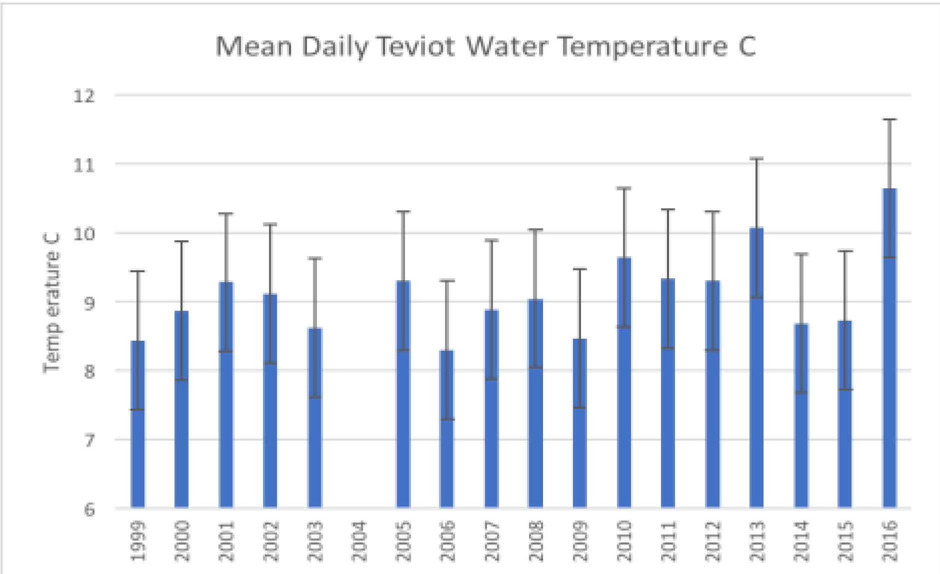

Figure 9: Mean daily water temperature on the Teviot River with 95% CL.

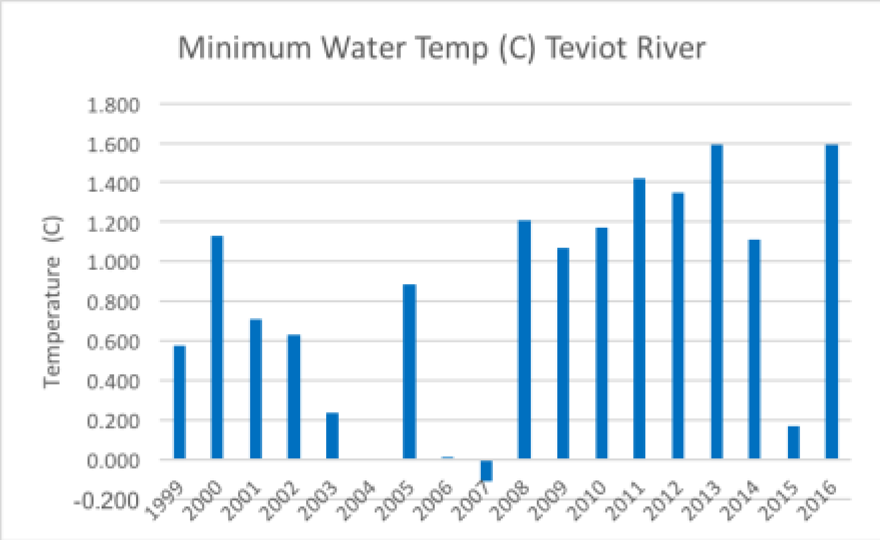

Figure 10: Minimum water temperature on the Teviot River as a surrogate for Lake Onslow water temperatures.

Rainfall data is available for Lake Onslow and is shown in figure 11 as distributed quarterly for each year. Heaviest rainfall occurs in the 4th quarter while the least falls in the 3rd where most precipitation is probably snow.

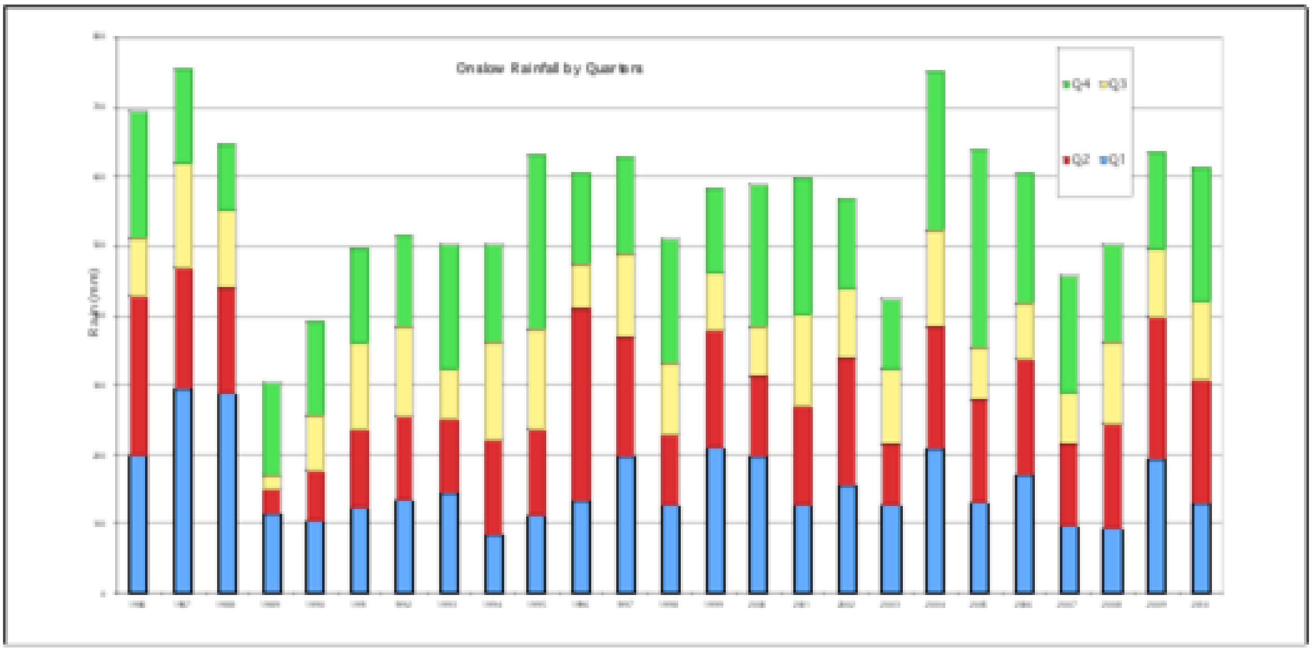

Figure 11: Lake Onslow rainfall expressed as quarterly totals, 1986-2010. (Courtesy Pioneer energy Ltd.)

Table 13: Quarterly rainfall at Lake Onslow derived from 1986-2010 record.

	Q1	Q2	Q3	Q4
Mean	156.10	146.21	100.80	169.80
Max	294.5	278.5	148.5	284.5
Min	85.5	36.5	19.5	0

Discussion

The major differences between the 1993 Cawthron study at the "boat ramp" and the recent surveys are invertebrate density, number of taxa, abundance of annelids, and the presence of caddis and the sphaerid bivalve.

This seems most likely to be related to the mean lake levels. In the three years prior to 1993 mean lake level was rising steadily from approximately 9.3m to 12.3m, a rise of 3m. As such new habitat was becoming increasingly available and the invertebrate population was probably responding positively to this new habitat with significantly increased productivity. It is likely the relatively stable habitat preceding the 2016-17 samples reflects more of an equilibrium state where production is settled at lower levels. This follows a pattern of response, described in the literature, by organisms to newly available habitat.

Sources of control on Lake Onslow productivity:

1. The effect of wave lap was sometimes identified in the literature as a factor in limiting habitat.
2. Changes in detrital biomass contribution to the lake since cultivation and forestry.
3. Lake level, stable versus highly variable.
4. Mean lake level.
5. Unusually dry years and consequent low lake level.
6. Water temperatures/altitude.

The nearby Horseshoe Bend wind turbine power production records were checked for seasonal variation. These indicate higher winds in spring and early summer but at this time Onslow tends to be full and therefore wind action effects are limited to the "near full" shoreline. The consequent effect of muddied water around margins will be to limit light penetration and therefore perhaps shallow water production levels will be depressed. This would fit with the observed higher abundances at mid to deeper water levels, 2-4m. If this zone is limited by light penetration then it follows that a receding shoreline has less impact on invertebrate production as this zone is already constrained by poor light penetration.

Operating regime

The scheme has operated more or less unchanged since it began in 1983 - that is at a 200mm/week draw-down restriction and a minimum level of -5m. The lake level chart, figure 3, shows that a similar regime exists year to year with a low about once a decade and that the lake level is usually operates within a 2.5m variation.

What does it mean for change in draw-down rate?

The consented maximum take is 6 cumecs but the 200mm/wk does not allow this take to be exercised, restricting the maximum rate of take to approx 3.5cumecs in limited situations. The current allowable draw-down rate of 200mm/week was based on an opinion from Cawthron Institute that considered there should probably be no adverse effect at 200mm/week but that a lower rate may not offer any advantage. Some of the literature discussed above suggests that the disturbance created by draw-down may actually be an advantage by "creating" new habitat with re-flooding on a rising lake, and allowing light penetration to greater depths during draw-down. In some studies manipulation of lake level is seen as a way to increase fish and invertebrate production.

The invertebrate fauna described by the 2016 and 2017 surveys is typical of a hydro lake, comprised of species that can/have adapted to the lake level change regime. As well, it is a community representing a period of stability, hence differences in species composition compared to the recolonisers of a recently flooded lake-bed which the 1993 sample seems to represent.

The invertebrate fauna we recorded is similar to that recorded from other lakes. Typically, low density and with chironomids and oligochaetes being major taxa represented.

Mean lake levels, minimum levels, lake level variation and the timing of these, along with effects of wind and wave action are likely to be major drivers of the invertebrate production and distribution. Onslow has been operating under these effects since 1983.

Conclusion

A major reduction in lake level seems to be the primary controller of habitat rather than draw-down rate and this effect is described in several studies where lake level is manipulated to increase freshwater productivity. Invertebrates seem to be able to cope with/have adapted to, the draw-down regime in Onslow and it is the lowest lake level that has the greatest controlling effect, ie the greatest invertebrate density and taxonomic richness is preceded by dry years and very low lake levels and subsequent to this invertebrate populations flourish on a refilling lake and then stabilize at a lower density.

The higher density of invertebrates in the 1993 sample almost certainly reflects the type of recovery described, for example, in the lake Kariba study (McLachlan 2006) where steady gains in new habitat (as lakebed re-flooded) saw an increase in productivity. In comparison, the 2016 and 2017 Onslow surveys recorded a steady state scenario typical of more stable lake levels and therefore relatively unchanging amounts of habitat.

From the literature, it seems that while there will be losses in the invertebrate community as lake-bed is dewatered this is substantially compensated for by the increase in production as light penetrates deeper zones and as the lakebed is re-flooded. An increase in draw-down rate seems unlikely to produce a significant adverse effect and the losses that do occur are more than compensated for by enhanced production in other zones where the change improves habitat.

The effect of more rapid draw-down (200mm/wk to 500mm/wk) seems likely to be largely overshadowed by:

1. the effect of a dry year when the lake level reduces substantially (<4m)
2. the range of variation in lake level
3. changing production as light reaches previously deeper water
4. annual rainfall amount and seasonal distribution
5. recovery as lake levels rise

I have not found evidence that draw-down rate is likely to play a significant role in controlling invertebrate production or that a change to a maximum 500mm/week draw-down would be inherently damaging to invertebrate production.

A conservative approach may be to monitor the invertebrate fauna after a period where an increased draw-down has been in practice.

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Appendix 1.

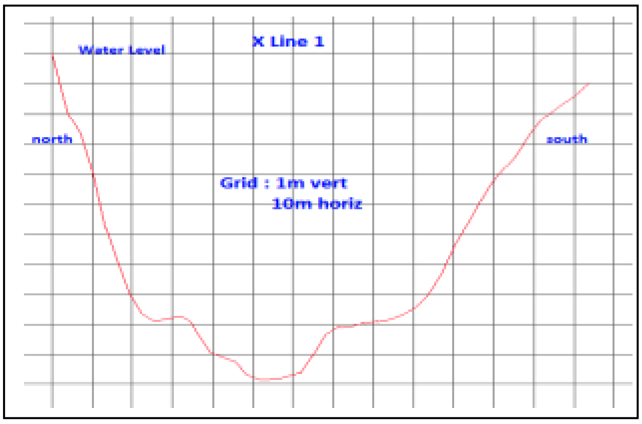
Locations of surveys sites and general bathymetry.
See separate A3 document attached.

Appendix 2.

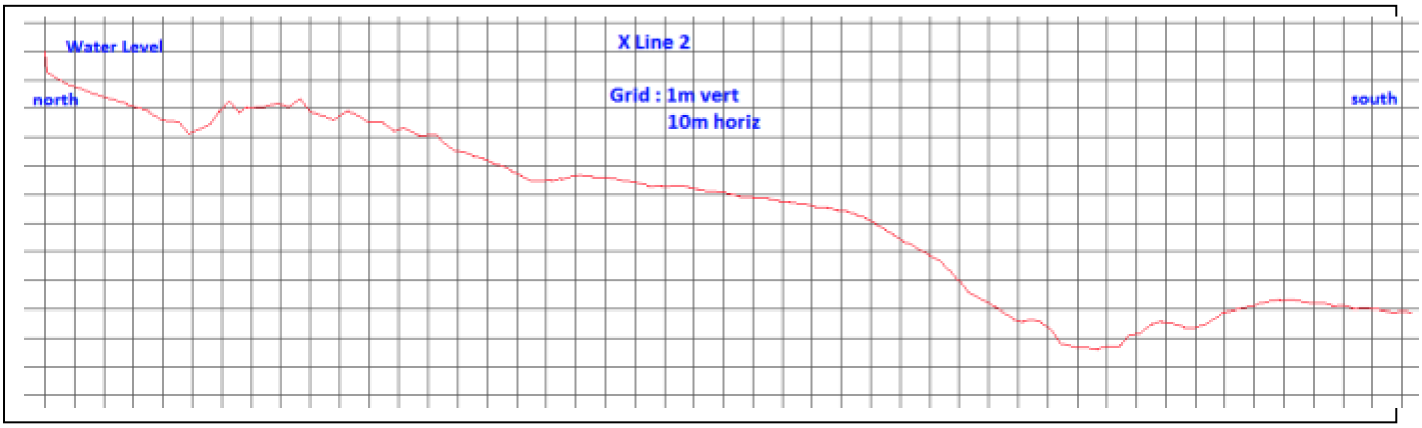
Lake Onslow – Survey Profiles 15 October 2017

Note – Water level on the day was 333mm below the crest of the dam weir.
All profiles are based on water level on the day.

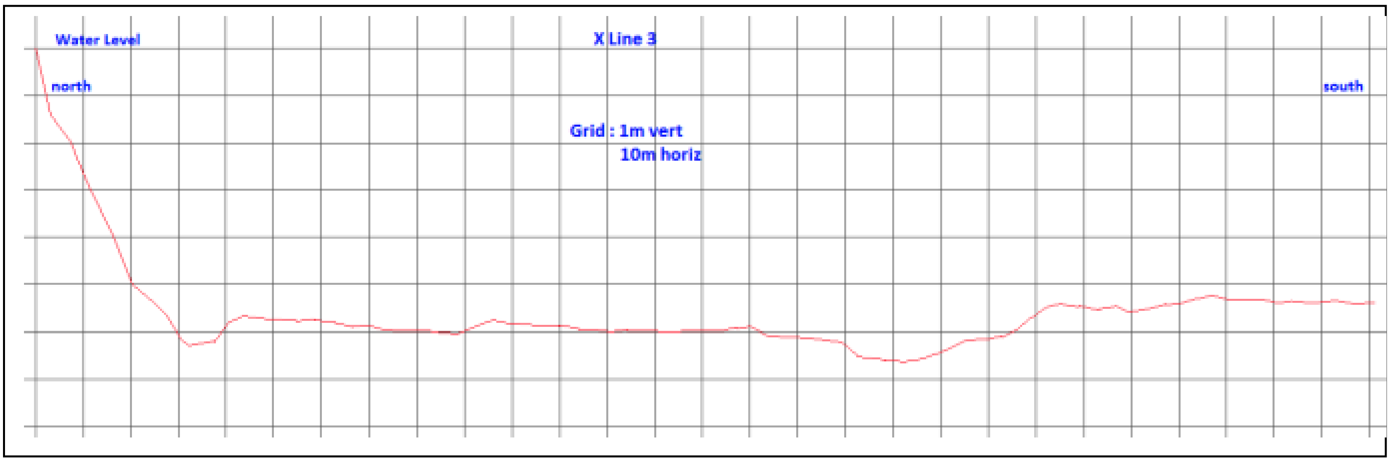
Profile – Line 1



Profile – Line 2



Profile – Line 3



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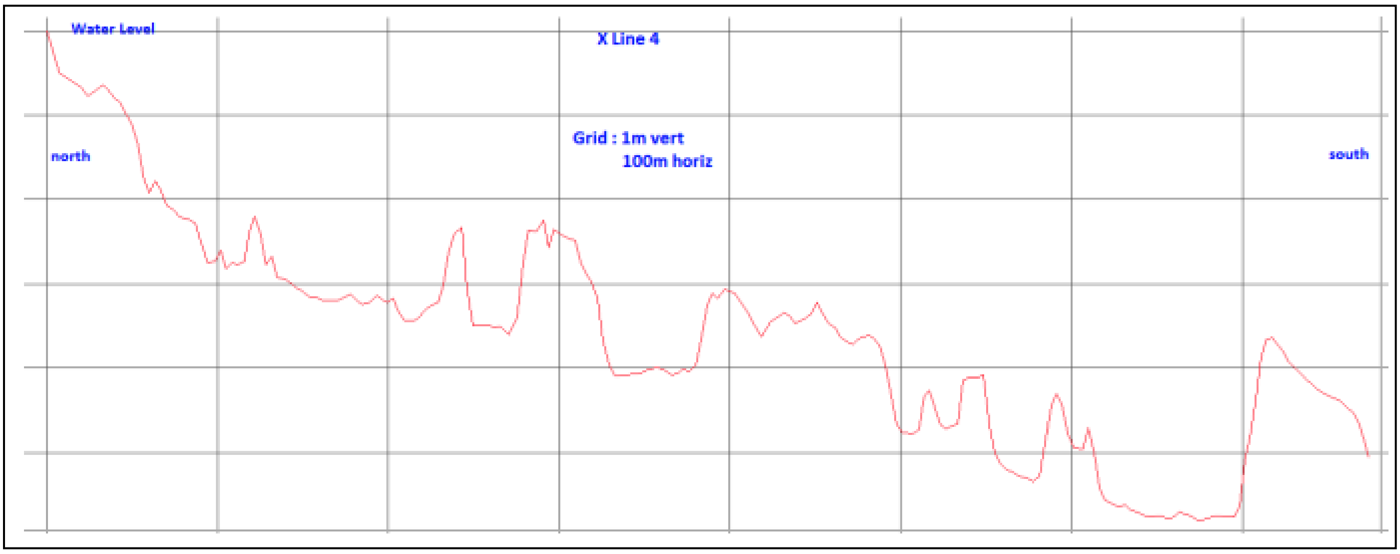

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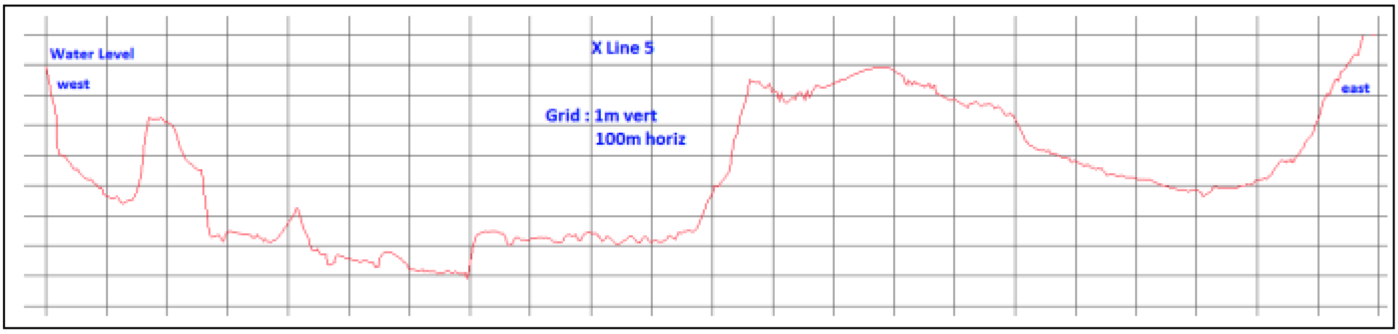

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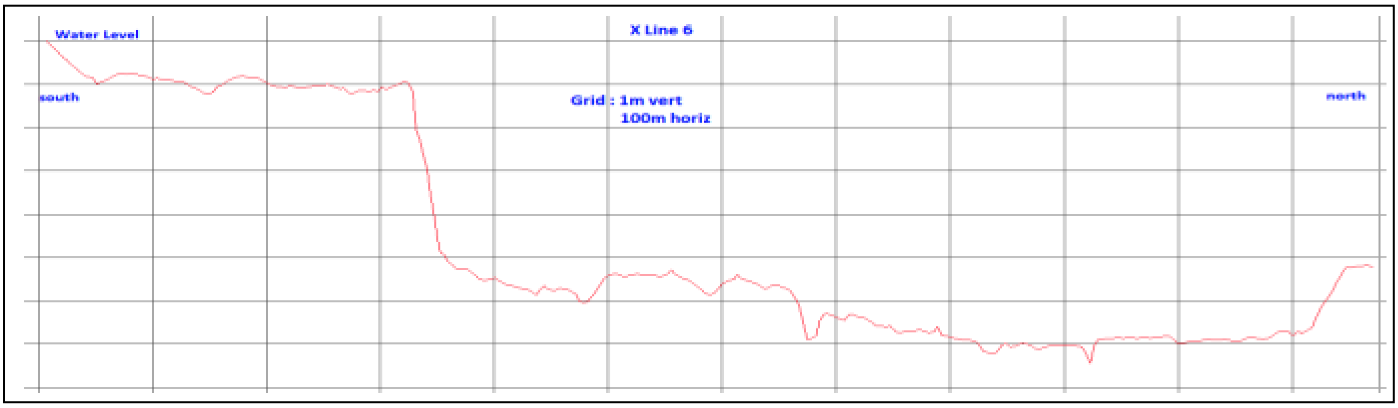

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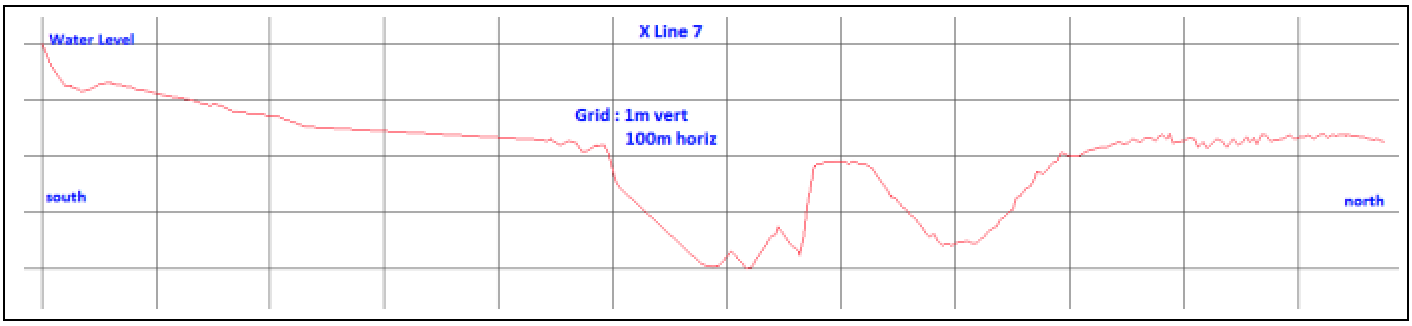
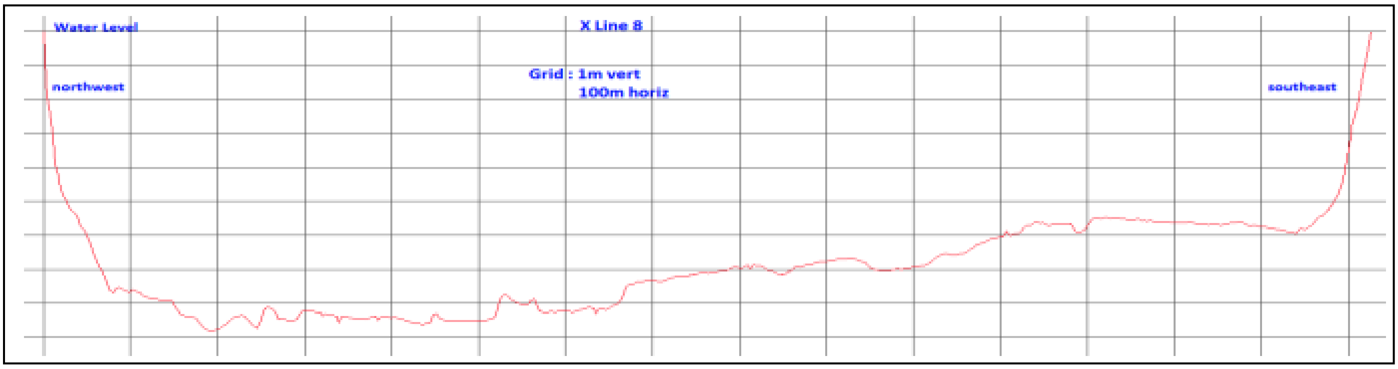


Profile – Line 8



Profile – Line 9